PLANT DISEASES

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"Dedicated to Dr. Abdus Sattar, former Plant Pathologist and Principal Agricultural College and Research Institute, Lyallpur (Faisalabad) as a small token of gratitude for his laying down the foundation of plant Pathology in Pakistan and carrying out pioneering work in this field."

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FOREWORD

The non-availability of indigenous agricultural text books in Pakistan is one of the major constraints holding back the achievement of desired improvement in the national agricultural education system. During recent years, there has been a wide-spread realization that the imported books being currently used by the educational institutions seriously lack in relevance to the local agricultural conditions. Particularly, the books imported from the the developed countries do not meet our educational requirements, because these are written to cater to specific needs of the agricultural systems of developed countries, which are operating under distinctly different agro-climatic and socio-economic situations than ours. It is, therefore, imperative that local efforts are mobilized to undertake the preparation of text books on various agricultural subjects. These books should be based on the local experience and contain information relevant to the prevalent farm situations and farmers problems in the country, in order to effectively link the agricultural education and research systems.

To undertake the preparation and publication of agricultural text books, the Pakistan Agricultural Research Council (PARC) plans to establish a special publication unit. To accomplish its assigned task, this unit will carry out in-depth study of the present course contents and curriculae of the universities and suggest modifications to strengthen the tenuous links between the education and the research system. On the basis of this study, a comprehensive list of required text books alongwith their detailed table of contents and the names of prospective authors will be compiled. PARC will provide necessary facilities and incentives to the prospective authors to write these books. We earnestly hope that many accomplished scientists will come forward and assist the Council in this undertaking.

The book entitled "Plant Diseases" is the first in the series of quality agricultural text books written in Pakistan. This book has been authored by Dr. Abdul Hafiz, who is a world-renowned agricultural expert with a long experience at national and international level. He is well known for his valuable contributions in the field of agriculture, especially in the Near East and North Africa Region, as an FAO expert, for nearly two decades. In recognition of exceptional dedication and achievement in promoting cereal improvement and production in the Region he was presented with the highest FAO prize namely, B.R. Sen Award in 1973. I would like to express my deep appreciation of the efforts made by Dr. Abdul Hafiz in producing this quality text book which I hope will be prescribed as an approved text for graduate students in the field of Plant Pathology.

Amir Muhammed
Chairman
Pakistan Agricultural Research Council
Islamabad

November, 1986

PREFACE

World population is growing rapidly at the challenging rate of more than 80 million people per year and this growth syndrome is likely to accelerate manifold, if family planning is not practised effectively. On the other hand, the global resources are limited and population is out-streching the food production, constantly increasing food: population gap. At present more than 500 million people are either hungry or suffering from malnutrition. There are already waves of famine engulfing many countries, which can turn into sea of famine, if allowed to spread unabated. About twenty-five years back there were twelve countries, which had sizeable food export surpluses while at present this number has dwindled to only four (USA, Canada, Australia and Argentina). If all the countries do not take earnest steps to increase the food production it is apprehended that even the present food exporting countries will not be able to meet the fast expanding global needs. The time has almost passed when the world's food problem could be solved by huge overseas shipments of food grains from surplus countries. Unless mankind is wise and compassionate enough to increase food production and design a better food security system, we may be seeing the beginning of the end of our civilization.

It has been estimated that in developing countries per unit area yields of important crops are still very low equalling about one-fifth of the experimental yields. The production levels can be markedly increased through introduction and integration of science and technology with systems of farming. The improved methods of plant production and protection can help in achieving this noble objective. Plant diseases and pests, rodents, birds and weeds are taking heavy toll running into more than four billion rupees every year in normal years, affecting the economy and prosperity, which Pakistan can illaford. Even one-year failure of an important crop can bring havocs as it is evident from the 1983-cotton crop in Pakistan, reducing the total production by 3 million bales and causing a monetary loss approximating Rs. 6,500 million. This also resulted in huge expenditure of foreign exchange on the import of raw cotton and at least 100,000 metric tons of additional edible oil, apart from consequential curtailment of several economic activities in agriculture, manufacturing, trade and commerce.

These calamities can be averted, if fraction of money gone into such huge losses, is made available on regular basis for agricultural research, which at present receives only one-sixth of one per cent of the national G. D. P. Unfortunately, we always seem to prepare for the crisis when we are already in its grip and it is too late to reverse the effects. The question is why? The Near East Region alone is importing 50 per cent of her food requirements at an annual cost of US $ 15 billion as against 1.3 billion in

1969/71, showing a galloping rate of increase. In fact, Pakistan can serve as a bread basket for the neighbouring needy countries thereby earning huge sums of foreign exchange for the developmental programmes of the country.

Plant Pathology constitutes a major part of plant protection, covering diseases caused by fungi, bacteria, viruses, nematodes, phanerogamic, plants, nutrient imbalances besides the damage done by weeds, which also serve as reserviors of pathogens. Plant pathological activities, although initiated as early as in 1907 on a small scale, did not receive proper attention till 1947 after the establishment of Pakistan. This discipline is still below the needed level, although a good deal of research has been in progress, yielding some outstanding achievements. This includes the development of control measures of certain diseases besides publication of many research papers and scientific monographs on systematic mycology and plant pathology. The latter included "Researches on Plant Diseases in the Punjab" by A. Sattar and A. Hafiz and "Studies on Plant Diseases of South West Pakistan" by Mustafa Kamal and S. M. Moghal published in 1952 and 1968, respectively. These monographs dealt with the diseases at provincial level embracing the highlights of the plant pathological investigations carried out in each province upto the above mentioned periods.

However, it was felt that an overview account of the important plant pathological research so far carried out in Pakistan at various research institutes and universities should be prepared. This publication should be based on collecting, collating and compiling all the available information systematically in order to take cognizance of the achievements and formulate future lines of investigations. The present book entitled "Plant Diseases is the outcome of such efforts. In the beginning, it was proposed to allocate some specific chapters to the selected Plant Pathologists and compile the book under joint authorship. Since this approach did not materialize, all the concerned scientists were requested to send their published and unpublished research papers, ideas, views and references. The materials thus received and the information collected from the two scientific monographs, library, meetings and individual discussions, were sorted out and arranged into different parts connecting the results of research findings related to allied topics in a systematic and readable form, without mentioning the names of the research workers except under references, appended with each chapter.

The book contains 24 chapters; 13 dealing with Fungal Diseases; 3 with Bacterial, Viral and Nematodal Diseases; one each with Phanerogamic Plants, Weeds and Nutritional Diseases; 3 with Varietal, Biological and Cultural Control Measures; and one with Benefical Micro-organisms. The last chapter describes Research Guidelines with priorities to the problems of practical nature. It also includes an Index to facilitate consultation of the book.

It is hoped that the book will help the Departments of Agriculture in making use of the results of already available research findings in controlling the diseases leading to enhanced crop productivity. The book will also assist in educating the scientists in the formulation of their future research programmes at national, institutional and International levels through multidisciplinary approach, avoiding unnecessary duplications. It will also prove of immense value in the education of graduate students at the universities of agriculture, helping them in their career development. It will also open new vistas for the practical solution of the complex problems, requiring team approach and joint efforts of various disciplines. The book will also encourage an integrated approach for the control of diseases, insect pests and weeds through various means embracing use of sanitary measures, cultural practices, rotations, resistant varieties and chemical and biological control. We are confident that the book will emphasize the great importance and the role of plant protection, receiving its full recognition from the Government, scientists, administrators, planners, bankers, industry and the farmers. In short the book will ultimately help in streamlining and strengthening plant pathological activities leading to disease control and increased crop production.

Sincere thanks are due to Dr. Amir Muhammed, Chairman, Pakistan Agricultural Research Council, Islamabad for providing the necessary office facilities and liberal encouragement throughout the period of two years, spent in writing of this book. Special gratitude is extended to Drs. Abdus Sattar and Mustafa Kamal, the senior authors of the two scientific monographs for permitting to make use of the relevant materials. The help of many friends and colleagues is highly appreciated in making available their research papers (published or in the form of manuscripts) which constitute main basis of the book. To name a few Dr. Abdul Ghaffar (university of Karachi), Dr. Manzoor Saeed (PCSIR, Karachi), Mian Talib Hussain (Central Cotton Research Institute, Multan), Mr. A. Salim and Dr. M. Salim Mirza (AARI, Faisalabad), Dr. Mohammad Akhtar, Dr. M. A. R. Bhatti, Mr. M. Saeed Akhtar and Dr. Abdul Hamid Khan (Agricultural University, Faisalabad), Dr. M. Attaullah (Agricultural University, Peshawar), Dr. Hassan Jaffar (Agricultural Research Institute Sariab, Quetta), Dr. Bahadur Ali (P. T. B.), Dr. M. Ikram Mohyuddin (CBCI), as well as Dr. M. Aslam, Mr. M. A. S. Kirmani, Mr. S. S. A. Rizvi, Dr. Iftikhar Ahmad, Dr. Saif Khalid, Dr. A. K. Khanzada, Dr. A. A. Hashmi and Ms. Tahira Zafar (National Agricultural Research Centre, Islamabad); deserve special thanks for providing pertinent materials, reading some chapters and giving useful suggestions. Among them the author is extremely grateful to Dr. S. M. Moghal, Dr. Maqbool Ahmad and Mr. Sultan Mahmood Khan for respectively contributing materials for three chapters on Viral diseases, Nematodal diseases and on Mushrooms. Dr. Moghal de-serves additional gratitude for his continued and untiring help provided during the entire compilation period without which the book would not have been completed on time.

The author expresses his profound indebtedness to Dr. Noel Robertson, Professor Emeritus of Agriculture, Edinburgh University and lifelong teacher and practitioner in Plant Pathology for his kindly going through the manuscript and making valuable suggestions and improvements both language and subject wise.

Last, but not the least the author is also thankful to his Secretary, Mr. Abdul Qayyum, for willingly typing and retyping hundreds of pages many times.

It is earnestly hoped that the time, labour and the money spent in the compilation and printing of this book will serve a useful purpose in the long run in improving, strengthening, and stimulating the plant pathological activities in Pakistan leading to enhanced crop productivity and profitability. However, useful suggestions and ideas for future improvements of the book will be most welcome.

November, 1986 — Abdul Hafiz

PLANT DISEASES

Fungal Flora and Seed Mycoflora

Fungal Flora

Early work on the record of fungal flora and plant diseases was done in British India by Butler and Bisby (1931) and Mundkur (1938), recording no more than 3,000 species of fungi (including only 198 from the region, which now constitutes Pakistan). Ahmad (1956) published a monograph on Fungi of West Pakistan (Now Pakistan) adding 1,000 new records with indices to genera and hosts. The records include a total of 1258 fungi; 47 belonging to Myxomycetes, 88 to Phycomycetes, 304 to Ascomycetes, 544 to Basidiomycetes and 275 to Fungi Imperfecti. For each entry the names of the hosts and habitats have been given. This pioneering and pains-taking work constitutes a landmark for furthering and stimulating research in the fields of systematic Mycology and Plant Pathology. Additional accounts by Ahmad (1956-72) entitled Further Contribution to the Fungi of West Pakistan I-XV; Sattar and Hafiz (1952); Researches on Plant Diseases of the Punjab; Ghaffar et al. (1968-72) Fungi of Karachi, I-III; Khan (1952) Wood Rotting Fungi of West Pakistan, Khan and Kamal (1968) Fungi of South West Pakistan; Kamal and Moghal (1968) Studies on Plant Diseases of South West Pakistan and by Ghafoor and Khan (1976) List of Diseases of Economic Plants in Pakistan added a wealth of information on fungal flora. Kamal and Khan (1968) have listed the names and times of appearance of 104 fungal diseases of 37 different crops, vegetables and fruit plants in Sind province.

The list of diseases of economic plants included 286 host species arranged alphabetically under their families, genera and common names, providing basic information to plant pathologists for carrying out research programmes. Mirza and Qureshi (1978) published a comprehensive account entitled "Fungi of Pakistan" by updating and bringing all the recorded fungi together for the benefit of research workers and students. The distribution according to major groups of fungi covers 847 genera and 3383 species (Table 1.1).

Table 1.1. Major groupwise distribution of fungi of Pakistan:

Group	No.of Genera	No.of Species
1. Myxomycetes	24	68
2. Phycomycetes	43	176
3. Ascomycetes	306	933
4. Basidomycetes	216	881
5. Deuteromycetes	256	1321
6. Mycelia sterilia	2	4
Total:	847	3383

Ahmad (1982) published a list of wood-destroying fungi from Azad Kashmir covering 18 parasitic and saprophytic fungi isolated from forest trees and timber causing economic losses.

The present brief review of the fungal flora along with main references shows the extent of intensive and extensive studies carried out in the country for the benefit of the two disciplines of Mycology and Plant Pathology, providing a sound and solid base. However, there is a need to continue with such studies through post-graduate students and to establish schools of research on special groups of fungi with herbaria (including live cultures) in various Universities, in order to keep the continuity of the work, build up trained manpower, provide facilities for systematic studies and services for authentic identification, besides developing productive relationships of systematic Mycology and Plant Pathology with plant breeding.

Seed Mycoflora

A good deal of work has been carried out on isolation and identification of seed mycoflora of important crop plants with some studies on pathogenicity, losses caused by reduced seed germination and yield. Work has also been done on seed treatment bringing out the importance or seed-borne diseases and their control. The highlights of the research work, reported so far, are given below:

Cotton

Kamal and Moghal (1968) have reported the presence of both externally and internally seed-borne fungi, predominantly consisting of species of *Rhizopus, Aspergillus, Penicillium* and *Fusarium* with prevalent species of *Curvularia, Helminthosporium* and *Alternaria* besides bacteria in a few cases. These isolates can reduce seed germination by 13 to 32 per cent; *Penicillium, Fusarium* and *Curvularia* spp. being most harmful. Chemical seed treatment and/or delinting with (H_2SO_4) has improved seed germination and yield of the crop. Saleem et al. (1975) have isolated 42 species of fungi belonging to 28 genera (27 being new to cotton and 15 recorded for the first time on cotton in Pakistan). The authors have collected and compiled alphabetically all the available information leading to a total of 80 species belonging to 40 genera. The live cultures of the isolated fungi have been deposited at the Cotton Research Institute, Multan and also at the Commonwealth Mycological Research Institute, Kew, Surrey, England for ready reference.

Hussain and Yaqoob (1976) have found ten organisms associated with fuzzy cotton seed of variety 149 F; the more frequent isolates belong to species of *Alternaria, Aspergillus, Fusarium, Rhizopus* and *Monilia*, and their frequencies vary with temperature, culture medium and test chemicals. The suitable temperatures are 20° C for *Alternaria infectoria*, 25° C for *Fusarium solani* and 28° C for *Aspergillus niger*, with appropriate media being Potato Dextrose Agar for *Aspergillus* sp. and Czapek's agar for *Fusarium*. Out of eleven tested fungicides, Busan 72, Vitavex and Captan, when used in 0.2% concentration, have controlled almost all the isolated fungi while the remaining nine fungicides and hot water treatment have given partial success.

As the soil temperature during cotton sowing period varies between 25 and 30° C, most of the seed-borne and even some soil-borne fungi are likely to reduce seed germination and cause pre and post-emergence death of seedlings, ranging 1 – 1.7 per cent in the Punjab and Sind.

Panhwar and Jagirdar (1978), after carrying out extensive and intensive surveys of cotton fields in Sind province, have reported occurrence, prevalance and distribution of several seed-borne diseases viz; seed rot, pre and post-emergence death of seedling, root rot, leaf and stem spots and boll rot caused by a large number of pathogens (fungi and bacteria) isolated from seeds. Of the micro-organisms isolated, major ones in order of their frequency are *Aspergillus niger, A. flavus, Rhizoctonia bataticola* and species of *Fusarium, Rhizopus, Curvularia, Helminthosporium* and *Alternaria*. The incidence of various diseases varied from year to year and field to field, depending upon the infectivity of different pathogens and the nature of environmental conditions such as humidity. These diseases have been found not only to reduce the stand, health and growth of the crop but also yield and quality of fibre and oil. The fungicidal treatments significantly enhanced seed germination and yield and the best results being obtained with Agrosan, followed by Emcon and Copper Sandoz, Terracolor and Benlate.

In view of the above results, chemical treatment of cotton seed has been strongly recommended to control seed-borne fungi and also some of the soil-borne organisms.

Wheat

Kamal and Moghal (1968) have isolated in varying frequencies, from apparently healthy wheat seeds of C-518, C-591, H-68, Penjamo and Mexipak, species of *Alternaria, Aspergillus, Helminthosporium, Rhizopus* and *Fusarium,* which reduced seed germination by 47 to 76 per cent; *Rhizopus* being more deleterious. Seed treatment (with Agrosan GN, Emcon and Dieldrex) appreciably improved both the seed germination and yield of the crop.

Hussain, Jagirdar and Kamal (1969) have isolated wheat seed mycoflora from Mexipak and Penjamo 62, comprising species of *Alternaria, Rhizopus, Aspergillus* and *Helminthosporium,* in descending order of contamination (varying between 2 to 50 per cent in case of Penjamo and 10 to 39 per cent in Mexipak). The isolates reduced the germination capacity of the seed, both *Alternaria* and *Rhizopus* caused higher degree of losses. Of the fungicides tested, Agrosan and Emcon increased the seed germination as well as stand and yield of the crop. In view of the results obtained, chemical seed treatment has been recommended. The later studies have shown the predominance of *Aspergillus* and *Penicillium* species in stored grains over the other fungi, which are probably killed due to increasing temperature and higher CO_2 concentrations. *Aspergillus* and *Penicillium* have also been isolated from wheat flour regardless of source and type of flour mill. Untimely rains during April, 1982, gave rise to a high incidence of seed-borne fungi, reducing seed germination from 70 to below 10 per cent.

Barley

Ten varieties of barley collected from Tandojam and Faisalabad in 1976 and tested for the presence of seed-borne mycoflora have yielded 19 species of fungi comprising *Alternaria tenuis. Aspergillus niger, A.*

flavus, *Aspergillus* spp; *Chaetomium olivaceum*, *Cladosporium cladosporioides*, *Curvularia lunata*, *C. pallescense*, *Drechslera hawaiiensis*, *D. halodes**, *D. papendorfii**, *D. rostrata**, *D. tetramera*, *Fusarium moniliforme**, *F. semitectum**, *Penicillium* spp., *Rhizopus nigricans*, *Stachybotrys atra**and *Trichothecium roseum*. Out of the isolates, six asterik-marked fungi are new records from Pakistan. The average percentages of the group of 19 fungi as determined by the blotter and agar plate methods have been recorded as 87.1 and 73.25, from seeds as such and 32.3 and 24.8, from surface-sterilized seeds; four fungi namely (*R. nigricans*, *F. semitectum*, *S. atra* and *C. cladosporioides*) could not be isolated from surface-sterilized seeds. Some varietal differences in degree of infestation have also been observed along with indications that the blotter method has yielded quantitatively more fungi than the Ulster method.

Rice

Kamal and Moghal (1968) have isolated from apparently normal seeds of Kangni 27, Sonhari Sugdasi, Sonhari Kangni, Bengalo, Dokri Basmati, Jajai 77 and Kangni X Torh, nine different organisms in various frequencies. The infection being the highest in case of bacteria (13 to 65 per cent), followed by *Tricholiobolus padwickii* (31 to 41 per cent), *Aspergillus* sp. (1 to 39 per cent but was absent in Kangni 27 and Kangni X. Torh), *Cochliobolus specifer* (1.9 to 3.5 per cent), *Curvularia verruculosa* (1.5 to 3.5 but upto 20 per cent in case of Dokri Basmati) and *Nigrospora siate* (1.5 to 3.6 per cent). Only two varieties (Kangni 27 and Jajai 77) have been found to be infected with *Chaetomium* (1.5 to 2.5 per cent) while *Alternaria* from Sonhari Sugdasi (3.6%) and *Fusarium* sp. from Bengalo (1%) have been isolated. These organisms have been found to impair the germination by 2-3 per cent in different varieties while seed treatment with Agrosan GN and Ceresan M increased both the seed germination capacity and the yield level by approximately 16.6% where Ceresan M was used.

Nawaz (1961) while carrying out studies on *Helminthosporium* blight has reported enhanced germination of rice seeds treated with seed dressing fungicides leading to higher number of tillers, ears and yield increase and similar results have been obtained by spraying the crop with chemicals such as Perenox, Zerlate, Parzate, Fermate or Dithane.

Similar studies carried out in the Punjab yielded average infections of 73 and 47 per cent from surface and interior of the seeds, respectively. In order of prevalance, the isolated fungi were *Curvularia*, *Helminthosporium*, *Aspergillus*, *Fusarium*, *Alternaria*, *Mucor*, *Denaryphiella*, *Cephalosporium* and *Helicoma*; the first two being more predominant. They reduced the seed germination causing seedling mortality and could be controlled through seed dressing..

Nayeemullah and Kafi (1978) while discussing the role of rice diseases in the economy of rice production and necessity of seed treatment for controlling seed-borne diseases, have described the methodologies of fungal isolation methods (Blotter and Agar plate) and given the names of various fungi isolated from rice seeds. These are *Alternaria tenuis* (26.2%), *Alternaria tenuissima* (5.2%), *Trichoconis padwickii* (50.7%), *Drechslera oryzae* (41.0%), *Curvularia lunata* (17.5%), *Curvularia geniculata* (5%), *C. oryzae* (4.5%), *Fusarium equiseti* (2.2%), *F. moniliforme, Gibberella fujikuori* (5%), *F. semitectum* (17%), *F. graminearum* (1.7%) and *Nigrospora oryzae* (6.2%). On the basis of these results, the necessity of seed health testing and treatment has been emphasized to ensure distribution of healthy seeds.

Maize

(3)Thirty representative samples of maize seed (sound and damaged) collected during 1964, 1965 and 1967 from different places in Pakistan have given very high percentages of fungal isolations (upto 90-96%) with averages of 71.7% from sound and 83.7% from damaged grains. The fungi, in order of prevalence, included species of *Aspergillus, Penicillium, Mucor, Hormodendrum, Fusarium, Cephalosporium, Helminthosporium* and *Alternaria* with very little difference in the nature of isolates from sound and damaged seeds. However, in case of surface-disinfected seeds, species of *Mucor, Aspergillus* and *Penicillium* have not been isolated. The cultural studies have shown their optimum temperature requirements for growth as 20-30° C and 30-35° C for different groups, while the disinfectants like Arasan and Dieldrex have increased the seed germination capacity. In later studies, *Aspergillus* and *Penicillium* have been found to be predominantly present on stored grains, showing differences in varietal reaction.

Sorghum

Junejo and Malik (1967), after carrying out a survey in Sind province have isolated species of 15 fungi with maximum of 90% contamination in Sakrand and minimum of 61% in Larkana from unsterilized sorghum seeds compared with the corresponding percentages of 64 and 48 from surface-sterilized seeds in Khipro and Mirpurkhas, respectively. The isolated organisms consist of *Mucor, Rhizopus, Aspergillus, Penicillium, Chaetomium, Phoma, Hormodendrum, Alternaria, Helminthosporium,* *Cochliobolus, Curvularia, Monilia, Hetrosporium* and *Acrothecium* as well as bacteria. The most frequent ones being *Aspergillus, Helminthosporium, Curvularia* and *Fusarium. Pathogenicity tests have shown that all the 15 isolates reduced the germination of sorghum seeds by between 7 and 60% both in the laboratory and in the field* (*some being more deleterious*). *Similarly, 11 fungi have been isolated from sorghum grains in the Punjab.*

Kamal and Moghal (*1968*) *isolated a number of fungi both from unsterilized and surface-sterilized sorghum seeds collected from different localities of Sind, showing varying frequencies based on varieties as well as localities. Percentages of sorghum seeds carrying fungi externally varied from 61 to 90 with an average of 75. The most predominent isolates have been Aspergillus* sp. followed by species of *Helminthosporium, Alternaria, Fusarium, Curvularia* and *Rhizopus*. In case of surface-sterilized seeds, 48 to 64% with an average of 57.2% seeds showed the presence of fungi. Fungal species isolated were *Cochliobolus* (*Helminthosporium*), *Aspergillus, Fusarium, Alternaria* and *Curvularia*. These fungi have also been found to reduce seed germination considerably while in seeds artificially infected with *Fusarium* and *Cochliobolus* spp. the percentage of pre-emergence kill has been very high. The seed treatment increased both the seed germination and the yield. The chemicals in order of their effectiveness were Orthocide HCB, Copper carbonate, Mergon, Emcon, and Agrosan GN. The need for seed treatment has been highlighted.

Although no work has been carried out on the economics of seed treatment, the beneficial effects of seed dressing can be visualized to be large.

Brassica

(٩٠) Ninety representative samples of *sarson* (colza), toria (rape) and *raya* (mustard) collected from fields and stores in Pakistan have given quite high percentage of infestation (as high as 85-90%) while these figures are lower (almost half) in case of surface – disinfected seeds. The fungi infesting the seeds include, in order of prevalence, the species of *Aspergillus, Penicillium, Mucor, Alternaria, Rhizoctonia, Fusarium, Helminthosporium* and *Sclerotium* with predominance of *Aspergillus, Penicillium* and *Alternaria*. These fungi greatly reduced the germination and yield. Fungicidal treatments with Granosan M, Granosan N, Agrosan GN, and Arasan have controlled the deleterious effects.

Groundnut

Ali and Nayeemullah (1960) have investigated the effect of 9 fungicides (4 mercurials, 2 thirams and 3 fungicides combined with insecticides) on the control of seed-borne diseases and yield of groundnut for a period of three years. The reported isolated seed-borne fungi are *Rhizoctonia bataticola* (22%), *Fusarium* spp. (29.3%), *Aspergillus* sp. (15.3%), *Penicillium* sp. (28%) and *Cephalosporium* sp. (4%), which caused seed rot, root rot or seedling rot. The results on seed treatment have shown increased percentage of germination by controlling the mortality of seeds and seedlings and increase in the yield by 360 kg/ha. Out of the chemicals tested, Dieldrex, Seedox and Arasan SFX have been found to be safer and more effective, while mercurial compounds showed toxicity with slight increase over the recommended dose of 1 g per 1.5 kg of seed.

This shows the beneficial effects of seed treatment in controlling seed-borne and in some cases soil-borne diseases resulting increased yield of groundnuts.

Kamal and Moghal (1968) have studied the fungicidal treatment of groundnut with different chemicals against the artificially infected seed with a culture of *Fusarium coeruleum* (causing wilt diseases), and found that seed treatment with Granosan M increased the seed germination by 2.3-13.5% and yield by 250-600 kg/ha.

Safflower

Studies carried out at the Agricultural University, Faisalabad have indicated external and internal infestation of safflower seeds ranging between 45-93 and 37-71%, respectively. The isolated fungi are the species of *Aspergillus, Rhizopus, Helminthosporium, Curvularia, Fusarium, Sclerotium* and *Alternaria*. Infected seeds sown in infested soils have given much more reduced germination, particularly with the combination of all the fungi; *Fusarium* being highly pathogenic.

Summer Vegetables

Fifty two seed samples of five summer vegetables (cucumber, bitter gourd, okra, tomato and marrow) collected from different localities in Pakistan have given quite high percentages of fungal infestations with averages ranging between 57-67.5% while these figures are lower in the case of surface – disinfected seeds (19.8-31.8%). The fungi generally isolated include species of *Aspergillus, Penicillium, Alternaria, Fusarium, Sclerotium, Chaetomium, Curvularia* and *Helminthosporium*. These fungi have reduced the seed germination and increased mortality of seedling whereas the usual fungicidal treatments have proved to be effective in controlling the deleterious effects. The most effective and wide-ranging chemicals are Arasan, Dieldrex and Agrosan GN.

Castor Bean

Studies carried out at the University of Agriculture, Faisalabad, on seed-borne fungi have shown heavy external and internal infestation of castor beans, with respective averages of 70 and 50%. The isolated fungi are species of *Curvularia, Helminthosporium, Fusarium, Botryodiplodia, Nigrospora, Alternaria, Aspergillus, Rhizopus, Mucor, Thielavia, Sclerotium* and *Penicillium;* the first two being predominant. These fungi have shown reduction in seed germination within 12-21% range. Out of the seed dressing fungicides, Brassicol has proved to be the best, followed by Topsin M and Quinolate.

Chillies

Out of the eight fungi, comprising species of *Colletotrichum, Fusarium, Alternaria, Curvularia, Aspergillus, Mucor, Rhizopus* and *Penicillium,* isolated from chillies the first four have proved to be pathogenic, producing seed rot and fruit rot; *Colletotrichum capsici* being more destructive. The fungicidal treatment improves seed germination, the best results have been obtained by using Benlate followed by Brassicol and Moreston. Spray fungicides (like Zerlate and Perenox) have effectively controlled the anthracnose disease (*C. capsici*) in the field.

Rosaceous Fruits

The isolations made from rosaceous fruits have been found to include 3 species of *Alternaria*, 5 of *Aspergillus* one each of *Cladosporium, Curvularia, Fusarium, Helminthosporium, Mucor, Monilia, Paecilomyces,* and 3 each of *Penicillium* and *Rhizoctonia,* most of them proving to be pathogenic.

Miscellaneous Crops

Studies carried out at the Department of Plant Pathology, University of Agriculture, Faisalabad, on seed-borne fungi of many crops have shown varying degrees of seed infestation; paddy (75-92%), sorghum (35-38%), cotton 60-90%), and winter vegetables (60-70%) with a number of fungi; predominant being species of *Aspergillus, Penicillium, Alternaria, Helminthosporium, Fusarium, Curvularia, Mucor, Rhizoctonia, Rhizopus,* *Sclerotium* and *Chaetomium*. In most of the cases, seed treatment has controlled the seed-borne diseases, giving higher germination, better crop stands and increased yields.

Investigations reported by Nayeemullah, (1972) on the isolation and incidence of micro-organisms on seeds of nine plant species collected from grain markets of Lahore, Sahiwal, Sialkot, Rawalpindi, Peshawar and Quetta, by using Blotter Method, have revealed the presence of a large number of fungi in varying frequencies (Table 1.2).

Table 1.2. Incidence of fungi isolated from seeds of different crops

Crop	Fungi	Percentage range of infection 1/
1. Rice (*Oryzae sativa*)	*Alternaria padwickii*	20.5 - 50.7
	Curvularia lunata	5.5 - 17.5
	*Curvularia geniculata**	2.2 - 5.0
	*Curvularia oryzae**	2.5 - 4.5
	Drechslera oryzae	18.5 - 41.5
	*Fusarium equiseti**	2.0 - 2.2
	*Fusarium moniliforme**	4.2 - 5.0
	*Fusarium semitectum**	0.0 - 1.7
	*Fusarium graminearum**	0.0 - 1.7
	Nigrospora oryzae	5.0 - 6.2
2. Wheat (*Triticum aestivum*)	*Alternaria tenuis*	49.0 - 97.0
	*Alternaria triticina**	7.7 - 10.0
	Drechslera sorokiniana	3.0 - 6.5
	*Fusarium equiseti**	0.0 - 2.2
	*Fusarium moniliforme**	3.2 - 3.5
3. Maize (*Zea mays*)	*Aspergillus flavus*	4.6 - 6.2
	Aspergillus niger	3.0 - 6.2
	Gibberella zeae	2.5 - 3.0
	*Drechslera maydis**	2.2 - 2.7
	*Fusarium moniliforme**	3.2 - 5.5
	*Fusarium semitectum**	0.0 - 2.5
4. Sorghum (*Sorghum vulgare*)	*Botryodiplodia* sp.*	2.7 - 4.5
	*Curvularia eragrostidis**	2.7 - 3.7

Crop	Fungi	Percentage range of infection 1/
	*Drechslera oryzae**	3.0 - 3.7
	Drechslera sorghicola	0.0 - 2.7
	*Fusarium moniliforme**	3.5 - 6.7
	*Fusarium semitectum**	1.7 - 2.5
5. Barley (*Hordeum vulgare*)	*Drechslera sorokiniana*	3.5 - 5.7
	Drechslera teres	2.7 - 5.0
	*Fusarium moniliforme**	3.5 - 4.5
	*Fusarium semitectum**	0.0 - 3.2
6. Linseed (*Linum usitatissimum*)	*Fusarium moniliforme**	0.7 - 3.0
7. Lentil (*Lens esculentum*)	*Fusarium moniliforme**	0.0 - 0.2
	verticillium sp.*	0.0 - 0.5
8. Gram(*Cicer arietinum*)	*Alternaria tenuis*	5.0 - 15.0
	*Fusarium moniliforme**	0.0 - 3.0
	*Fusarium equiseti**	2.0 - 2.7
9. Coriander (*Coriandrum sativum*)	*Alternaria porri**	0.0 - 3.2
	Botryodiplodia sp.	2.2 - 2.7
	*Fusarium moniliforme**	2.0 - 2.7

1. Five samples each crop, consisting 400 seeds per sample were tested.

*New records for Pakistan

Most of the fungi isolated have already been reported from Pakistan or elsewhere except the new records (identified in the Table 1.2); some of these micro-organisms can cause serious damage to the crops.

Similarly, studies carried out on Brassica species, have shown the presence of a bacterium (*Xanthomonas campestris*), which can become serious sometimes. In view of large-scale seed infestations, the importance of seed health testing and seed treatment has been emphasised.

Stored Grains

Studies carried out at the University of Agriculture, Faisalabad, from stored grains have yielded sixteen fungal isolates. Silica gel thin layer technique applied for determining aflatoxin B1, B2, G1 and G2 has yielded aflatoxin from many isolates; all the four toxins being produced by

Aspergillus nidulans, A. wentii, A. candidus, A. niger and *A. parasiticus*.

Later studies have confirmed these findings and have further shown that the quantities of aflatoxin increase with storage period as well as with type of stores conducive to higher moisture. The aflatoxin producing species were *Aspergillus flavus, A. parasiticus* and *A. ochraceus*.

Poultry Feeds

In view of the increasing importance of the manufactured poultry feeds, Jamal and Ghaffar (1974) after investigating the mycoflora of poultry feed samples (wheat, rice, millet, rye and fishmeal) with pH 5.-5.6 and moisture percentage of 7.6-9.6, have reported heavy infestations ranging between 4,000 to 38,000 of fungal propagules per g of fresh samples. The dominant fungi being *Aspergillus fumigatus, A. niger, A. candidus, A. flavus, A. caespitosus, Cladosporium herbarum, Fusarium oxysporum, F. solani, Monilia sitophila, Paecilomyces varioti, Penicillium* and *Mucor* spp. Of the fungi isolated, *Aspergillus fumigatus* has been reported to produce "brooders pneumonia" in birds, especially in chickens while some isolates of *A. flavus* can produce large amounts of aflatoxin.

Necessary steps for manufacturing and storing including certification of poultry feeds are essential to safeguard the health of poultry and the consumers.

On the basis of the reported studies, all the isolated micro-organisms have been summarized alphabetically in Table 1.3 in order to indicate their association with various hosts for the benefit of the research workers.

Table 1.3. Consolidated list of fungi/bacteria isolated from seeds of different crop plants.

Micro-organisms	*Crops*
1. *Alternaria*	Cotton, wheat, rice, maize, sorghum, gram, brassica, safflower, summer vegetables, coriander, castor beans, fruits.
2. *Aspergillus*	Cotton, wheat, rice, maize, sorghum, brassica, groundnut, safflower, summer vegetables, castor beans, fruits, poultry feed.
3. *Botryodiplodia*	Sorghum, coriander, castor beans.
4. *Cephalosporium*	Maize, groundnut.
5. *Chaetomium*	Rice, sorghum, summer vegetables.
6. *Cladosporium*	Fruits, poultry feed.

Micro-organisms	Crops
7. *Cochliobolus* (*Helminthosporium*)	Rice, sorghum.
8. *Helminthosporium*	*Cotton, wheat, maize, sorghum, brassica, safflower,* summer vegetables, castor beans, fruits.
9. *Curvularia*	Cotton, wheat, rice, sorghum, safflower, summer vegetable, castor beans, fruits.
10. *Drechslera*	Wheat, rice, barley, maize, sorghum.
11. *Fusarium*	Cotton, wheat, rice, barley, maize, sorghum, gram, brassica, groundnut, safflower, linseed, lentil, summer vegetables, coriander, fruits, poultry feed.
12. *Gibberella*	Rice, maize.
13. *Hetrosporium*	Sorghum.
14. *Hormodendrum*	Maize, sorghum.
15. *Monilia*	Cotton, sorghum, fruits, poultry feed.
16. *Mucor*	Sorghum, brassica, castor beans, fruits, poultry feed.
17. *Nigrospora*	Rice, maize, castor beans.
18. *Paecilomyces*	Fruits, poultry feed.
19. *Penicillium*	Cotton wheat, maize sorghum, brassica, groundnut, summer vegetables, castor beans, fruits, poultry feed.
20. *Phoma*	Sorghum.
21. *Rhizoctonia*	Cotton, brassica, groundnut, fruits.
22. *Rhizopus*	Cotton, wheat, sorghum, safflower, castor beans.
23. *Sclerotium*	Brassica, safflower, castor beans.
24. *Tricholiobolus*	Rice.
25. *Trichoconis*	Rice.
26. *Verticillium*	Lentil.
27. *Bacteria*	Cotton, rice.

Note: Later studies of 1974 on 81 seed samples of 21 important cereals, pulses and vegetables have shown the presence of 30 fungal species belonging to 12 genera with wider host ranges of *Aspergillus, Drechslera* and *Fusarium* and one of a bacterium (*Xanthomonas campestris* on onion and mustard).

All the isolated fungi from the seeds of different crop plants (Table 1.3) show the presence of 26 genera with preponderance of *Alternaria,* *Aspergillus, Curvularia, Drechslera, Fusarium, Helminthosporium, Penicillium* and *Rhizopus*, each representing several species. While the remaining 18 genera are specific to one or two crops, mostly grown during summer (cotton, rice, maize, sorghum and groundnut) under high humidity and temperature, causing comparatively bigger losses. Most of the fungi are surfaceborne while a few are carried inside the seed (e.g. *Rhizopus*). Some of the fungi are saprophytes, developing under moist storage (high moisture contents of seed and/or stores) while many are pathogenic, producing various symptoms-seed rot, root rot, stem rot, seedling blight, leaf spot, boll spot and boll rots. The losses due to reduced seed germination, stand of the crop and low yields, are higher under conducive conditions of high humidity and temperature as well as when there is a combined infection of fungi and associated bacteria or of seed-borne and soil-borne fungi. Moreover, starchy grains and high energy oilseeds provide good substrates for the rapid growth of fungi, producing deleterious effects on flour, oil and other by-products; *Aspergillus* species are more harmful because of their quicker growth rate and production of aflatoxins. Some pathogens are weak parasites, causing infection in the presence of wounds or injuries while others are quite aggressive in nature, causing considerable damage during storage and/or in various stages of crop growth and can be controlled with suitable seed treatments. In view of the high losses caused, it is necessary to introduce grain storage sanitation and seed treatment, with surface protectants and systemic chemicals, besides seed health certification in the country on compulsory basis. Very little work has been done on seed-borne micro-organisms of vegetables, condiments and grain legumes (many of them also having seed-borne infection of viruses such as tomato mosaic virus). These studies can better be taken up at national level in a well established Seed Pathology Laboratory, which has now been set up at Karachi under the auspices of PARC.

Seed Dressing Fungicides and Toxicity

A number of seed dressing fungicides for wheat, oats, barley, paddy, cotton, sugarcane, sorghum and groundnut have been tested with a view to finding out their safe limits, avoiding injury due to over-dosing. In general, seed dressing fungicides applied at the recommended rates have enhanced germination of treated seeds and given higher yields. Products combining fungicides and insecticides have proved to be better, especially for maize and groundnut. The deleterious effects of overdosing vary with the type of seeds and the nature of the chemicals. For example, Granosan M does not show any injurious effects on wheat when used 16 times the recommended doze while it injures paddy seeds even at 4 times concentration. Most of the chemicals for various crops are: Granosan M, Agrosan GN, Dieldrex, Spergon (for wheat), Arasan and Spergon (for cotton), Dieldrex, Cerenox Special and Zerlate (for sugarcane), Arasan and Spergon (for sorghum) and Dieldrex and 1.D-a combined fungicide and insecticide (for maize and groundnut). The chemicals with wider range of safe application are Arasan, Spergon, Dieldrex and Granosan M. Overdozing and humid storage conditions have been found to produce deleterious effects on seed germination and these conditions have to be avoided by using the right type of chemical application machinery and dry store houses.

The dressing of *khatti* (*Citrus limon*) seeds with Arasan and Dieldrex has proved helpful in controlling damping off and seedling diseases and increasing the seed germination appreciably.

Summary

This chapter describes the fungal flora and the seed mycoflora of Pakistan. It traces the history of the work done on fungal flora covering the period of 50 years from 1931 to 1982 resulting into many surveys and publications of several accounts describing 847 genera and 3383 species arranged into six major groups apart from the list of wood-destroying fungi. This work provides a sound basis for future studies at the schools of research to be established in various national universities for authentic identification and the development of productive relationships between systematic mycology and plant pathology with plant breeding.

The seed mycoflora of important crops like cotton, wheat, barley, rice, maize, sorghum, oleiferous brassica, groundnut, safflower, chillies, castor beans, summer vegetables and fruits as well as of stored grains and poultry feeds have been described alongwith their deleterious effects on seed germination and yield and their control through the use of chemical disinfectants. The fungi isolated fall into 26 genera with preponderance of *Alternaria, Aspergillus, Curvularia, Drechslera, Fusarium, Helminthosporium, Penicillium* and *Rhizopus*, each representing several species; the remaining genera are specific to one or two crops only. Most of the fungi are surface-borne while a few are carried inside the seed. Many being pathogenic, produce various symptoms of seed rot, root rot, stem rot, seedling blight, leaf spot and boll spot and cause considerable damage, which can be controlled with suitable seed disinfectants. In view of the great importance of the losses caused by seed-borne micro-organisms, the introduction of grain storage sanitation, seed treatment and seed health certification have been emphasized.

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Wheat and Barley

Wheat

Wheat occupies a position of paramount importance amongst world's crop plants both in extent of area and magnitude of food production. Pakistan grows annually 5.5 to 6 million hectares of wheat, from which the annual production amounts to more than 12 million tons of grain (as against 3.4 million tons from 3.8 million hectares in early fifties). Although Pakistan has made an outstanding progress in total production and per unit area yield, the productivity level is still low lagging behind many advanced countries. Barley occupies 172,000 ha and is usually grown on marginal lands with very little fertilization. However, its importance is increasing on account of rising demand in cattle feed. There are many constraints including the heavy losses caused by a number of diseases to the wheat and barley crops in Pakistan. A brief account of the work carried out so far on diseases of wheat and barley in the country is given in the text.

Loose Smut, *Ustilago tritici* (*Pers.*) Rostr.

Occurrence and Symptoms

Loose smut of wheat, which is characterized by the appearance of black sooty ears containing spores of the causal fungus instead of normal grains, occurs commonly throughout the country. Initially spores are covered by a delicate silvery membrane which bursts before the emergence of ears. The spores are blown away by wind, leaving behind naked rachis (Fig.2.1). It causes on an average 1% damage, but in humid parts of the country and foothill districts, the damage caused by the disease can be as high as 10-20%, depending upon the wheat varieties under cultivation. Epidemeological studies have indicated that if no action is taken to control the disease, it will go on increasing every year in some localities, in others it will decrease gradually while in still others it will remain constant. This peculiar behaviour of these fluctuations is due to the variations in humidities prevalent at the time of earning at various places.

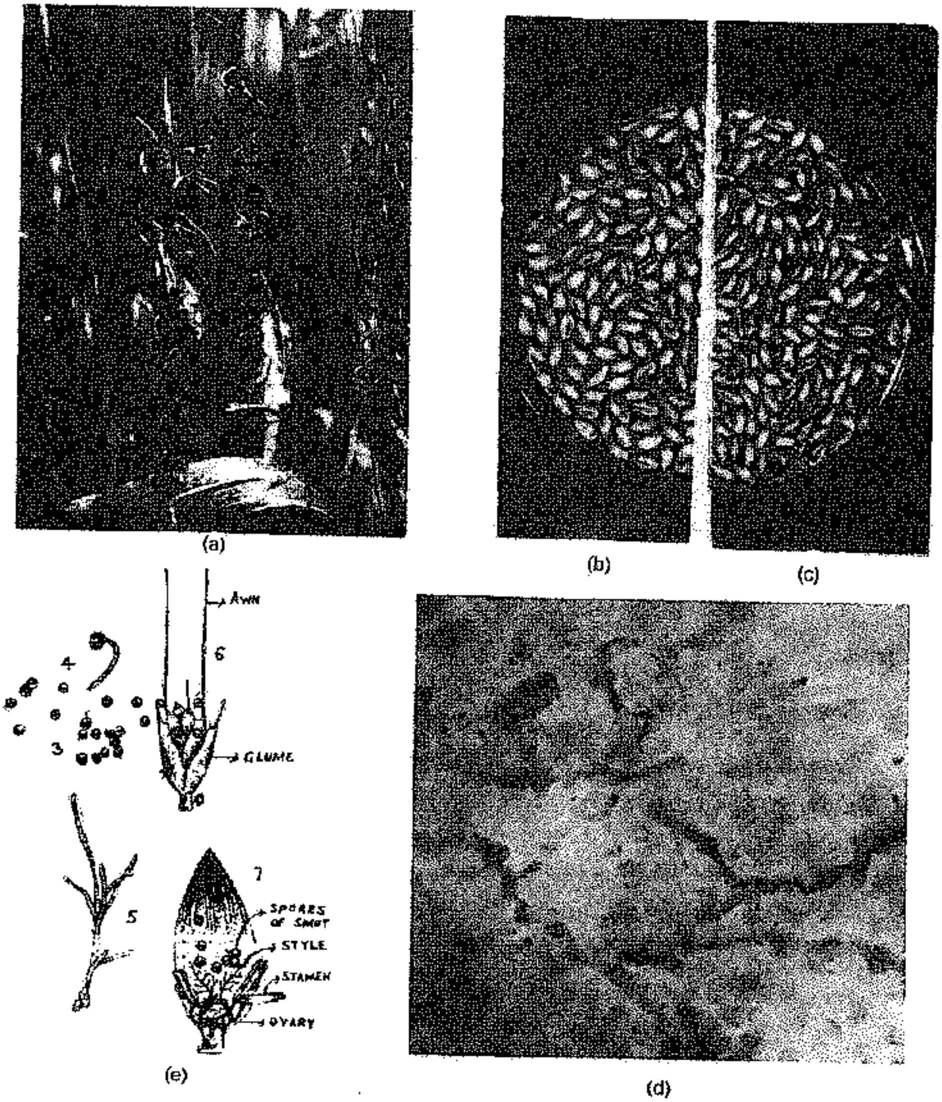


Fig. 2.1: Loose smut of wheat. (a) Smutted heads, (b) Seeds from inoculated heads, showing shrivelling; (c) Grains from healthy heads; (d) Dispersal of chlamydospores, causing floral infection; and (e) Hibernating mycelium in crushed embryo as seen under microscope.

Perpetuation

The smutted ears appear earlier at the time when normal heads are flowering; these become infected with the wind-blown spores of the fungus, which on germination penetrate the ovary. The fungus remains as dormant mycelium inside the embryo. The disease is perpetuated from year to year through sowing seeds containing hibernating mycelium inside, although they look normal apparently. The mycelium resumes growth as the seed germinates, and causes systemic infection, giving rise to smutted ears.

Methods of Inoculation

Wheat heads of C-591 inoculated at anthesis stage by (a) hypodermic needle, and (b) partial vacuum technique (Moore, 1936) produced 90-100 and 75-80% infections, respectively. As the former method is tedious and time consuming, the latter has been used in all the studies. In order to accelerate the varietal screening programme the investigations carried out have indicated that the inoculated grains when either (a) embryo-tested by Simmond's method* or (b) field-tested, show high correlation with disease percentages varying between 38-62, showing difference of only 2% between the two tests. Thus embryo testing can accelerate the varietal screening and early development of resistant varieties.

Control

Hot Water Treatment

The earlier studies on the modification of hot water treatment of the infected grains, as recommended in advanced countries, have given the following results:

- If wheat seed presoaked in water at room temperature 18-24°C for four hours is immersed in hot water at 46°C for two minutes and then for ten minutes at 54-56°C, the disease is eliminated without adversely affecting the seed germination capacity;
- The disease is also eliminated if presoaked seed is first immersed in hot water at 49°C for five minutes and then for seven minutes at 53-56°C. Even presoaking upto eight hours does not affect the

*Wheat grains are soaked overnight in 10% sodium hydroxide solution to facilitate embryo separation. These are then thoroughly washed and gradually boiled for 30-40 minutes in lactophenol solution (lactic acid and phenol 10 cc each, mixed in 50 cc of distilled water) until they become transparent. They are then stained in cotton blue and placed on a slide (20-30 embryos per slide), which is then covered by another slide to crush the embryos for examination under micro scope. Dark stranas of mycelium become clearly visible in infected embryos.

seed germination capacity.

On the basis of the above results a simple method of hot water treatment was evolved, which is described below:-

Simplified Hot Water Treatment

Equipment

i) Two heaters locally called Hamams each with a capacity of about 35 gallons of water;

ii) Two galvanized iron tubs, each with a bottom measurement of 100 cm and having level marks on the sides at 25 gallons of water;

iii) A big tub or a vessel of any other kind to be used for pre-soaking of seed wheat;

iv) Two sheets of coarse cotton cloth, each measuring about 2X1.5m;

v) One stirrer preferably a small vessel;

vi) One centigrade thermometer;

vii) One or more sheets of cloth of suitable size on which seed is to be spread for drying after treatment.

Method

The two heaters (*Hamams*) with the two standardized tubs, which may be designated as No.1 and No.2, are placed opposite to one another in a well ventilated room. Charcoal is used to heat water in *Hamams*, and temperature of water is brought near to the boiling point before the treatment is commenced. During the course of the treatment draught should be avoided to prevent rapid fall of temperature of water in the tubs.

Approximately 90 kg seeds of wheat are soaked in water in the morning at about 7 O' clock for four hours, if the treatment is carried out in September when the temperature in an ordinary room is about 29°C. If wheat is to be treated in October or November, it should be soaked for 5 and 7 hours respectively, as the temperature falls to 21 and 15°C. In warm weather water soaks into the grains more quickly than under cooler conditions. As the temperature in October and November is lower, more time has to be given to let water penetrate into the grains properly. The soaked wheat seed is taken out and divided into nearly five equal lots.

About 10 gallons of ordinary water are put in each of the two tubs, and hot water from the *Hamams* is run into them until the level of water is brought up to the 25 gallons' mark and the thermometer shows 56°C. Then one lot of the soaked wheat, carried in a cloth sheet, is dipped in water in tub No.1 for five minutes. The grains are shaken by means of a stirrer. The temperature will fall to about 48-50°C. Wheat is then taken out and immersed for 7 minutes in tub No.2, where the initial temperature of water is also 56°C. The grains are stirred and the temperature falls to about 55°C. If it drops further it should be kept at 54.5°C or above but not beyond 56°C during the required immersion time of 7 minutes by adding hot water. In case the temperature does not fall below 54.5°C hot water need not be added.

The treated seed is then spread out in the shade on a cloth sheet to dry. The remaining four lots of wheat are treated in the same way successively. By this method 350 kg of seed can be conveniently treated in a day of 8 hours with one set of equipment. The treated seed should not be dried under the sun which can markedly impair the germination because of double treatment i.e. hot water and solar heat.

The treated seed after drying can be sown immediately or if desired, can be stored for two months but thorough drying is essential previous to storing to protect the seed from mold fungi.

As the germination of seed is likely to be reduced by about 5% on account of heat, it is recommended that the seed rate should be increased accordingly in order to get a normal stand.

Single-Bath Sun-Heated Water Method

Similarly further experiments carried out have shown that soaking of seed at 40°,43° and 46° C for 8,6 and 4 hours respectively, is adequate to get rid of the disease (Fig.2.2).

On the basis of these results single-bath sun-heated water method was evolved. This method is as follows:-

A galvanized iron vessel (35 cm high and 45 cm in diameter) blackened from outside, is half filled with water and placed in the sun in the morning at 8 O'clock on a bright sunny day in summer. The seed is added at 12 noon, when the temperature of water rises to 35-38° C. At 2 pm the temperature further rises by 2-5° C and at 4 pm it often reaches 45-54° C. The seed is then taken out and dried in the shade and stored till sowing time.

Solar Energy Method

Later experiments, which have been carried out with a view to utilizing the solar energy in getting rid of the disease, have yielded a very simple and fool-proof procedure, which has been named the "Solar Energy Method". In this case seed is soaked in water for four hours (8 a.m to 12 noon) on any bright sunny day; then it is taken out and exposed to the sun in a thin layer till it dries thoroughly.

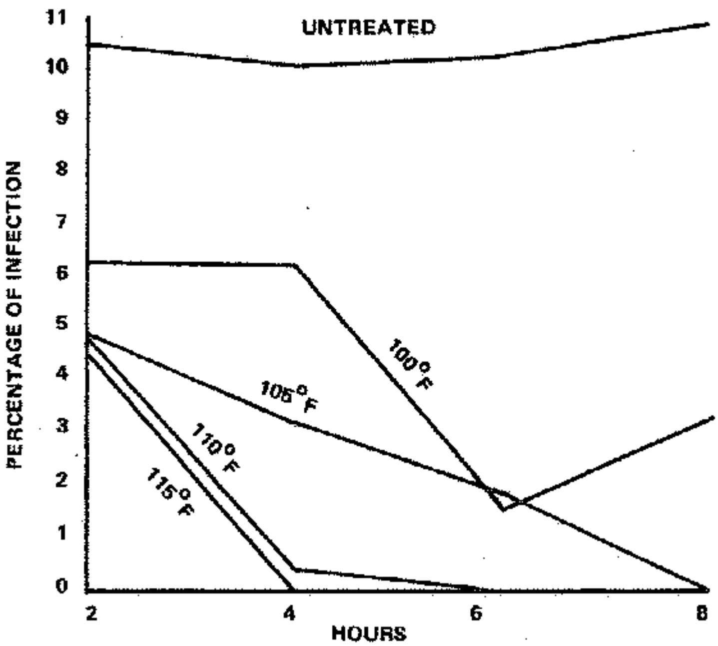


Fig 2.2 The efficiency of single bath sun-heated-water-method in controlling loose smut of wheat.

It has been found that in localities where maximum temperature under shade goes above 38° C, "Solar Energy Method" is efficient. This method is, therefore, recommended in all the districts of the plains while in hilly tracts simplified method of "Hot Water Treatment" is recommended. The underlying principle of this treatment includes activation of dormant mycelium by soaking, followed by its killing with high temperature. These methods can be used either by individual farmers for treating their seeds or by seed producing Agency for the treatment of basic seed to be multiplied into certified seed.

Treatment with Systemic Fungicides

Control of diseases caused by embryo-borne infection through systemic fungicides is an important milestone. Studies carried out in Pakistan with infected seed of Sonalika and in Denmark with cultivars MY-1329 and Maris Ranger by using three systemic fungicides namely, Triadimenol, Fenfuram and Carboxin in Pakistan and Fenfuram in Denmark have shown

100 per cent effectiveness of Fenfuram at the rate of 2g/kg with an increase of 8-15 per cent in yield both in Pakistan and Denmark. Triadimenol can also effectively control the disease while Carboxin does not completely eliminate it. Similar results have been obtained with Vitavex, Benlate, Topsin M, Panoram and Baytan at the rate of 2.5 g/kg. Solar energy method is as effective as systemic fungicides. However, in view of high cost, the use of systemic fungicides is recommended for treatment of basic seed to be multiplied into certified seed at the seed multiplication farms or use of solar energy method should be encouraged.

Use of Resistant Varieties

Plant pathologists have been testing the contemporary cultivars from time to time for resistance against loose smut and have found substantial varietal differences. In one study during 1968, thirty three varieties have been arranged into six groups (0-6% lowest and 61-100% highest) according to the scale suggested by Aamodt (1930). Seven varieties, H. Rojo, L. Rojo, W-274, Mexi Pak, Penjamo 62, H.23-42 and (CH 53 X N 10) Y-54 have fallen in the first group, C-591, 5747, Nainari 60 and Drik in the last group and others in between, showing high susceptibility of local varieties (excepting H 23-42). The reactions of present cultivars are given in Chapter XX. It has also been reported that varieties with more closed glumes show greater resistance and this morphological character can be successfully incorporated into the breeding programmes. The use of high-yielding varieties resistant to loose smut is a practical and economical method of controlling the disease as well as of reducing the chances of its spread and multiplication over the years.

2. Flag Smut, *Urocystis tritici* Koern

Occurrence

In the unpartitioned Punjab, flag smut was first noticed in 1906 at Faisalabad by Butler. Later on it became widely prevalent in Gurdaspur, Ferozepur, Hoshiarpur, parts of Ludhiana, Ambala and Kangra districts of India, with an average incidence of 5% and upto 60-70% in individual fields. In Pak Punjab the disease causes about 1% damage of the wheat crop sown in the districts of Campbellpur, Sialkot, Gujrat and Jhelum. As a result of cultivation of Barani-70 and Pothohar, upto 12% incidence was recorded during 1972-76 period. The disease destroyed 70% plants of Barani-70 at the Agricultural Farm, Rawalpindi in 1972-73 and was found to be present in the districts of Rawalpindi, Campbellpur, Sialkot and

Loralai. It can be a potential threat in the rainfed areas, if susceptible varieties are cultivated continuously.

Symptoms and Progress

The disease appears on the leaf blades in the form of black swollen streaks running parallel to the veins. These streaks, when ruptured, expose a black powder consisting of multitudes of spores. The affected leaves assume a drooping form, which is followed by withering (Fig.2.3).

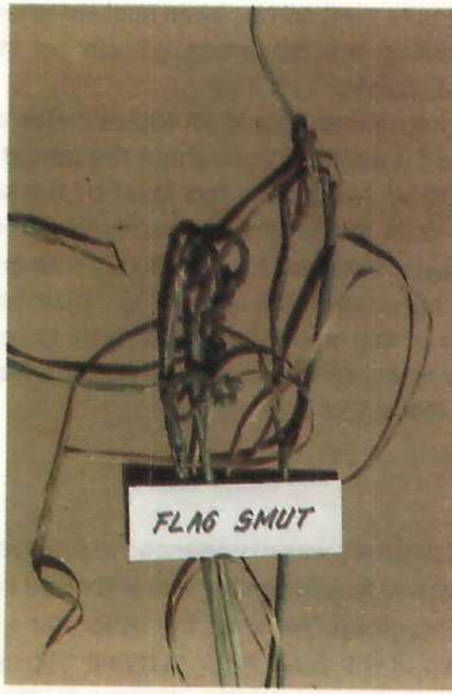


Fig. 2.3: Flag smut of wheat.

As a rule every shoot of the plant is infected in the case of a susceptible variety.The tillering capacity of the infected plants is decreased by 30 to 75%. Eighty-five to ninety per cent of infected plants fail to produce ears and where the ears develop the few grains produced are shrivelled.

The earliest recorded lesions have been observed on 40-day old plants and this period varies from 40 to 71 days. The disease may appear on plants in any stage of growth, but it has not been observed to appear after 10th of April at Lyallpur and Gurdaspur.

The maximum number of infected plants appears in the 2nd, 3rd and 4th weeks of February and after that the number declines.

METHODS OF SOIL INFECTION AND POT EXPERIMENTATION

Soil Infection

A good deal of difficulty was experienced in the beginning in securing an adequate soil infection in field experiments with the spores of *Urocystis tritici*. Moreover, big quantities of smutted material were needed to infect the soil on a large scale.

The following simple method has been evolved after intensive experimentation for obtaining the maximum amount of infection with the minimum amount of spores.

The spores are kept buried in a small sub-plot after crop is harvested. The plot thus infected is watered throughout the period at regular 7 days intervals. At the time of sowing the top layer of the soil is worked out into a fine tilth and used in infecting the required plot by putting it over the seed in a thin layer, followed by covering it with an ordinary soil.

Thus it may be concluded that in order to obtain high percentage of infection in the case of flag smut of wheat, spores to be used, must have been kept under moist conditions in the soil for a period of a few months before conducting the actual sowing.

Pot Experiments

Similarly, great difficulty was experienced in producing artificial infection in pots in the case of flag smut of wheat and other smuts belonging to the seedling infection group. While on the other hand it was easy to reproduce the disease in the field. After carrying out experiments, it has been found that the incidence of the disease in pots varies in direct proportion to the depth of sowing probably due to the fact that seeds sown at greater depths take longer time for their shoots to reach the soil surface and hence more infection is produced. In addition to this, it is also observed that the highest percentage of infection occurs if the soil moisture varies between 8.5 to 11.3 per cent during the germination period and the incidence is reduced to a great extent when sowings are done in wet soils, on account of the unsuitability of the higher moisture contents of the soil for the germination of spores. It is thus seen from the nature of the results that the failure to produce artificial infection in pots is mainly due to two factors, namely shallow sowing and daily watering of the pots. The former is responsible for promoting the early emergence of the seedlings and thus reducing the period for which the seedlings remain liable to infection while the latter results in increasing the moisture contents of the soil and thereby creating unsuitable conditions for the germination of spores. Hence a method of conducting pot experiments has been developed and standardized in which case these two important points have been given due consideration. Use has been made of large-sized earthen pots in order to accommodate large quantities of soil to permit the germination of the seedlings without further application of water to the pots. Secondly, care is exercised to sow the seed at a depth of not less than 8 cm in order to prolong the emergence period during which the seedlings are liable to be infected and thirdly care is taken not to water the pots till all the seedlings have emerged. The technique described above has been found to be very suitable and efficient not only for conducting artificial infection experiments on flag smut of wheat but also in other smuts like covered smuts of barley and oats (*Ustilago hordei* and *U. kolleri*), loose smut of oats (*U. avenae*), grain smut of sorghum (*sphacelotheca sorghi*) and sugarcane smut (*U. scitaminea*), where seedling infection takes place.

Germination of Spores

Germination of spores can be obtained by presoaking them in water for three days and then transferring to a watch glass containing diluted sap solution extracted from freshly germinated wheat seedlings. The watch glass is covered by another watch glass after applying a thin layer of vaseline to the edges and then kept at 22-24° C for 18 to 24 hours.

The germination is very much influenced by sealing the watch glass in which spores are kept. This is probably due to some beneficial effect of certain volatile substances coming out of the sap solution. The germination of the spores is more than 50 per cent when small pieces of infected leaves are used as compared with the use of powdered spores alone with 22 per cent germination. The minimum, optimum and maximum temperatures for the germination of the spores are 15°, 22-24° and 27-30° C, respectively.

Modes of Perpetuation

The disease has been found to be carried over from year to year by the following two methods:-

i) The disease is produced by sowing seed which becomes contaminated with the spores at the time of threshing and winnowing;
ii) The disease is perpetuated through soil contamination with diseased straw of the previous wheat crop. Plants may also catch infection if seed is sown in soil containing either compost manure prepared from diseased wheat straw or dung obtained

from animals fed on diseased straw.

Soil-borne infection is more important than seed-borne infection under natural conditions (Table 2.1).

Table 2.1: Mode of perpetuation and relative importance of seed and soilborne infection.

Year	Percentage of infection-Av. of 3 replications		
	Inf. seed healthy soil	Healthy seed inf. soil	Inf.seed inf. soil
First	46.2	37.9	55.6
Second	21.7	51.7	67.8
Third	25.2	53.6	68.5

Viability and Longevity of Spores

The spores of *Urocystis tritici* have been found to remain viable and retain their infective capacity in soil for at least four years under natural conditions at Lyallpur (Table 2.2).

Table 2.2 Viability of spores of *Urocystis tritici* under natural field conditions in five successive years.

	Percentage Infection			
Year	Plot A	Plot B	Plot C	Plot D
Base Year	27.0	27.0	27.0	27.0
First	41.1	Fallow	Fallow	Fallow
Second	44.6	17.9	Fallow	Fallow
Third	57.1	28.9	5.1	Fallow
Fourth	62.3	34.5	9.7	0.2

The spores can retain their infective capacity in compost manure prepared from diseased wheat straw. They can also remain viable even after passing through the alimentary canals of the farm animals.

Factors Influencing the Incidence of the Disease

Relation to Temperature

The minimum, optimum and maximum soil temperatures required by spores of *Urocystis tritici* to cause infection are 10° C, 15.5° C to 24.8° C and 29° C, respectively, producing 15, 50-70 and 14% infections.

It has been proved that under Lyallpur conditions wheat sown in the first fortnight of October is absolutely free from the disease even under artificial conditions of high infection; when sown in the second fortnight the incidence of the disease varies from 0 to 2.0 per cent. The intensity of the disease increases gradually with the delay in sowing till it reaches 70-80% in wheat sown in the third week of November. This high percentage of infection is maintained in all the sowings carried out up to end of December.

Relation to Moisture

The highest percentage of infection occurs at 8.5 to 11.3 per cent moisture content of soil during the germination period and the incidence of the disease is reduced by 38 to 50 per cent when the moisture content of the soil is kept at 18.0 to 21.7 per cent.

The incidence of the disease is two to three times higher if infected seed is sown in healthy or infected soil with 8-11 per cent moisture as against sowings in dry soil, watered immediately afterwards. Application of water either 12,24 or 48 hours after sowing reduces the incidence of the disease but the amount of reduction becomes proportionately less and less with delayed watering and showing no reduction when water is applied six days after sowing.

Relation to Depth of Sowing

The incidence of the disease increases with the depth of sowing. From 2 to 7.5 cm the percentage of disease increase is much more than from 7.5 to 12.5 cm. This happens because in deeper sown seeds more time is taken by the seedlings to emerge, rendering them liable to infection for a longer period.

Relation to Previous Summer Rainfall

The incidence of the disease caused by soil-borne spores is directly influenced by the amount of rainfall in the previous summer. The disease intensity is six times higher at 400 mm. as against 75 mm. This factor is the most important in the distribution of the disease, which is prevalent mostly in the districts where the summer rainfall is above 425 mm. This is in accordance with the results already mentioned under method of artificial soil infection where it has been stated that the infective capacity of the spores is increased if they are kept buried in soil during summer under moist conditions.

Control Measures

Disinfectants

Seed treatment with disinfectants such as copper carbonate, powdered copper sulphate at the rate of 4g/kg and formalin (dipping the seed in a solution containing one part of formalin in 320 parts of water for three minutes and then covering under moist gunny bags for two hours and finally drying it before sowing) is effective to check 70-85 per cent of the seed-borne and 10-40 per cent of soil-borne infections. Efficiency of these disinfectants is reduced in highly infested soils. As copper sulphate and formalin treatments may reduce the germination of seed, it is recommended to increase the seed rate to maintain optimum crop stand. However, copper carbonate has no injurious effects on seed. Ceresan has been found to check 70-90 per cent of seed-borne as well as soil-borne infection. Seed treatment with ceresan at the rate of 4 g/kg is therefore, recommended in the infected localities. The new promising fungicides are Baytan, Vitavex, Benlate, Topsin-M and Panoram.

Rotations: Leaving the field fallow for at least two season reduces the incidence of the disease considerably provided such fields are not contaminated from the adjacent infected crops. Green manuring with guar (*Cyamopsis psoralioides*) reduce the disease incidence by about 25 per cent.

Roguing: The disease can be checked considerably by roguing out and burning the infected plants as soon as they appear during the growing period.

Date of Sowing

It has been proved that under Lyallpur conditions wheat sown in the first fortnight of October is absolutely free from the disease, even under artificial conditions of high infection. When sown in second fortnight, the incidence of the disease varies from 0 to 2.0 per cent only. In order to obtain a crop almost free from the disease it is advisable to sow the crop at times when the soil temperature is above 27° C. It may vary from locality to locality. This condition is prevalent during first fortnight of October in the central and sub-montainous districts and in second fortnight at Lyallpur. It has been found out that sowings done in the fourth week of October at Lyallpur have given quite normal yields.

Methods of Sowing

The disease incidence is reduced by about 50 to 75 per cent when seed is broadcast in moist soil and by 75-94 per cent when broadcasting is carried out in dry soil to which water is applied immediately afterwards as against plantings done by drilling in moist soils.

In moist soil, water applied one, two or three days after sowing, helps to reduce the incidence of the disease, but the reduction is almost indirectly proportional to the delay in the application of water.

In the late sowings wheat broadcast in dry soil and watered immediately afterwards out-yields the one sown by normal method. As in the case of early sown wheat, the percentage of germination of wheat seed is not reduced, it is presumed that the yield will also not be lowered

Sowing Methods and Seed Disinfectants

The efficiency of copper carbonate and Ceresan for reducing the the incidence of the disease is still increased when the infected seed treated with these chemicals is sown in dry soil followed by immediate watering.

Ceresan has shown its superiority over all other seed disinfectants so much so that under Lyallpur conditions the incidence of the disease was almost negligible when infected seed treated with Ceresan was sown, even at 12 cm depth in highly contaminated dry soil which was watered soon after sowing. When infected seed treated with either copper carbonate or Ceresan was sown in a moist field irrigated within three days of sowing, the reduction in the disease incidence was similar to that shown by infected seed, without dusting, which was sown in dry soil receiving immediate irrigation.

Resistant Varieties

It has been proved that in order to find out the true resistance of wheat varieties to flag smut, the varietal trials should be carried out under conditions of high infection and seasonal variations. This has been done by studying the incidence of the disease in different types of soil for a number of years by sowing seed wheat coated with the spores of *U. tritici* in highly infected soil. It has been found that the percentage of infected tillers is directly correlated with the susceptibility of a certain variety consequently reducing the yield proportionately. The incidence of the disease should, therefore, be recorded on the basis of the infected tillers.

The Punjab durum types 1, 2 and 3 and an Australian variety Nabawa are almost immune to flag smut while Imperial Pusa types 4, 80-5 and 111 are highly resistant. Out of the 926 varieties/lines tested during 1972-76, 111 remained resistant for three years, providing useful sources of resistance, which need to be exploited. Since none of the 28 present cultivars (Chapter XX) is resistant, therefore dry broadcasting of disinfected seed wheat should be resorted in areas of high infection. However, in recent studies out of 74 only three varietis namely (Triticale 183, K-342 and Naeem 82) have shown resistance.

Physiological Specialization in *Urocystis Tritici*

Flag smut of wheat (U. tritici) is known to occur in almost all the wheat growing countries of the world. As regards its physiological specialization, twelve races have been described to exist in China and two races in the United States of America. No work had been done elsewhere to compare collections of *U. tritici* from different countries. Such an attempt has been made with eleven collections from United States of America, Australia, China, Italy, Cyprus and Indo-Pakistan sub-continent. The following main conclusions are drawn from the results of these investigations:

a. Four collections, namely, the Australian, the two Italian and the American race No.2 are similar and constitute one race, which is however, different from those occurring in Southern China;
b) The two collections from the sub-continent of Indo-Pakistan are identical and represent a separate race;
c) The cyprus collection might resemble one of those from China which are in fact three separate races from that country. This remained unconfirmed on account of the fact that the differentials got from China gave very poor germination.

3. Septoria Leaf Spot, *Septoria* spp.

Septoria is a common disease of wheat as it occurs almost throughout the country. A comparative study of the local isolate with two cultures of *Septoria tritici* Desm. and *S. nodorum* Berk obtained from Centraabureau Schimmelcultures, Baarn; Holland has been made as regards their morphology and physiology. Mode of perpetuation and measures to control the disease have also been studied.

Symptoms

The local isolate attacks leaf and leaf sheaths producing more or less circular or oval irregular spots studed with black pycnidia. Stems and awns are rarely attacked without any definite spot but the pycnidia are present. Under artificial conditions of inoculations *Septoria tritici* produced similar symptoms, while *S. nodorum* developed small, irregular chocolate brown spots mostly on glumes giving rise to black dotted pycnidia (Fig. 2.4).

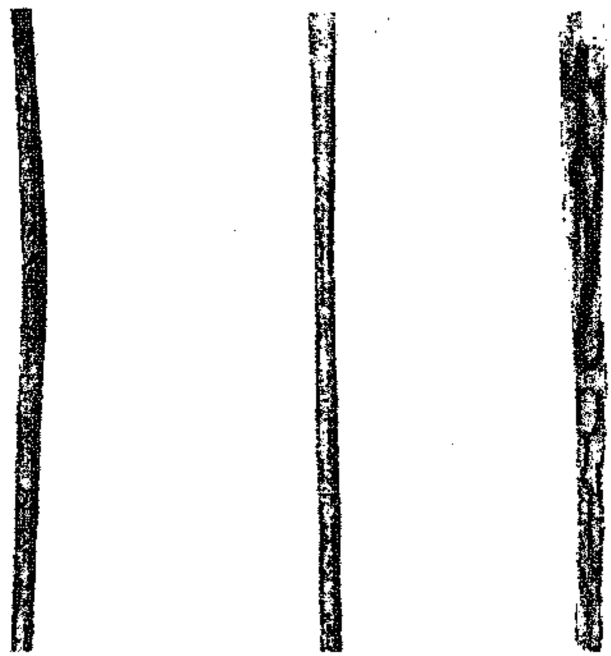


Fig. 2.4: Septoria of wheat: Local sp. on (a) leaf, (b) Sheath and (c) Stem.

Morphology and Physiology

The results of the comparative studies on size of pycnidia, pycnospores, septation, temperature and pH requirements of the three cultures are given in Table 2.3.

Table 2.3: Morphological and physiological characteristics of the three *Septoria* cultures.

Characteristics	Sepotria cultures Local isolates	*S. tritici*	*S. nodorum*
Pycnidial formation	Forms pycnidia on all Media	Same as in local isolate	Forms pycnidia only on oat meal agar and potato dextrose agar

Size of pycnidia	150x100µ	150x100µ	109x92µ
Size of pycnospores	55x2.6µ (also produces conidia)	55x2.6µ	21x3.6µ
Septation of pycnospores	1-4 septate with higher frequency of 3 septate	2-5 septate with higher frequency of 3-4 septate	1-3 septate with higher frequency of 3 septate
Growth rate	Comparatively slow	Same as in local isolate	3-4 times faster than the other two cultures with abundant aerial mycelium
Growth temperatures	Optimum 20° C Maximum 25 to 30° C, Minimum 5° C.	Same as in local isolate	Same as in others
Growth pH	Optimum 4.6-6 Maximum 3 Minimum 9	Same as in local isolate	Optimum 3-8
Pathogenicity and Inoculation period	Virulent parasite on wheat only. 14-16 days	Virulent parasite on wheat only. 14-16 days	Virulent parasite on wheat only. 14-16 days

Thus it may be concluded that the local isolate of *Septoria* is identical in almost all essential respects with *Septoria tritici* and differs distinctly from *S. nodorum,* which has shorter pycnidia and pyconospores with lower septation, faster growth and production of aerial mycelium in culture besides its attack on glumes of wheat only and rare occurrence on leaves in nature.

Perpetuation and Spread

The pycnospores of the fungus, embedded inside the pycnidia on the diseased wheat straw (used for storing *wheat chaff*), remain viable throughout the summer and cause infection in the next season.

The fungus also remains viable in chaff made from diseased straw and also in diseased leaves which may remain lying on the surface of the

*Oat meal agar, Potato dextrose agar, Brown's agar, Czapeck's, Wheat leaf decoction and Onion leaf decoction.

soil during summer, serving as a potential source of inoculum. The spread of the disease takes place through wind and rain.

Control Measures

The disease can be controlled by suppressing the sources of infection, but in practice it faces several difficulties. The relative resistance of the Punjab wheat types has, therefore, been studied and it has been found that the durum types 1,2 and 3 are almost immune while Compactum and Vulgare types are susceptible to the disease. Work needs to be done on the development of resistant and high-yielding varieties.

4. Foot Rot, *Helminthosporium sativum* Pamm, King and Bakke

Foot rot of wheat, commonly known as *Ukhera* and erroneously attributed by the farmers to white ant attack, is a serious disease in the seedling stage. The incidence may vary from place to place and from field to field. It is more severe in the rainfed areas than in the irrigated tracts. Fungi isolated from root rot affected plants in different parts of the country comprised in order of predominance and adverse effects, *Helminthosporium sativum* (72.3%), *Fusarium* sp. (19.7%) and *Alternaria* sp. (8%). *Helminthosporium sativum* has also been found to cause leaf spot disease of wheat in the Hyderabad region ranging between 2-7 per cent. It appears on lower leaves forming oval to oblong spots (upto 1 mm. in diameter), which gradually enlarge turning the leaves brown but causing negligible damage.

Symptoms

The attack of the disease has been found to start soon after the emergence of the seedlings from the soil. In severe cases the seeds as such may even rot in the soil and thus affect the germination very badly. The rootlets of the infected plants are completely destroyed and the basal portions exhibit a greyish brown tinge containing dark brown lesions of the causal fungi. In some cases, the disease may re-appear in the months of March and April when the temperature again becomes favourable for its development and thus it gives rise to deaf ears (white coloured ears without grains) which results in low yield. In brief, it causes pre-emergence blight and seedling mortality as well as reduced germination, number of ears, number and weight of grains and grain yield. It may also cause brown leaf spot of varying size (Fig. 2.5). The infection from three fungi (*Helminthosporium, Fusarium* and *Alternaria*) has proved more harmful than each of them alone.

Fig. 2.5: Foot rot of wheat.

Cause of the Disease

a) The disease has been found to be caused mainly by the fungus *Helminthosporium sativum,* which is sometimes accompanied by *Fusarium* and *Alternaria* spp. also;
b) The fungus causing foot rot and the one producing leaf spot are identical.
c) Black-pointed wheat grains infected with *Helminthosporium sativum* can also cause foot rot, when sown in the field.

Perpetuation

a) Wheat grains infected with black-pointed ends give rise to diseased wheat plants;
b) The infected debris and dead seedlings contaminate the soil with causal fungi, which also give rise to the infected crop next year.

Factors Influencing the Incidence of the Disease

The optimum temperature for the growth of the fungus has been found to be between 25°C and 30°C. The infection is, therefore, greatly reduced at lower temperatures with the result that the crop sown in 3rd week of November remains practically free from the disease.

Soil moisture above 16 per cent reduces the infection both in pots and in the field. Moreover, when wheat is sown in dry soil to which water is applied immediately afterwards the incidence of the disease goes down by 40 to 50 per cent. Plant mortality is reduced by 40-60 per cent in case the first irrigation is applied 15 days after sowing against the control where irrigation is applied 35 days after sowing.

The incidence of the disease decreases with the reduction in the depth of sowing. It is further reduced (by about 80%) if shallow seeding is done in dry soil, to which water is applied immediately afterward.

When complete plant food material (Helner's solution) is supplied to the plants, the incidence is insignificant and on the contrary, it is the highest in cases where nitrogen or phosphorus are omitted. The same type of results have been obtained in the field under manurial experiments where green manuring or the application of well rotten farm-yard manure reduced the incidence of disease by about 60 per cent. Later experiments have confirmed that low nutrient concentrations, which tend to weaken the plant growth, can stimulate the pathogen activity, resulting into higher infections. This shows the usefulness of balanced fertilizer application for controlling the disease. Similar results have been reported in case of root rot of barley and blight of rice.

Control Measures

The following control measures have been emphasized:

Seed dusting: Dust the seed with either powdered copper sulphate or Ceresan at the rate of 2 g/kg. Out of the six fungicides (Dieldrex, Granosan M, Granosan N1, Agrosan GN, Arasan and Delsan) tested recently, Dieldrex has given the best results in increasing seed germination, reducing seedling mortality, enhancing tillering, earing and number and weight of grains.

Cultural methods: Sow the crop in dry soil and then irrigate the field immediately afterwards. Delay the sowing till the 3rd week of November and apply the first watering 15 days after sowing.

Varietal resistance: None of the varieties is resistant to the disease except Punjab types, 4, 7 and 9 in which case percentage of infection varied from 2.1 to 2.7 as against 10-20 per cent in other varieties.

5. Black Point Complex, *Alternaria, Helminthosporium* etc.

Occurrence, Symptoms and Control

This disease, first noticed in 1948, is quite commonly found in various wheat cultivars grown in different parts of the country, particularly in humid localities or under wet conditions during harvesting and threshing. The complex microflora comprising species of *Alternaria, Helminthosporium, Fusarium, Curvularia* and *Stemphylium* infect the grains in the field causing shrivelling and development of black ends. Such infected grains reduce the quality of the produce, seed germination, number of seedlings and tillers as well as the yield (Fig. 2.6). Although no work has been done on the control measures, protecting the crop from humidity during harvesting and threshing operations, drying the grains under the sun before storage and seed disinfection can greatly help to check the disease.

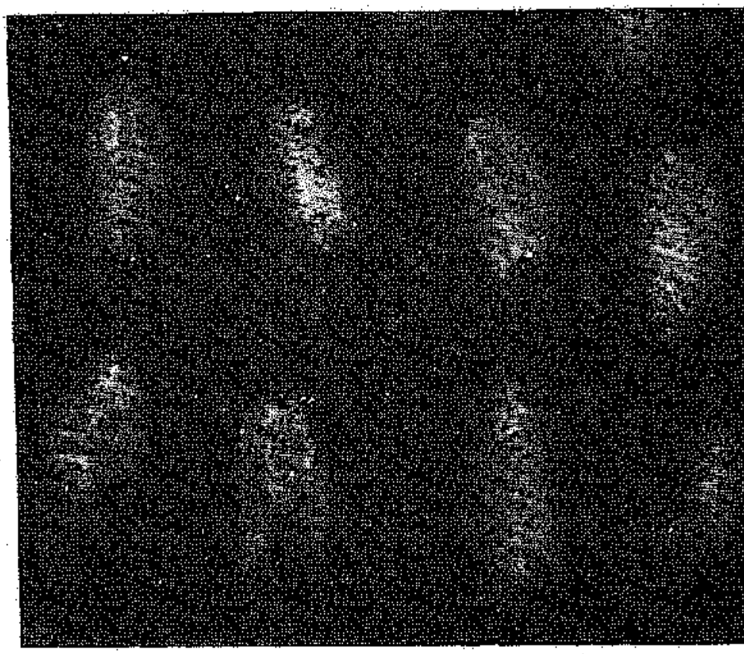
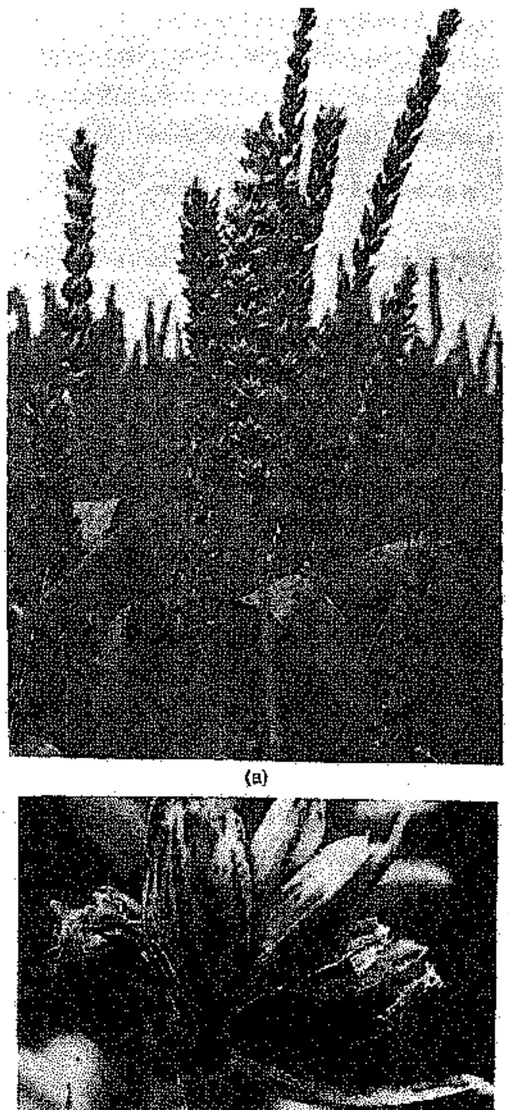


Fig. 2.6: Black point, Complex of Wheat.

6. Bunt or Stinking Smut, *Tilletia tritici* (Bjerk) Wint.

Occurrence and Symptoms

Bunt is an important disease of wheat. It mostly occurs in the hilly tracts of Murree, North Western Frontier Province and Baluchistan; causing on an average 20-25 per cent damage, which may increase upto 60-70 per cent in epidemic years. It is essentially a disease of wheat grains, which when formed are found to be filled with black powder of spores of the causal fungus instead of starch. These spores on crushing, give out an offensive smell like that of a rotten fish, spoiling the quality of wheat flour. Usually the diseased ears get very much reduced in size. But at Kulu (India) under severe conditions of soil infection the diseased ears have shown pronounced elongation which vary from 35-45 cm as compared with 10 to 14 cm in the case of healthy ears (Fig. 2.7).



(a)

(b)

Fig. 2.7: Complete bunt of wheat (a) Infected head (b) bunted grain.

Perpetuation

This disease, which was considered to perpetuate through contaminated grains in the Indo-Pakistan sub-continent, has now been definitely proved (by conducting experiments at Kulu for a number of years) to be carried over from one year to another both through seed-borne as well as soil-borne spores. This is also possibily true in Murree and Quetta hills.

Similarly, from the restricted occurrence of the disease in the hilly tracts, it was considered that the disease essentially belonged to the high lands. Now it has been definitely found out that it can be reproduced to a very high intensity even in the plains simply by delaying the sowing of artificially infected wheat grains till the end of December, when the soil temperature becomes suitable for the germination of spores.

Factors Influencing the Incidence of the Disease

The date of sowing, on account of soil temperature, has a direct influence on the incidence of the disease, which varies between zero, 1-30 and 30-74 per cent when wheat is sown in the second fortnight of October or in the second fortnight of November and during December, respectively.

The incidence of the disease increases with the depth of seeding. Hence the percentage of attack is more where wheat is sown by drilling as compared to sowing by broadcasting.

The spores have been found to survive and be capable of producing infection even after passing through the alimentary canal of farm animals.

Seed disinfectants like copper sulphate and copper carbonate can lower the incidence of disease to a great extent when wheat is sown in a healthy soil. Under infected soil conditions, Ceresan has proved much better than copper-based disinfectants.

The sixty-one wheat types tested at Lyallpur can be arranged in the following six groups according to their disease reaction, when seed of wheat was inoculated with spores obtained from Kulu proper (Table 2.4).

Table 2.4 - Varietal resistance to bunt of wheat.

Infection percent	Types/Varities
No infection	Pb. T.1, Pb. T.2, Pb. T.3, Pb. T.6 and Pb. T.15
1 – 5	C.245, C.247, C.248, C.217, C.296, C.275

6 – 20	T.5, T.6, T.7, T.8, T.10, T.11, T.12, T.13,T.14, T.15, T.16,T.22,T.23,T.25,8.A,9.C.9D,C.409,C.499,I,P,4, I.P.12, I.P.80-5, I.P.111, I.P.114, C.250, C.256, C.258, C.262, C.270.
21 – 40	T.9, T.18, T.19, T.20, T.21, 8B, C.231, C.244, I.P.52, I.P.120, I.P.150, C.237.
41 – 70	T.24, T.217. C.228, C.230, C.518, I.P.101.
More than 70	C.215, I.P.165.

Control

Copper-based or organo mercurial seed disinfectants have proved effective in controlling the seed-borne infection and the latter soil-borne infection also to some extent. While experiments on seed treatment with a new group of fungicides carried out during 1976-78 on artificially inoculated seeds (2-3 g spores/100 g seed) have shown the best control by Vitavex 200 at the rate of 2.5 g/kg seed, followed by Vitaflo (5 g/kg) and R.H.124 (2.5 g/kg) and the reductions obtained were 98.6, 90.0 and 89.2 per cent, respectively. In recent experiments, seed treatment and Nitrogen fertilization have almost doubled the yield in Baluchistan.

Soil disinfectants so far tried have not yielded good results but in the case of formalin and toluene the incidence of the disease has been lowered down by 63 and 31 per cent, respectively. As soil disinfection is laborious and costly, the combined use of resistant wheat varieties and seed disinfectants will be practical and economical under such conditions. Out of the present cultivars the variety Zamindar has proved to be resistant while Zarghoon and Khyber 79 have shown intermediate reaction. The remaining 25 varieties are susceptible.

7. New Bunt or Partial Bunt, *Neovossia Indica (Mitra)* Mundkar

Occurrence and Symptoms

As new bunt of wheat was first recorded in the year 1933 by Mitra from Karnal, it is also called Karnal bunt. At that time on examination of 10 years' old samples of wheat grains at Lyallpur, a few diseased grains were found, which showed that the infection had been present in the Punjab since long. The disease attracted attention only when its incidence increased due to the cultivation of new improved types particularly I.P. 52, which happened to be very susceptible. However the disease is restricted to the foot hill districts and is found in traces (2-5 per cent) and sometimes upto 20 per cent in susceptible varieties like C-273.

The disease is not noticeable till the grain formation has taken place. When the grain ripens, the diseased spikelets are more open, the outer glumes spread out giving enough space to the inner glume and the palea to expand with the result that the bunted grains become visible between the glumes. In badly infected spikelets, the glumes spread apart and later on fall off, thus exposing the bunted grains, which also fall to the ground with the slightest disturbance. It has been seen that only individual grains are attacked and they are also partially affected, generally in the grooves or at the tips of the grains (Fig. 2.8). In the diseased portion, spores like those of complete bunt are produced but their size is almost double. The diseased grains, if present in high percentage, can spoil the quality of the wheat flour.

Mode of Infection

It has been found that infection takes place by air-borne sporidia when the wheat ears are in preanthesis stage. In nature, the spores shed in the soil at the time of threshing and winnowing, remain viable till the succeeding months of January, February and March, when they germinate and produce sporidia. They being lighter than air, are carried by wind and fall on developing individual grains where they grow and cause infection of grains in the same season. The pathogenicity of the fungus has been

Fig. 2.8: Partial bunt, wheat grains showing infection of groves and tips.

proved through artificial inoculations carried out with the culture of the fungus in preanthesis stage of the ears. Experiments carried out to test seedling infection by seed-borne and soil-borne-spores have so far given negative results.

Factors Influencing Disease Development

It has been found that weather conditions prevailing at the time of ear and grain formation exercise a profound effect on the disease development. In the absence of adequate rainfall at the time of ear emergence during February and March, the disease does not appear, whereas in years with high rainfall during this period the disease is very much pronounced.

The time of sowing has been found to influence the incidence of the disease indirectly in so far as it affects the time at which ear formation takes place. Early sowings are infected more severely if rains in the spring are early and similarly late sown crops are attacked more if the rains set in late. Therefore, no definite sowing dates can be recommended for raising wheat crop free from new bunt. Further it has been seen that the incidence of the disease is always comparatively higher in the lodged crops due to prolonged high humidity.

Control

Because of the aerial and localized nature of the infection, the disease cannot be controlled with seed disinfectants. The only possible approach is to use resistant varieties. Out of the present 28 cultivars, only one variety i.e. Yecora has been found to possess medium resistance under artificial conditions of inoculations. Adjustments in time of sowing and long range rotations can also help to eliminate or reduce the incidence of the disease.

8. Ear Cockle, *Tylenchus Tritici* **(S) Bast***

Occurrence, Symptoms and Perpetuation

Ear-cockle disease of wheat is of common occurrence and is mostly found in the districts of Dera Ghazi Khan, Muzaffargarh and Jhang, especially in areas irrigated by tube wells. It was first reported from Baluchistan in 1948 in traces and steadily became quite serious, causing 10-15 per cent damage. The disease may be noticed in young plants by the wrinkling, rolling and distortion of the leaves and enlargement of the stems of the affected shoots. The effects of the disease are very much pronounced in the heads, which are generally twisted, yellowish. sticky and remain green for a

*As rule it should have been included in chapter XVI on nematodal pathogens but for its earlier investigations along with fungal diseases.

longer period and are shorter than the normal ones. The infected grains are black,round,hard and shortsized.They are called galls,which on breaking reveal the presence of a large number of eel-worms when seen under the microscope(Fig.2.9). The disease perpetuates, from year to year through galls mixed with the seed or those lying in the soil. The eel-worms cause infection in the seedling stage. It has been seen that the eel-worms can remain dormant in the galls over a period of more than ten years, capable of causing infection when sown with the seed.

Control

It has been shown by experiments that ear-cockle of wheat can be controlled by sowing seed free from galls. The seed can be cleaned by win-

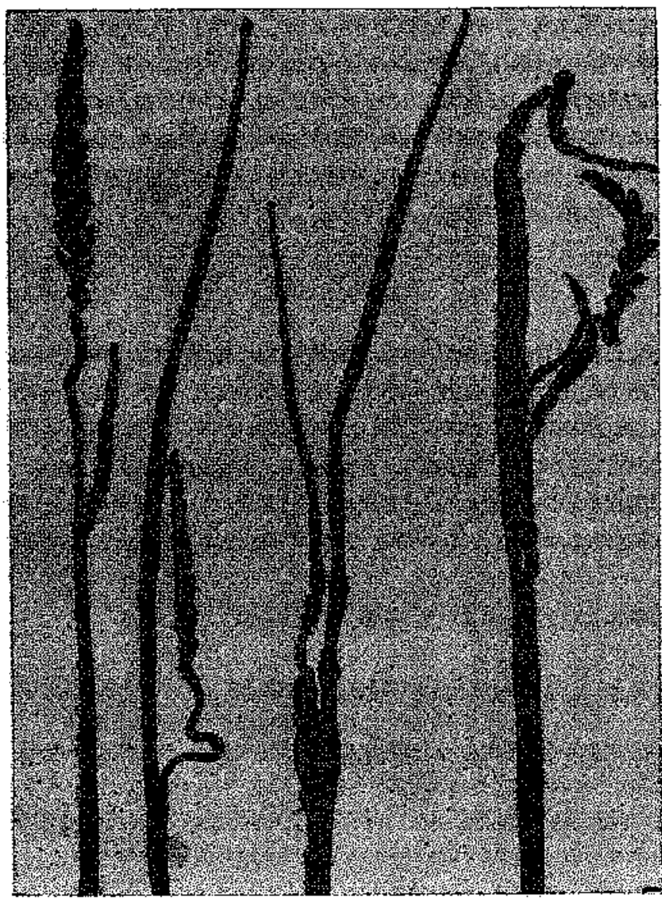


Fig 2.9: Ear Cockle of wheat showing distorted heads.

nowing and sieving or by immersing it in 2 per cent aqueous solution of common salt in which case the galls float on the surface and can be skimmed off very easily. Three nematocides (Nemagon, Nemaphos and Telone) have been tested in artificially infested fields achieving good control by using Nemagon at the rate of 2.5 gallons/acre. However, comparing with the floating method, the farm-application of costly nematocides is doubtful. In varietal trials six varieties have been found to be immune and twelve highly susceptible while the remaining thirty-one varieties showed various degrees of infection ranging between 5-20 per cent. Introduction of resistance into high yielding wheat varieties can be a practical approach, if jointly pursued by breeders and plant pathologists. Long-range rotation can also be useful for the control of soil-borne infection.

9. Rusts *Puccinia* spp.

Occurrence

All the three rusts (a) black or stem rust (*Puccinia graminis tritici*),(b) orange or brown or leaf rust (*Puccinia recondita tritici*) and (c) yellow or stripe rust (*Puccinia striiformis tritici*) are of major importance and periodically develop into epidemic forms causing heavy losses.

Stem rust used to be of wide occurrence throughout the country. It has now been contained with the introduction of resistant varieties from 1966 onwards.It appears generally by mid-February in the southern coastal region, by mid-March in the central region and by mid-April in the northern regions.

Leaf rust occurs widely, making its first appearance in the southern and coastal regions and by early March and April in the central and northern regions, respectively. Its incidence started increasing with the introduction of stem rust resistant varieties which happened to be susceptible to stripe and leaf rusts, resulting in an epidemic in 1978.

Stripe rust is generally confined to northern foothill districts and Quetta and to some extent in the central region, appearing in January and continuing upto March, depending upon the prevalence of low temperatures, causing more damage when it also attacks ears and grains (Table 2.5).

Table 2.5: Time of appearance of the three rusts.

	Regions			
Rusts	Coastal	Southern	Central	Northern
Stem rust	Mid-February	Mid-February	Mid-March	Mid-April
Leaf rust	Early-February	Early-February	Early-March	Early-April
Stripe rust	—	—	January	January-March

The incidence of the three rust varies from year to year depending upon the varietal pattern, favourable conditions of suitable temperatures and high humidity, succulent plant growth due to excessive use of inputs like nitrogenous fertilizers and irrigation water, and time of appearance of rust. The annual losses from rust have been estimated at Rs. 30-40 million while in epidemic years they are very large. For example, the 1977-78 epidemic of stripe and leaf rusts reduced the total wheat production by 2.2 million tons worth US$ 330 million.

Symptoms

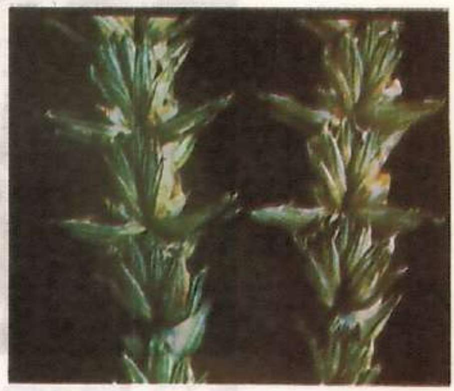
Studies carried out on the symptoms of the three rusts have emphasised the following distinguishing characters.

In case of stem rust, elongated, reddish brown pustules appear on leaves, stem and stem sheaths and ears. They increase in number and size ultimately rupturing the cuticle and disturbing the supply of water and rate of photosynthesis. Within the pustules, uredospores are produced which may repeat the cycle of infection several times during the crop season. On maturity black spores (teleutospores) are produced which over-summer on stray wheat plants at higher elevations or infect barberry plants (*Berberis* spp.) and produce new infections on next year's wheat crop. New races may also originate through hybridization on barberry plants. The damage done to the crop is quite heavy if the infection appears in developing stages of grains accompanied by sudden rise in temperature and prevalence of hot winds, resulting in lodging of crop and production of shrivelled and lightweight grains.

In leaf rust, the pustules produced are small, eliptical and yellowish-orange in colour. They develop scattered on the leaves and leaf sheaths and their number increases through repeated reinfections during the season. Early infections may even kill the plants while the late infections reduce the overall yield. The mature spores of leaf rust may over-summer in aecidial stage on *Thalictrum*, an alternate host plant.

The stripe rust appears on leaves, leaf sheaths and stems as small yellowish, pustules arranged in lines, resembling thread stitchings and may develop sometimes on the ears (out and inside the glumes filled with spores). Like other rusts, there are repeated infections during the growing season and over-summering on stray wheat plants in the hills. The damage caused depends upon the severity and time of infection, resulting into yield reduction (Figs. 2.10, 2.11 and 2.12).

(a)



(b)

(b) Head infection

Fig. 2.10: Yellow rust of wheat (a) Leaf infection

(a) (b)

Fig. 2.11: Brown or leat rust of wheat (a) Leaf infection (b) Stem infection.

It will be interesting to give below some of the salient features of the work carried out by Mehta, during pre-partition period under a rust scheme sponsored by the Government of undivided India.

Fig. 2.12: Black or stem rust of wheat.

Early Investigations

Germination of Spores

Teleutospores formed in the plains are not viable but those formed in the hills at lower temperatures can be made to germinate when after some period of rest, they are frozen for about one week in ice and then kept at about 4.4° C.

The failure to infect barberry plants in the beginning was due to the fact that the plants present in the Himalayas had been wrongly named as *Berberis vulgaris*. Later on it was possible to infect barberry plants raised from the seeds obtained from England.

Uredospores of black stem rust stored at 5° C under conditions of 50 per cent relative humidity, have remained viable for about one year.

Alternate Host Plants

Berberis lysium, *Berberis aristata* and *Berberis coviarie* are the three alternate host plants of *Puccinia graminis*. These have been found to play very little role in the annual outbreak of black rust in the plains, because the aecidia are formed on their leaves at such a time when the wheat crop in the hills is over and by the time the next wheat crop is sown, aecideospores are not in a viable form. Similarly, Thalictrum which is possible alternate host plant for brown or leaf rust, does not play any important role. No alternate host plants have been found for yellow or stripe rust.

Annual Outbreak

In the plains, the summer heat that follows the harvest, kills all the *uredospores* of the three rusts. Consequently there is no local source of infection when the next wheat crop is sown in the plains.

In the hills, on the other hand, all the three rusts have been found to over-summer in stubbles, volunteer wheat plants and out-of-season wheat crops at different altitudes ranging from 1350-2500 m. (Yellow rust from 2500-3000 m, leaf rust from 2000-2300 m and black rust from 1300-1600 m).

Wheat crops in the hills become infected rather early in the season in the neighbourhood of rusted volunteer wheat plants and the *uredospores* are disseminated by winds to the foot hills which are responsible for causing further infection in the plains.

The direction of air currents in the months of January, February and March has been found to be from hills towards the plains.

Spores of all the three rusts have been caught on aeroscope slides at a large number of stations in the plains before the local appearance of rusts, showing thereby that the spores are introduced through air currents coming from hills.

Black rust is able to withstand warm weather better than yellow rust, which thrives under cool conditions, the leaf rust occupies an intermediate position. As a consequence of temperatures prevailing during the growing season the yellow and leaf rusts are common during January-February and black rust in the months of March-April.

Physiological Races

As already mentioned under alternate host plants, the role played by barberry plants is of very little importance in the outbreak of rusts in Pakistan and therefore due to less frequent chances of hybridization the number of physiological races is also very small as compared to that found in foreign countries. Nine races of black rust, 8 of leaf and 10 of yellow rusts were discovered upto 1933 in the sub-continent of Indo-Pakistan.

Control Measures

Clean up campaign of self-sown wheat plants in the hills had been recommended in order to eradicate the foci of infection. This campaign, however, did not hold out any good promise on account of it physical impossibility and uneconomic nature. Suspension of wheat and barley crops in the hills was further recommended. This was also not practicable. The best method is to evolve rust resistant types of wheat.

Varietal Resistance

None of the wheat varieties was found to be resistant to all the races of the the rusts.

Post-Partition Studies

A good deal of work has been carried out during the post-partition period on the rusts at different research stations, especially under the coordinated programme of the Cereal Diseases Research Institute, initially started in 1955. The main achievements are given in Chapter XX showing that productive and well-coordinated research programmes have been in progress which have paid rich dividends in containing the three rusts. However, there is a need to continue and strengthen such programmes for safe guarding against the new physiological races in order to maintain stabilized production and avoid epidemics.

The salient features worth mentioning are that although during the past 50 years there have been fluctuations in the frequency of races, the number of races remained constant for leaf rust while it increased by 2 and 4 in case of stem rust and stripe rust, respectively (comparing with those reported by Mehta in 1933 (Table 2.6).

Table 2.6: Number of races of the three rusts reported in 1933 and 1982.

Rust	1933	1982
Stem rust	9	11
Leaf rust	8	8
Stripe rust	10	14

This is probably due to less chances of hybridization because of the little role played by barberry and other alternate plants in the sub-continent of Indo-Pakistan. It facilitates the breeding programmes unlike in European countries where the number of races is comparatively much larger. Moreover, these races have not shown any regional specificity as they are mostly present in the four provinces of Pakistan as well as in the countries of the Near East region. Amongst the alternate hosts, barberry and *Thalictrum* spp. have been found to help over-summering besides the volunteer wheat plants in hilly areas. It is interesting to note that *uredospores* of stem rust were found to over-summer in the experimental wheat plots sown side by side at weekly intervals during May-October, 1955-59 at the Tarnab Agricultural Research Institute (temperature going beyond 42° C). This shows that *uredospores* of *Puccinia graminis tritici* can survive high temperatures of summer, if fresh wheat plants are available for infection; which is contrary to the earlier conclusions reported by Mehta.

Since 1975, efforts are underway on the analysis of virulence genes in stem and leaf rust pathogen populations by testing them under green house and field conditions against the known monogenic lines containing Sr and Lr genes. Investigations on genetics of resistance carried out by Attaullah (a Pakistani Scientist) in Australia have shown that *Khapli* emmer possess two dominant genes for resistance to Australian stem rust strains 21-2 and 222-4 and one dominant gene to strain 126-1. The gene *Srt 1* conditions type 1-reaction to all strains while *Srt 2* produces 1-X type-reaction to strains 21-2 and 222-4. Both the genes have been found to produce additive effect. Adult plant resistance also depends upon the dominant genes, which are either same or closely linked with those responsible for seedling reaction in the green house. Similarly, two Ethiopian wheat (St. 464 and C.I. 7778) have been found to possess the same allelic or very closely linked genes for resistance to Australian strains of stem rust. They seem to have three dominant genes designated as *Srt 1*, *Srt 3* and *Srt 4*. Similar studies carried out on four durum varieties have shown that each of these varieties have two different dominant genes (*Srt 1* and *Srt 5*, *Srt 3* and *Srt 10*, and *Srt 8* and *Srt 9*) and one variety has two recessive genes (*Srt 16* and *Srt 17*). Studies on inheritance of leaf rust resistance in two varieties have shown that resistance in C.I. 7809 to Australian strain 135 D is conditioned by a dominant gene *Lrt 1* and two recessive genes *Lrt 2* and *Lrt 3*; *Lrt 1* being epistatic to other two genes. Its resistance to strains 68 C and 64 A is conditioned by gene *Lrt 1*, and *Lrt 1* and *Lrt 2*, respectively. The resistance in the other variety (P.I. 109593) is controlled by two recessive genes (*Lrt 4* and *Lrt 5*). Similar type of results have been reported from studies carried out in Pakistan. All these investigations indicate good possibilities of locating genes for resistance in *Tetraploid* and *Hexaploid* wheats for the prevalent rust races and of transferring them to high yielding varieties. Thus these investigations hold good promise of developing broad-based resistant varieties of more lasting nature, containing both vertical and horizontal sources of resistance. Promising high-yielding resistant lines must be always kept in the pipeline for the early replacement of varieties, developing susceptibility.

Work carried out during 1972-76 on stem rust of wheat has identified some resistant varieties under artificial inoculation conditions both in the green house and in the field. This has provided useful sources of broad-based resistance either for yield testing and direct introduction or for use as resistant parent stocks (for details see chapter XX).

Recent studies carried out at Faisalabad on control of leaf rust through fungicidal sprays have shown above 100 per cent average increase in 1000 kernel weight and nominal to above 150 per cent yield increase in two wheat varieties (WL-711 and Blue Silver); fungicides Indar 70LC, Daconil 75 WP, Bayleton 25 WP and Plantvax 75 WP giving better results. However, its large-scale application on time is questionable.

10. Downy Mildew – *Scleropthora (Sclerospora) macrospora* (Sacc.) Shaw and Naras

Symptoms and Incidence

With the large scale introduction of Mexi-Pak, the occurrence of mildew was first time recorded in 1969 from Hyderabad region, showing upto 5 per cent infection and was later on reported from the Punjab in 1976. It infects mostly varieties of Mexican origin. Since then it has been present in traces here and there and has not and is unlikely to assume an economic importance because of lack of favourable temperature conditions in wheat growing areas of the country. The infected plants show variable symptoms including dwarfed thickened and twisted upper leaves, distor-

Fig. 2.13: Downy mildew of wheat.

ted ear heads, elongated and twisted or bent-back rachis and curled and distorted awns (Fig. 2.13) which resemble to those reported by foreign scientists. Examination of transverse section of leaf sheaths, has shown the presence of oospores around the vascular bundles and some remanents of intercellular mycelium.

The other minor diseases reported are powdery mildew (*Erisiphe graminis*), leaf blight (*Helminthosporium sativa*), alternaria blight and head blight (*Fusarium* sp.) on which practically no work has been done (Fig.2.14).

(a) (b) (c) (d)

Fig. 2.14: Minor diseases of wheat. (a) Powdery mildew (b) Helminthosporium blight (c) Alternaria leaf blight and (d) Head blight.

Control

No work has been done on control measures. In view of the large scale introduction of Mexican genetic stocks, it is necessary to screen the material thoroughly to avoid inadvertent spread of the disease. However, built-in varietal resistance may lead to practical control of this potentially threatening disease.

Barley

1. Loose Smut, *Ustilago nuda* (Jens.) Rostr.

Occurrence and Symptoms

The disease occurs throughout the country in traces and upto 3 per cent in more humid areas, fluctuating according to the climatic conditions during the flowering period. Like loose smut of wheat, it is essentially a disease of ears, which emerge earlier than normal ones, containing smutted grains covered with delicate membrane rupturing with time and releasing a mass of dark brown spores (Fig.2.15). The extent of damage corresponds to the percentage of infected heads.

Fig. 2.15: Loose smut of Barley.

Pathogen and Perpetuation

The spores of the *Ustilago nuda*, the causal fungus, are dispersed by wind, rain and insects, falling on the healthy flowers, where they germinate and infect the developing grains, which when used as seed produce smutted plants.

Control

Like loose smut of wheat, hot water treatment or use of systemic fungicides can help in controlling the disease. Some exotic varieties, found to be loose smut resistant, need to be yield-tested and used in the breeding programmes.

2. Covered Smut, *Ustilago hordei*

Occurrence and Symptoms

Covered smut has been found to be present in almost every field of barley throughout the country from traces upto 5 per cent, with higher intensities in sub-mountainous areas. Like bunt (Tilletia tritici) of wheat, the disease appears at the heading stage developing diseased or smutted ears, which are produced on all the tillers of an infected plant. The smutted grains in the ear are enclosed in a sac which does not break except during harvesting and threshing operations (Fig. 2.16). It reduces the yield proportionate to the diseased plants.

Fig. 2.16: Covered Smut of barley.

Pathogen and Perpetuation

The spores of the fungus *Ustilago hordei* when coated on the surface of the seed have produced the diseased plants in experimental crops. These spores have been isolated from the barley seeds due to their contamination during harvesting and the threshing operations. The mode of perpetuation is seedling infection like bunt of wheat, showing the disease symptoms at ear formation stage.

Factors Influencing the Dicsease Incidence

Like other seedling infections, covered smut of barley is also influenced by depth of sowing, high soil moisture and optimum temperature at the seeding time, consequently facilitating its control through modifications in cultural methods. Varietal variation in disease reaction has also been discovered.

Control

If resistant varieties are not available, the disease can easily be controlled by:

i) Seed treatment with any of the copper-based fungicides or organomercurials as recommended in the case of bunt of wheat;
ii) Change in seeding time or method (shallow sowing in dry soil, with immediate application of water);
iii) Using healthy seed obtained from a healthy crop.

3. Leaf Spot, *Helminthosporium sativum* Pam; King and Bakke

Occurrence and Symptoms

Leaf spot or spot blotch is found to occur throughout the country in various intensities but the damage caused is not serious, except under high conditions of infection. The disease can appear in different stages of plant growth causing seedling blight and crown rot resulting into poor stand of crop in early infections. On older plants it causes round or elongated leaf spots which grow in size and number coalescing to form large dry blotched areas. Sometimes flowers and kernels are also infected developing brown discolouration, shorter culms, sterility or improperly developed grains (Fig. 2.17).

Pathogen and Perpetuation

The fungus *Helminthosporium sativum* has been isolated from contaminated seeds as well as from diseased plant debris and has proved to be pathogenic on inoculation. The disease is carried over either by sowing infected seed or healthy seed in infected field containing crop residue. It also produces spores, which cause secondary infection during the growing season, when blown by wind or rain splashes. It can also attack wheat and some grasses and the related species like oats and rice.

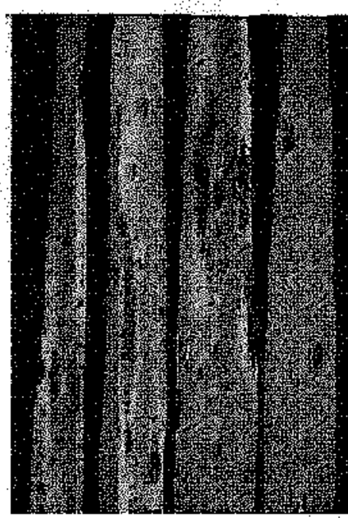


Fig. 2.17: Leaf Spot of Barley.

Control

Many seed disinfectants have controlled the seed-borne disease but not the debris-borne or the secondary infections. Development of resistant varieties is the only possible and economical control measure on which work needs to be concentrated.

4. Powdery Mildew *Erysiphe graminis hordei* E. Marchal

Occurrence and Symptoms

The disease occurs in traces mostly in cooler areas of the country, causing slight losses to the crop. It starts with the appearance of powdery fungal growth on leaves, leaf sheaths and sometimes on floral bracts as scattered spots, which increase in number and size covering large areas. The affected leaves and plant parts turn yellow and dry subsequently, affecting the weight and size of the grains (Fig. 2.18).

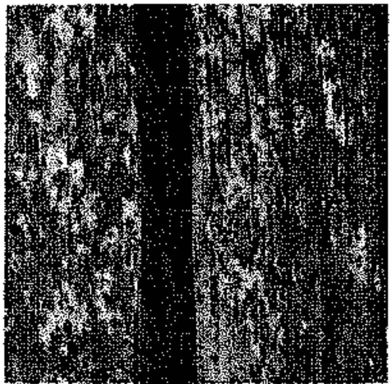


Fig. 2.18: Powdery Mildew of Barley.

Pathogen and Perpetuation

The disease is caused by *Erysiphe graminis* which has a wide range of host plants comprising grasses and cereals. The fungus remains viable in the form of spores enclosed in black dot like fruiting bodies, while the secondary infections take place through conidia disseminated by wind during the growing season. Variation in varietal reaction has been noticed; most of the local varieties being susceptible.

Control

Since fungicidal control is uneconomical and impracticable, development of resistant varieties is the only practical method. Very little work has been carried out in the country except some varietal screening under natural conditions of infection.

In short, very little work has been done on diseases of barley in Pakistan except on seed-borne fungi and the above mentioned preliminary studies. Although the area under barley is medium, this crop has a big scope for expanded hectarage through replacing wheat in marginal land (rainfed and/or saline areas) and its use as a fodder and feed for livestock and poultry. Much more concerted efforts are needed on the development of high-yielding and disease resistant varieties (meant for grain or forage) suited to various ecological conditions in the country.

Summary

Salient features of investigations carried out on loose smut, flag smut, septoria leaf spot, foot-rot, black point, bunt, new bunt, ear cockle, rusts and downy mildew of wheat have been given.

For the control of loose smut of wheat hot water treatment of infected grains has not only been simplified but also a very simple and fool proof solar energy method has been developed. This consists of soaking the seed in ordinary water on a clear sunny day for four hours in the morning and spreading it in the sun in thin layers to dry. New systemic fungicides like Vitavex or Benlate have also been found to control the disease effectively which should preferably be used at the seed multiplication source because of their high cost and intricated nature of treatment.

In the case of flag smut of wheat, which is a serious disease of submountainous districts, its modes of perpetuation, factors affecting the incidence and control measures consisting of seed disinfection, cultural methods and resistant varieties, have been determined. It has been found that seed-borne infection can be successfully controlled by seed disinfectants like ceresan and copper carbonate, while soil-borne infection can be reduced considerably by broadcasting the seed in a field to which water is applied immediately after sowing or by sowing wheat early. Work has also been carried out on the physiologic specialization of *Urocystis tritici*, the causal fungus of flag smut, by comparing 11 collections from USA, Australia, China, Italy, Cyprus and Pakistan.

Septoria leaf spot has been studied in detail as regards physiology and morphology of septoria species isolated from locally infected plants and two other spp., *Septoria tritici* and *Septoria nodorum*. Modes of perpetuation, factors affecting the incidence and measures to control the disease have also been worked out. Apart from suppressing the sources of infection, the most economical and practical way for controlling the disease is the development and large-scale use of the resistant varieties.

Foot rot of wheat, erroneously attributed by farmers to white ant attack, has been found to be caused by the fungus *Helminthosporium sativum*, which is sometimes associated with *Fusarium* and *Alternaria* spp. The fungi causing foot rot and the one producing leaf spot have been shown to be identical. It has also been found out that *Helminthosporium sativum*, isolated from black-pointed grains can also cause foot rot. Factors affecting the incidence and measures to control the disease by seed disinfection, cultural methods and resistant varieties have been studied.

Bunt of wheat, which was hitherto considered to be exclusively

carried through contaminated seeds, has been discovered to be soil-borne also. It has been found out that under severe conditions of infection the diseased ears also show pronounced elongation varying from 30-45 cm as compared to 10-12 cm, the normal size of healthy ears. Factors affecting the incidence of the disease and control measures including seed disinfectants and resistant varieties have been worked out.

In the case of new or partial bunt of wheat, the infection has been found to take place by air-borne sporidia when the wheat ears are in preanthesis stage. Weather conditions prevailing at the time of earing and grain formation exercise a profound effect on the incidence of the disease. High humidity and comparatively lower temperatures at the time of ear formation are conducive to the development of the disease.

Ear cockle is controlled by sowing seed free from galls which can be removed by seiving and winnowing or by immersing the seed in salted water and skimming off the galls. Out of the tested nematocides, Nemafos and Telone have provided good control but their farm-application is costly.

Rusts of wheat, which constitute a continuing threat to healthy cultivation of wheat, have been found to perpetuate through uredospores which remain viable during summer on stubbles and volunteer wheat plants and out-of-season wheat crops at different altitudes ranging from 1350-3000 m (yellow rusts from 2500-3000 m, leaf rust from 2000-2300 m and black rust from 1300-1600 m). Wheat crops at high elevations get infected rather earlier during the season in the neighbourhood of rusted volunteer wheat plants and the uredospores are disseminated by winds to the foot hills and then to the plains, causing infections. The direction of air currents in the months of January to March have been found to be from hill towards the plains. Alternate host plants, which have been determined for black and leaf rusts, have been found to play very little role in the annual outbreak of rusts in the plains. No alternate host plant has so far been discovered for yellow rust. Stem rust has been made to oversummer in experimental wheat plots sown side by side at weekly intervals. Work carried out on the development of resistant varieties from 1966 onwards has paid rich dividends in containing the three rusts. It needs to be strengthened and continued embracing other diseases also.

As regards diseases of barley a brief account of loose smut (*Ustilago nuda*), covered smut (*Ustilago hordei*), leaf spot (*Helminthosporium sativum*) and powdery mildew (*Erysiphe graminis*), has been given covering occurrence, symptoms, pathogens, perpetuation and control measures. In view of the increasing importance of barley much more concerted efforts are needed on the development of high-yielding and disease resistant varieties suited to the different ecological conditions in the country.

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Rice

The rice occupies an important position amongst the food grain crops and is very suited for the localities where either *Kharif* (summer) water supply is abundant or where due to rise in the ground water table it is not possible to grow other crops. Although rice is grown in small areas in many parts of the country, central and southern districts of the Punjab and Sind, respectively, are very well suited for its cultivation. The area under this crop is about 1.9 million hectares, with an average yield of 1571 kg/ha. Pakistan grows both fine and coarse varieties; out of which *Basmati* (a fine type) has an established overseas market and sells at a high premium. The country has not only achieved self-sufficiency, it also exports sizable quantities of rice (0.4 million tons) earning an appreciable amount of foreign exchange. This crop is subjected to many diseases and the results of the investigations carried out on some of them are given below:-

1. Stem Rot, *Sclerotium oryzae* Catt.

Stem rot of rice is an important disease as it brings about losses varying from below 1 to 25 per cent, while in many individual fields the damage caused surpasses even 80 per cent or more. The average losses can be taken at 2 per cent.

Symptoms

The plants, when they are about 2-3 months old, begin to wither and ultimately dry up, the sheaths soon turn somewhat dark and start rotting.

At this time the fruiting bodies (Sclerotia) of the fungus appear as small black dots at the base of the dried leaves and certain leaf sheaths. At first, small darkish spots appear and then the infection spreads involving the whole internode below the affected leaf sheath. The infected part of the stem begins to rot and becomes so soft that it collapses and the plant falls down. In severe cases the affected shoots dry up altogether and if they remain green, the ears are totally or partially sterile (Fig. 3.1).

Fig. 3.1: Stem rot of Rice.

Pathogen

All the isolations, made from the dark spots present on the infected stems and leaf sheaths, yielded the fungus *Sclerotium oryzae*. Detailed cultural studies were carried out on this fungus in the laboratory.

Inoculation experiments, conducted in pots as well as in the field, showed that the fungus *Sclerotium oryzae* was parasitic on rice plants. Seeds, contaminated with diseased rice stubbles or pure cultures of the fungus, produced infections ranging between 4-15 per cent in pot experiments.

Modes of Perpetuation

The disease is produced when seed is sown directly or when transplanted seedlings are raised on infested soil. Rice grown on land, which carried a diseased crop in the previous year also becomes infected.

Nature of the Pathogen

Sclerotium oryzae is pleomorphic fungus, producing 3 kinds of differentiated fruiting organs viz., the sclerotium, perithecium and conidium in its life cycle. These stages of the fungus are respectively recognized as *S. oryzae, Magnaporthe salvinii* and *Nakatea sigmoidea*. In Pakistan only the sclerotial stage is associated with stem rot of rice while the perithecial and conidial stages have not been observed either in culture or in field.

Population and Viability of Sclerotia

A wet sieving and floatation technique, developed to study the population of sclerotia of *S. oryzae* in soil, has shown that the number of sclerotia is high under wheat (26-35 g^{-1}) or fallow fields (12-15 g^{-1}) as compared to rice crop (4 g^{-1}). Greatest numbers of viable sclerotia have been found in surface soil with a gradual decline in numbers at increasing soil depths. The sclerotial population increases when soil is turned over irrespective of the removal of stubbles. *S. oryzae* was also first time found on *Echinochloa* sp. growing as a weed in paddy fields.

Antagonism

Of the 63 different isolates of fungi and 27 other micro-organisms (16 of *actinomycetes* and 11 of bacteria), obtained from soil and infected paddy stubbles, many have inhibited the growth of *S.oryzae* in agar culture. The important ones are *Trichoderma hamatum, T. harzianum, Stachybotrys atra, Aspergillus flavipes, A.rugulosus, Penicillium purpurpogenum, Pseudoarachinotus roseus, Streptomyces albus, S.nouresi, S. rimosus* and *Bacillus* spp. It has also been found that *T. hamatum* reduced the sclerotial production and parasitized the sclerotia of *S atra*.*T. harzianum, Streptomyces* sp., and *Bacillus* spp. have neither reduced sclerotial numbers nor affected their viability. Of these, two strains of *Bacilli* are more effective in reducing the viability as compared to fungi or *actinomycetes*.

Factors Influencing Sclerotial Population

Among the inorganic fertilizers, nitrogen, phosphorus and potassium have shown little difference in population density of sclerotia. However, none of the sclerotia can remain viable after 10 days in ammonium sulphate and urea at 1000 and 10,000 ppm. Urea used at the rate of 200 ppm in field has shown increased sclerotial viability with no significant difference in Disease Severity Index.

The soil amendments with dried stems and leaves of lucerne at 5 per cent w/w have not changed the population of sclerotia but reduced their viability to zero after 40 days, as compared to rice, wheat and mustard amendments. Amendment at 1 per cent level has been less effective. Combined effect of organic amendments and ammonium sulphate has shown considerable loss in viability of sclerotia at 75 and 100 per cent moisture levels. The production of sclerotia is greatly reduced in soil during early stages of decomposition of mustard, lucerne, rice and wheat residues; probably due to volatile substances, produced during decomposition which also inhibit germination of sclerotia. The nature of the volatile substances has not been studied.

Repeated cycles of hydration and desiccation have not affected the viability of sclerotia while solarization of soil through mulching with transparent sheeting of polyethylene has resulted in complete loss of sclerotial viability. It has been found out through experiments at 3 places (Karachi, Sakrand and Lahore) that mulching of soil infested with *Sclerotium oryzae*, moist or dry, with transparent polyethylene sheeting during May and June increased soil temperature from 37°C ambient to 48°C and resulted in loss of viability of sclerotia. Mulching of soil has not affected the number of sclerotia but reduced their viability by 100 per cent to a depth of 5 cm after a minimum of 3 day mulching treatment. Sclerotia from 20 cm depth, when brought back to the surface, were also killed after another 4 days mulching treatment. Although mulching treatment has shown increase in yield by 22.8 per cent, there has been no significant difference ($p = 5$ per cent) in number of culms and Disease Severity Index (DSI). Similarly mulching of soil during winter months has reduced sclerotial viability by 40-60 per cent in 7 days.

These results hold out a promise of developing some practical cultural control measures based on the use of soil amendments through suitable crop rotations, combined use of soil amendments and ammonium sulphate, exposure of rice stubbles on the soil surface, use of some antagonistic organisms and mulching techniques for raising soil temperature above 48°C.

Varietal Resistance

Nineteen varieties were tried and it was found that they differed markedly as to their relative susceptibility to the disease. Varieties No. 14, 349, 346, 360, 3/30, 337/A, 202, 125 and 278 were susceptible, the infection percentage varying from 72 to 96, while Basmati varieties like 370 and 7 were less susceptible although the infection percentage in some cases was as high as 20.

Control Measures

1. Infection is reduced if late sowing or late transplanting is carried out but is not recommended on account of its having adverse effect on the yield of the crop.

2. Keeping water stagnant throughout the growing period of crop increases the incidence of the disease. If water is drained off frequently, the incidence of the disease is reduced.

3. The *Basmati* and *Mushkin* groups have been found to be resistant to the disease while *Sathra* and *Son* are very susceptible.

4. Burning of diseased rice stubbles in situ eliminates the disease whereas it varies from 6-18 per cent when the diseased rice stubbles are not burnt.

5. Use of cultural control measures including soil amendments (through suitable crop rotations), antagonistic organisms, mulching and exposure of rice stubbles on the soil surface holds good promise.

2. Blight or Brown Spot, *Helminthosporium oryzae* Breda de Haan.

Occurrence, Symptoms and Perpetuation

Rice blight (which was formerly known as brown spot) occurs in all the rice-growing areas of Pakistan in various degrees, appearing in the middle of August because of comparatively lower temperatures and higher humidity. It can attack the plant at any growing stage, causing seedling and adult plant infections. Infected seeds show rotting and poor germination, which reduce the crop stand. It appears on foliage as scattered brown spots, which coalesce and result in withering and yellowing of leaves. It also causes sterility, reduced seed setting, shrivilling and low yield of grains (Fig.3.2). The causal organism, *Helminthosporium oryzae*, has been extensively studied in culture for its growth, morphological characters, nutritional and temperature requirements and pathogenecity, showing wide nutritional and host range requirements. The disease is seed-borne as well as produced through disease plant debris and infested soil. The secondary infections develop through air-borne spores and irrigation water.

Cultural and Pathogenic Variation

Fourteen monoconidial isolates of *Helminthosporium oryzae* obtained from typical blight lesions occurring on different rice varieties, have been studied on five culture media (basal medium adjusted to pH 7) at six temperatures. The main results are:-

- The monoconidial isolates comprised at least nine cultural races differing in colony diameter and other cultural characters;
- Five isolates have shown the best growth on Richard's agar, four on basal medium, three on oat meal and two on potato dextrose agar, showing varying nutritional requirements;
- The size of conidia was almost the same in all the isolates while three isolates have shown marked difference in conidial septation;
- The isolates have also shown some differences in their temperature requirements of either 35° C or 30° C, while the best sporulation of three isolates occurs at 35° C. There is a reduction in conidial size at higher temperatures. The minimum and maximum temperatures are 5° C and 40° C while the lethal temperature is 55° C.
- All the isolates have shown good growth within the pH range 3.2 to 8.1; the optimum pH being 6.0.
- On the basis of pathogenecity tests on four rice varieties, the 14 isolates can be grouped into five pathogenic races (Table 3.1).

Table 3.1. Reaction of four varieties of paddy to five pathogenic races of *Helminthosporium oryzae**.

Race	Basmati 370	Palman 246	Sathra 278	Jhona 349	Isolates
1	R	S	S	S	2,3,9
2	R	R	S	S	5,7,11
3	R	S	R	S	8
4	S	R	S	S	13
5	S	S	S	S	1,4,6,10, 12 and 14

*R and S denote resistant and susceptible reaction.

In view of the wider requirements of the pathogen and occurrence of five physiologic races, the development of resistant varieties is complicated and assumes greater importance, needing more concerted efforts to find polygenic resistance.

Varietal Resistance

Rice varieties have shown a great variation in their disease reaction;

some of them (Hybrid Kangni X Kolumbia 184 called Silver Jubilee and Hybrid 38-845-70) have a high degree of resistance while Kangni 27, Sonhari, Dokri Basmati and some IRRI varieties have medium resistance.

Control

The seed (or primary) infection has been found to be controlled either by hot water treatment (54° C for 10 minutes) or with seed dressings (Cupric oxide, Dieldrex, Granosan N1, Arasan or I.D) while the secondary infection is controlled by repeated sprays with chemicals such as Perenox, Zerlate, Parazate, Fermate or Dithane. Soil-surface borne infection can be eliminated by destruction of diseased plant debris and clean cultivation. This integrated approach, to be followed by all the farmers, is quite difficult and impractical. The best possible control measure, therefore, lies in the built-in resistance of the rice varieties.

3. **Bunt,** *Tilletia barclayana* (Berf.) Sacc. and Syd.

Occurrence and Symptoms

Bunt or Kernel smut has been recorded in Sind on all the IRRI varieties with the percentage of infection ranging between 0.8 to 5.5 and in other varieties like Kangni 27 and Jajai 27. It has also been reported from Hafizabad and Kala Shah Kaku in the Punjab. Surveys carried out from 1967 onwards have shown the presence of the disease in almost all the rice growing areas from traces to appreciable amounts. IRRI varieties have been infected as well as others like Sathra 278 and Jhona 349. The disease appears as minute black pustules or streaks bursting through the glumes, while the grains (which contain masses of black spores) are partially or completely inffected (Fig.3.3).

Perpetuation

The disease could not be produced through artificial seed or soil infections while floral inoculations using Moore's partial vacuum method with aqueous sporidial suspension could produce the disease in upto 84 per cent of plants.

Varietal Resistance

The 364 rice varieties, tested under artificial inoculation conditions during 1967-71 at Kala Shah Kaku, were arranged into three groups separately on head basis (0-10 per cent = Resistant, 11-40 per cent = Intermediate and 41-100 = Susceptible)and on grain basis (0.02 per cent = Resistant, 0.3-1.5 per cent = Intermediate and 1.6 per cent or more = susceptible). Only seven fine varieties (622 B, 66107 B, Imperial blue rose, 197 B, 198 B, Jajai and Bengalo) have been found to be resistant (0.2 per cent grains infected), 29 varieties intermediate (0.3-1.5 per cent grains infected) and the remaining varieties susceptible (which also included most of the coarse varieties). However, it will be interesting to correlate the varietal reaction with the temperature, humidity, wind velocity during the flowering period.

Fig. 3.2: Brown Spot of Rice.

Physiologic Specialization

Inoculations of 12 selected varieties with 19 representative samples of the pathogen, collected from various places, have not indicated the presence of different physiologic races in the country.

Control

Since the disease perpetuates through floral infection in preanthesis stage, the development and large-scale cultivation of resistant varieties is the only practical solution.

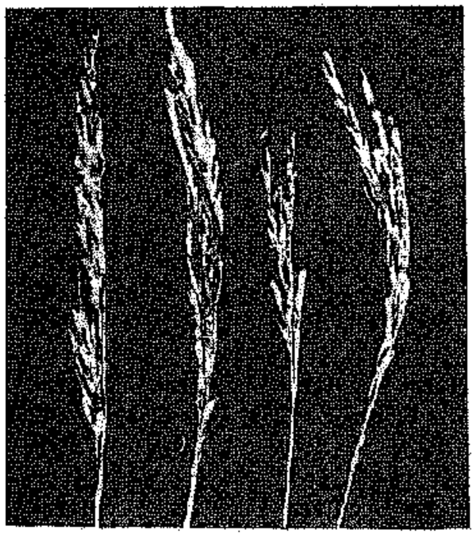


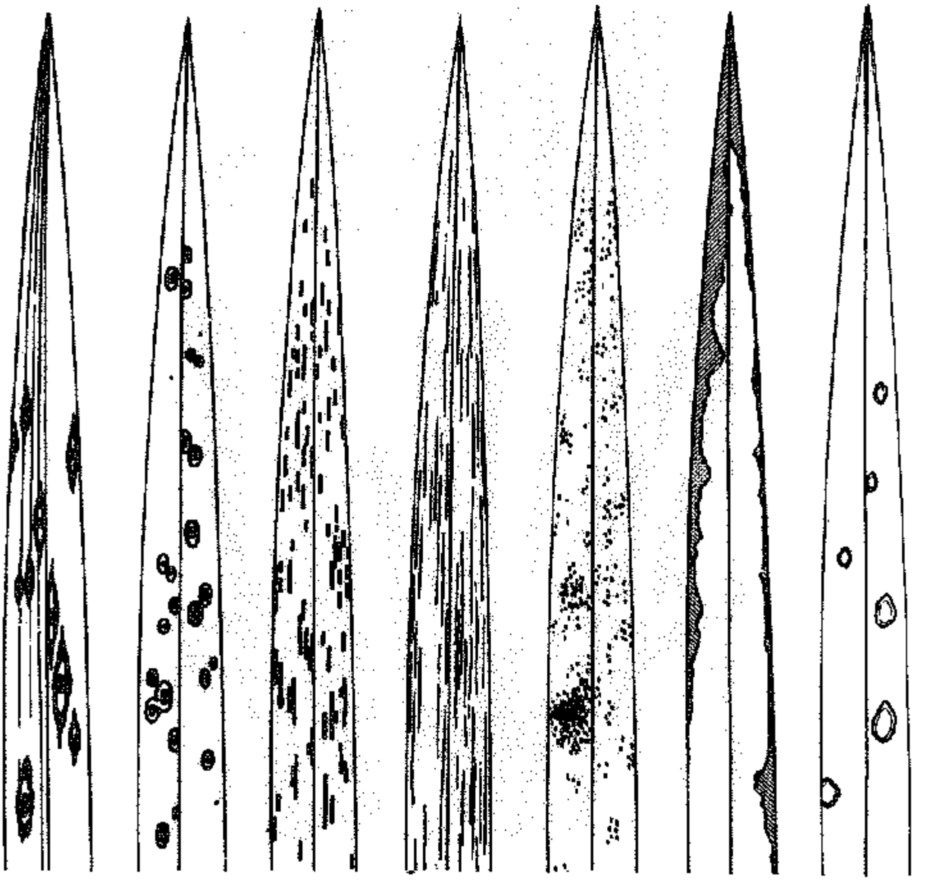
Fig. 3.3: Bunt of Rice.

Fig. 3.4: Blast of Rice.

4. Blast, *Pyricularia oryzae* Cav.

Blast has been recently recorded in traces in Sind on IRRI varieties and is still a minor disease. Higher fertilization of the crop is conducive to the development of the disease. However, it is a serious disease of many South Asian countries. The IRRI scientists have identified 255 races of *Pyricularia oryzae* and only a few varieties have consistently shown a broad spectrum of resistance, suggesting thereby that quantitative resistance may probably be the only hope (Fig. 3.4). The bacterial and viral diseases of rice have been given in separate chapters. However, typical leaf lesions produced by seven rice diseases are shown in Fig. 3.5.

Typical Leaf Lesions of Seven Rice Diseases



All the diseases illustrated above are found throughout southeast Asia, although leaf smut and stackburn disease are rare. The diseases are caused by the following organisms:

Blast, or rotten neck: *Piricularia oryzae* – a fungus.
Brown spot, brown leaf spot, sesame leaf spot, Helminthosporium leaf blight or spot: *Cochliobolus miyabeanus* (-*Helminthosporium oryzae*) – a fungus.
Cercospora leaf spot or blight, narrow brown leaf spot, narrow brown spot: *Sphaerulina orizina* (-*Cercospora oryzae*) – a fungus.
Bacterial leaf streak: *Xanthomonas translucens* f sp. *oryzae* – a bacterium.
Leaf smut: *Entyloma oryzae* – a fungus.
Bacterial leaf blight: *Xanthomonas oryzae* – a bacterium.
Stackburn disease: *Trichoconis padwickii* – a fungus.

Summary

As rice provides staple food and earns foreign exchange, it occupies an important position in Pakistan agriculture. The rice crop is subject to a number of diseases both of minor and major nature causing considerable losses.

Stem rot manifests itself on 2-3 months old plants causing withering and drying,rotting of stem near the soil level and ultimately the plants fall down. Fruiting bodies of the fungus(sclerotia) appear as small black dots on the infected portions. In severe cases the affected shoots dry up and if they remain green the ears are totally or partially sterile. The disease is produced when seed is sown directly in infested soil or when seedlings raised in infested soil, are used. Rice grown on land, carrying the diseased crop in the previous year, becoms infected. Investigations carried out on nature of the pathogen, population and viability of sclerotia, antagonistic fungi and factors influencing sclerotial populations have given some interesting results, indicating the possibility of developing cultural control measures based on the use of soil amendments, antagonistic organisms, mulching and exposure of rice stubbles on the soil surface. Varietal resistance trials have shown that varieties differ markedly in their relative susceptibility to the disease. Work has also been conducted with a view to finding suitable control measures other than use of resistant varieties.

Blight or Brown spot which occurs in various intensities throughout the country appears in the middle of August and is influenced by comparatively low temperatures and high humidity. It can attack plants at all stages causing rotting of the seed, poor germination, withering and yellowing of leaves, and sterility or reduced seed setting. Studies have been carried out on cultural and pathogenic variation of the causal fungus *Helminthosporium oryzae* showing its wider nutritional requirements and host range. On the basis of pathogenecity tests, 14 isolates have been grouped into five pathogenic races. Investigations on varietal resistance have shown a great variation in their disease reaction. As a result of work on control, some measures have been suggested including hot water treatment of seed, seed dressing and chemical sprays; although the best possible control measure lies in the development of resistant varieties.

Bunt or Kernel Smut is present in various intensities throughout the country. It is essentially a disease of the grain which is partially or completely infected and contains a mass of black spores, perpetuating from year to year through floral infection. The varieties tested have shown a range of reaction to the disease falling into different groups; a few being resistant. Because of the floral nature of infection, the development and cultivation of resistant varieties is the only practical way of controlling the

disease. This aspect needs more concerted efforts.

Some preliminary studies have been reported on minor diseases such as cercospora leaf spot and leaf scald with suggestions to strengthen and pursue researches at national level.

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Sorghum, Millet and Maize

The sorghum or *Jowar*, occupying about half a million hectares, is one of the important crops of certain areas of Pakistan, where it serves a dual purpose, being used for fodder and as grain. Sorghum is a *kharif* crop and is sown in April-July and harvested in July – November. It occupies an important position in the Divisions of Rawalpindi, Sargodha, Multan, Bhawalpur, D. I. Khan, Sukkhar, Hyderabad and Sibi, where it is mostly used as a grain crop. This crop is subjected to a number of fungal diseases, which reduce the yield and bring about heavy losses. Some of the diseases like grain smut, long smut, red leaf blight and leaf spots have been under investigation for a number of years. The results of importance are summarized below.

Sorghum

1. Grain Smut, *Sphacelotheca sorghi* (Link) Clint.

Occurrence and Symptoms

Grain smut is of common occurrence and is found almost in all the fields ranging between 3 to 10% and sometimes as high as 30 to 50 per cent. As it is essentially a disease of grains, it is noticeable in the grain forming stage. Mostly all the grains on the head are infected, and are transformed into white greyish sacs (smut sori), which are slightly pointed to oval in shape and are filled with chlamydospores of the causal fungus instead of starch (Fig. 4.1). Such infected heads on harvesting and threshing break up releasing a multitude of spores, which either fall on the soil or stick on the surface of healthy seeds causing contamination.

Perpetuation

The disease is caused by *Sphacelotheca sorghi*, which produces round to slightly oval spores, brown to brownish olive in colour (measuring 5-9 μ); and can germinate easily in water over a wide range of temperatures. The disease is carried over from year to year through contaminated seeds. The appearance of the disease is influenced by the soil temperature at the time of sowing; 25-30° C being more suitable. The incidence of the disease is reduced in late plantings when the soil temperatures are 35-40° C.

Fig. 4.1: Grain Smut of Sorghum.

Control

1. All the local cultivars have been found to be susceptible, with infections ranging between 20-60 per cent. Of the 25 varieties tested in 1973, five varieties (Lyallpur Hybrid, 1616 X PRS, SS1, V-3 and Sorokartoho) proved to be tolerant; producing upto 10 per cent infection.

2. The disease can be completely controlled if the seed is dusted before sowing with either powdered copper sulphate, copper carbonate, ceresan or sulphur at the rate of 4 g/kg. Seed treatment with formalin solution (one part of formalin in 320 parts of water) is also an efficient method of control. In recent studies many other chemicals (organomercurials and

copper or sulphur – based) have been found to control the disease successfully. Seed treatment also improves the germination capacity, vigour of seedlings and yield by 20-30 per cent besides being the cheapest method of controlling the disease.However, heavily contaminated seed is more difficult to disinfect than lightly contaminated. Seed samples collected from various places have been found to be lightly to heavily contaminated with viable smut spores (31-65 per cent). As there is good correlation between laboratory tests on spore germination and field experiments on infection, the seeds meant for sowing can be easily evaluated in the laboratory. In addition to seed treatment, the following useful cultural methods of control have been developed.

3. The disease can be reduced by 70-90 per cent when seed is broadcast-on dry soil to which water is applied immediately after sowing.

4. The dates of sowing exercise a great influence on the incidence of the disease. The percentage of attack is the highest (23.7 per cent) when sown in the month of May, soil temperature being 32-35°C while the incidence of the disease varies from 1-2 per cent in sowings carried out during the month of June, when the soil temperature is 37-39° C.

2. Long Smut, *Tolyposporium ehrenbergii* (Kuhn) Pat.

Occurrence and Symptoms

Long smut of sorghum was first recorded at Mirpurkhas (Sind) in 1915 and from Dera Ghazi Khan in 1930. It is also prevalent in various intensities in the districts of Multan and Muzaffargarh and central parts of Sind. The incidence of the disease on an average comes to 5-7 per cent. Losses from 40-60 per cent have been observed in individual fields. The individual grains are transformed into smut sori, which are scattered all over the surface of the ear, (1 to 30 per head) with more concentration on the upper parts. The spores sacs are cylindrical, protruding, and their length varies from 6 to 28 mm (Fig. 4.2). They are full of black masses of spores of the causal fungus and also contain 8-10 long dark brown filaments or threads in place of the central columella. During harvesting and threshing operations, the smutted grains break and release a multitude of spores, which either fall on the soil or stick on the surface of healthy grains (as recorded on the grain samples collected from infected areas).

The life history of this disease was unknown in the scientific world upto 1945. The main conclusions drawn from the research work carried out on this disease are given below:

Modes of Perpetuatsion

The disease has been found to perpetuate by the following methods:-

- By sowing contaminated seed in the soil;
- By sowing seed in soil which is contaminated with spores in the previous season;
- Secondary infection in the same growing season also takes place either from the spores shed on the soil in the previous year or from the spores produced in the infected sacs in the same year;
- Inoculations with sporidial suspensions in the flower buds with the help of a pipette can produce upto 90 per cent infection. Air-borne sporidial infection at the flowering time appears to be of major importance.

Fig. 4.2: Long Smut of Sorghum.

In later experiments very high percentage of disease could be produced by Moore's method for floral inoculation or by using sporidial suspension prepared from a culture grown on potato dextrose agar.

*Germination of Spores**

The spores start budding after 3 1/2 hours, while sporidia are formed in 7-8 hours when the percentage of germination reaches 81-90.

The range of optimum temperature for germination of spores is between 25-30° C. The minimum and maximum temperatures for germination of spores are 10-12° C and 38.8-39.5° C, respectively. The sporidial formation is absent at about 37.7° C and below 13.3° C. Distilled water, glucose solution and glucose peptone solution (0.5-3 per cent) are suitable media for spore germination, but glucose peptone solution is not good for sporidial formation. Luxuriant sporidial growth takes place when mannitol and sodium nitrate are used as carbon and nitrogen sources in Richard's medium. The fungus can grow in pH ranging from 4 to 9; optimum pH being 7.

Perpetuation

The spores in the separated form are killed by:
- Dipping them in either 1.0 per cent or 0.5 per cent copper sulphate solution for 1 minute and 10 minutes respectively;
- Dipping them in 1.0 per cent or 0.5 per cent mercuric chloride solution for 1 minute and 5 minutes, respectively;
- Treating them in formalin solution from 1:320 to 1:640 strengths and covering them with a moist cloth for 2 hours.

The spores in the broken sacs are killed by:
- Dipping them in 3 per cent mercuric chloride solution for 10 minutes;
- Immersing them in 1 per cent liquid ammonia without covering or in formalin solution (1:320) with covering.

Genetic of Smuts

Studies carried out on the genetics of *Tolyposporium* smuts (*T. ehrenbergii* of sorghum and *T. penicillariae* of millet) and *Ustilago scitaminea* of sugarcane have shown that the two *Tolyposporium* smuts are heterothallic, segregating on 2:2 basis for sex and cultural characters either in the

*There are two types of spores-large (14-16 μ) and small (6-8 μ). Large spores could not be germinated during these experiments.

first or second division of fusion nucleus with no evidence of segregation on the basis of independent factors. The four monosporidial isolates arising from single chlamydospores of the two smuts comprised two cultural groups for the colony diameter and other cultural characters when grown on a synthetic medium. The possibility of recombination of factors through compatible sporidia, arising from different chlamydospores, is higher in *Tolyposporium* smuts resulting into greater variation. Like wise sugarcane smut has also proved to be heterothallic as it happens in other species of the genus *Ustilago. The segregation for sex factors is on 2:2 basis with evidence of occurrence of physiologic specialization.*

Factors Influencing the Incidence of the Disease

The disease generally appears at Lyallpur in the sowings done in April and May and the crop sown in June is either free from the disease or the incidence is reduced considerably. In July sowings the disease does not appear at all. The factors responsible for this variation appear to be mean soil temperature during germination period and the amount of rainfall during the flowering period. In April and May the mean soil temperature is favourable for the germination of spores while in June and July it is unfavourable, which consequently checks or reduces seeding infection. Moreover, there is usually no rainfall during the flowering periods of the crop sown in June and July, whereas the flowering periods of the crops sown in April and May fall in the rainy weather and hence more chances of aerial infection. Similar results have been achieved in Sind, showing higher incidence of disease in crops which flower in rainy seasons confirming the greater role played by aerial infection.

Varietal Reaction

All the eleven varieties observed under natural conditions in Sind showed susceptibility with infections ranging from 1.9 to 46 per cent except some exotic stocks, particularly dwarf and early maturing ones showing lesser degree of infection (*probably due to escape mechanism*). *In artificially inoculated trials during 1967-71, seven varieties (NK-125,NK267, Aus-6, C-45, NK-404, Martin and Caprock) have shown resistance with infections ranging between 0 to 0.2 per cent on grain basis. Varieties with closed glumes have proved to be more resistant than with open glumes. Such morphological characters need to be fully investigated and utilized in breeding programmes.*

Control Measures

All the seed treatments such as hot water, formalin, dusting with copper carbonate, copper sulphate and other chemicals are ineffective in controlling the disease. This is most probably due to the fact that soil and secondary infections also take place. The following methods are, however, suggested for the control of disease at this stage:

- *Seed should be obtained from a healthy crop;*
- *Seed should be treated with copper carbonate or any other* suitable chemical at the rate of 4 g/kg as this will help in reducing the seed-borne infection;
- Infected sacs should be destroyed by carefully picking and burning them, as far as possible. This step can greatly help in controlling secondary infection as well as grain contamination;
- A gap of few years in the rotation should be practised, if possible;
- Disease resistant or tolerant sorghum varieties should be grown, as and when available because preventive and chemical methods may prove ineffective.

3. Red Leaf Spot, *Phyllosticta sorghina* Sacc.

Occurrence and Symptoms

Leaf spot caused by *Phyllosticta sorghina* was recorded for the first time in the Punjab in 1947 and it has proved to be one of the important disease of sorghum, causing considerable damage to this crop. Small red spots appear on the leaves and stems, later on joining and giving rise to large infected areas, which ultimately result in the drying up of the plants (Fig.4.3).

Cultural Studies

Studies have been carried out on this disease and some of the important results are summarized below:

The disease was found to be produced by the fungus *Phyllosticta* sorghina either through infected seed or through diseased plant debris lying in the soil. In Sind, *Trichometashaeria taurica* Luttrell has been recorded as the causal pathogen.

The maximum, optimum and minimum temperatures for the growth of the fungus are 35-40° C, 25-30° C, and 10-15° C, respectively.

The optimum pH for the growth of the fungus in culture is 6.5 and the maximum and minimum are 2.8 and 9.3, respectively.

The maximum, optimum and minimum temperatures for the germination of the spores are 35° C, 25° C and 10-15° C respectively. The spores are killed when they are immersed in 1.1 per cent mercuric chloride solution for 2 minutes. The thermal death point of the spores is 68° C. The control lies in seed disinfection and destruction of diseased plant debris.

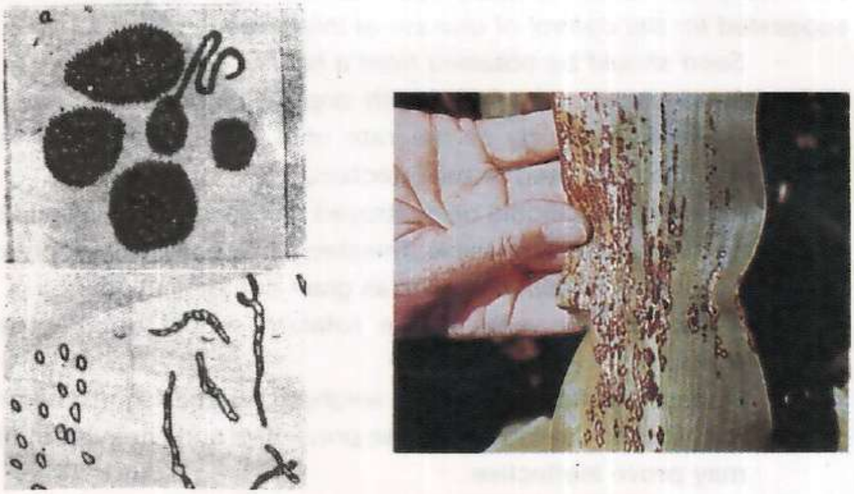

Fig. 4.3: Red Spot of Sorghum Pycnidia and Conidia.
(a) Pycnidia and conidia showing germination.
(b) An infected leaf.

4. Red Leaf Blight, *Colletotrichum graminicolum* Cess. Wil.

Occurrence and Symptoms

The disease is more common than the *Phyllosticta* leaf spot and has been doing much damage to the sorghum crop. The symptoms are essentially the same as described for the *Phyllosticta* leaf spot. They start appearing at the seedling stage and continue to develop throughout the growing period; with maximum intensity during periods of summer rains, the disease being favoured by high humidity and high temperatures. In the beginning, small, ovate to irregular red spots appear scattered on the leaves which later on increase in number and size covering large areas of foliage. The diseased leaves become reddish brown, developing necrosis, drying up of plants, premature ripening and formation of shrivelled grains (Fig. 4.4). Studies carried out on the disease during 1946-48 have yielded the following important results:

Morphology and Physiology of Pathogen

The causal fungus of the disease has been found to be *Colletotrichum graminicolum*.

The fungus has not sporulated throughout cultural studies on a variety of media* except that a very small amount of spores was produced in a culture grown on potato dextrose agar. On a previous occasion two forms of this fungus were isolated, one highly sporulating and the other non-sporulating.

The maximum, optimum and minimum temperatures for the growth of the fungus are about 40°, 25° and 10° C, respectively.

The optimum pH for germination of conidia is 4.2 to 6.8, the maximum and minimum being above 1.2 and 9.2, respectively.

Later studies have shown that the fungus produces black, circular to oval acervuli superficially on the lower sheaths. Conidia are hyaline, single celled, spindle shaped and slightly curved measuring 3.7 X 16-34 μ and each conidiophore has a single terminal conidium.

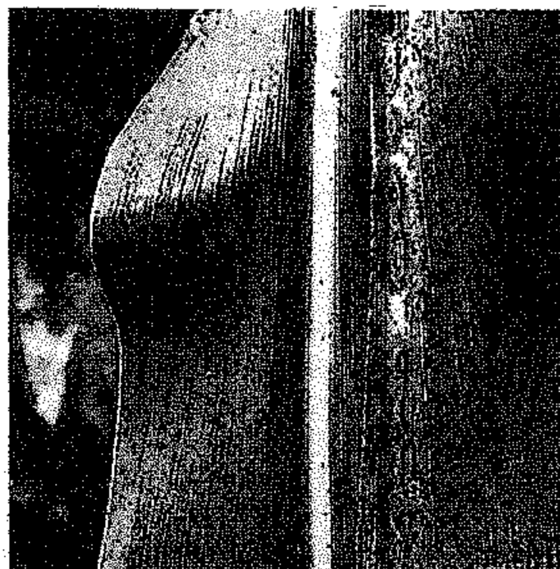

Fig. 4.4: Red Leaf blight or Anthracnase of Sorghum.

*Oatmeal agar, Richard's agar, Brown's agar, Brown's starch agar, glucose peptone agar and nutrient glucose agar.

Modes of Perpetuation

The disease has been found to be carried over from year to year by the following methods;

- By sowing seed artificially contaminated with conidia;
- By sowing diseased seed. In this case the seed is found to be infected by the fungus which gives rise to acervuli on the seed coat if placed under moist conditions;
- By diseased plant debris lying in the soil.

Control Measures

The following methods have been recommended for controlling the disease:

1. Sowing hot water-treated healthy seed. The treatment consists in soaking the seed in ordinary water for 4 hours and then immersing it for 1 1/2 hours in hot water at 55.5° C;
2. Carefully removing and destroying diseased plant debris;
3. Spraying the infected crop in the early stages with 5:5:50 Bordeaux mixture or any other suitable copper-based fungicide;
4. Using resistant or tolerant varieties. The present cultivars have shown varying degrees of infection ranging between 5-50 per cent. The variety Acho Kartuho has shown moderate resistance, in Sind.

5. Grain Mold, *Fusarium, Curvularia* etc.

Occurrence and Symptoms

Grain mold is widespread particularly under wet conditions. An extensive survey carried out in 1977 showed the presence of grain mold upto 70 per cent in farmers' fields at Sahiwal and D.I.Khan while it was upto 20 per cent at Dadu, Sukkhar, Mirpurkhas, Islamabad and Peshawar. This disease is known by different names of head mold, grain mold, grain weathering and head blight because of the various parts affected and the symptoms produced. The symptoms vary depending upon the causal fungi, time and severity of infection. Severely infected grains are completely covered with pink or black mold (breaking during the threshing operation), slightly infected grains show slight pink or black discolouration and even from apparently healthy grains fungal spores can be isolated. In case of head blight the inflorescence is invaded showing various degrees of head destruction. The disease adversely affects both the quantity and quality of the grain, depending upon the disease intensity (Fig. 4.5).

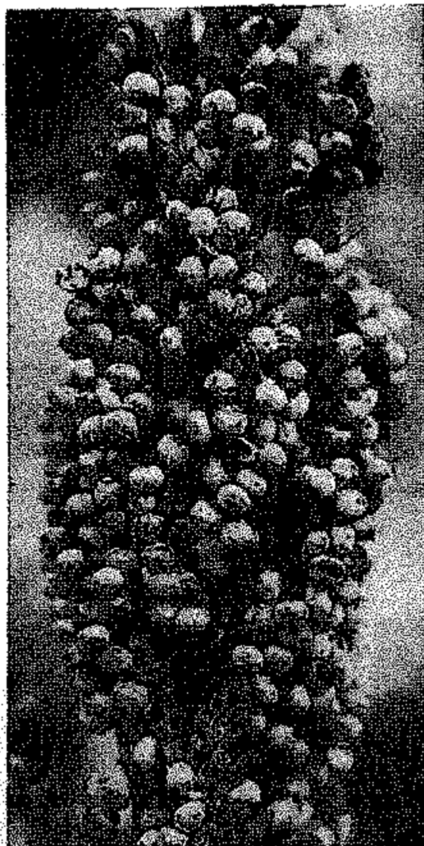

Fig. 4.5: Grain mold of Sarghum.

Pathogen and Perpetuation

In Pakistan fungal species of the genera *Fusarium, Curvularia, Alternaria and Ascochyta* have been isolated as primary grain molds from infected heads. A number of other fungi have been isolated from sorghum grains (listed in Chapter I) which reduce the seed germination and stand of the crop. Fungi belonging to 32 genera have been reported from other countries out of which five (*Fusarium, Curvularia, Alternaria, Aspergillus* and *Phoma*) have shown their predominance. In pathogenicity tests, carried out at anthesis stage, the *Fusarium* and *Curvularia* fungi proved to be the principal pathogens, producing even embryo infections ranging between 16-23 per cent. *Fusarium moniliforme* has shown greater pathogenicity than *F. semitectum*. Wet weather during flowering period is conducive to attack. Molds can also develop as saprophytic fungi on heads or grains, if left in the field under moist conditions.

Control

Since chemical control through spraying is impractical and uneconomical, the development of resistant varieties is the only possible solution. In varietal testing trials in Pakistan, ten varieties were found to be moderately resistant and two moderately susceptible (with 2 and 3 ratings, respectively) according to 0 to 5 scale. Some sources of resistance have been identified by the sorghum breeders and are being utilized in the development of resistant varieties. Such varieties are now available in India, in which heads mature while the stalks are still green and are used as fodder.

The other minor fungal diseases recorded are downy mildew (*Peronosclerospora sorghi*), rough leaf spot (*Ascochyta sorghi*), grey leaf spot (*Cercospora sorghi*), zonate leaf spot (*Gloeocercospora sorghi*), sooty stripe (*Ramulispora sorghi*), head smut (*Sphacelotheca reiliana*) on which practically no work has been done (Fig. 4.6).

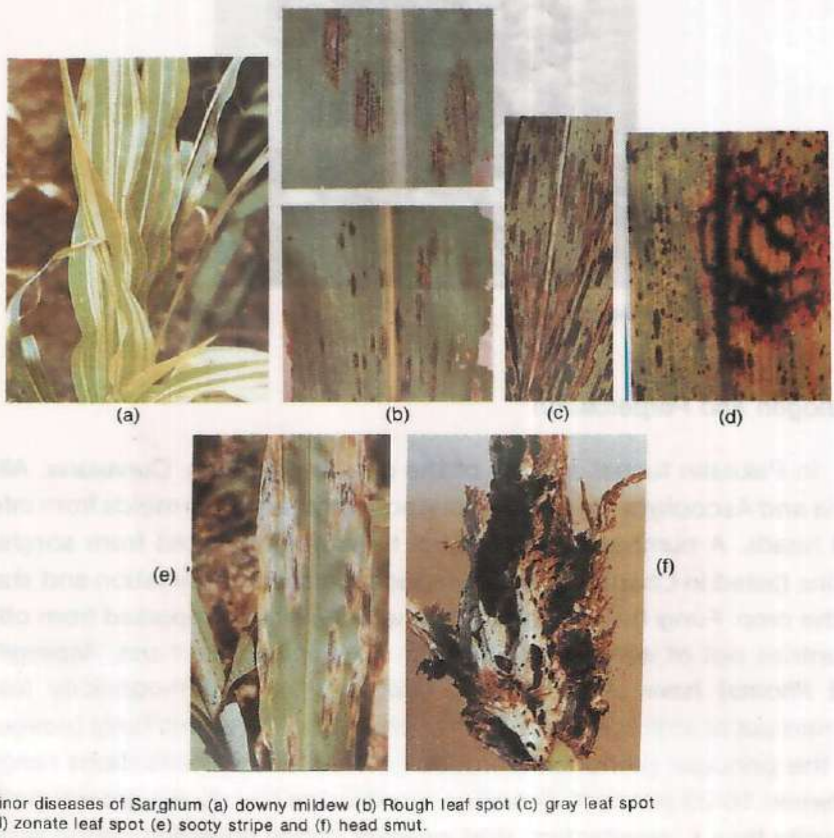

Fig. 4.6: Minor diseases of Sarghum (a) downy mildew (b) Rough leaf spot (c) gray leaf spot (d) zonate leaf spot (e) sooty stripe and (f) head smut.

Millet

Millet or *Bajra* (*Pennisetum typhoideum*) occupying more than 600,000 hectares is an important crop of low rainfall and marginal areas and is used both for fodder and as grain. Out of the four diseases recorded (green ear – *Sclerospora graminicola*, grain smut – *Tolyposporium penicillariae*, rust – *Puccinia penicillariae* and leaf spots caused by *Curvularia penniseti* (Mitra) Boed and *Helminthosporium hawaiiense* Bong) the first two are of economic importance. The salient features of the work done at Tando Jam are given below:

Green Ear –*Sclerospora graminicola* (Sacc.) Schroet.

Occurrence and Symptoms

The disease is found in almost all the millet – growing areas in varying intensities, causing reduction in the yield due to deformation of ears which produce no grain. The disease is noticed at ear formation stage when the leaves become distorted, twisted, crinkled and lose their green colour. Ears are transformed into green leafy structures with enlarged glumes turning wholly or partly into loose heads (Fig. 4.7).

Fig. 4.7: Green ear of millet.

Pathogenicity and Perpetuation

The disease is caused by the fungus *Sclerospora graminicola* through the diseased plant debris containing oospores, lying on the soil, infecting the plants in the seedling stage. The secondary infections take place from the production of a large number of zoospores which fall on the plants through wind or rain splashes. The mycelium of the fungus produces non-septate sporangiophores (268 µ long) giving rise to hyaline and elliptical sporangia, measuring 12-35 X 12-24 µ, containing thick walled and round oospores (35 µ in diameter).

Control

In the absence of resistant varieties, only sanitary and cultural measures can help to keep the disease under check. These include (a) collection and burning of diseased plants as soon as they appear; (b) destruction of diseased plant debris; and (c) use of 2-3 years rotation. However, more intensive studies are needed to have a full insight of pathogen and factors affecting the incidence, with a view to developing more reliable control measures including breeding of resistant varieties.

Grain Smut, *Tolyposporium penicillariae* Bref.

Occurrence and Symptoms

The disease occurs in traces here and there in lesser frequencies than "green ear". It manifests at the head formation stage converting healthy grains into diseased ones, scattered or concentrated on the surface of head like long smut of sorghum. The smutted grains are thick, slightly elongated, covered by tough and blackish green membrane filled with spores. The reduction in yield is in direct proportion to the percentage of the diseased grains (Fig. 4.8).

Fig. 4.8: Grain smut of millet

Pathogenicity

Apart from seed-borne infection, the disease perpetuates mostly through air-borne sporidia released from germinating chlamydospores lying on the soil as in the case of long smut of sorghum.

Control

In the absence of resistant varieties, early collection and burning of diseased ears is a good preventive measure. However, much more work remains to be done on various aspects of the disease and development of resistant varieties.

Maize

Maize is an important crop of Pakistan, occupying more than 0.7 million hectares with total annual production of 0.9 million tons. It is multipurpose crop used for fodder and grain as well as for production of edible oil, starch and glucose. Because of improvement programmes, its average yield has been increased to 1300 kg/ha besides its successful introduction as a spring crop. The yield can be further improved through the use of good husbandry practices and control of some important diseases. A summarized account of such diseases is reproduced below:

1. Leaf Blight, *Helminthosporium maydis* Nisik and Mity.

Occurrence and Symptoms

The disease also known as southern leaf blight, is of common occurrence being present in almost all the fields in varying intensities. It can be observed on all the plant parts (leaves, stalks, leaf sheath, ear husks and cobs) but it is conspicuously visible on the leaves, which develop well defined and elliptical lesions of varying size with reddish brown colour, which progressively increase in number involving large areas. A black, sooty mold may cover affected kernels. The fungus sporulates profusely in the centres of the lesions and the conidia disperse by air and rain, causing additional secondary infections on the newly emerging leaves. In severe cases the leaves die inflicting damage to the crop in the form of its reduced stand and grain yield (Fig.4.9).

Pathogen and Perpetuation

Apart from *Helminthosporium maydis*, two other species *H. turcicum*

(Northern leaf blight) and *H. carbonum* have also been reported which produce rather distinct symptoms and are confined to certain specific areas with cooler temperatures. The lesions are rectangular and give burning look to the leaves.

The disease perpetuates from the infected plant debris, infected grains or by the spores carried from distinct areas or from the other host plants like sorghum, Sudan grass and other grasses. The secondary infections take place by the spores formed on the lesions during the growing period.

Fig. 4.9: Leaf blight of maize.

Control

Since fungicidal sprayings are uneconomical, the development of resistant or tolerant varieties is the only practical solution of controlling the disease. No work has been reported to be carried out in Pakistan, except that the variety Pool-20 has medium tolerance. However, some progress has been made in the advanced countries.

2. Stalk Rot, *Fusarium moniliforme* and other Pathogens.

Occurrence and Symptoms

The disease is present in many maize growing areas of the country. No systematic studies have been carried out on the incidence, losses caused, control and other related aspects of the disease. The disease is not visible outwards as the infection develops internally involving the stalk or ears in some cases. The plants become weak with the progress of the disease till the stalks start breaking near the maturity period. The infected stalks show rotting on spliting while a few kernels may also develop rotting symptoms. The causal fungi produce different discolourations (Table 4.1). The disease produces lodging and yield reduction as well as poisonous effects, when infected grains mixed with normal ones are used for eating (Fig. 4.10).

Fig. 4.10: Stalk rot of Maize (*Macrophomina Phaseoli*).

Table 4.1: Nature of symptoms produced by different pathogens.

Name of pathogen	Symptoms
Fusarium moniliforme	*Produces rotting of roots, basal parts and lower* internodes; giving rise to whitish pink to salmon discolouration of the pith, breaking of stalks and premature ripening. Sometimes also produces kernel or ear rot characterized by pink to white powdery or moldy growths which are toxic in nature.
Rhizoctonia bataticola	Causes charcoal rot in seedlings or plants approaching maturity, converting the lower internodes grayigh in colour. It develops shredding of the pith and abundance of black sclerotia.
Gibberella zeae	Produces rotting of ears starting from the tip and gives rise to pink to red discolouration. Infection takes place through and around the silks after pollination.
Cephalosporium acremonium	Produces white flufy mycelium under the husks affecting the quality of the grains.
Diplodia maydis	Causes browning of pith of basal internodes accompanied by abundant pycnidial formation on the surface.
Erwinia carotovora	Causes bacterial stalk rot of upper ground parts, producing discolouration of internodes which become soft and mushy, emitting unpleasant odour. Plants often wilt and die.

Pathogen and Perpetuation

There are a number of stalk rot fungi including *Fusarium* (as imperfect stage) and *Gibberella* (as perfect stage), *Diplodia* and *Cephalosporium acremonium* present alone or in combination, depending upon the weather conditions. They also infect wheat and barley crops, causing blight and scab diseases. The other stalk rots are charcoal rot (*Rhizoctonia bataticola*), bacterial stalk rot (*Erwinia carotovora* var. *zeae*). Pathogenicity experiments have shown that plants two weeks after tasseling become more vulnerable to the disease, which can be produced in high intensity with the combined cultures of *Fusarium moniliforme* and *Macrophomina phaseolina*.

It perpetuates through the infected plant debris while secondary infections can take place during the growing period of the crop, depending upon suitable temperature and humidity.

Control

The use of resistant varieties is the only economical and lasting control measure as the other methods are both unsatisfactory and uneconomical. Out of the twelve varieties tested under artificial conditions of inoculation in Pakistan, none was found to be resistant; disease rating scale ranging between 3.1 to 3.6 (3 = 51-75 per cent infection).

3. Smut, *Ustilago maydis* (DC) Cda.

Occurrence and Symptoms

The disease, although present in the country, is of rare occurrence causing negligible damage. It develops white to greyish-white galls of different sizes (2.5-15 cm diameter) on plant parts – leaf midribs, base axils of the leaves, stems, tassels or ears. The galls, which are light coloured in early stages, become blackish on maturity enclosing masses of black spores. Seedling infections result in distorted and dwarfed-plants and infections can take place on any vegetative part during the growing period; mechanical injuries making the plants more vulnerable. The ear infections are very conspicuous due to their large-sized galls involving the entire head (Fig. 4.11).

Fig. 4.11: Smut of maize and head smut of maize.

Perpetuation

The disease perpetuates through infected plant debris while the secondary localized infections can occur throughout the growing period by spore dispersal through wind and rain splashings.

Control

Since the fungicidal sprays are not economical, development of resistant varieties is the only possible solution. No work has been done in Pakistan, except on preliminary screening of some germ plasm stocks.

4. Seed and Seedling Rot, *Pythium* spp.

Occurrence and Symptoms

The seed and seedling rot, which is also called damping-off has been found to occur in cold places having poorly drained and wet soils, causing pre or post-emergence rotting, which reduces the stand of the crop and consequently the yield. The main symptoms include rotting of the seeds, wilting and chlorosis of leaves and rotting of stems at ground level. The disease may also appear on adult plants under favourable temperature (8-10°C) and moist soil conditions (Fig. 4.12).

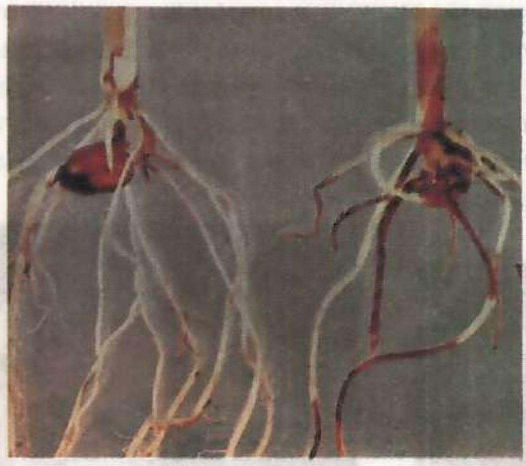

Fig. 4.12: Seed and seedling blight of maize.

Pathogen and Perpetuation

Many soil and seed-borne fungi may infect germinating maize seeds but the most important group is *Pythium* spp., which also infects sugarcane, sorghum and related crops. The disease is carried over from year to year through infested soils and diseased plant debris.

Control

In the absence of resistant varieties, phytosanitary measures (burning of diseased plant debris, crop rotation, planting on well-drained soil, avoiding cold weather and seed injuries) as well as use of seed disinfectants can greatly help to reduce the incidence of the disease and damage to the crop.

There are some other diseases of minor importance. These are rust (*Puccinia sorghi*), downy mildew (*Sclerospora* spp.), nematode and viral diseases as well as striga (which have been discussed separately). A new disease called Banded Leaf and Sheath Spot, has been reported from Pakistan, which was reproduced by inoculating the ear husks with the culture of *Hypochnus saskii*, isolated from the infected ears (Fig. 4.13).

Maize rust may appear in higher hills, producing golden – brown pustules on leaves later on becoming brownish – black and killing the leaves in severe cases. The inheritance of the pathogen is controlled by a single gene. Downy mildew is caused by many species of *Sclerospora* (such as Philippinesis, sorghi, sacchri or maydis), producing leaf streaking, chlorosis and stunting.

Many types of ear rots caused by different fungi (*Gibberella, Claviceps, Penicillium, Aspergillus* and *Physalospora*) have been recorded. In all 33 fungal, 3 bacterial and 5 viral diseases have been reported.

Fig. 4.13: Minor diseases of maize (a) rust (b) downy mildew and (c) Banded leaf sheath spot

Summary

Work carried out on grain smut, long smut, red leaf spot diseases and grain mold of sorghum is discussed in this chapter. Grain smut of sorghum (*Sphacelotheca sorghi*) has been found to be checked by disinfecting the seed with any one of the chemicals like copper carbonate, powdered copper sulphate, sulphur or ceresan. In addition to this, it has been discovered that the disease can be checked by about 70 to 90 per cent when the sorghum seed is broadcast on dry soil and water is applied immediately afterwards. The date of sowing has also a great influence on the incidence of the disease. Sowings carried out during June and July when soil temperature is above 38°C (which is unfavourable for spore germination) tend to reduce the incidence of the disease considerably.

Long smut of sorghum (*Tolyposporium ehrenbergii*), which causes a good deal of damage in certain areas of the Punjab and Sind has been investigated for the first time as regards its life history, which was unknown to the scientific world upto 1945. The disease has been found to perpetuate either by sowing contaminated seed, sowing seed in contaminated soil or through secondary infection (which takes place from spores shed on the soil in the previous year or spores produced in the infected grain sacs in the same year). The aerial infection plays a major role in the perpetuation of the disease. Work has also been carried out on spore germination and effect of toxins on spores. Factors affecting the incidence of the disease have been discovered and it has been found out that the disease generally appears in the sowings done in the month of April and May and the crop sown in June is either free from the disease or the incidence is considerably reduced, because in the former case flowering period coincides with rainy season, which is more conducive to aerial infection. Control measures have been developed which include disinfection of seed, destruction of diseased heads and a few years' rotation. Studies carried out on genetics of *Tolyposporium* smuts (*T. ehrenbergii* of sorghum and *T. penicillariae* of millet) and *Ustilago scitaminea* of sugarcane have shown that *Tolyposporium* smuts are heterothallic, segregating on 2:2 basis for sex and cultural characters with more possibility of recombination of factors with compatible sporidia resulting into greater variation. *Ustilago scitaminea* also proved to be heterothallic like other species of *Ustilago*.

Work carried out on red leaf spot diseases has shown that there are two types, one caused by *Phyllosticta sorghina* and the other by *Colletotrichum graminicolum*. These diseases are perpetuated either through infected seed or through diseased plant debris lying in the soil. The

disease caused by *C. graminicolum* is more common than the other. Physiology and morphology of both the fungi have been studied and the control measures have been worked out which consist in soaking seed in ordinary water for four hours and then immersing it for 1 1/2 hours in hot water at 55°C. Careful removal and destruction of the diseased plant debris is also very helpful in checking the diseases.

Grain mold caused by many fungi with predominance of *Fusarium* and *Curvularia* spp. has been studied as regards its occurrence, symptoms, causal fungi and varietal reaction. It has widespread occurrence particularly under moist conditions during the flowering period. The principal control measure lies in the development of resistant varieties, for which sources of resistance have been identified.

In case of millet, out of the four diseases recorded some preliminary studies have been carried out on green ear and grain smut diseases covering symptoms, pathogenicity, perpetuation and possible control measures. However, much more work needs to be done to fully understand the nature of the diseases and develop suitable resistant varieties.

Salient features of some investigations carried out on diseases of maize including leaf blight (*Helminthosporium maydis*), stalk rot (*Fusarium* spp.), smut (*Ustilago maydis*) and seed and seedling rot (*Pythium* spp.) have been given suggesting the need for development of resistant varieties because of uneconomic control by fungicidal treatments. In addition, the presence of some minor diseases (rust and downy mildew) as well as a newly recorded disease (banded leaf and sheath spot, caused **by *Hypochnus saskii*) has also been reported. So far identified diseases comprise 33 caused by fungi, 3 by bacteria and 5 by viruses.**

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Sugarcane

The importance of sugarcane crop is quite great in Pakistan as it occupies 0.75 million ha with an average production of 37 tons/ha, which is comparatively much lower than many sugarcane producing countries of the world. Its value lies in the fact that it is not only cash crop for the farmers but it also provides them with a very good substitute for sugar in the form of jaggery, sugarcane tops as fodder and baggasse as fuel. Since the establishment of Pakistan, the importance of sugarcane was further enhanced because Pakistan, being deficient in sugar, had to depend heavily on costly imports till 1981. Later on self-sufficiency was achieved due to varietal improvement, use of good husbandry and introduction of guaranteed price for the produce. However, the per unit area yields are still low. It is, therefore, evident that all efforts, directed towards improving the present output of sugarcane, will prove ultimately beneficial to the country. The protection of this crop against diseases will go a long way in improving the present situation. Some of the important results of the work carried out on smut, stem canker, red rot, mosaic, yellowing, chlorosis and leaf spot diseases of sugarcane, which reduce the yield, are given below:

1. Smut, *Ustilago scitaminea* Syd.

Occurrence and Symptoms

The smut disease which has been reported from at least 36 countries, is prevalent throughout Pakistan with varying degree of incidence being comparatively higher in neglected and ratooned cropping areas. The infection percentage is between 1 - 2, on an average basis going as high as

30-40 in some individual fields. It has been found to decrease the yield by 0.7 to 0.8 per cent for each unit 1 per cent increase in infection. It is essentially a disease of thin and medium varieties. The affected canes produce long, black whiplike and coiled or curved shoots, which are covered with a thin silvery membrane containing masses of chlamydospores of the fungus. The smutted shoots may arise from the top of the cane or from lateral buds (Fig. 5.1). Later on the thin membrane ruptures releasing a multitude of spores, which contaminate soil and the standing crop. In certain cases the infected plants remain stunted in growth with increased tillering of little value.

Fig. 5.1: (a) Whip smut of Sugarcane.

Germination of Spores

The optimum temperature for the germination of spores is about 30° C, the maximum being 36 to 40°C and the minimum lies between 5-13°C. The spores on germination produce either one or two germ-tubes, bearing sporidia at all the temperatures except at 30°C and above. Glucose solution (0.5 to 5 per cent) and sugarcane leaf decoction (0.12-1N) are the best for the germination of spores. The germination in these solutions is so rapid and vigorous that observations on percentage of germination and length of germ-tubes have to be recorded after 5 hours, whereas in other cases these are recorded after 9 hours. Germination does not take place in 1.0 per cent solution of sodium carbonate and sodium chloride and 0.5-1N concentrations of dung extract. Germination is less than 1.5 per cent, after 22 hours in 0.5 to 1.0 per cent solutions of magnesium sulphate, potassium sulphate, sodium nitrate, 1N soil extract, 1.0 per cent potassium nitrate and ammonium sulphate and in 0.06-0.12N of dung extract. Fair or good germination is obtained with lower concentrations of the nutrients stated above and in 0.1-1.0 per cent of potassium phosphate and potassium chloride solutions and distilled water.

Viability of Spores

The spores kept in the laboratory at different temperatures varying from 5 to 35°C for 210 days gave germination up to 70 per cent. The spores, when buried in the soil at a depth of 2.5, 5 or 15 cm, lose their viability within 4-7 months, while those, which are kept on the surface, do so within 7-10 months.

When spores are buried after coating them on cane setts at a depth of 10-20 cm at different temperatures varying from 14 to 31°C and kept moist, they lose their viability after 3 weeks. Spores remain viable when buried in ice for even 120 hours. The thermal death point of the spores is 62°C.

Modes of Perpetuation

It has been found that the disease is carried over from year to year by the following methods:-

(a) By planting setts taken from smutted shoots of cane. The mycelium of the causal fungus lies dormant in such canes and begins to grow as the buds sprout and produces smut (30-50 per cent infection).

(b) By spores adhering to the buds of setts at the time of planting. The spores germinate as the buds sprout and the germ-tubes penetrate the young seedlings and then the mycelium grows inside the seedlings and produces smut (average infection 23.5 per cent).

(c) When the cane crop is in the field, the spores from smutted canes are carried by wind and may fall on the buds of standing canes and produce germ-tubes which enter the buds and cause infection. Some of the infected buds sprout during the same season and produce smutted side-shoots. Those which do not sprout contain mycelium, which remains dormant. When setts with such buds, having dormant mycelium inside, are planted next year, the canes produced are smutted (30-50 per cent infection).

(d) By ratooning smutted canes. The mycelium remains dormant in the stumps and resumes growth as the canes grow and produces 100 percent smutted canes. Although all the four modes of perpetuation are effective, ratooning of the crop is the most serious.

Physiologic Races

Six collections have shown five different races on the basis of their pathogenicity tests on four differential varieties of sugarcane, Co-312, Col-44, Col-38 and Co-2.

Varietal Resistance

Twenty eight sugarcane varieties tested can be arranged in the following groups according to their resistance to this disease. (Table 5.1).

Table 5.1. Reaction of sugarcane varieties to smut.

Infection	Name of variety
No infection	None
1-10	Col. 4,5,8,9,12,30,31,22,24,28. Co. 285, 617, 360, 421, 453. S. 1150, 1234, 125, 1199, 1200 and COK. 30.
11-20	Co. 312, 313 and COL. 62.
21-30	COL. 99.
31-50	COL. 11.
Above 50	Katha.

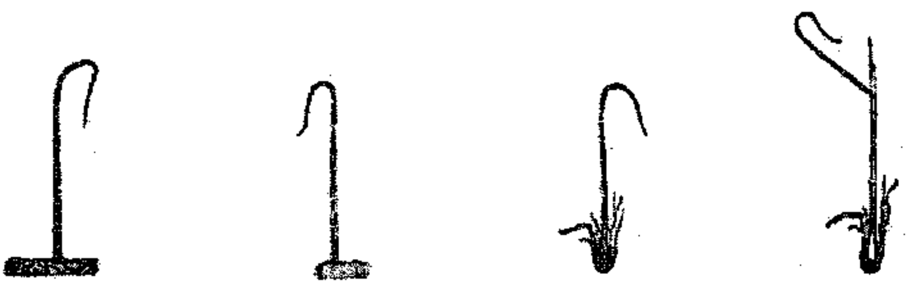


Fig. 5.1(b) Diagrammtic sketch showing perpetuation of sugarcane smut

The later studies have shown that out of 76 varieties tested at Tando Jam none is resistant, seven have shown 1-10 per cent infection (the important being Co. 622 and PR 100), eighteen (11-20 per cent), twelve (21-30 per cent), sixteen (31-40 per cent), seven (41-50 per cent) and sixteen (above 50 per cent). Varietal tests carrid out at Faisalabad have shown that early varieties (Col. 65, BL-5 and 11, S-2349) and late varieties (BL-7, 9, 14, S-2727, 2811, Col-61) have proved to be some what resistant. Similar results were obtained at AARI, Lyallpur (Faisalabad). Work on the development of resistant and tolerant varieties needs to be concentrated.

Factors Influencing the Incidence of the Disease

Soil moisture during germination period plays a very important role on the incidence of the disease. With high soil moisture contents the spores of the causal fungus show poor germination, resulting in low infection. The incidence of the disease is reduced by 75 per cent when the plantings are carried in dry soil to which water is applied immediately afterwards.

Since 30°C is the optimum temperature for the germination of the spores of the pathogen, soil temperatures at the time of sowing can also affect the infection percentage, as is evident from the pathogenicity tests where the infection is much higher in September/October plantings than in March plantings. Autumn planting of the crop should, therefore, be avoided.

Control

The following measures have been found to be effective and are recommended to the farmers:-

1. Setts from smutted canes should not be used for planting.

2. Seed-setts should be disinfected either in 0.1 per cent mercuric chloride solution for 5 minutes or in 1.0 per cent formalin solution for 5 minutes, followed by 2-hour covering under a moist cloth. The other effective chemicals are Antimucin, Aretan 6, Cerenox special, Granosan new improved, Dithane M-45 and Agallol. These treatments apart from reducing the disease incidence, give higher emergence, vigorous seedlings and increased yield. Hot water treatment of setts (at 52°C for 18 minutes) can help eliminate the internal infection.

3. Smutted plants should be rogued out carefully and burnt as soon as they appear, preferably before the bursting of the spores.

4. Ratooning of the diseased crop should be discouraged. Instead, suitable rotations with non-host crops should be practised.

5. Dry sowing of the crop should be carried out in areas where disease is prevalent.

6. Autumn planting of sugarcane should be avoided.

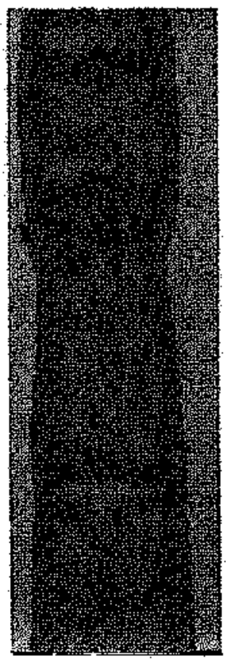
7. The use of resistant varieties such as BL-4, BL-16, Triton, L-116 and PRO-1999 should be encouraged.

2. Stem Canker, *Cytospora sacchari* Butl.

Symptoms

The disease manifests itself in different forms. In its most serious form the disease causes wilting of canes. The affected canes show drying of leaves from top downwards as if they are suffering from drought. The cane stems are shrivelled with considerable reduction in quantity and quality of juice. The whole stool or only a few canes in a stool may be affected. It has been seen that the mother setts of such stools bear pycnidia of the causal fungus. Holes and wounds facilitate the entry of the fungus and in such cases the fungus remains confined to few internodes only.

The pycnidia of the fungus develop when the cane has completely dried up. Pycnidia have been found even on buds of some badly diseased nodes or in the hollows of diseased cane stems. The fungus also attacks the leaf sheaths. The pathogen has been found to be more virulent when the cane approaches maturity. The disease also damages the canes which are buried for seed purposes, as practised by the farmers, in order to protect them from frost (Fig. 5.2).



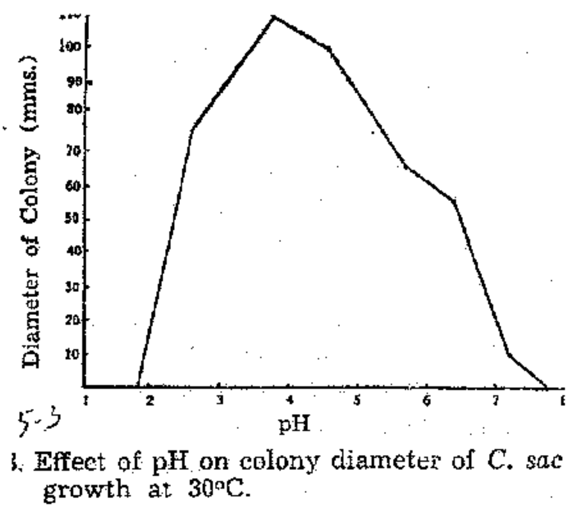


Fig. 5.2: Stem canker of Sugarcane.

Fig. 5.3: Effect of pH on colony diameter of C.*Sachhari* after 6 days growth at 30°C.

Inoculation experiments have shown that the fungus *Cytospora sacchari* is more parasitic when canes are reaching maturity.

Modes of Perpetuation

The fungus remains viable in diseased canes, which remain lying in the fields after the crop is harvested. The spores formed in pycnidia on such canes can initiate infection next year. Results of inoculation experiments have shown very high degree of pathogenicity of the fungus, resulting into 100 per cent infection of the tested varieties (Co. 312, 313, 323, 371 and 373).

Physiology of the Fungus

For linear growth of the fungus, gur (jaggery) agar, oatmeal agar and Richard's agar are better than nutrient glucose agar, Brown's agar and Brown's starch agar. The maximum growth of the fungus takes place on 1-2N concentrations of Richard's agar. Above and below these concentrations the growth falls. Elimination of sucrose from Richard's agar reduces the growth of the fungus by about 50 per cent, but the individual elimination of potassium nitrate, potassium dihydrogen phosphate or magnesium sulphate from the medium does not substantially affect the growth if pH of the medium is adjusted at 5.0.

When glucose or lactose is substituted for sucrose in Richard's agar, the growth of the fungus falls by about 40 per cent but when maltose is substituted for sucrose, the growth remains unaffected. The growth gradually increases with the increase in the amount of sucrose in Richard's agar till it reaches its maximum when the amount of sucrose is raised to 200 g per litre.

The optimum temperature for the growth of the fungus is about 30°C, the maximum lies between 35 and 40°C and the minimum is below 15°C.

The maximum growth of the fungus is at pH 3.8; on the acid side growth stops at pH 1.8 and on the alkaline side at pH 7.8 (Fig. 5.3). The importance of this interesting behaviour of the fungus in relation to pH is helpful in controlling the disease.

The fungus forms pycnidia on *gur* (jaggery) agar and oatmeal agar but none on other media (Richard's agar, Nutrient glucose agar, Brown's agar and Brown's starch agar) within 35 days of growth. The number of pycnidia produced on oatmeal agar varies in direct proportion to the concentration of the medium as well as to the amount of sucrose added in oatmeal agar (Table 5.2). Light and maltose also favour the formation of pycnidia.

Table 5.2. Effect of different amounts of sucrose on the formation of pycnidia after 37 days' growth at 26°C.

Quantity of sucrose g/1000 ml	Formation of pycnidia
200	Abundant
100	Abundant
50	Moderate
25	Moderate
12.25	Scanty
6.25	Scanty
0	Scanty

Fig. 5.4(a): Red rot of Sugarcane

Fig. 5.4(b): A cane set showing the fruiting bodies of the fungus at the node.

Control

Since the soils of canal colonies in Pakistan are alkaline and unfavourable for the growth of the causal fungus, it will not grow in these soils but it can remain alive in diseased canes lying in the field from where it can cause infection next year. Therefore, the destruction of cane plant debris alone would control the disease in such places. However, the development and use of resistant varieties will be a more practical and economical control measure.

3. Red Rot – *Collectotrichum falcatum* Went.

Symptoms

Red rot of sugarcane was first recorded from Java in 1883 and in the sub-continent of Indo-Pakistan by Barber and later on by Butler in 1906. It is a serious disease of Ponda cane (thick chewing variety) and is caused by the fungus *Colletotrichum falcatum*. The attack on thin varieties is generally slight. The disease first appears as red bright lesions on the mid rib of leaves and shows itself in the form of drooping and changing of colour of upper leaves when the plants approach maturity from September onwards. Withering of the leaves proceeds downwards with the progress of the disease. Usually third or the fourth leaf from the top is affected and later on the whole crown withers and droops. In severe cases complete destruction of the stools is brought about. When the infected canes are split open they give out an alcoholic smell due to fermentation and show reddened areas, varying in size according to varietal reaction. The infection spreads through the nodes to the adjoining internodes. The pith gradully dries up with the progress of the disease and ultimately the *rind* falls in, thus giving rise to longitudinal depressions and the cane becomes very light in weight. With the drying of the cane, fruiting bodies of the causal fungus are noticed on the rind usually just below or above the nodes (Fig. 5.4). In resistant or tolerant varieties the symptoms are masked and remain restricted.

Pathoen

The causal fungus *Colletotrichum falcatum*, has its perfect stage as *Physalospora tucumanensis* Speg. While some scientists have named it as *Glomerella tucumanesis* Von Arx and Muller. It produces oval acervuli with setae, hyaline and septate conidiophores and one-celled hyaline conidia.

Perpetuation

It has been found that the disease is perpetuated from year to year by planting setts from infected canes (which carry the fungus in bud scales or inside the cane) and also through the fungus which remains viable on diseased canes, lying in the fields after the crop is harvested. Secondary infections take place during the rainy period through conidia, falling on the nodes.

Control

In addition to planting of setts from healthy canes and destruction of diseased cane debris for the control of the disease, non ratooning and use of resistant varieties is recommended. Disinfection of setts with fungicides (Dithane M-45 or Benlate) can help in getting rid of surface-borne spores. Earlier two varieties of ponda cane (BFS 12(17) and B 6308) were found to be resistant to the disease. Recent studies on 68 varieties have shown four commercial varieties (COL-54, BL-4, Triton and L-118) to be resistant while COL-44, COL-29 and L-116 are highly susceptible.

4. Leaf Spot – ***Helminthosporium*** **spp.**

Occurrence and Symptoms

The disease was first time recorded in 1966 at Tando Jam both at the Agricultural Research Institute and in the farmers' fields occurring in traces to five per cent. The disease manifests itself on leaves as small lesions, measuring 3-5 mm. in diameter, which gradually enlarge along the mid rib and assume dark red to brown colour. In severe infections the leaves become dry affecting photosynthesis. It has not been found to do much damage to the crop.

Pathogenicity and Perpetuation

Artificial inoculations with the culture of the fungus both in the laboratory and in the field have given positive results. The disease perpetuates through the fungus present in the infected leaves lying in the field and spreads through fresh crops of conidia falling on leaves of adjacent plants.

Morphology of the Fungus

The morphological studies have shown that the mycelium of the fungus consists of septate and profusely branched hyphae. Conidiophores are septate and dark olivaceous in colour with conidia of same colour, straight, elongated and elliptical, tapering towards the round ends. The conidia are usually four-celled, measuring 14-35 X 8-12 μ and germinate by producing germ tubes from each polar region.

Control

No work has been done on the control measure. Phytosanitary precautions in suppressing the sources of inoculum should greatly help in reducing the incidence of the disease.

5. Pokkah Boeng – *Fusarium moniliforme* Sheldon

Occurrence and Symptoms

Pokkah boeng (meaning distorted top in Javanese) although reported from Java since long, its causal agent was not established till 1927 by Bolle. It is now present in many countries including Pakistan. Very little work has been reported except some preliminary studies. The disease appears in different stages representing development of chlorotic areas at the basel parts of the lower leaves, development of irregular reddish specks or stripes and appearance of top rot followed by total killing. The young leaves may also show pronounced wrinkling, twisting and shortening, depending upon the varieties and climatic conditions. In tolerant varieties there may be recovery of growth, when the conditions improve. (Fig. 5.5).

Fig. 5.5: Pokkah, boeng of Sugarcane

Pathogen

The causal fungus is *Fusarium moniliforme* which has *Gibberella moniliformis* (Sheldon) Wineland as its perfect stage. The perithecia are usually 8 spored, measuring 68-109 X 9-14 μ and ascospores are almost straight, rounded at the ends and are 1-3 septate.

Control

The practical control measure lies in the cultivation of resistant varieties. Out of 31 tested varieties a few have shown 0 to 4 per cent infection (R-366, HF-147, COL-54, BF-142, BF-142) while in others the incidence ranged between 5-34 per cent. If resistant varieties are not available care should be observed not to use seed setts from diseased plants.

The other diseases reported from Pakistan are ratoon stunting, yellow spot (*Cercospora koepheli*), rust and genetic varigation of leaf and sheath on which no work has been done.

Summary

Work carried out on smut, stem canker, red rot, leaf spot and pokkah boeng diseases of sugarcane has been described. Smut is common disease of thin varieties. The physiology of the causal fungus, *Ustilago scitaminea* has been studied and the viability of the spores has been determined both under laboratory and field conditions. The disease has been found to perpetuate through either infected setts (carrying dormant mycelium of the fungus), buds of setts contaminated with spores, infected buds containing dormant mycelium, or by ratooning the infected crop. Work has also been carried out on varietal resistance. Out of the 28 different varieties tested, none has been found to be resistant to this disease, while there are a few varieties in which the degree of resistance is quite tolerable. Later studies, on field testing of 76 varieties, have given similar results. Factors affecting the incidence of the disease and control measures have been worked out.

Stem canker, caused by *Cytospora sacchari* brings about drying of leaves from the top downwards. The cane stem becomes shrivelled and is very poor in juice. The pycnidia of the fungus develop when the stem has completely dried up. The fungus is more virulent on canes nearing maturity. The canes buried for seed purposes, are also damaged. The disease is perpetuated through the fungus, which remains viable in diseased plant portions lying in the field. Studies on the physiology of the causal fungus have revealed that sucrose enhances the growth of the fungus to a great extent. Destruction of diseased plant debris helps in controlling the disease. The fungus does not thrive in the soils of canal colonies which are alkaline.

Red rot of sugarcane caused by *Colletotrichum falcatum* has been found to perpetuate through setts taken from diseased canes and also through the fungus that remains viable on diseased canes lying in the field after the crop is harvested. The ratooning of the infected crop also produces the disease. In addition to planting of setts from healthy canes, destruction of diseased cane debris is helpful for the control of the disease. Sugarcane varieties, which have been found to resist the disease are also recommended for growing.

Studies on *Helminthosporium* spp. leaf spot (a minor disease) have shown the pathogenicity of the fungus and its perpetuation through the infected leaves lying in the field. Morphology of the fungus has been determined and control measures suggested. Pokkah boeng (top rot) caused by *Fusarium moniliforme* has been described as regards symptoms and some control measures have been suggested.

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Cotton

Cotton is one of the most important cash and foreign exchange earning crops of Pakistan, occupying 1.9 million hectares with an average lint yield of 284 kg/ha (which is very low by world standards). At present the normal annual production of cotton in Pakistan is above 4 million bales out of which nearly 50 per cent are exported.

The cotton crop is subject to the attack of a number of diseases; some are minor and others serious, causing heavy losses to the crop both in quantity and in quality.

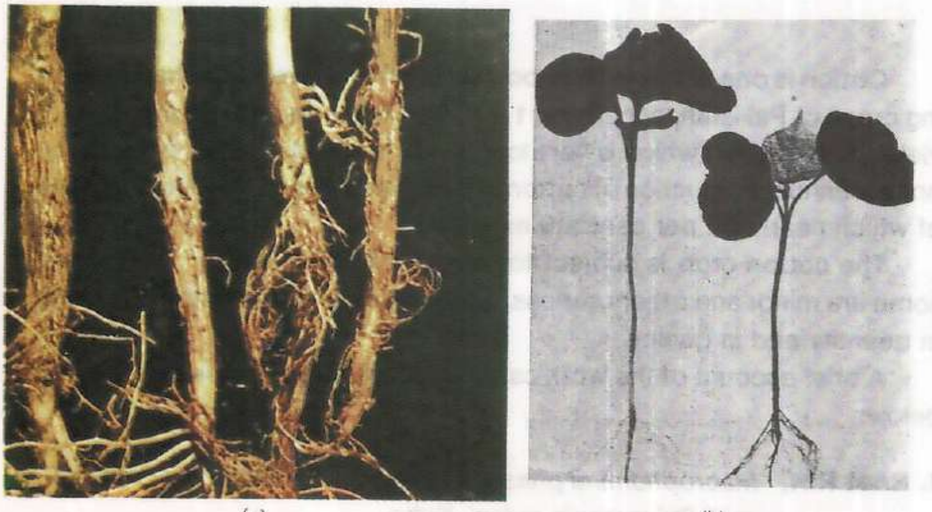
A brief account of the work carried out on different diseases is given below.

1. Root Rot, *Macrophomina phaseoli* (*Rhizoctonia bataticola* C strain) and *Phizoctonia solani*, Kuhn.

Occurrence and Symptoms

Root rot is prevalent in traces or in high intensities in localized areas throughout the cotton growing tracts of the country. As the name implies, the disease affects the roots exclusively causing pre wilt shedding of cotton leaves, yellowing of foliage, disintegration of root tips, discolouration and shredding of roots, exudation of drops of smelly liquid from the rotted areas, producing at first, wilting of shoots, which ultimately results in the death of the entire plant (Fig. 6.1). The attack starts when the cotton plants are about six weeks' old. The disease appears in June and within a fortnight the percentage of attacked plants reaches its maximum. It, however, continues to be vigorous throughout the month of July. In August the death rate of plants gradually declines and the disease almost ceases to appear by the end of September. Both American and *desi* (old world) varieties are affected equally. The incidence of the disease varies from field to field but on an average the loss has been estimated at 3 per cent of the total area under cotton, amounting to destruction of about 570.000 hectares of cotton, producing 162 million kg. of lint valued at Rs. 2800 million according to 1984 price.

The following important results have been obtained from the systematic investigation carried out for 9 years at Lyallpur (Faisalabad) by a special research staff under a scheme sponsored by the Indian Central Cotton Committee. The results of the later studies, carried out at the Central Cotton Research Institute, Multan and at the other Research Institutes including Universities are given at the end.



(a) (b)

Fig. 6.1: Root rot of cotton (a) shreded roots and (b) wilted seedlings.

Pathogenicity and Morphology of the Causal Fungi

The disease is caused by the two fungi, viz, *Macrophomina phaseoli* (*Rhizoctonia bataticola*) and *Rhizoctonia solani*.

Both are fairly fast growing fungi with optimum growth at 30°C. Above 30°C there is a fall in the rate of growth and desiccation occurs at 40°C on Richard's agar, cotton leaf and root extract agars and cotton root synthetic agar but on Brown's agar *Rhizoctonia bataticola* exhibits slight growth upto 40°C, which stops at 45°C. The minimum temperature for both the fungi is below 20°C. They have very wide range of tolerance to acidity and alkalinity, producing fairly good growth between pH 3.2 and

8.5, and growing best at pH 6 to 7.

Rhizoctonia solani fails to grow when exposed to 60°C for 5 seconds and in the case of *Rhizoctonia bataticola* an exposure of 5 seconds to 68°C is required to kill the fungus.

The parasitic activity of *Rhizoctonia solani* increases in the presence of certain other fungi, when these are added in the inoculum.

Mercuric chloride 0.09 per cent, copper sulphate 0.3 per cent and phenol 0.5 per cent solutions are effective in checking the growth of the fungi. Sclerotia of the fungi, when exposed to the moist condition for 45 minutes in hydrocyanic acid gas, lose viability but under dry conditions they remain viable even after one week's exposure.

Hydrocyanic acid gas penetrates in the soil up to a depth 45cm after 6 days and kills the sclerotia of both the fungi.

Chemical Composition of Plants

Reducing sugar and sucrose are higher in all parts, i.e. roots, stems and leaves of diseased than in the corresponding parts of the healthy plants. Similarly, N, Fe, Ca and K contents have been found to be higher in diseased roots.

Factors Affecting Incidence of the Disease

Cotton plants suffer higher mortality from root rot due to *Rhizoctonia solani* and *Rhizoctonia bataticola* at temperatures of 35 and 37°C, respectively. Although *Rhizoctonia bataticola* is actively parasitic over a range of temperature varying from 25-39 °C, there is a noticeable fall in the parasitic activity of *Rhizoctonia solani* above and below 35°C.

Soils on which disease develops usually contain higher amount of acid soluble calcium and higher calcium/magnesium ratio.

Soil fumigation with calcium cyanide, para-dichloro-benzene and various cultural treatments comprising addition of farm-yard manure, removal of diseased debris, removal of diseased debris combined with the application of farm-yard manure and the application of artificial fertilizers such as ammonium sulphate, superphosphate alone or ammonium sulphate plus superphosphate do not reduce the incidence of the disease. Similarly, the addition of mineral elements such as borax, zinc sulphate and magnesium chloride has no effect on the disease.

The incidence of the disease is however reduced considerably if cotton is, either sown late (after 20th June) or very early (in the beginning of April).

The incidence of the disease can also be reduced considerably by sowing cotton mixed with moth (*Phaseolus radiatus*) or sorghum which should not be removed from the field before 15th August.

There is no significant difference in the incidence of the disease whether cotton is sown on ridges or on flat land.

Later Studies

The salient features of the results of the later studies are given below:-

1. The work carried out on the disease at the Plant Pathological Section, Lyallpur (Faisalabad) has shown that contrary to the results obtained under the scheme, it has not been possible to produce infection by artificial inoculations with *Macrophomina phaseoli* (*Rhizoctonia bataticola*) and *Rhizoctonia solani* either in the field or in pots, indicating the presence of some unknown soil factors which predispose the cotton plants to the pathogenic or saprophytic attack of the causal fungi.

2. The investigations made at the University of Agriculture, Lyallpur (Faisalabad) have shown that out of about 10,000 root-rot affected cotton samples, collected over a period of 11 years from all over Pakistan, 56.9, 1.9 and 1.7 per cent yielded fungi, bacteria and nematodes, respectively, on isolation. The important fungi included *Rhizoctonia bataticola, Rhizoctonia solani* and *Fusarium* spp. with 26.7, 20.3 and 26.5 per cent occurrence while the other isolated fungi belonged to fourteen genera. The above mentioned three fungi have failed to produce the disease with artificial inoculation. However, the filtrates of these fungi have caused wilting in cotton seedlings because of their toxic nature. The other results are:

- It has been possible to produce for the first time the pycnidial stage of *S. bataticola* on cotton leaves through the use of stems of *Seasum indicum* inoculated with *Macrophomina phaseoli* culture;
- Fungi belonging to 55 genera have been isolated from cotton growing soils of the country;
- There is no effect of deep cultivation and application of irrigation water on the disease;
- Intercropping cotton with *Vigna aconitifolia* reduces the disease incidence but decreases the yield (except in highly infected patches);
- Growing of or green manuring with winter legumes have not reduced the disease in the succeeding cotton crop;
- The incidence of the disease is high when cotton follows oats and low when it follows barley, while it is in between when cotton is sown after wheat.

3. The results of the studies made at the Central Cotton Research

Institute, Multan have shown that:

- Inspite of higher frequencies of isolations of *Rhizoctonia solani, R. bataticola* and *Fusarium* spp. from diseased plants and soil as compared to healthy ones, the fungal cause of the disease has not been established so far;
- Presowing and postsowing chemical treatments of the known root-rot affected patches have not reduced the incidence of the disease. In some cases it has even doubled the mortality, which may be due to killing or suppressing of the soil antagonists and saprophytes;
- Intercropping with *moth* has effectively controlled the disease (O vs. 13.2 per cent) and has also reduced the frequency of *Rhizoctonia solani* by about 50 per cent but increased that of other soil fungi and bacteria. This pattern of soil fungi and bacterial population may be responsible for controlling root rot in cotton intercropped with *moth*, but scientific explanation is still lacking;
- None of the varieties, previously tested, has shown resistance. Some of the hexaploid cottons (developed by doubling the chromosome numbers of *Gossypium sturtianum* followed by crossing with *Gossypium hirsutum* with branching root system) have shown some escape rather than genetic resistance to root rot caused by *Phymatotrichum omnivorum* in Texas, USA. Such lines (TX-MAR-76C, TX-GOR-76C and TX. GN-76C) when tested in root-rot affected patches in the Punjab have given 7-14 per cent infection vs. 94 per cent in the check. Work is in progress to make use of these genetic stocks. At present CIM-70 has shown high degree of tolerance.

4. The main results of the investigations carried out at the Department of Botany, Karachi University have shown that:

- The cotton seedlings inoculated with *Macrophomina phaseolina* infected the root system, producing brown lesions and microsclerotia without showing any above ground symptoms (which appears to be a case of weak parasitism);
- The deficiency or excess of N–and K+ in soil over a wide range do not predispose cotton plants to wilting due to *M.phaseolina* infection unlike the results reported regarding *Fusarium* and *Verticillium* wilts;
- Cotton plants when subjected to water stress, are more predisposed to *Macrophomina* wilting (Table 6.1) and such conditions are of common occurrence during cotton growing season;

- Total protein contents of inoculated plants, subjected to water stress, are twice as high compared to those of regularly watered plants;
- A number of antagonistic fungi have been identified which include *Penicillium nigricans, P. urticae, Stachybotrys atra, Trichoderma virides, Streptomyces griseus, S. albus,* and *S. noursei.* Addition of organic substances like alfalfa meal and barley straw enhance the population of antagonistic fungi, actinomyces and bacteria in soil resulting into increased antagonistic action; which probably explains the beneficial affect of mixed sowing of cotton with *moth;*
- When buried in soil under dry conditions the mycelium of the fungus *M. phaseolina* dies in 7 days and sclerotia remain viable upto 10 months. Complete elimination of sclerotia can be obtained after one week mulching of moist or dry soil with transparent polythene sheets, irrespective of using lucerne or wheat soil amendments because of very high temperatures reaching 52°C or above;
- Although inoculum (sclerotial) density is directly related to the disease severity, the infection has been found to be obviously conditioned by soil moisture and progressively reduced at its increasing levels. For 50 per cent infection at 25 per cent WHC, inoculum levels of sclerotia per g. of soil are 5 for black gram, 20 for okra/guar and 40 for cotton. Sclerotial populations decline rapidly in high soil moisture regimes of 75-100 (WHC). Under these conditions the sclerotial populations are reduced by 86-96 per cent with 1 per cent alfalfa, clover or mustard amendments and by 27-33 per cent with wheat amendment after 3 weeks' interval.

Table 6.1 Effect of water stress on development of root rot of cotton caused by *Macrophomina phaseoli.*

	No. of plants treated/No. of plants affected			
	Subjected to water stress		*Watered regularly*	
Fungi	*Wilted*	*Infected*	*Wilted*	*Infected*
M. phaseoli inoculum[a] in water	6/6	8/8	8/0	8/0

M. phaseoli inoculum in 1% sucrose	7/5	7/7	8/0	8/0
M. phaseoli inoculum in Czapek's solution	8/7	8/8	8/0	8/1
1% sucrose solution	8/0	8/0	8/0	8/0
Czapek's solution	8/0	8/0	8/0	8/0
Noninoculated, watered only	8/0	8/0	8/0	8/0
Inoculated but not watered	2/2	2/0		

a. Seven-week-old cotton plants in 4-inch pots of plaster sand were inoculated with 20 ml/pot of a mycelial suspension of *M. phaseoli*; at temperatures ranging between 25-40° C.

b. Infection was indicated by the presence of micro-sclerotia on roots and discolouration of both cortical and xylem tissues without showing any above ground symptoms (weak parasitism).

5. The salient features of the investigations carried out at Tando Jam are as follows:

- The disease has been found to be quite severe (1-60 per cent) in the cotton growing areas of Nawabshah and Khairpur districts, where the ground water table is cmparatively higher.
- In isolations, *R. solani, R. bataticola* and *Fusarium* sp. have predominated while the presence of other fungi (*Aspergillus, Penicillium*), bacteria and nematodes is associated with advanced stage of the disease which therefore appear to be of saprophytic nature. Similarly, the micro-organisms obtained from healthy or diseased soil are more or less the same;
- The pathogenicity tests carried out under optimum conditions have remained inconclusive except some indications of weak parasitism in seedling stage;
- The two fungi (*R. bataticola* and *R. solani*) have shown protopectinase activity, varying with the strains and growth conditions; being higher in more active strains and in the presence of pectin at the optimum temperatures;
- There is no effect of dates of sowing, number of waterings and fertilizer application on the incidence of the disease while intercropping with *moth* reduces the disease to some extent;

- Certain specific conditions of soil, temperature, moisture and nutrition, causing stress on the plant growth, are a prerequisite for the appearance and spread of the disease.

All the later studies have clearly shown no parasitism (or very weak parasitism on cotton seedlings) of the *Rhizoctonia* species and *Fusarium* sp. alone or in combination and pre-requisite requirements of certain conditions of soil, temperature, moisture and nutrition for the development of the disease. This view is further strengthened by the fact that the disease appears in patches in the field and remains always confined to those patches inspite of all the cultural operations carried out year after year. Even sometimes the disease from these patches has also been found to disappear, which might be due to the improvement of soil brought about by continuous deep ploughings and some other cultural operations.

It is, therefore, surmised that the presence of some unknown factors in these patches is responsible in predisposing the cotton plants to the attack of the fungi either directly or indirectly by injuring the roots and thus making them susceptible. It is, therefore, obvious that on account of the failure of the previous attempts to find out the predisposing factors the methods devised to control the disease are of empirical nature and based on principles which lack scientific explanation. The lower mortality of cotton plants in June-sown crop as compared to that sown in the month of May, has been attributed to the comparatively low soil temperature in the month of June but actually it has been seen that the temperatures prevailing at this period are quite suitable for the growth of the causal fungi showing thereby the invalidity of the explanation as advanced above. Similarly, the reasons of lowered temperatures in mixed crops as compared to those in the pure crops also do not hold good as they have been found to be 29°C and 33°C, respectively, and both of them are suitable for the growth of the causal fungi. As mentioned earlier in the later studies also, intercropping with *moth* has definitely reduced the disease but it is not due to lower temperatures. The possible factors may be reduction in the frequency of *Rhizoctonia* spp. and increased population of some antagonistic fungi, which in the presence of *moth* as a soil amendment, help in reducing the incidence of the disease. Moreover, sowing date and *moth* intercropping methods of control, although effective to some extent, are open to the following two important objections:

- Late sowing of cotton is not practicable in the whole area on account of the reason that in the canal colonies, sowing of cotton, like other crops, is governed by the availability of water and it is not possible to sow more than 1/3 of the area on one water-turn.

– Mixed sowing of *moth* with cotton has been found to affect the yield adversely. Moreover, the advantage of *moth* as source of extra fodder is forteited on account of the reason that its removal is not advisable before the 15th August, the period when actually there is shortage of fodder, as later on it does not exist.

6. Further work has been carried out in the Plant Pathological Section, Lyallpur (Faisalabad) to establish the connection of *Rhizoctonia bataticola* isolated from cotton plants and some other isolates of *Rhizoctonia bataticola*. The results obtained are reproduced below:

During the earlier investigations on root rot of cotton, it was not possible to produce pycnidia of *Rhizoctonia bataticola* artificially and therefore, this fungus could not be connected with any spore forming stage. Similarly, forms of *Rhizoctonia bataticola* which occur commonly on tobacco (*Nicotiana tabacum*), citrus and chillies (*Capsicum annum*) in Pakistan have not been connected before with any such stage. On *Sesamum indicum*, however, *Rhizoctonia bataticola* freely produces the pycnidial stage of *Macrophomina phaseoli*. With a view to establishing the connection of *Rhizoctonia bataticola* (occurring on these hosts) with the sporing stage, inoculation experiments, were carried out on various living plants in pots as well as in field, and also on cut pieces of twigs of various plants in potato test tubes at 30°C. The following important results have been obtained:

All the isolates have infected living plants of *Sesamum indicum, Arachis hypogaea, Glycine hispida, Citrullus vulgaris.* var. *fistulosus, Nicotiana tabacum, Citrullus vulgaris, Phaseolus radiatus* and *Vigna catiang.* However, they could not infect *Gossypium, Ricinus communis* and *Cucumis melo* var. *utilissima.*

All the isolates have formed only sclerotia on all the infected plants except on sesamum where both sclerotia and pycnidia have been produced.

Inoculations done on cut pieces of twigs of different plants have always given rise to sclerotia and pycnidia on sesamum and less frequently on citrus twigs. Single pycnospore isolations from pycnidia of all the isolates have given sclerotial cultures identical with those with which the inoculations had been made.

The pycnidial stage has been identified as *Macrophomina phaseoli* (Malub.) Ashby.

The above results are important from both an academic and economic points of view. As far as the academic point of view is concerned it is the first record of the establishment of the connection of *Rhizoctonia bataticola*, (which, according to earlier studies, is one of the two causal fungi of root rot of cotton in Pakistan) and *Rhizoctonia bataticola* occurring on tobacco, citrus and chillies with the pycnidial stage, *Macrophomina phaseoli*. Moreover, pycnidia of many isolates of *Rhizoctonia bataticola* can be formed at will on twigs of living or dry sesamum plants and also less frequently on citrus twigs.

From economic point of view it is important to note that the inclusion of sesamum in the rotation in localities, where crops susceptible to *Macrophomina phaseoli* are grown, is dangerous because a single sesamum crop can help in large-scale multiplication and dispersal of inoculum in the form of pycnospores, exposing various crops to the danger of disease attack.

As already reported in the earlier studies that *Rhizoctonia bataticola* freely attacks cotton and produces root rot, but the later experiments carried out at various research institutes and the University of Karachi tend to show that neither the isolates from cotton, nor those from tobacco, sesamum, citrus and chillies have been able to attack cotton. This view has been invariably strengthened by the results of the experiments over a number of years indicating the inability of the fungus to attack without the pre-requisite specific conditions.

Control

Inspite of about 50-year research activities it has not been possible to find out clear cut control measures because of the failure to establish the pathogenicity of the fungus. Thus it is evident that the disease is of complex nature and will require specific approach for its control. Since it is found in localized patches, the control measures should only be confined to such areas, which can be easily earmarked by each farmer. The possible methods may be: development of varieties with branched root system (providing more roots to withstand the attack)and use of cultural practices including intercropping with *moth* besides using antagonistic fungi in *moths* or with other soil amendments. Such packages of control measures should be extensively tested in root-rot infested areas and demonstrated to the farmers. These results clearly indicate that unless certain soil factors which may be in the form of hard pan or higher concentration of salts, or water stress are present, the fungus probably will not be able to attack cotton. There is a great need to test and demonstrate the cultural control measures including the use of antagonistic fungi.

2. Boll Rot, *Aspergillus niger, Fusarium oxysporum, Rhizopus oryzae* and *Xanthomonas malvacearum*.

Occurrence

Boll rot is an important disease of all cotton growing areas, becoming very serious under high humidity conditions of monsoon rains, which favour development of both insects and fungi causing boll rot. Correlation and regression analysis, under Sind conditions has shown that 1 per cent boll rot infection reduces the yield by 0.22 per cent.

The incidence of the disease has been reported to range between 3-18 per cent in Sind province (being higher in more humid conditions in the South), while the survey carried out in the Punjab has shown maximum infection of 60 per cent caused by *Botryodiplodia* sp. and of 33.3 per cent caused by *Xanthomonas malvacearum* in the districts of Sahiwal and Lahore, respectively.

Symptoms

Work carried out in Sind province has identified four distinct types of boll rot, caused by specific groups of pathogens in decending order of incidence; (a) *Aspergillus* rot, (b) *Fusarium* rot, (c) *Rhizopus* rot, and (d) *Bacterial* rot. *Aspergillus* rot is more common and the bolls become pinkish brown and finally sooty black due to overgrowth of the fungus. In *Fusarium* rot the bolls are dried with colour assuming reddish and brownish tinge and showing white fluffy fungal growth inside the bolls. *Rhizopus* rot turns the bolls greyish covered with fungal growth, while in Bacterial rot caused by *Xanthomonas malvacearum*, water-soaked areas develop on the bolls giving out gummy substance and foul smell. The other associated fungi are *Helminthosporium spicifer* and *Penicillium* sp.

In the Punjab, mycoflora representing 24 genera (associated with cotton bolls both externally and internally) have been isolated. Out of them *Aspergillus flavus, Alternaria macrospora, Cladosporium cladosporioides* and *Fusarium semitectum* are predominant. These fungi besides additional ones like *Aspergillus niger, Rhizopus oryzae, Botryodiplodia* sp. *Mucor* sp., *Circinella* sp, *Trichoderma koningie* and some bacteria have also been isolated even from apparently healthy bolls. Recently, *Diplodia gossypina* has been found to be the causal pathogen of boll rot instead of *Botryodiplodia.*

The symptoms have been classified into two categories (a) those produced by strong parasites like *Botryodiplodia theobromae, Colletotrichum capsici, Xanthomonas malvacearum* and *Myrothecium roridum* and (b) those produced by weak parasites like *Alternaria infectoria, Fusarium semitectum, Fusarium solani* and *Trichothecium theobromae.* As in Sind the symptoms also vary in the Punjab with the associated pathogens (Fig. 6.2).

Pathogenicity and Perpetuation

In Sind, artificial inoculation experiments have shown that the disease can be reproduced by introducing the inoculum into wounds made on the surface of bolls, (upto 100 per cent in case of *Aspergillus niger*) while spraying the pathogen suspension in water has failed to produce the disease. This shows that the disease is associated with the injuries caused by insects and could be controlled with their elimination.

In the Punjab, out of 21, three isolates (*Colletotrichum capsici, Botryodiplodia* sp. and *Myrothecium roridum*) can cause infection without injury, seven are wound parasites and others non parasitic. The bacterium *X. malvacearum* has caused maximum incidence, followed by *Botryodiplodia* and *Colletotrichum capsici.*

The disease perpetuates through diseased bolls lying in the field and by sowing contaminated seeds.

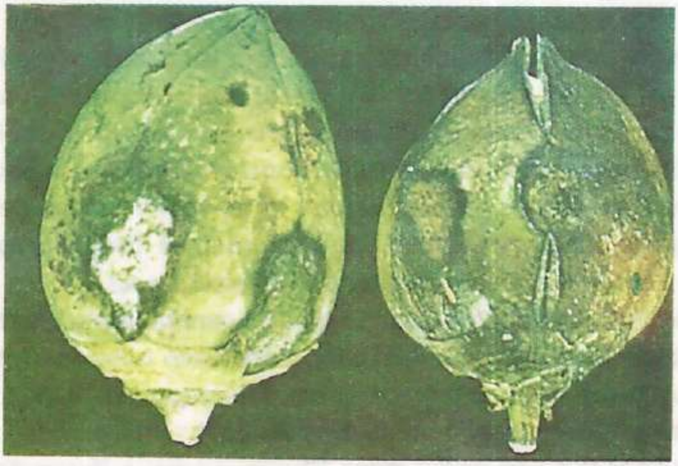


Fig. 6.2: Boll rot of cotton.

Control

Apart from survey, isolations, symptoms and pathogenicity no systematic efforts have been made either to develop resistant varieties (all cultivars have been found to be susceptible) or to find out other practical control measures. However, it has been reported that primary infection arising from seed-borne pathogens can be checked by seed dressing with suitable chemicals (Agrosan) while at later stages spraying with insecticides and a compatible copper-based or an organic fungicide (Perenox at the rate of 2 1b/100 gal; 4:4:50 Bordeaux mixture or mixture of 0.1 per cent Toxaphene and 0.2 per cent Cupravit) can provide an effective control, the economics of which needs to be investigated.

3. Anthracnose, *Colletotrichum gossypii* and *Colletotrichum capasici* (Syd.) Butl.

Occurrence, Symptom and Perpetuation

The disease occurs widely in the Punjab (excepting in dry localities). Prolonged humid conditions are highly conducive for its development and spread. These conditions have direct association with the time of appearance and amount of rainfall. Infections upto 100 per cent have been recorded. The disease has also been reported from other parts of the country.

In the beginning, small, light coloured (usually reddish) spots with ashy centres appear on the leaves. Later, the affected parts develop necrosis with masses of fungal spores appearing in the centre. On bolls the pathogen (*Colletotrichum gossypii*) forms sunken spots, with the result that they are deformed and dried up. It can also cause damping off as well as stem lesions and boll rots (Fig 6.3).

Fig. 6.3: Anthracnose of cotton.

The disease perpetuates through the contaminated seeds and/or diseased plant debris, both causing primary infection. The intensity of the disease can increase during the growing period through secondary infections caused by masses of the fungal spores.

Control

All the 22 varieties, tested under artificial inoculation conditions, have been found to be susceptible. However, seed dressing with 3 fungicides (Benlate, Vitigran blue and Vitavex) has proved to be effective in controlling the growth of the causal fungus *in vitro*. Repeated fungicidal field applications will be needed for controlling secondary infections, which may not be economical except in case of high disease intensities.

4. Various Pathogens

Four types of leaf spot diseases have been reported from various parts of the country. These are described below:

A) Myrothecium Leaf Spot – *Myrothecium roridum* Tode. Ex. Er. Syst. Myed.

Symptoms and Pathogenicity

Leaf spot disease caused by *Myrothecium roridum, appears* as *circular*, white, purple ringed spots with definite margins on the leaves. Later on, the spots join with each other and develop concentric rings under favourable conditions giving rise to black pin-head size sporodochia on both sides of the leaf. With aging, the diseased tissues fall out producing shot holes in the leaves. The fungus can produce the disease when inoculated on uninjured or injured leaves, appearing earlier in the latter case. The pathogen can also infect some weed plants, which can serve as sources of inoculum.

No detailed work has been done on the incidence, prevalence, intensity of damage, varietal resistance and practical control measures of the disease, excepting that the vitigran blue can reduce the incidence of disease by about 50 per cent (which is not a satisfactory control).

B) Cercospora Leaf Spot – *Cercospora gossypina* Cke.

It attacks both the upland and indigenous cottons not in young-leaf stage but on mature leaves during October – November. Round or irregular spots, which are yellow brown in colour and brown to black at borders, appear on leaves. The spots coalesce and form bigger lesions. Under severe conditions of infection, defoliation takes place, particularly in *G. arboreum.*

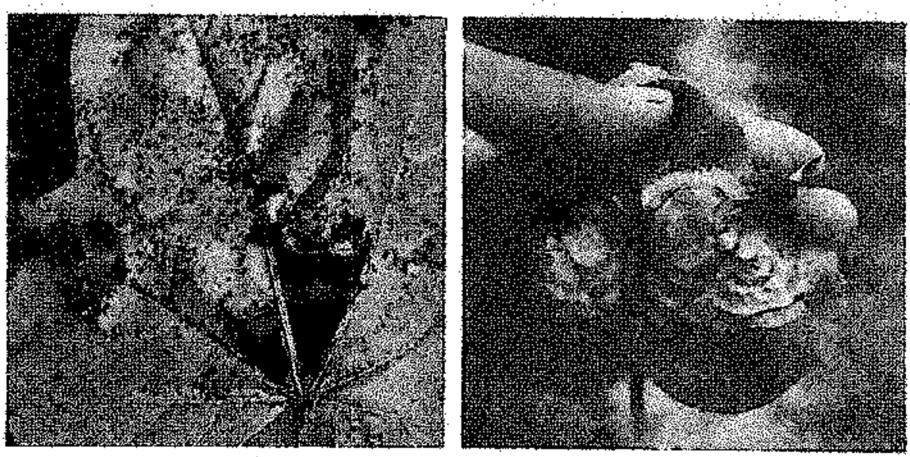
C) Alternaria Leaf Spot – *Alternaria tenuis* Nees.

The pathogen is highly virulent under humid conditions giving rise to dark brown to black spots on the leaves, which ultimately fall to the ground. Indigenous cotton appears to be somewhat resistant. Spraying is effective for controlling the disease. Polyram combi and Brestan-60 have given promising results.

D) Sooty Mold – *Microsphierella hibiscifolia*

It being first reported from Sind in 1972, is now found in all the cotton growing areas of the country. Dark specks are found on the lower surface of the leaves near the glandular parts, which change their colour from yellow to red and black. Black patches of the fungus are easily noticeable on the surface. The disease can spread to the whole leaf surface, stems, branches and bolls. Sucking insects with honeydew production favour the spread of disease.Indigenous cotton varieties, which are non-glandular escape the disease. This character is being exploited in the breeding programmes on the development of resistant varieties (Fig. 6.4).

In conclusion leaf spot diseases caused by four different pathogens mostly infect leaves and sometimes branches and bolls producing defoliation. the extent of damage depends upon the time of disease appearance and degree of leaf shedding, which may not be deleterious if it appears late. Humid conditions and presence of sucking insects are more conducive to attack. Because of the aerial type of infections, use of resistant varieties or combined fungal and insecticidal sprays (if economical) and phytosanitary measures through cultural practices will help to control the leaf spot diseases.



(a) (b)

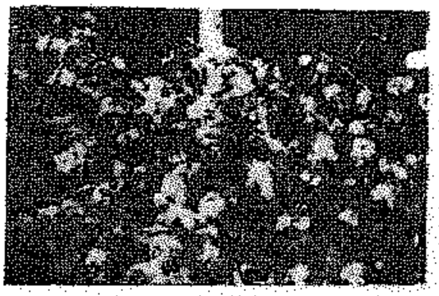
Fig. 6.4: Leaf spot of cotton (a) Myrothecium leaf spots, and (b) Alternaria leaf spots.

5. Tirak or Premature Opening of Bolls

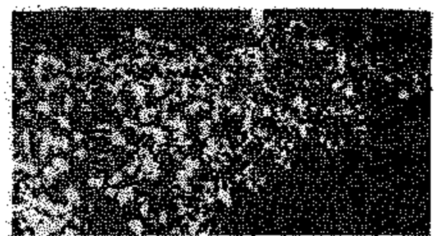
Symptoms

This disease is characterized by bad opening of bolls and can, therefore, cause heavy reduction in yield upto 75 per cent in years of epidemics (1926-28 and 1931-32). Detailed observations made on *tirak*-affected cotton plants have shown some abnormalities in the tissue of the leaves.

These include accumulation of starch in the mesophyll cells of the leaves by July or later and that of tannins in the palisade and spongy cells at about the beginning of flowering stage. These abnormalities preceed the outer symptoms of *tirak* consisting of yellowing and reddening of leaves towards the beginning of reproductive phase. This is due to the break-down of photosynthetic apparatus. On the other hand the accumulation of tannins is not found in the healthy plants at any stage of the growth. In diseased plants there is a relationship between nitrogen metabolism and the accumulation of tannins in the leaves indicating a total nitrogen of the leaves less than 2.5 per cent. Leaves of plants grown in unmanured plots give a positive test for tannins by the beginning of September while the test is negative in the fertilized plots. The indication of the positive tannins test at the flowering phase (August – September) is thus an index of nitrogen deficiency, which can be remedied by applying 80-100 kg of ammonium sulphate per acre at that time. The bad opening of bolls affects both quantity and quality of the lint produced as well as the development of the seeds, which remain unmatured (Fig. 6.5).



Healthy plants



Diseased plants

Fig. 6.5: Premature opening of cotton bolls.

Soil Factors

The leaves of the plants grown in good soil neither show tannin accumulation nor bad opening of bolls, those from medium soil exhibit slight symptoms while the plant raised in bad soil indicate large accumulation of tannins at an early stage of growth. The bad soils are found to contain abnormal amounts of sodium salts (0.2 per cent) or more in the sub-soil from 3rd or 4th foot downwards. Sodium in soluble or exchangable form is higher than calcium. If the quantity of total salts is 0.01 to 0.15 per cent, *tirak* does not appear under favourable conditions of weather and adequate water supply but it can develop in such soils in years of hot weather and/or absence of adequate water supply. Sodium carbonate has proved less harmful in the presence of chloride. There is also deficiency of potash at the fruiting stage in *tirak* – affected plants, resulting into immature seeds. The comparison of four types of soils (normal sandy soils; sandy loam with saline sub-soil; light sandy soil with nitrogen defeciency; and light sandy soil with nitrogen deficiency and saline sub-soil) has shown suppression of growth of all parts of cotton on saline sub-soil by the injurious effect of sodium salts on the root system due to physiological drought. Thus the physical texture of soil, the sodium, calcium ratio and the relative amounts of different sodium salts are important soil factors that increase or decrease the intensity of *tirak*. Another soil type conducive to *tirak* is light sandy soil, which produces defeciency of nitrogen in plants at the flowering stage.

The *tirak* years are characterized by hot and dry months of September and October; even ten days of a spell can produce the disease.

Control

The control measures given below are governed by the type of soils.

1. In sandy soils which are deficient in nitrogen with saline or alkaline sub-soil, late sowing and application of extra water at the time of fruiting are recommended. The application of nitrogen on such soils does not improve the opening of bolls although it may increase the yield through more profused bearing. Closer plantations should be carried out in late sowing to overcome yield depression.

2. In light sandy soils deficient in nitrogen, application of ammonium sulphate (80-100 kg/acre) is advised.

6. Stunting or Reduction in Size of Leaves

A survey was made on this condition during 1932-34 in the Punjab. It was found to be serious in the fields of Punjab Agricultural College estate. The incidence was above 40 per cent but it was of no consequence in other parts of the cotton belt of the Punjab. It was found primarily to attack the varieties of American cotton grown at the institute while very few plants of indigenous varieties were affected. The attack started when the plants were about one month old. The disease was very active during August and early parts of September. The affected plants remained small and stunted in size and the boll development was either absent or very small bolls could develop. The spread of the infection in the plant was quite regular throughout but sometimes a few branches remained healthy.) The condition was not found to be of hereditable nature. It could not definitely be established whether the condition was of physiological or of virus origin. It thus shows that the occurrence of the small leaves or stunting in American cotton only, was probably not a disease but was due to the environmental effects of early acclimatization period and, therefore, the abnormal growth of the plants disappeared after the establishment of the varieties.

The later studies reported in 1977 have shown that stunting of cotton is a serious physiological disorder occurring only in the case of newly introduced exotic varieties when planted earlier (March-May) and the incidence varies from year to year and locality to locality (the highest recorded infection being 64 per cent at Multan). The disorder appears within 1-8 weeks of germination showing a range of symptoms including discolouration of leaves and stems, shortening of internodes, reduction in size of leaves, cessation of growth, poor development of roots and rootlets, reduction in size, number and weight of bolls. Soil and root isolates mostly (*Fusarium, Rhizoctonia* and *Aspergillus* spp.) have failed to reproduce the disease in pathogenicity tests. March planting showed the highest infection, followed by April and May while in June sowings the incidence was almost negligible. Out of 58 varieties, 34 remained free of stunting. Manifestation of stunting is, therefore, due to genotypic-environmental interaction rather than pathogenic in origin and it is likely to disappear after acclimatization period, which may differ for each variety. While some varieties may not need any acclimatization because of the similar climatic conditions of their places of origin with those found in Pakistan.

7. Nematodes

First observation made in 1958 had shown a close association of nematodes with *Fusarium oxysporum* and *Fusarium vasinfectum*, the causal pathogens of cotton wilt. Later on, in 1968 two species of nematodes (*Aphelenchus* and *Pratylenchus*) were reported in Sind ending up into isolation of 30 genera of nematodes from cotton roots and cotton soils of Lyallpur by 1973. Of these the important species belong to *Aphelenchus, Dorylaimus, Hoplolaimus, Xyphinema, Tylenchorhynchus* and *Pratylenchus*. Similarly, 19 genera from 133 samples have been reported to be isolated at Multan, 40 per cent belonging to parasitic group with greater frequencies of *Tylenchorhynchus*, (44.3 per cent) and *Hoplolaimus* (23.3 per cent) and average populations 10.8 and 11.9 per sample, respectively.

While soil forms representing 10 genera have shown the common occurrence of *Cephalobus* and *Cervidellus*. Later studies have shown 91.7 per cent samples from 81.7 per cent localities having 0-25 population range of parasitic nematodes per sample, while high population ranges of nematodes (26-100) have been recorded from very low percentages of samples and localities (1.5 - 8.7). Since very high nematode populations are needed to produce deleterious effects (Table 6.2), the low populations recorded in Pakistan (because of unfavourable ecological conditions, rotational and varietal pattern, and soil factors) do not produce any serious damage in cotton and are therefore not alarming.

Table 6.2. Minimum soil populations of different nematodes essential for producing damaging effects*.

Nematode	*Minimum Population*
Trichodorus christie	14580/500 g
Hoplolaimus tylenchiformis	25500/pint
Hoplolaimus coronatus	500/10 g
Belonolaimus gracilis	8903/pint
Rotylenchulus reniformis	30000/pint
Pratylenchus sudanensis	100/200 g

Summary

The chapter includes the work carried out on root rot, boll rot, anthracnose, leaf spots, premature opening of bolls, stunting or reduction in size of leaves and nematode diseases of cotton. The earlier investigations on root rot of cotton have shown that it is caused by *Macrophomina phaseoli* (*Rhizoctonia bataticola*) and *Rhizoctonia solani*. Symptoms of the disease and physiology of these two fungi have been studied in detail and it has been found that temperatures ranging between 35-37°C are optimal for their growth. Chemical analysis of healthy and diseased plants has been carried out. Factors affecting the incidence of the disease have been studied and tentative methods to control the disease have been devised consisting of late sowing and intercropping with *moth*. Further studies carried out over a number of years have shown that it is not possible to produce infection by artificial inoculations with the cultures of *Rhizoctonia bataticola*, *R. solani* and *Fusarium* sp. alone or in combination and that there are some factors (soil, temperature, moisture

*For details see Chapter XVI on diseases caused by nematodes.

and nutrition) which predispose the cotton plants to the attack of fungi. This view is further strengthened by the fact that the disease appears in localized patches inspite of all the cultural operations carried out year after year and sometime the disease automatically disappears. Some interesting results have also been obtained in controlling the disease through the use of antagonistic fungi and certain soil amendments. Experiments on *Rhizoctonia bataticola* occurring on cotton, tobacco, citrus and chillies have established its connection with the sporing stage and the pycnidial stage has been identified as *Macrophomina phaseoli* (Malub.) Ashby.

Boll rot is an important disease of all cotton growing areas becoming very serious under high humidity conditions of monsoon rains. Work has been carried out on symptoms which differ with three groups of boll rot-causing fungi; some of them are strong parasites while others are weak (dependent on injuries caused by insects). Pathogenicity and perpetuation have been studied alongwith control measures comprising seed dressing to control seed-borne infection and insecticidal sprays on the cotton crop.

Anthracnose of cotton caused by *Colletotrichum* spp. has been studied as regards its occurrence, symptoms and modes of perpetuation. All the 22 cotton varieties tested, have been found to be susceptible. Seed dressing with Benlate, Vitigran blue and Vitavex has proved to be effective in controlling the growth of the pathogen *in vitro*.

The studies on leaf spot diseases have shown that these are caused by four groups of fungi (*Myrothecium, Cercospora, Alternaria* and *Microsphierella*), producing different symptoms on various parts of the plants. The extent of damage depends upon the time of disease appearance and degree of leaf shedding, which may not be deleterious if it appears late. Because of aerial type of infections use of resistant varieties has been recommended.

Tirak of cotton, which is characterized by bad opening of bolls, has been investigated in detail. Analysis of infected plants has shown that there is break-down of photosynthetic apparatus in leaves and development of tannins. Largest accumulation of tannin occurs in plants growing either in alkaline soils or unmanured plots. Development of tannin has been correlated with the deficiency of nitrogen in soils with presence of abnormal amounts (0.2 per cent or more) of sodium salts. Disease incidence is also higher in sandy soils deficient in nitrogen. Late sowing and application of extra water at the time of flowering and fruiting has proved to be successful in remedying *tirak* on soils which are not only sandy and deficient in nitrogen but are also saline or alkaline in the sub-soil. June sowing decreases the disease irrespective of the *tirak* promoting soil conditions. Application of Nitrogen is recommended to sandy soils.

Some preliminary investigations carried out on stunting or reduction in size of leaves in American cottons have shown that the disease could not be associated with physiological or virus origin and moreover it occurred only when American cotton was newly introduced in the Punjab. It has thus shown that reduction in size of leaves in American cotton was not probably a disease but was due to the environmental effects of an early acclimatization period.

Similar results have been obtained in case of later studies carried out on many exotic varieties, showing that stunting is due to genotypic-environmental interaction rather than being pathological in origin.

The studies made on nematodes have shown their close association with *Fusarium oxysporum* and *Fusarium vasinfectum*, the causal pathogens of cotton wilt. A large number of genera of neamtodes have been isolated, some of them have been found to be parasitic with greater frequencies of *Tylenchorhynchus* and *Hoplolaimus*. Investigations carried out on population range of parasitic nematodes per sample have shown that as a result of low populations recorded (because of unfavourable ecological conditions, rotational and varietal pattern and soil factors) the nematodes do not pose any serious problem to the cotton crop.

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Chapter VII

Oilseeds and Oilseed Crops

Oilseed plants include all those crops which are well known for their high oil contents and are, therefore, cultivated throughout Pakistan with a view to meeting the need for vegetable oils of the country. The importance of these crops has been greatly enhanced due to increasing requirement of edible oils. The domestic production is meeting only 35 per cent of the total requirements, which are annually increasing by 10 percent. In 1981-82 out of 750,000 tons of edible oil consumed in the country, 65 percent (487,500 tons) were imported at a cost of Rs. 3 billion in foreign exchange. It has been estimated that from within the country cotton alone provides 56.5 percent of the total oil requirements followed by 33 percent from rape and mustard and the rest (10.5 percent) from other crops such as groundnut, sesame, soybean, sunflower and safflower (which are now gaining importance). The oilseed crops occupy about 535,000 hectares at present, with a further scope of increasing area under non conventional crops which should be sufficient to meet the domestic requirements, if yield levels are increased through different means including control of diseases, discussed below:

Sarson (Rape)

1. Downy Mildew – *Peronospora parasitica* (Pers ex Fr) Fr.

Occurrence and Symptoms

Downy mildew occurs on several brassica species throughout the country, with *sarson* (rape) being the most important host, suffering appreciable losses; particularly when it is accompanied with white rust infection. Irregular spots appear on the surface of leaves, which are greyish white on the lower and yellowish brown on the upper side. The spots increase in number and size ultimately covering large areas of foliage followed by defoliation and infection of stems also, causing considerable losses in yield (Fig. 7.1).

Morphology of the Fungus

Peronospora parasitica has been isolated from the diseased spots of many brassica crops. The fungus produces conidiophores (180-480 X 9-15 µ) while the conidia are hyaline, globose to elliptical, measuring 15.5-26.3 X 15.5-23 µ. The production of conidia is very much enhanced in cool and humid weather, which is also conducive to secondary infections.

Perpetuation

The fungus which over-summers in the form of oospores in diseased plant debris or on seeds, has proved to be pathogenic on brassica crops under artificial conditions of inoculation. The disease has been found to perpetuate mostly through diseased plant debris lying on the soil and sometimes by sowing contaminated seeds.

Control

In the absence of resistant varieties, the disease can be greatly checked through (a) collection and burning of diseased plant parts and debris

Fig. 7.1: Downy mildew of rape and mustard.

for checking the primary infection, and (b) carrying out 2-3 sprays at 15 days interval with 4:4:50 Bordeaux mixture or Cupravit (2 1b/100 gal. of water) or Polyram M for containing the secondary infection. Dithane – M, Deconil and Captan have also proved to be effective sprays. Seed treatment can control seed-borne infection.

2. White Rust – *Albugo candida* (Pers. ex. Hook) Kuntze

Occurrence and Symptoms

White rust is a disease of cruciferous plants, being more serious on rape. It is found all over the country in various intensities varying from year to year, depending upon the weather conditions. Early infections attack all aerial parts of the plant doing more damage. The disease usually appears at flowering period (early in Sind and later in the Punjab and other provinces). The disease principally attacks the leaves, which become thickened. It also appears on stems, floral parts and pods, with the development of whitish pustules, increasing in number and size and coalescing to form bigger patches. These pustules, which are formed under the epidermis with raised up surface, ultimately rupture releasing powdery mass of conidia of the causal fungus (Fig. 7.2).

Fig. 7.2: White rust of Crucifers.

Pathogenicity and Perpetuation

The disease is caused by *Albugo candida*, through diseased plant debris, harbouring oospores of the fungus, responsible for producing primary infection when temperature and humidity conditions are favourable. The fungus produces conidia in chains measuring 12-18 μ, which spread the disease through secondary infections.

Varietal Reaction

All the cultivars tested proved to be susceptible with varying degrees of infection (28-50 percent).

Control

In the absence of resistant varieties, the disease can be checked through (a) destruction of diseased plant debris, which is a source of primary infection, (b) collection and burning of diseased plant parts as soon as they appear to check secondary infections, and (c) spraying with fungicides like Melprex, Polyram and Cupravit three to four times before flowering, keeping in view the benefit: cost ratio. Timely sprays have been found to reduce the disease by about 80 per cent.

3. Powdery Mildew – *Erysiphe polygoni* DC

Occurrence and Symptoms

The disease occurs throughout the contry in various intensities on almost all the cultivars, reaching its maximum by the month of March. It makes its first appearance in January as white powdery spots on leaves, stems and pods which increase in number and size with the time, covering foliage like a talcum powder. The affected leaves ultimately droop, stems, rot, and pod and seed formation are badly affected.

Pathogenicity and Perpetuation

The disease is caused by *Erysiphe polygoni* on artificial inoculation and is carried over from year to year through diseased plant debris or volunteer host plants, while secondary infections are produced through conidia, formed in chains on vertical conidiophores, after falling on healthy plants. The conidia are hyaline eliptical to cylindrical, measuring 35-45 X 15-19 μ.

Control

Destruction of diseased plant debris after the harvest of the crop is useful in controlling the source of primary infection. While for controlling the spread of the disease dusting the crop with sulforon at the rate of 25 1b/acre is beneficial, which also increases the yield. However, economics of dusting will have to be taken into consideration.

4. Blight – *Alternaria brassicae* (Berk) Sacc.

Occurrence and Symptoms

Blight is a common disease of *brassica* causing spotting on leaves (including cotyledons), branches and twigs with the result that the plants are heavily damaged. The incidence of disease is severe in dense and closely planted crops but light in poor and thin plantations because of higher degree of secondary infection in the former case. Humid weather conditions are more conducive for the development and spread of the disease.

Pathogenicity and Perpetuation

The disease can be artificially produced by spraying the culture of the fungus in aqueous solution on the different *brassica* crops. Under natural conditions the disease has been found to be carried over from year to year by either sowing infected seed containing hibernating mycelium of the causal fungus or by the spores which remain viable in diseased plant debris of the previous year's crop.

Control

The mycelium in the seed is killed by soaking it in hot water at 45° C for 10 minutes.

Spraying with Bordeaux mixture (4:4:50), Polyram (500 g/ha) or Deconil (1.7-2.3 kg/ha) is quite effective in checking the spread of the disease. The economics of spraying, however, requires to be taken into consideration. Growing of resistant varieties constitutes the most effective control measure.

5. Wilt of Toria– ***Fusarium* sp.**

The disease appears mostly in the seedling stage. It has been found to be caused by *Fusarium* sp., infesting the soils.

The optimum, maximum and minimum temperatures for thr growth of the causal fungus are 25° C, above 40° C and below 10° C, respectively.

The incidence of the disease is the highest when the crop is sown in the first fortnight of September on account of high soil temperature, which is suitable for the growth of the causal fungus. The incidence decreases with the delay in sowing. No work has been carried out on varietal reaction and control measures.

6. Stem and Root Rot – *Sclerotinia sclerotiorum* (Lib.) de. Bary

Occurrence and Symptoms

This disease was recorded for the first time from Pakistan on a mustard crop in 1980 in Rawalpindi area in traces under rainfed conditions and has not been reported so far from other places. It can attack leaves, stems and pods showing white cottony mycelial growth containing sclerotia of variable size; ultimately killing the infected parts and reducing the yield. The seeds are also infected through the pod walls in severe cases of attack.

Pathogen and Perpetuation

The fungus *Sclerotinia sclerotiorum,* which is soil-borne, has been isolated from the infected plants, and it has proved to be pathogenic on artificial inoculations. Morphological and cultural characteristics of both the perfect and imperfect stages of the causal fungus have been studied. The disease perpetuates through either infected seeds, seeds contaminated with small bits of infected plant parts or debris lying on the soil. The fungus having a wide host range including sunflower, soybean, lentil, peas, alfalfa, beans, lettuce, can survive in the soil for long periods.

Control

In the absence of resistant 'varieties', phytosanitary measures including destruction of diseased plant debris and volunteer host plants, seed cleaning, long rotation as well as repeated foliar sprays with suitable fungicides (Topsin M at the rate of 0.7 - 1 kg/ha) can help to keep the disease under check.

7. Storage Rots – *Rhizoctonia bataticola* and *Aspergillus, Penicillium* and *Fusarium* spp.

For the study of storage conditions a number of store houses were examined throughout the Punjab and the following conclusions have been drawn:

Conditions of Storage

Sarson (*Brassica campestris*): In the markets after a bargain has been struck sarson seed is filled in gunny bags and sent to the purchaser's stores where it is unsacked and thoroughly dried. It is again filled in gunny bags, which are piled on brick flooring in *pucca* stores. Concrete flooring is rarely met with. Store houses are usually dark, where sunshine and air have no free access. Some store houses, which are located in areas where water table is high, are damp. In villages the local oilseed crushers store only a small quantity of seed in gunny bags on *kacha* flooring. This type of storing does not matter as the stocks are generally consumed within a few days.

Toria(*Brassica napis*): *Toria* is handled and stored under exactly the same conditions as sarson, with the difference that it is frequently sun-dried after showers of winter rains, which generally follow its harvest.

Linseed (*Linum usitatissimum*): The produce is marketed in small quantities by farmers individually. It then flows to bigger markets where it is handled and stored exactly in the same fashon as *sarson* and *toria*.

Groundnut (*Arachis hypogaea*): Groundnut is marketed before it is partially dried and has a lot of earth sticking to the surface of the pods. Before storing the nuts, they are thoroughly dried, bagged and piled on brick flooring in *pucca* stores.

Nature and Amount of Damage

Sarson and Toria: Under humid conditions of storage the brassica oilseeds form lumps, which with rise in temperature begin to rot. The growing mycelium of the fungi binds the grains together and the size of the lumps increases with the progress in rotting. The cotyledons of rotten seeds turn brown. Oil content of rotten *brassica* oilseeds often decreases to nil besides deterioration in quality and seed germination. The percentage of rotting varies according to conditions of storage. It has been found to vary from 4 to 42 percent in different stores with an average of 14 percent.

Linseed: Linseed suffers much less rotting than *brassica* oilseeds. The outside lustre fades away with the age of storage. During storing big lumps are formed, if moisture is available. The percentage of rotting varies from 2 to 20 with an average of 7.

Groundnut: Groundnut suffers three kinds of losses in stores:

i) Prolonged storage combined with humid conditions cause discolouration of pods and kernels;

ii) The testa of the kernels become bitter;

iii) The kernels are totally or partially destroyed by the fungi.

These losses bring about a substantial reduction in oil contents. Apparent damage done to groundnut in storage varies from 5 to 38 percent.

Causal Organisms

The isolated fungi can be arranged into four different groups namely, *Aspergillus* sp; *Penicillium* sp; *Fusarium* sp; and other saprophytic fungi. In the case of groundnut *Rhizoctonia bataticola* has also been isolated.

Inoculation experiments have been carried out in the laboratory for testing the pathogenicity of the fungi isolated from the rotten samples. The results have shown that the isolated fungi are highly pathogenic and cause big damage under suitable conditions of temperature and humidity.

The pathogenic fungi have been studied in detail regarding their growth behaviour under different environmental conditions. The optimum temperature for *Fusarium* sp. and *Penicillium* sp. is 25° C and for *Aspergillus* sp. it is 30° C.

Rotting of seeds of *sarson, toria,* linseed and groundnut has been found to vary in direct proportion to the degree of wetness in store houses. This is due to the fact that the seed testas become soft at higher humidity and are therefore, vulnerable to the easy attack of these fungi.

Control Measures

The following recommendations have been made for checking the rotting in storage:

a) The store houses should be provided with concrete flooring to prevent the soil moisture contact with oilseeds;

b) In order to minimise chances of infection with the seed rotting fungi, oilseeds should be frequently sundried. It is more important in the case of *toria* and groundnut than in the case of *sarson* and linseed;

c) Fumigation of the store houses should be carried out occasionally with suitable chemicals available in the market.

Linseed

Wilt – *Fusarium lini* Bolley.

Occurrence and Symptoms

Linseed (*Linum usitatissimum*) wilt is one of the very important fungal disease of this crop. The extent of damage goes as high as 50-80 percent in the years when the conditions are favourable for the development of the disease.

The seedlings as well as mature plants are affected. The end points of branches begin to droop and subsequently the whole plant dries up. In advanced stages of attack, the root bark becomes loose and shredded The disease has been found to be caused by the fungus *Fusarium lini*, which has also been proved through artificial inoculations.

Physiology of the Pathogen

The linear colony growth of the fungus is the highest on Richard's agar which is followed by potato dextrose agar and Brown's agar. On the other media tried, the growth is also fairly good.

The minimum, optimum and maximum temperatures for the growth of the fungus are below 20° C, 25° – 30° C and 38° C, respectively.

The fungus grows on wide range (3.0 to 9.0) of pH. The maximum growth takes place at pH 4 and no growth occurs at pH 2.6.

The colony growth of the fungus is the greatest in the normal concentrations of Richard's agar followed by 0.5, 0.25, 0.12, 2, 4 and 8N in the order named. The colony growth of the fungus is optimum on complete Richard's agar and Richard's agar lacking potassium dihydrogen phosphate but it is very much affected when either cane sugar, potassium nitrate or magnesium sulphate is omitted.

The average size of spores is 21.2 X 3.6 µ at 25° C and 30° C. Larger spores are produced at 4.4 to 6.4 pH values and comparatively small spores at the remaining pH values of the medium.

Sporulation is fairly good both in light and in darkness. Sporulation is abundant on oatmeal agar, Richard's agar and potato dextrose agar while it is fairly good on the other culture media tried. There is no difference in the amount of sporulation at temperatures ranging from 20° C to 35° C.

Spores start germinating in distilled water after 2 hours and percentage of germination reaches upto 68 after 8 hours. Nutrient solutions such as sodium chloride, potassium sulphate, potassium chloride, potassium nitrate and glucose favour the germination of spores.

Factors Affecting the Incidence of Disease

In infected soil the disease appears earlier at 25 to 30° C than at 20° C and 35° C. Similarly, it starts to develop a few days earlier at low soil moisture contents (8-12 percent) than at high soil moisture contents (15-18 percent).

The incidence of the disease is greatest in early sowings carried out between 5 to 25 October than in late sowings, during the month of November. This is due to low soil temperatures present in the latter case.

Control

The incidence of the disease is reduced by 21 percent when seed is sown in dry soil to which water is applied immediately afterwards, as compared to normal *vattar* sown crop.

The seed disinfectants like copper sulphate, copper carbonate and sulphur are not helpful in reducing the incidence of the disease.

One percent toluene, 2 percent copper sulphate and 1:160 formaldehyde solutions when tried in potted soil as soil disinfectants reduced the incidence of the disease by 52, 45 and 43 percent, respectively.

Out of 223 crosses and varieties of linseed tried in highly infected soil, 64 showed a degree of resistance towards wilt disease. The varieties are:-

(1) Derivatives of the cross C.12-4 X Danubian, P.174, P.186 and P.189;

(2) Derivatives of the Danubian X C.123, P.16 and P.260.

(3) Derivatives of the Danubian X T.5, P.11 and P.12.

Since the disease is soil-borne, the most effective control lies in the use of resistant varieties or antagonistic fungi or by following 2-3 years rotation with inclusion of those crops which are not affected by *Fusarium.*

Groundnut

Groundnut crop has assumed greater importance after the creation of Pakistan and the area under this crop has been steadily increasing with the result that it now occupies 43,000 hectares, producing 59,000 tons with an average production of 1348 kg/ha. The salient features of the work done on root rot and wilt as well as on Tikka disease at Lyallpur (Faisalabad) and Tando Jam, are given below·

1. Root Rot and Wilt – *Rhizoctonia bataticola* and *Fusarium* sp.

Root rot and wilt diseases had been found to cause 5 to 100 percent damage to the groundnut crop in the districts of Ludhiana, Hoshiarpur and Jullundur (Bharat) in pre-partition period. The isolations and inoculations carried out have shown that the fungi (*Rhizoctonia bataticola*) and *Fusarium* sp. are responsible for causing root rot and wilt diseases, respectively. In later studies *Fusarium coeruleum* (Lib.) Sacc. has been identified as the pathogen of wilt disease and *Botryodiplodia theobromae Pat.* as an additional pathogen for causing root rot. (Fig. 7.3).

Control

Later studies have shown that seed treatments with Arasan or Granosan M have enhanced the seed germination by 2-13 percent and yield by 200-500 kg/ha. Hence seed treatment and destruction of diseased plant debris can help in controlling the diseases.

2. Stem Rot – *Diplodia* sp.

This disease is characterized by withering of the top shoots and consequent wilting of the whole plant. The percentage of attack has been found to vary from 15 to 25.

In all cases the fungus *Diplodia* sp. has been isolated from the diseased specimens. The fungus has been proved to be pathogenic on groundnut plants. Further work is required to be done with a view to finding out some suitable control measures.

As mentioned earlier, groundnut also suffers from kernel rot in storage under high temperature and humid conditions resulting in discolouration of pods, substantial reduction in oil contents and production of aflatoxin. Its one of the causal fungi is *Aspergillus*. This renders the product unsafe for consumption and reduces its market value.

3. Tikka – *Passoflora personata* (B and C) S.A.Khan and Kamal.

Occurrence and Symptoms

It is common and wide spread disease throughout the groundnut growing areas; sometimes occurring in epidemic forms causing heavy losses (as it happened in 1960 at Tando Jam). It appears, when the crop is about two months old, as conspicuous dark brown circular to sub-circular spots, measuring 2-6 mm in diameter on leaves. Later on these lesions are surrounded by light yellowish haloes, making the leaves to shed, which affects the yield considerably (Fig. 7.3).

Fig. 7.3: (a) Tikka disease of groundnut (b) Root rot and wilt of groundnut.

Physiology of the Pathogen

Previously, *Cercospora personata* (B and C)Ell. and Ev. was reported to be the causal fungus but the microscopic studies (described below) have revealed the pathogen to be more close to the genus *Passolora* rather than *Cercospora*. Hence it has been suggested to rename the fungus as *Passolora personate*. The studies have shown that conidiopores are amphigenous, developing in large numbers on lower surface of leaves with light brown colour, 0-3 septation without constriction, unbranched but curved measuring 23.2-49.8 X 5-8 µ. Conidia are obelavate to cylindrical or spindle shaped, light brown, 1-4 celled and rarely 5 or 6-celled, measuring 16.60-53.12 X 5-9.96 µ.

Perpetuation

The disease perpetuates through the diseased plant debris lying in the field, starting primary infection while the secondary infections take place during growth period through a large number of fresh crops of conidia.

Control

Destruction of diseased plant debris to avoid primary infection, seed treatment and copper fungicidal repeated sprays can help in minimizing the incidence of the disease. The real control lies in the development of resistant varieties.

The occurrence of leaf spot disease caused by *Alternaria tenuissima* (Nees Ex. Fr.) Wilt. has also been recorded but no work has been done so far.

Sesamum

Sesamum (*Sesamum indicum*) occupying 30,000 hectares is an important oil crop and also used in confectionery. It suffer from three diseases, namely root and stem rot (given below) leaf curl and phyllody (Chapter XV) in varying intensities all over the country. The main results of the work carried out at Tando Jam are given below:-

Root and Stem Rot –*Macrophomina phaseoli* (Maubl.) Ashby and *Botryosphaeria ribis* Grossenb and Dogg.

Occurrence and Symptoms

This disease has been recorded since many years in sesamum growing areas where it ranges from 1-5 percent, with occasional incidence upto 80 percent in badly infected areas. The disease usually makes its appearance in June and continues spreading till the end of August. It mainly attacks roots and stems, causing discolouration and rotting. As a result the leaves turn yellow, wilt and wither. A large number of pycnidia and sclerotia appear as dot like structures on the infected plant parts, which contain a multitude of spores capable of causing secondary infection during the growing period of the crop under humid weather conditions (Fig. 7.4).

Pathogenicity

Out of the three isolated fungi (*M. phaseoli, B. ribis* and *Fusarium* spp.), the first one is the main cause of the disease, which has also been proved under artificial conditions of incoulation. Recently *B. ribis* has also shown its pathogenic nature when inoculated on injured or un-injured roots. The combined presence of both these fungi may prove to be more harmful.

Fig. 7.4: Root rot and stem rot of sesamum.

Physiology of the Pathogens

M. phaseoli produces good mycelial growth on Richard's agar when glucose and ammonium nitrate are used as sources of carbon and nitrogen while manitol and ammonium chloride are more suited to *Botryosphaeria ribis*. The optimum growth temperatures are 30-35° C for *M. phaseoli* and 28-30° C for *B. ribis* while the best pH values are 5.5 and 6.5, respectively.

Perpetuation

The disease is carried over from year to year through infected plant stubbles, in which the pathogens, being soil-borne in nature, can survive for a long period.

Control

In the absence of resistant varieties, phytosanitary and cultural measures can help to keep the disease under check. These include collection and destruction of diseased plants before the fungi produce pycnidia and sclerotia; late sowings in the months of June-July; and practising 3-4 years rotation. Repeated sprays with copper-based chemicals can also reduce the occurrence of secondary infections.

Soybean

Soybean, a miracle crop, because of its multiple uses, is a new introduction in Pakistan now occupying 2500 hectares in Sind and NWFP but has a good potential of large-scale production in the plains, if sown in spring between two intervening cotton crops (which is steadily catching on). The main results of the work done on stem and root rot of soybean at Tando Jam are reproduced below:-

1. Stem and Root Rot – *Macrophomina phaseoli* (Maubl.) Ashby.

Occurrence and Symptoms

The disease has been found to occur in Hyderabad region with infections ranging between 9.2 to 14.4 percent (as recorded in 1965 and 1967) doing substantial damage to the crop. The disease attacks seedlings, which become water-soaked and conspicuously black and show rotting in 2-3 days. The surviving seedlings develop lesions typical of stem rot within two months and the plants start wilting and ultimately die. Sometimes roots are healthy but plants show drying from top to bottom. In some cases one or more branches are attacked at nodal portions, turning ashy brown with silvery bark embedded with black pycnidia. Usually the disease occurs in scattered patcheds. Most of the affected plant parts or plants are ultimately killed (Fig. 7.5).

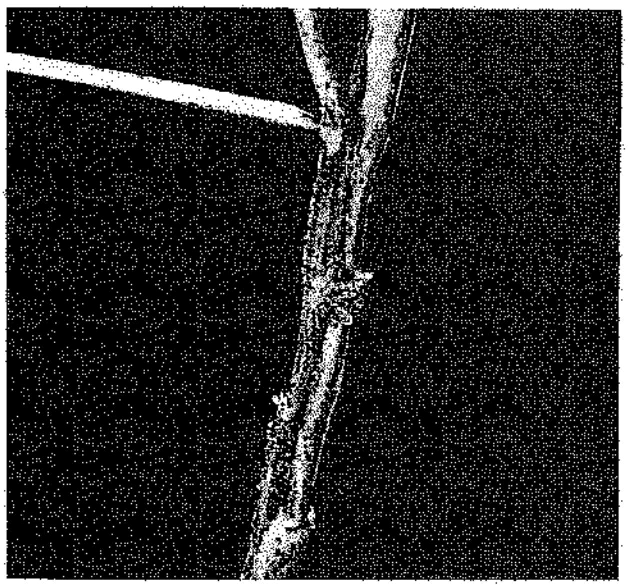

Fig. 7.5: Stem rot of Soybean.

Pathogen and Physiology

Macrophomina phaseoli has been invariably isolated from the diseased plant parts and it has also produced the disease symptoms on artificial inoculations through soil or spraying. This fungus has a wide range of host plants including *mung*, castor, sunhemp and groundnut. The wide host range, providing greater chances of carry over on a variety of crop stubbles together with its capacity of saprophytic survival, longevity in the soil and its aggressive nautre, make the pathogen more difficult to control. The fungus not only remains viable but multiplies in infected stubbles over a long period even after irrigation and ploughing of the fields. It is, therefore, not possible to get rid of the fungus through conventional crop production practices. The laboratory studies carried out on the fungus have shown that:

- Richard's agar is the best medium for its linear and mycelial growth;
- The fungus can grow over a wide range of temperatures, with optimum of 30° C and at pH range of 4.7 to 8.4 with a tendency to change the reaction of the medium to alkaline side. It also produces protopectinase enzyme, increasing with the addition of 1 per cent pectin.

Control

Until resistant varieties are evolved, collection and burning of stubbles can greatly help in checking the primary source of infection. Rotations including maize, sorghum or other non host crops will markedly reduce the fungus in the soil. Use of antagonistic fungi, if developed, may also prove fruitful.

2. Purple Seed Stain – *Cercospora kikuehli* (T.Matsu and Tomoyasu) Chupp.

This disease has been first time recorded at Islamabad and Swat on cultivar William in traces to 5 per cent, producing dull colour and cracking of seeds. The fungus also being seed-brone, is presumed to have been introduced into Pakistan. So far no work has been done on this disease. (Fig. 7.6).

Sunflower

Leaf Spot – *Septoria helianthi* Ell. and Kell.

Occurrence and Symptoms

The disease was recorded for the first time at the Natiinal Agricultural Research Centre, Islamabad in 1980 with intensities ranging between traces to severe infections. Dark brown spots, more or less circular and 2-7 mm in diameter, appeared on the leaves. The lesions frequently coalesced to form irregular patches in severe cases of infection. Minute black pynidia developed in mature lesions primarily on the lower side of leaves. The fungus was isolated and identified as *S. helianthi.*

No detailed studies have so far been carried out on the various aspects of the disease.

The other three reported diseases are rust (*Puccinia helianthi* Schw.), leaf spot (*Cercospora helianthicola* Chupp and Viegas) and *Plasmopora helianthi*, on which no work has been done.

Fig. 7.6: Purple seed stain of Soybean.

Summary

The importance of edible oil producing crops can not be over-emphasized as domestic production can onlv meet 35 percent of the total requirements, necessitating annual imports worth US$ 400-500 million. There are a number of reasons for this short-fall including the low levels ot production because of many factors including losses caused by diseases. The main results of the researches carried out on these diseases are embodied in this chapter.

The diseases of rape and mustard include downy mildew (*Peronospora parasitica*), white rust (*albugo candida*), powdery mildew (*Erysiphe polygoni*), blight (*Alternaria brassica*), wilt (*Fusarium* spp.), stem and root rot (*Sclerotinia sclerotiorum*), and storage rots. For all these diseases, symptoms, pathogenicity, perpetuation and control measures have been worked out. Since most of these diseases perpetuate through diseased plant debris lying on the soil, the destruction, collection and burning of infected plant parts and the use of chemical sprays to check secondary infections have been recommended. In case of storage rots, which have been found to be caused by four different types of fungi (*Aspergillus*, *Penicillium*, *Fusarium* and *Rhizoctonia* spp.), initial infections coupled with favourable storage conditions (high temperatures and high humidity) are mainly responsible for substantial damage affecting both the oil content and oil quality. On the basis of these findings suitable control measures have been suggested.

Wilt of linseed has been found to be produced by *Fusarium lini*, the physiology of which has been worked out in detail. It has been discovered that the incidence of the disease is controlled by the time of planting; being higher in early sowings and lower in later ones owing to the influence of the soil temperature on the growth of the fungus. The disease is reduced considerably by carrying out sowings in dry soil, which is watered immediately. Seed disinfectants have failed to control the disease while soil-disinfectants have given promising results but may be a costly proposition.

In the case of groundnuts, three diseases (root rot and wilt, stem rot and tikka) have been studied. Root rot and wilt are produced by *Rhizoctonia bataticola* and *Fusarium coeruleum*, which are soil-borne and can be checked through destruction of diseased plant debris, long rotation and use of resistant varieties (if available). Stem rot is caused by *Diplodia* sp. on which more work needs to be done.

The tikka disease has been found to be caused by *Passolora personate*. Its physiology has been worked out along with perpetuation and control measures of the disease.

As regards, root and stem rot of sesamum, caused by *Macrophomina phaseoli* and *Botryophaeria ribis*, symptoms, pathogenicity, phsiology of pathogens, perpetuation and control measures have been studied. For both the pathogens, sanitary and cultural control measures have been suggested in the absence of resistant varieties.

Soybean, which is a new crop, has been found to be attacked by *Macrophomina phaseoli* causing stem and root rot. Symptoms, pathogenicity, perpetuation and control measures have been investigated. Because of the soil-borne nature of the fungus and its wider range of host plants coupled with its ability to survive as a saprophytic colonizer, it is very difficult to suggest effective control measures since resistant varieties are not available at present.

In addition, purple seed stain caused by *Cercospora kikuehii* has been recorded first time on the cultivar William at Islamabad and Swat producing cracking of the seeds.

Sunflower leaf spot disease caused by *Septoria helianthi* was recorded first time in 1980 but no detailed studies have been carried out.

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Chapter VIII

Chickpea

The gram, which is an important pulse crop, occupies about one million hectares in Pakistan, with an average yield of 550 kg/ha. Its greatest value lies in the fact that it is almost the only *rabi* crop that can be successfully grown in the vast sandy *barani* (rainfed) tracts and therefore carries a great economic importance for the bulk of the farming community of these areas. Unfortunately, this important crop is subject to two very destructive diseases, namely, blight and wilt apart from a condition causing reduction in size of leaves and some minor diseases. Since more intensive studies have been made on diseases of chickpea, these are included in this chapter, which is separate than the one embodying diseases of other food legumes. A brief account of the research work so far carried out is given below.

1. Blight –*Mycosphaerella rabiei* Kovačeveski (*Ascochyta rabiei* Pass.) Labrousse.

Occurrence and Distribution

This disease has been reported from 26 countries out of which it is quite severe in 16 e.g., Algeria, Bulgaria, Cyprus, Greece, Iraq, Israel, Jordan, Lebanon, Morocco, Pakistan, Romania, Spain, Syria, Tunisia, Turkey and the USSR. In Pakistan it mostly occurs in the districts of Attock, Jhelum, Bunnu, Karak, Mianwali, D.I.Khan, Khushab, Bhakkar, Leiah and parts of Jhang and Bhawalnagar; thus its distribution is correlated with the amount of winter rainfall. The disease attracted attention first of all after a succession of four severe epidemics during 1936–37 to 1939–40, followed by more epidemics in the later years. Surveys carried out during two crop seasons ending 1981-82 revealed high infections (ranging between 50-100 percent) in all the above mentioned districts with drastic reduction in production levels; the severely hit areas were Attock, Bannu and Sargodha districts. Whereas in 1982-83 the incidence of the disease was comparatively low in Khushab, Bhakkar and D.I.Khan, it was higher in Karak, Bannu and Attock districts. The last epidemic years drastically reduced the total production, obliging the Government to import large quantities of gram at a heavy cost of foreign exchange. The disease, therefore, has the capacity to cause heavy losses both in volume of commodity and to farmers' income.

Symptoms

The affected plants cannot be distinguished in early stages from a distance. From February onwards such plants show partial or total drying. At this stage brown spots of varying size are noticed on stems, branches, leaf-stalks and leaflets. At first, individual diseased plants may be observed scattered over the field but later the disease spreads in circular patches. The diseased plants appear to be scorched by fire and therefore the disease is erroneously attributed by the farmers to the effect of lightening, which usually accompanies the rainfall. If the weather during February-April becomes rainy, the whole field may be completely destroyed. If the plants survive to produce pods, the diseased spots develop on them with great vigour and there is rapid formation of abundant pycnidia, in characteristic concentric zones. In severe cases, the fungus can penetrate into the pods and thereby gives rise to blackish infection spots on the grains, which remain shrivelled (Fig. 8.1). Under favourable growing conditions the diseased plants may regrow but there is seldom any grain formation in such regrowths if late, while some yield may be obtained from early regrowths.

This disease can also appear in seedling stages on the plants, which are killed out right and provide source of inoculum for the spread of the disease during the spring rainfall, when the temperature and humidity are suitable for the growth of the pathogen.

Pathogenicity of the Fungus

The fungus causing gram blight in Pakistan (G) has been compared as regards the symptoms produced as well as morphology and physiology with other *Ascochyta* cultures. These included two cultures of *Ascochyta* *pisi* Lib. isolated from *Pisum sativum* i.e., *A. pisi* (India) designated as (P) and *A. pisi* (England). The other *Ascochyta* species comprised (V) isolated from *Vicia sativa* at Slough, England; (L) isolated from lentil at Palampur, India; *Phyllosticta rabiei* (Pass.) Trotter isolated from gram at Madrid, Spain and two cultures of *Mycosphaerella pinodes* (Berk and Blox) Stone and *Ascochyta pinodella* Jones obtained from Centraalbureau Voor Schimmel Cultures Baarn, Holland (Fig. 8.2). Cross inoculations with these fungi were also carried out on gram, lentil, pea, wild and cultivated *Vicia sativa* and broad beans.

Fig. 8.1 (a): Ascochyta blight of chickpea.

Fig. 8.1 (b): Blighted field under gram crop.

The following conclusions are drawn from the experiments carried out in this connection:-

The fungus, causing the blight of pea in Pakistan, is typical *Ascochyta pisi* Lib.

The fungus, causing blight of gram in Pakistan, is identical with *Phyllosticta rabiei* (Pass.) Trotter, but in the light of research carried out by Kovaceveski, it is correctly designated as *Mycosphaerella rabiei* Kovaceveski (*Ascochyta rabiei* (Pass.) Lab.).

Ascochyta pinodella Jones and *Ascochyta pinodes* Jones (*Mycosphaerella pinodes*) (Berk and Blox) are confirmed as good species and are distinct from *Ascochyta pisi* Lib. and *Ascochyta rabiei* (Pass.) Lab.

Each fungus, with the exception of *Mycosphaerella pinodes* and *Ascochyta pinodella*, is specialized largely to its own host plant.

Mycosphaerella pinodes and *Ascochyta pinodella* cause severe foot rot while the others cause leaf, stem and pod blights.

A fungus isolated from peas in Pakistan in association with *Ascochyta pisi* Lib. is considered to be a weak parasitic race of *Ascochyta pinodella* Jones.

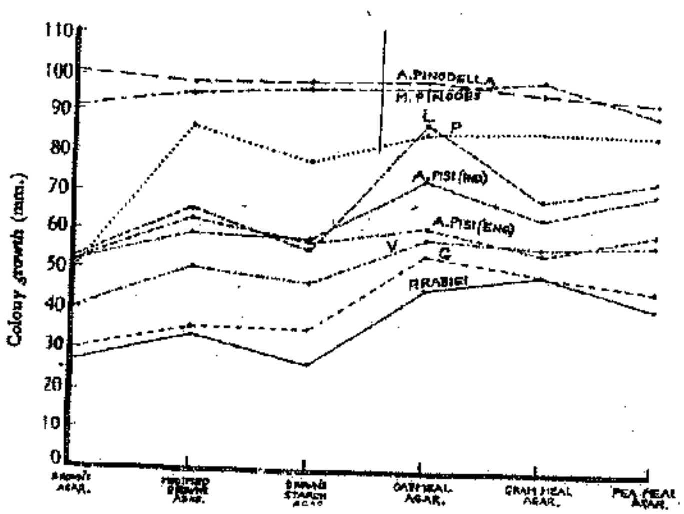

Fig. 8.2 (a): Colony growth on different culture media at laboratory temperature (18-23°C) after twenty-one day's growth.

Morphology and Physiology of *Mycosphaerella rabiei* (*Ascochyta rabiei*)

The main results are:-

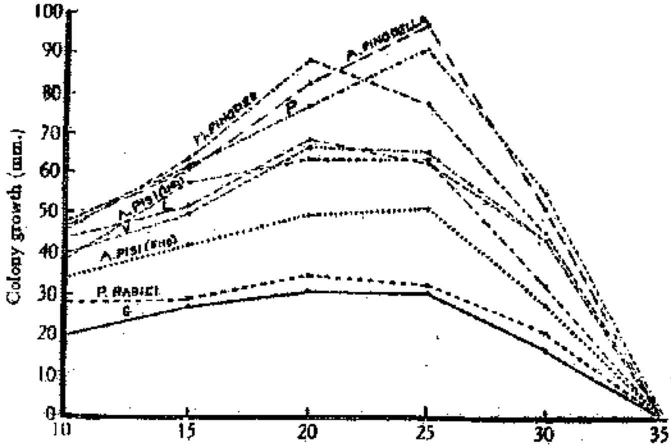

Fig. 8.2 (b) Effect of temperature upon colony diameter, after fourteen days' growth on oat meal agar.

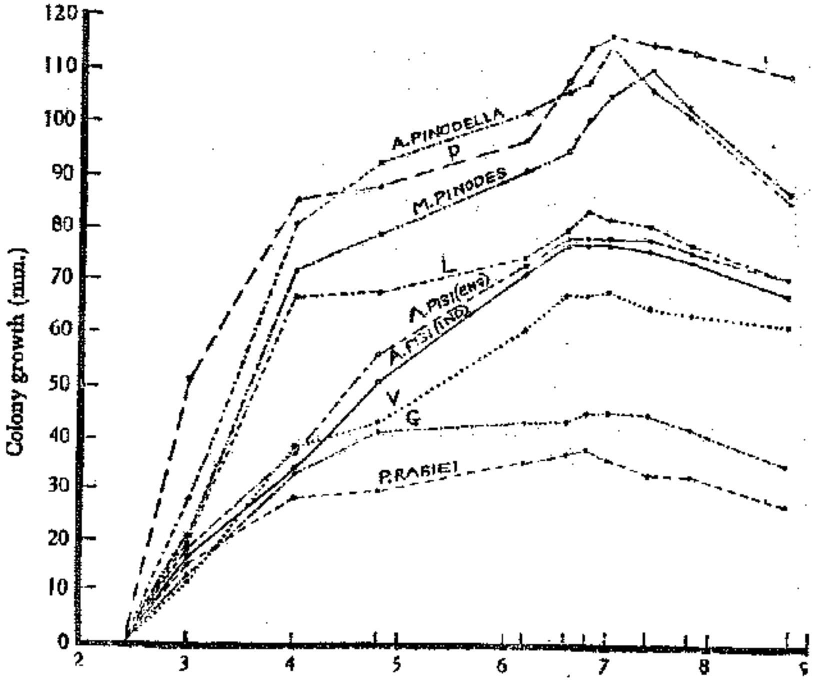

Fig. 8.2 (c): Effect of pH on colony growth (twenty-one days' growth at 20°C on Brown's starch agar).

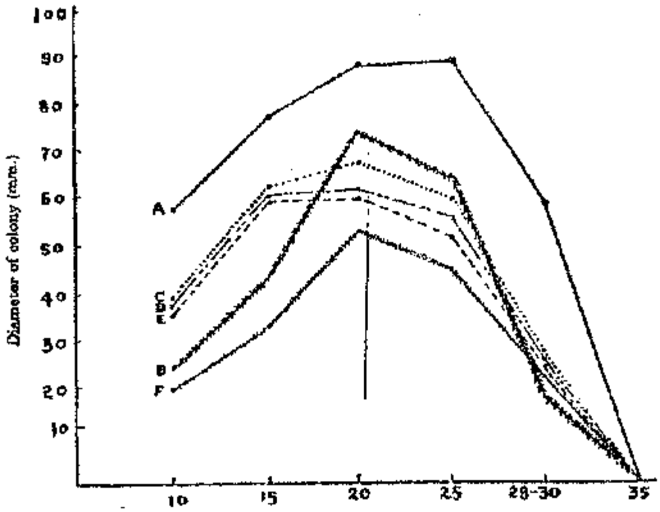

Fig. 8.2: (d) Effect of temperature on colony growth of the six forms of *A. rabiei* on oat meal agar at the end of three weeks.

The perfect stage has not been found in Pakistan. The studies on the imperfect stage have shown that the average size of pycnidia is 182 x 159 µ; while the average size of pycnospore is 10 x 4µ. Under dry conditions imperfect stage have shown that the average size of pycnidia is 182 x159 µ; while the average size of pycnospore is 10µx4 µ. Under dry conditions 99.0 percent spores are non-septate and only 1 percent are septate, but under very moist conditions the percentage increases to 10. The optimum, maximum and minimum temperatures for growth are 25°, 32.5° and below 10°C, respectively. This fungus has the lowest growth rate of the group of the fungi mentioned above.

Though the fungus has maximum growth at about the neutral point, it grows fairly well over a range of pH varying from 4.0-8.8.

The germination of spores and length of germ tubes are very meagre, slow and uncertain in water and is greatly improved in the presence of 0.5 to 0.25 per cent malic acid concentrations or an acidified medium.

The maximum, optimum and minimum temperatures for the germination of spores are 32.5°, 25° and below 10°, respectively, which agree with those for the growth of the pathogen in the field.

Viability of the Fungus

In Diseased Gram Debris Lying on the Surface of Soil

The fungus remains viable in the infected debris lying on the surface of the soil. During the summer rains the amount of inoculum may increase due to the saprophytic spread of the fungus on the dry but healthy stems lying beside infected ones. The diseased stems exposed on the surface of a field for one year, when used for inoculation of healthy crop, can produce 100 percent infection as against only 9 percent produced by those exposed for two years. The fungus is killed totally, if diseased stems are allowed to remain lying on the surface of a field for 3 years, showing thereby that after three years it is safe to cultivate gram in such fields.

In Diseased Gram Debris Buried in the Soil

The fungus cannot survive in the infected debris when it is buried under ground during summer, provided there is rainfall in this period. For total destruction of the fungus, the least burial depth should be 5 cm.

The duration of burial for obtaining complete kill varies with the amount of summer rainfall. The more the rainfall, the shorter is the period required and *vice versa*. When the rainfall is 50 mm; a period of 60 to 70 days is sufficient to kill the fungus totally.

There is no adverse effect on the viability of the fungus if infected debris is buried in dry soil due to lack of pycnidial bursting and initiation of spore germination, showing thereby that it is not the dry heat of the summer which kills the fungus but instead it is the wet heat which is deterimental to the mycelium and spores of the fungus.

If the infected material is buried in a manure pit for a sufficiently long time (2-3 months), it is completely freed from infection and the manure resulting therefrom is safe for use in the fields.

Furrow turning ploughs like Meston, Raja and Hindustan have been found to reduce considerably the infective capacity of the diseased plant debris by burying a greater percentage of them in the soil. In this case care has to be exercised not to replough such fields, atleast for three months, otherwise the buried stems will tend to come to the surface of the soil and help fungus to remain viable.

In Diseased Seed

The viability of the fungus in infected seeds decreases gradually with the increase in time of storing of the seed so much so that it is not possible to isolate the fungus from blighted seeds kept for two years in the laboratory. Such seeds are quite safe for sowing purposes, after testing their germination capacity. The fungus is also killed in 3-4 months, if the diseased seeds are stored in air-tight containers due to the high concentrations of CO_2 build up through respiration of seeds.

In Artificial Culture

The fungus when grown in culture and kept as such in dried form retains its viability even after eight months.

Under Other Conditions

The fungus present in the diseased material is killed when it is fed as hay to cattle. It is thus clear that the diseased *bhusa* can be safely used for feeding purposes. Prolonged freezing in dry state has no adverse effect on the viability of the fungus.

Development of Pycnidial Concentric Zones on Pods

Observations made in the field showed that the fungus produced pycnidia on pods in concentric circles but that sometimes they were absent. Hence work was carried with a view to finding out the factors responsible for this behaviour on culture in laboratory as well as on pods in field.

Brown's starch agar was selected for carrying out detailed studies and the results obtained are summarized in Table 8.1 and shown in Fig. 8.3.

Table 8.1: Factors affecting zonation of the fungus in culture

Factor	*Zonation*
Qantity of medium 20cc per petridish (110 mm diameter)	Normal
Higher or lower quantities of medium	Abnormal due to change in growth habit
Normal concentration of medium	Normal
High or low concentrations of medium	Abnormal
N. source omitted	Normal
High concentration of N source	Abnormal due to abundant pycnidial formation
Glucose and starch omitted	Normal
High concentration of starch	No zonation due to higher mycelial growth
Phosphates omitted	No zonation due to absence of pycnidia

pH range (4.2 to 6.8)	Normal
Alternate light and darkness at same incubation temperature	No zonation due to similar type of growth
Alternate variation in incubation temperature (with 5°C or more difference) when one of the temperature is optimum	Normal
Minimum incubation period at each temperature (12 hours or more)	Normal

An analysis of these factors indicates that both the quantity and the quality of the medium are of importance in as much as they determine the type of the growth of the fungus which is essential for this purpose. The medium should be neither too rich or too great in quantity to give rise to intense mycelial growth or sporulation, nor too poor or too small in quantity to produce feeble growth of the fungus. With the former, the zones remain obscure because of overlapping arising from intense mycelial or pycnidial production and with the latter the zones are incomplete on account of under development of pycnidia.

The second important factor for the production of zones is the variation in the incubation temperature. It has been found that when the culture of the fungus is transferred to temperatures higher or lower than the optimum, it is induced to give rise to greater pycnidial production at the region to which its growing margin extends at the time of transition from one temperature to another. Hence a pycnidial zone develops at this place.

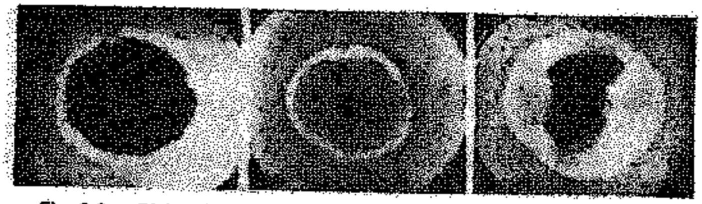

Fig. 8.3a Dishes kept at alternate temperatures of 25°C and 15°C under constant darkness.

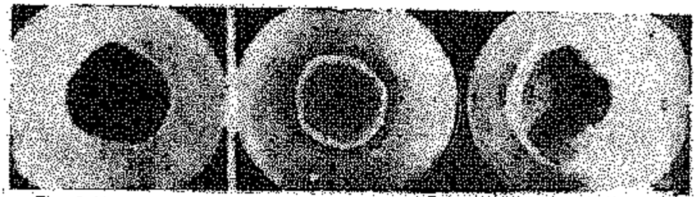

Fig. 8.3b Dishes kept at alternate temperatures of 25°C and 15°C under constant light.

Similarly, under field conditions the right type of the medium for the growth of the fungus is provided by the gram pods and the required variation in the incubation temperature is brought about by the daily and or day to night fluctuations of temperature. These conditions induce zonation on pods. The zones may not develop if required temperature variation is lacking.

Mode of Perpetuation and Spread

The disease is carried over from year to year by the following methods:-

1) By sowing infected seed. In any sample of the seed taken from a diseased crop, every gradation is seen from apparently healthy and fully developed seeds to those which are shrunken, discoloured and with large lesions on their surfaces. From such discoloured seeds some percentage of infected seeds can germinate and produce diseased seedlings. Even apparently healthy seeds (which carry infection inside) give rise to diseased seedlings on germination.

ii) The fungus remains alive in diseased plant debris lying on the surface of soil in threshing floors or in fields for three years and the spores in pycnidia present on such debris initiate infection in the next gram crop when there is rain. The amount of inoculum may also increase due to saprophytic spread of the fungus on healthy debris lying in the field.

The fungus also remains alive in diseased gram stems and the infection spreads when such material is carried from fields to the village or from one village to another

Effect of Environmental Factors

Rainfall: During summer it indirectly affects the incidence of the disease. Heavy rainfall washes the spore bodies from the gram stalks and thus reduces the inoculum while in scanty rainfall the inoculum is not reduced but sometimes even multiplied saprophytically.

The critical rainfall period is, however, from February to April which covers the flowering and fruiting stages. It has been seen that the disease appears in an epidemic form, in those years only, when the rainfall during this period is about 150 mm or more.

The occurrence of blight in the Indo-Pak Sub-continent seems to be highly correlated with the amount of rainfall during these periods. These results have been confirmed in the later studies reported in 1965, giving rainfall analysis of the epidemic years.

Temperature: A few spores germinate and cause infection during December and January due to very low temperatures. The spores, however, remain viable during freezing periods and cause infection in February and March, when the temperature varies from 20-27°C, which is optimum for the spore germination.

As the maximum temperature for the germination of spores is 32.5°C, the seed in pods will not be infected in localities where at the time of seed formation the temperature is about 32.5°C or higher. The disease in such localities will automatically disappear in a few years even if introduced, provided plant debris is destroyed.

Control Measures

To beginwith, the following control measures were devised and put into practice:-

a) Use of blight-free seed for sowing and removing of shrivelled grains by winnowing and sieving;
b) Elimination of diseased plant debris through:-
   i) Harvesting the crop by pulling out the plants by hand in sandy fields;
   ii) Sweeping the threshing floor and burning or burying the collected debris;
   iii) Ploughing the field with furrow turning plough, after the first shower of rain in summer in order to bury the remnants of diseased plants;
   iv) Discontinuing the making of *bhusa* stacks in field.
c) Mixed cropping of gram with wheat, barley or mustard to check the spread of the disease;
d) Suspension of gram crop for three years and cultivation of other crops like barley, rape and mustard or safflower.

As secondary infection also takes place to a great extent, these methods are only effective if all the farmers adopt them collectively. Under normal conditions they have proved effective but in years of abnormal rainfall the disease spreads from the un-attended fields. Work was, therefore, carried out to evolve high-yielding blight resistant types. For this purpose studies were first conducted on the physiological specialization of the pathogen.

Variation in Ascochyta rabiei

Six forms were isolated from diseased gram plants affected with *Ascochyta rabiei.* Detailed studies have shown that five of these forms distinguished as (B), (C), (D), (E) and (F) belonged to *Ascochyta rabiei* and the sixth form designated as (A) occurred on gram plants as a saprophyte. Though the five forms mentioned above differed some what in their colony growth, they were similar in their reaction on various gram types, showing thereby that they constituted one physiological race. Similar results have been reported from the later studies in Pakistan. However, in India two races (1 and 2) and one biotype of race 2 have been identified using 5 cultivars (1-13 , EC 26 435 , C 235 , F 8 and V 138) as differentials. This needs verification. It has also been reported that the fungus can infect cowpeas (*Vigna sinensis*) and beans (*Phaseolus vulgaris*) when inoculated artificially, producing mild symptoms, but that also needs confirmation.

New Method of Inoculation

A great deal of difficulty was experienced in carrying out inoculation of gram plants on a field scale by means of spraying spore suspension in water, although this method had previously proved to be very efficient in bringing about heavy infections under controlled conditions. It was not possible to utilize this method on a large scale unless some arrangements could be made to grow large amounts of the inoculum of the fungus for preparing spore suspension and to create artificial humidity over the field at least for three days. This handicap was overcome by evolving a very simple method in which case small pieces of blighted gram plants were very carefully broadcast on the standing crop in the field, after ensuring that the debris carried plenty of viable pycnidia. The infections automatically occurred after rain, even if it was received months after inoculation. This technique proved to be very easy and as successful as the original method of spraying spore suspension in water.

Resistant Varities

The work on testing of varieties was started in mid 1930s. At first 187 types and later on 392 types and collections of gram obtained from different places of Indo-Pak Sub-continent and foreign countries were tested as regards their relative resistance to *Ascochyta rabiei* through artificial inoculations both with spore suspension and diseased plant debris. All the Indo-Pak types were found to be susceptible to the disease while out of the exotic material three varieties (Pois-chiches Nos. 4 F32 , 199 and 281), which were renamed as F8 , F9 and F10 , respectively, showed high degree of resistance to the disease. Later on, about 400 additional collections from all over the world were also tested, but none was found to be resistant.

Of the three resistant types, F8 gave the highest yield and it also possessed other desirable morphological characters including the normal yellow grain colour. F8 was, therefore, selected for distribution to the farmers in the blight-affected areas. As this type was found to be low yielding than Punjab type 7 (the premier Punjab type already under cultivation) and susceptible to wilt, work was continued to evolve a type having yield and tolerance to wilt atleast equal to Punjab type 7. For this purpose, selections from natural crosses were made and also F8 was crossed with Punjab type 7. As a result of these activities, a number of disease tolerant varieties were developed and released from time to time. Some of them included C12/34, C62/18, C235, C612, C727, RC32 and C44. But none of them proved to have continued resistance resulting in occurrence of epidemic years (1956-59 and 1980-83). However, in view of the serious nature of the disease, the work on screening of varieties was intensified and enlarged in cooperation with ICRISAT and later on ICARDA. During the decade starting from 1972, thousands of varieties have been tested but none has shown real resistance, although some varieties such as ICL 195, NEG-138-2 and ILC 482 have indicated varying degrees of tolerance. This shows lack of sources of resistance in the so far available germplasm. Mutation may be a possible approach for creating genetic variability and making its use in conventional breeding. This is confirmed from the production of high degree tolerant mutants like CM68 and CM72 (obtained from irradiation of a local line No.6153); the latter is now under seed increase on the basis of its promising performance during 1982-83 crop season, occupying over 120 hactares. Since blight is a serious disease of more than 16 countries, ICRISAT and ICARDA should carry out basic studies as well as develop joint breeding programmes using mutation for obtaining genetic diversity.(Fig. 8.4).

Fig. 8.4: Range spectrum of *A. Rabiei*.

Basis of Resistance in F8 and F10

Work has been further carried out to determine the basis of resistance in types F8 and F10 and the following conclusions have been arrived at:-

The results of experiments so far carried out show that there are three factors which may be responsible for building up the resistance in these types.

Firstly, the hair population in the resistant plants is higher. There is a well known feature of the gram plant to give out an acid secretion (mostly malic acid) from the glandular hairs on its surface. This secretion increases with the advancing age of the plants both in susceptible and resistant types and in the latter on account of higher population of hairs its concentration becomes so high that it adversely affects the germination of spores.

At the advanced stage of growth, the spores, which may be present on the resistant types, do not germinate up to 48 hours and the germination remains feeble even after 72 hours with short germ tubes on account of the high concentration of malic acid. Many plants of the resistant type, therefore, escape infection. The importance of this factor seems to be great because the disease, due to rain and suitable temperature actually appears in the field when the plants are of advanced age.

Secondly, there is a slow penetration of the fungus in resistant types, which is due either to much delayed germination of spores or to some cuticular differences. As the presence of humid conditions is necessary for successful penetration of the fungus, the duration of such conditions must necessarily be longer in the case of resistant varieties. Under natural conditions, if high humidity is not maintained for longer period, plants of resistant types escape infection while those of susceptible types are liable to be infected. This, probably is also one of the main reasons why resistant types show up well under field conditions.

Thirdly, the progress of the disease is comparatively slow in the case of resistant types. This can possibly be attributed to some structural differences or to specific chemical properties of the cell-sap. The results obtained so far have shown that no structural difference has been detected in transverse sections of susceptible and resistant types, also the growth of the fungus is equally good in the cell sap of both types at different stages of growth. Microtomic sections of gram stems, which were cut passing through infected portions did not show the formation of any cork barrier. In fact, fungal hyphae have been observed invading right up to the pith. The cause of the slow progress of the disease in resistant types thus remains unexplained though it perhaps may be attributed to the production of some toxic substances which retard growth of the fungus.

Inheritance of Blight Resistance

The mode of inheritance of blight resistance in gram has been studied in a large number of reciprocal crosses of resistant types (F8 and F10) and susceptible types (Pb. 7 and C7). The following is the summary of the main results obtained in this direction.

The crosses between resistant types have given resistant progenies and those between the two susceptible parents susceptible offspring in F1 generation. All the F1 plants of crosses between the resistant and susceptible types have been found to be resistant to blight like the resistant parents; showing the dominance of resistance over susceptibility.

On the basis of disease reaction, F2 plants have been found to segregate into four classes, namely, resistant; moderately resistant; susceptible; and highly susceptible in the ratio of 22:5:5:4 (9.78: 2.22: 2.22: 1.78), showing thereby that there is a good possibility of combining blight resistance with other desirable characters because 22/36 (i.e., 60 percent) F2 plants are resistant.

Resistance to blight in gram has been found to be controlled by two genes (R1 and R2) which are linked in a recombination value of 32.22 percent.

Disease Rating Scales

Different disease rating scales have been used from time to time. Some of these scales are given below:-

Vir and Grewal 5-Point Scale

0 = No infection;

1 = A few minute localized lesions on stem and/or upto 5 percent foliage infection;

2 = Stem lesions 2-6 mm long which may girdle the stem and/or 5-25 percent foliage infection;

3 = Stem lesions bigger than 6 mm girdling the stem and/or 25-75 percent foliage infection;

4 = All young shoots and leaves are killed.

The other scales suggested are those of Morall and Mekenzie (6-point) and Singh *et al;* and Reddy and Nene (9-point).

Reddy and Nene - 9-Point Scale

1 = No lesion;

2 = Lesions on some plants, usually not visible;

3 = A few scattered lesions, usually seen only after careful

examination;

4 = Lesions and defoliation on some plants, not damaging;

5 = Lesions common and easily observed on all plants but defoliat-tion/damage not great;

6 = Lesions and defoliation common, few plants killed;

7 = Lesions very common and damaging, 25 per cent of the plants killed;

8 = All plants with extensive lesions causing defoliation and the drying of branches, 50 percent of the plants killed;

9 = Lesions extensive on all plants, defoliation and drying of branches more than 75 percent of the plants are killed.

Each of these rating scales has merit; however, there is a need to simplify the rating scale for adoption by the research workers on uniform basis.

Association of Morphological Characters with Blight Reaction

Along with studies on mode of inheritance of blight resistance, work has also been carried out on the association of morphological characters with blight reaction. It has been found that there is no significant difference between resistant and susceptible types as regards number of primary and secondary branches per plant and number of leaves and pods per main shoot; but resistant types (F8 and F10) are significantly taller, possess larger number of hairs per unit area of stem and leaf and have a smaller number of tertiary branches than susceptible types (Pb. 7 and C7).

Association has been found to exist between blight reaction and certain morphological characters. Blight resistance has been discovered to be positively correlated with hair density and weakly correlated with the height of plant and number of tertiary branches per plant. (These results are in confirmation with those already stated under basis of resistance). The character of dense hair population may prove useful for breeders working on the evolution of gram types resistant to blight.

Cytology of Resistant and Susceptible Gram Types

Cytological studies carried out have shown that both resistant (F8 and F10) and susceptible (Pb. 7 and C7) types possess 16 diploid and 8 haploid chromosomes and there does not exist any difference in the number and make up of chromosome complement.

Recent Studies

Chickpea blight being quite serious in many countries, the highlights of the studies carried out by ICARDA are given below:

1. Seed dressing with Calixin M (11 Tridemorph + 36 Maneb) alone or in combination with Benlate (0.3)6g/kg could completely eradicate the pathogen from the seeds. Repeated sprays (17 times) at 7-10 days interval with Bravo 500 alone or alternated with Calixin M on artificially infected susceptible cultivar also controlled the disease but in case of tolerant variety (ILC - 482) spraying at early podding stage was found to be enough.
2. The pathogen in addition to infected seeds and diseased chickpea plant debris, can also survive as a saprophyte on many food and forage legumes.
3. Sampling of blight pathogen populations during 1978-79 to 1980-81 has revealed the presence of three isolates, responsible for breaking down the recorded resistance or tolerance of some cultivars. Out of the genotypes tested, ICC-4107 has shown resistance and ILC-1929 susceptibility to all the three isolates. Based on the reaction of five isolates on seven genotypes, each isolate has behaved like a separate race of *A. rabiei* (Table 8.2).
4. Studies are underway on sporulation capacity of different isolates on various genotypes (showing great variation but no correlation has been found with disease severity); lesion size (lesions are not formed in resistant varieties); leaf wettability (not uniformly present among resistant lines); effect of humidity duration (disease severity increased with time and most of the lines developed infection in 15-day period, showing the main role of rainy period on disease development) and effect of cultural practices (deep-sown seed or burial of diseased plant debris at 10 cm reduced the sources of inoculum).

Table 8.2: Differential interaction of some chickpea genotypes with five isolates of *Ascochyta rabiei* from Syria and Lebanon.

Genotypes	TH-1	TH-2	TH-3	Lattakia	Terbol
ILC 72	R	R	S	R	R
ILC 194	R	R	R-T	S	S
ILC 249	R	S	S	R	R
ILC 482	R	T	S	S	R

ICC 4107	R	R	R	R	R
ICC 1591	S	R	S	S	T
ILC 1929	S	S	S	S	S

R = resistant, T = tolerant, S = susceptible reaction, TH = Tel Hadya.

The results are more or less in conformity with those reported above and reiterate the agressive nature of the pathogen and hence a need for the development of resistant/tolerant varieties and use of suitable cultural practices (excluding crop spraying, being uneconomical and not practical) for controlling blight of chickpeas.

2. Wilt – *Fusarium orthoceros* Var. ciceri

Symptoms

The second important disease of gram is wilt in which case the roots are attacked by the fungus with the result that the conducting vessels are clogged up. The plants start wilting and ultimately dry up (Fig. 8.5). The wilting of the plants takes place at two stages of growth, namely, seedling stage occurring in the months of September-October and flowering stage in the months of March-April. This is because of the fact that soil temperature at these two stages is optimum for the growth of the causal fungus.

Fig. 8.5: Wilt of chickpea.

Isolation and Pathogenecity

Isolations from roots of wilted gram plants yielded 90 percent *Fusarium orthoceros,* 0.5 percent *Rhizoctonia bataticola,* 0.5 percent *Penicillium* sp. and in 9 percent cases no organism could be isolated. It is thus clear that wilted plants mainly yielded *Fusarium orthoceros.* This fungus also proved to be pathogenic in artificial infection experiments. In later studies, the fungus *Verticillium alboatrum* has also been isolated along with above mentioned fungi and found to cause high degree of seed rot and wilting. A number of other fungi (*Operculella padwickii, Sclerotium rolfsii, Phytophthora* spp., *Ascochyta pinodella, Sclerotinia sclerotium* etc.) have been associated with the wilt disease in Pakistan and other countries.

Cultural Studies of the Fungus

The colony growth is the highest on oatmeal agar followed by Richard's agar, Brown's starch agar, glucose peptone agar and nutrient agar.

The maximum, optimum and minimum temperatures for the growth are 35-40°C, 20-30°C (growth at 20°, 25° and 30°C is almost equal) and below 10°C, respectively.

The maximum, optimum and minimum pH for the growth is above 8.6, 6.2 and below 2.8, respectively.

The spores are the biggest (18 x 5 µ) on Richard's agar followed by oatmeal agar (13 x 5 µ). On other media the size is about 10 x 4 µ. At 15-35°C the size of the spores is normal, but at 10° and 40°C it varies from 2 to 3 µ.

The spores are killed when exposed to 67°C for 5 seconds. The cultural studies carried out on *Verticillium alboatrum,* have shown production of abundant mycelial growth and sporulation on the three media at 20-25°C, highest being on Basal or Malt extract agars.

Factors Affecting the Incidence of the Disease

Experiments carried in artificially infected soil have shown that at 40°C germination is about 60 percent and all the plants wilt within a fortnight. At 35°C seed germination is 70 percent and all the plants wilt within 17 days. At 30°C seed germination is 100 percent and all the plants remain healthy for 45 days. It may be mentioned that the ungerminated seeds at temperatures of 35°C and 40°C have been seen to rot completely due to the fungus. At 30°C rotting of ungerminated seeds is partial while at 25°C it is extremely slow. All the plants, under different soil moisture contents, show that wilting is indirectly proportional to the percentage of soil moisture both in seedling and adult plant stages.

The experiments, carried out in the field for a number of years, have shown that the incidence of the disease is the highest when the sowing is done in September and it is gradually reduced with the delay in sowing time. It is almost negligible when the sowing is carried out in November, but the yield of the grain is reduced by about 50 percent as against October-sown crop. Keeping both the incidence of the disease and the yield of the grain in view, the best period during which the sowing should be carried out varies between 15th to the end of October at Lyallpur (Faisalabad). Accordingly the experiments carried out under controlled conditions have shown that 30°C soil temperature at the time of sowing is optimum for the maximum intensity of the disease. The best way to get rid of the first phase of this disease would, therefore, lie in avoiding sowing when soil temperature is high. The suitable time of sowing should, therefore, be in October, although it may differ in different localities. Application of supplementary irrigation during February-March will greatly help in reducing the incidence of the second phase of the disease.

Soil moisture near the saturation point and 9.5 percent moisture content are favourable for the development of the disease. When the soil moisture increases above 9.5 percent the incidence of the disease decreases and the decrease is marked upto 19.5 percent soil moisture. There is a rapid increase in the incidence of the disease if the soil moisture goes above this limit.

All the available Punjab types and crosses as well as exotic varieties have been tested for their relative resistance to *Fusarium orthoceros* but so far no type has been found resistant to the disease. Studies on wilt reaction and yield performance of eight gram varieties carried out over a period of five years (1963–67) at six different places, have shown that the wilt incidence is negatively correlated with the amount of rainfall received during the growing period, and the variety C-727 has shown comparatively better resistance (statistically non-significant) but giving significantly higher yield each year than C-612 (the standard variety). The blight resistant selections although high yielding in blight areas, have given lower yields in wilt infested areas. It has been concluded that C-727 combines moderate resistance to blight and wilt besides giving higher yield. The results further indicate that the varietal requirements for blight and wilt resistance are different, making the breeding programme more difficult.

Pakistan can be divided into three belts according to the distribution of blight and wilt diseases. The first belt comprises northern districts, where blight is a serious disease. The second belt includes the central districts, where both blight and wilt can coexist according to weather conditions prevailing in a certain year, while in the third belt (southern areas), where rainfall is low, only wilt is present. Work is, therefore, in progress with a view to evolving a blight resistant type for the first zone, a type resistant to both blight and wilt for the second and a wilt resistant type for the third zone. For further information see chapter XX.

3. Reduction in Size of Leaves. (Cause Unknown).

Symptoms

The growth of the plants is quite normal in the beginning but later on the diseased plants start showing symptoms of retarded growth which results in the reduced size of the various plant parts including leaves, leaflets, branches and stem. The plants remain stunted in growth, the leaves ultimately change colour, dry and shed, rendering the branches bare. In severe cases there is no pod formation at all while in others the pods formed are of reduced size with shrivelled grains.

This disease was first observed in 1944, practically confined to the crop at the Agricultural Farm, Campbellpur. It started appearing in traces and the incidence of the disease went on increasing gradually year after year till it assumed an alarming form in 1948-49. The intensity of the disease at the Farm was exceptionally high during 1949, and ranged between 80-100 percent. There were only few fields which either did not show any disease or where the incidence was very little, although the variety under cultivation and the dates of sowing were the same. From the survey of the gram crop at the Farm it appeared that the soil had to do something in influencing the conditions favourable for the development of the disease. A survey made in Attock district for the presence of smalling of leaves in farmers' fields showed that only traces of the disease could be located here and there and the crops on the whole seemed to be almost free from the attack of the disease.

Experiments carried out both at Campbellpur, and Lyallpur(Faisalabad) have definitely shown that the disease can be artificially reproduced by carrying out inoculations with the juice extracted from the diseased plants and the symptoms of the disease are pronounced when the plants are in early stages of growth. In late stages either the disease does not make its appearance or the symptoms remain masked with the result that after a few days interval the inoculated plants recover and they appear to be quite healthy. Similarly, it has been noticed that in inoculations carried out on tender growing points, better symptoms of the disease can be produced and the incubation period is also decreased when compared to the inoculations done on grown-up parts of the plants. On the other hand, the inoculations carried out, either by adding diseased plant debris in soil or by putting juice extracted from the diseased plants in the soil, have given negative results. Varietal trials carried out by sowing F8, C6 2/18, C12/34, B.R. 786, B.R. 334/1, Pb. 7 and local type in a field where the infection had been very high during 1947-48, have shown that all the varieties under test have caught the disease very severely (infection percentages ranging between 80–100) and the yield of the crop has been very much reduced, averaging between 100-500 kg/ha. in different varieties. However, from the yield data it has been seen that 334/1 and Pb. 7 are better varieties out of the whole lot.

Although from the account given above it is concluded that the disease can be reproduced by carrying out artificial inoculations with extracted juice from infected plants, the peculiar nature of the disease as regards its confinement to Agricultural Farm, Campbellpur, and its high intensity in particular fields of the farm lead one to suspect that some other unexplored factors of the soil are responsible for this typical behaviour, which needs to be investigated.

The other minor diseases of gram so far recorded are rust (*Uromyces cicris - arietini*), *Alternaria* and *Cercospora* leaf spots, powdery mildew (*Leveillula taurica*), Rhizoctonia root rot (*Rhizoctonia solani*), Verticillium wilt (*Verticillium alboatrum*), stem rot (*Sclerotinia sclerotiorum*), Botrytis grey mold (*Botrytis cinera*) and Stemphylium blight (*Stemphylium sarciniforme*); on which no research work has been done.

Summary

In this chapter the work carried out on three diseases of gram crop namely, blight, wilt and smalling of leaves has been described. As far as distribution of blight and wilt is concerned, Pakistan can be divided into three zones. In the first zone, which constitutes the districts of Attock, Jhelum, parts of Mianwali and Rawalpindi, blight is serious whereas wilt is of little importance. In the second zone, which comprises Lyallpur (Faisalabad), Sheikhupura, Lahore and Sahiwal districts, both blight and wilt coexist while in the third zone including Mianwali, Jhang and Multan districts wilt is the main problem.

Since gram blight started appearing in epidemic form during 1936–40, the work was taken into hand systematically. It has been found out that the disease is caused by the fungus *Mycosphaerella rabiei* (*Ascochyta rabiei*). The disease appears from February onwards with the advent of spring rainfall, producing brown necrotic spots of varying size on stems, branches, leaf stalks and leaflets. The disease also spreads to gram pods and through them on to the developing grains. The causal fungus has been compared with other allied fungi like *Ascochyta pisi; Ascochyta* spp. isolated from *Pisum sativum, Vicia sativa* and lentil; *Phyllosticata rabiei* isolated from *Cicer arietinum* (gram) from Madrid (Spain); *Ascochyta pinodella;* and *Ascochyta pinodes,* giving main conclusions. It has been determined that the disease perpetuates through infected plants debris from the previous year's crop and by sowing gram seeds having diseased lesions on them. Factors affecting the incidence of the disease have been worked out and control measures developed. Work has also been carried out on varietal resistance. Out of the types tested, three types, namely, F8, F9 and F10 have been found to be resistant to this disease. F8, being the best of the three has been used as one of the parents in evolving blight resistant varieties (C12/34, C6 2/18, C727, RC32 and C44 have been developed from time to time and distributed to the farmers). Ultimately all of them, with breakdown in resistance, fell prey to the disease, showing the continuing potential threat of blight resulting into epidemics. From 1972 onwards, researches have been strengthened in cooperation with ICRISAT and ICARDA. It appears that effective sources of resistance from the available germplasm are lacking, and hence mutation holds good promise for creating genetic diversity and making its use in conventional breeding. Till high-yielding and blight resistant varieties are available, the disease can be effectively controlled through the use of the healthy seeds and destruction of diseased plant debris at all farmers level. These methods have been fully described in the text. Studies have also been carried out on the inheritance of disease resistance and on the factors responsible for resistance, the results of which can help in improving the breeding programmes.

Wilt, which is the second important disease of gram crop, has also been studied and it has been found out that it is caused by the fungus *Fusarium orthoceros* var. *ciceri.* The fungus has been studied in culture. The factors affecting the incidence of the disease have been worked out and measures to control the disease suggested. Since the varietal requirements for resistance to blight and wilt are different, development of dual purpose varieties is difficult. The possible solution may be development of separate varieties for blight and wilt zones. Some preliminary work has also been carried out on reduction in size of leaves, a localized disease of gram crop, which made its appearance at the Agricultural Farm, Campbellpur in late 1940s. The present studies have shown its virus nature coupled with some soil factors, which remain undetermined.

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Chapter IX

Pulses and Legume Crops

Mung

Mung (*Phaseolus radiatus*), moth (*P. aconotifolius*) and mash (*P. mungo*) constitute the important pulse crops of Pakistan, occupying a total area of 150,000 hectares. These crops are subjected to two very destructive diseases, namely, blight and anthracnose. Investigations have been carried out in some details on these two diseases and the following important results have been obtained:-

1. Blight –*Phyllosticta phaseolina* Sacc. and *Ascochyta phaseolorum* Sacc.

Occurrence and Symptoms

The blight disease occurs in almost all the areas in various intensities, depending upon the cultivars and favourable temperature and humidity conditions; sometimes causing heavy losses in yield, quality and total production.

The disease affects leaves, leaf stalks, twigs and pods and the symptoms are like those produced in gram blight disease; resulting in total or partial drying of plants while the infected pods either produce shrivelled and infected grains or no grains at all. During rainy period the fruiting bodies of the pathogen burst, releasing multitude of spores, which fall on the neighbouring plants causing secondary infections.

Pathogenicity and Morphology of the Pathogens

Two fungi have been isolated from diseased plants. Out of them one designated as (A) has got small-sized spores (5.0-7.0μ x 2.0-2.6 μ), and the other designated as (B) has got big-sized spores (12.0-16.0u x 4.0-5.3 μ).

Both the fungi show good growth in artificial culture but fungus (B) is comparatively quick growing.

The optimum temperature for growth of both the fungi is 25° C, the maximum lies between 30-35° C and the minimum between 10-15° C.

The fungus (A) produces copious pycnidia in artificial culture media while the fungus (B) produces scanty pycnidia from which pinkish spore masses exudate. The optimum growth temperature is also optimum for sporulation. Sporulation of the fungus (A) is completely inhibited at pH 4.0, whereas the fungus (B) produces reduced amount of sporulation also towards the alkaline side.

Spores of both the fungi germinate within 6-8 hours of sowing.In the fungus (B) septa appear in about 70 percent of the spores prior to germination. The optimum temperature for the germination of spores of both the fungi is 25° C.

Inoculations have been made on a number of crops with the fungus (A) but with the fungus (B) only on *mung* and *mash*. The fungus (A) can attack all the four species of *phaseolus* and *sesamum indicum* to a slight extent while the fungus (B) attacks both *mung* and *mash*. The fungus (A) has proved to be comparatively more virulent than the fungus (B). On the basis of these studies the fungus(A) has been named as *Phyllosticta phaseolina* Sacc. and is considered to be synonymous with *Phyllosticta phaseolum* and *Phoma phaseolina*. The fungus (B) has been named as *Ascochyta phaseolorum* Sacc.

Perpetuation

The disease is perpetuated either by sowing infected seed (containing hibernating mycelium) obtained from previous year's infected crop or by sowing seed in a field containing diseased plant debris in which the fungus remains in a viable form.

The prevalence of suitable temperature and occurrence of rainfall during the growing period are very important factors, which help in the spread of the disease.

Control

In the absence of the resistant varieties, on which work needs to be done, the following control measures are recommended:-

- Use of healthy seed and destruction of diseased plant debris are very helpful in controlling the disease.

Mixed cropping of *moth, mung* and *mash* with sorghum or millet (*Pennisetum typhoideum*) can check the spread of the disease to a great extent.

Comparative Studies on *Phyllosticta* spp.

Since blights are common diseases of many cultivated and wild plants, comparative studies have been carried out on *Phyllosticta* isolates from seven plants; i.e; loquat (*Eribotrya japonica*), mango (*Mangifera indica*), ber (*Zizyphus jujuba*), ficus (*Ficus bengalensis*), guava (*Psidium guyava*), grape fruit (*Citrus maxima*) and sorghum (*Sorghum vulgare*) including one isolate of *Phoma* from mango. The main results are that:-

a) All the isolates have proved pathogenic on their respective specific host plants;

b) There is no difference in their requirements for minimum temperature and pH values of media while optimum temperatures are 30° C for isolates from loquat, ficus and sorghum and 25° C for other isolates;

c) Since no cross inoculations have been carried out, it is not possible to classify and group the isolates into different strains.

It will be interesting to continue such studies with a view of finding out different physiological races of pathogens and resistant plant varieties.

2. Anthracnose – *Gloeosporium phaseoli* Rich.

Occurrence and Symptoms

The disease is of common occurrence throughout the country, causing considerable losses under favourable environmental conditions. It affects leaves, leaf stalks, stems and pods. The diseased spot are scattered, to begin with, but later on they may join, giving rise to broad lesions and ultimately the areas lying below the infected spots become dead. The leaves sometimes become torn. The petioles, becoming badly affected, are unable to support the leaves. Similarly, seedlings raised from badly diseased seeds, show blackened cankers on the cotyledons and may die in case of severe infections. (Fig.9.1).

Pathogenicity and Morphology

The causal fungus has been identified as *Gloesporium phaseoli*, and it has been possible to produce the disease under artificial inoculation conditions.

The fungus grows well on all the media tried. The optimum temperature for growth is 30° C, the maximum and minimum temperatures lie between 30 -35° C and 10 -15° C, respectively.

The effect of pH value of the medium is very marked on sporulation, which is totally inhibited on alkaline side.

The spores of the fungus germinate freely in water and other nutrients.

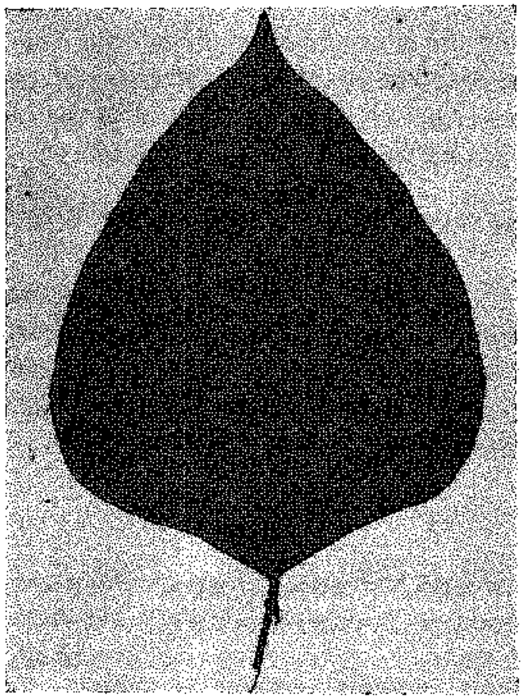

Fig. 9.1: Anthracnose on Mung

Control

Use of healthy seed, destruction of diseased plant debris and liming of soil are helpful in getting rid of the disease, till resistant varieties are available for cultivation.

Guar

Cyamopsis posraloides

Amongst the legume crops, other than pulses, work has been carried out at Tando Jam on the two diseases (wilt and powdery mildew) of guar (*cyamposis posraloides*) which occupies about 300,000 hectares and is used for food, fodder, green manuring and preparation of gum, glues and adhesives (fetching a substantial amount of foreign exchange). The salient features of the results achieved are given below:-

1. Wilt – Fusarium solani (*Mart.*) Sacc. and *F. semitectum*, Berk. Pers.

Occurrence and Symptoms

The disease is present throughout the country and surveys carried out during 1964 and 1965 in Sind province have shown the incidence ranging from 1.6 to 27.5 percent, with an average of 9.5 percent infection. As high as 50 percent infection has been noticed in some low lying areas. The disease starts developing in the seedling stage and may continue to appear throughout the growing period of the crop. The leaves show yellowing and drying, followed by wilting and drooping of the diseased plants, causing entire loss. Dark brown discolouration of the infected roots and stems near the ground level can also be noticed.

Pathogenicity and Physiology of the Pathogen

Two *Fusarium* species (*F. solani* and *F. semitectum*) have been isolated from the infected roots and stems, which reproduced the disease on artificial inoculation with the cultures of the fungi. Both the fungi have shown good growth on Richard's and potato dextrose agar media with optimum temperature of growth at 30° C.

Perpetuation

Studies carried out on modes of perpetuation have shown the carry over of the disease both through infected soil and diseased plant debris lying on the soil, where the fungi remain viable over a long period.

Control

In the absence of resistant varieties sanitary measures can help in checking the disease intensity. These include (a) uprooting and burning of diseased plants, (b) destruction of diseased plant debris, (c) 2-3 years crop rotation, and (d) avoiding cultivation of guar in low lying areas or practising good drainage.

2. Powdery Mildew, *Leveillula taurica* (Le'v.) Arnd.

Occurrence and Symptoms

The disease occurs in many areas but in lesser intensity as compared with wilt. It generally appears late in August, reaching its maximum intensity during September through the spread of the disease due to secondary infections. To begin with, greyish white spots develop on the leaves, which steadily increase in size and ultimately cover the entire leaf surface. The leaves turn pale yellow, followed by defoliation resulting in reduced yields.

Pathogenicity

The disease has been artificially reproduced with the fungus *Leveillula taurica*, isolated from the infected plants. The fungus has many host plants, which help in the build up of the inoculum.

Control

The disease can be effectively controlled through repeated dustings or sprays of sulphur-based fungicides (like Sulforon at the rate of 28.5 kg/ha or Cosan or Thiovit) starting early in August.

Summary

Mung, (*Phaseolus aconotifolius*), moth (*P. radiatus*) and mash (*P. mungo*) constitute the important pulse crops of Pakistan. They are subjected to two serious diseases, i.e.; blight and anthracnose. Blight, which produces similar symptoms to those of gram blight, has been found to be caused by two fungi namely, *Phyllosticta phaseolina* and *Ascochyta phaseolorum*. The physiology of both the fungi has been studied. In inoculation tests, the fungus *P. phaseolina* has proved to be comparatively more virulent than the other fungus. The disease is perpetuated either by sowing infected seed (containing hibernating mycelium) obtained from previous year's infected crop or by sowing seed in a field containing diseased plant debris. The prevalence of suitable temperature and occurrence of rainfall during the growing period help in the spread of the disease. Use of healthy seed, destruction of diseased plant debris and mixed cropping with sorghum or millet are helpful in checking the disease. Comparative studies carried out on *Phyllosticta* isolates from seven plants namely, loquat, mango, zizyphus, ficus, guava, grape fruit and sorghum have shown their specific pathogenicity on their respective hosts and similarity in their cultural requirements except having two optimal temperatures; i.e.; 25° and 30° C (for isolates from loquat, ficus and sorghum).

Anthracnose of pulse crops has been found to be caused by *Gloeosporium phaseoli*. The physiology of the fungus has been studied and it has been found that pH value of the medium has got a marked effect on the sporulation of the fungus which is totally inhibited on alkaline side. Use of healthy seed, destruction of infested plant debris and liming of soil are

helpful in checking the disease.

Two diseases of guar (wilt and powdery mildew), respectively, caused by *Fusarium* spp. and *Leveillula taurica* have been studied as regards symptoms, physiology of pathogens, pathogenicity, perpetuation and possible control measures. In the absence of resistant varieties, wilt can be controlled through sanitary measures including destruction of diseased plants in the field and diseased plant debris lying on the soil and following 2-3 years rotation while the powdery mildew can be checked by carrying out 3-4 sprays with sulphur-based chemicals, starting early in August, keeping in view its financial effectivity.

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Tobacco

Tobacco crop provides a good deal of profit to the farmers in addition to meeting their domestic requirements. It is grown over an area of 49,000 hectares annually with a total production of 70,000 tons giving an average yield of 1424 kg/ha. Both virginia and indigenous varieties are grown and used; respectively; for cigarette manufacturing and for local smoking. Appreciable quantities of cured tobacco and cigarettes are also exported earning a substantial amount of foreign exchange up to US $ 120 million per annum. The crop suffers from a number of diseases both of fungal and viral nature, reducing considerably the yield as well as the quality. The main results of the work done on some of the diseases at Lyallpur (Faisalabad) and Tando Jam are given below:

1. Root and Stem Rot – *Macrophomina phaseoli* and *Rhizoctonia solani* Kuhn.

Occurrence and Symptoms

One of the important fungal diseases of this crop is root and stem rot, which is also known as charcoal rot. It has been found to cause much damage to this valuable crop all over the country. As the name implies, the roots and stems show rotting symptoms when the plants are about 6-8 weeks old. The disease steadily progresses with the result that ultimately the affected plants wilt and the bark becomes covered with the embedded sclerotia of the fungus (Fig. 10.1)

Pathogenicity

Two fungi isolated in frequencies of 45 and 30 percent, respectively;

have been found to cause this disease. These have been identified as *Macrophomina phaseoli* (*Rhizoctonia bataticola* C strain Haigh) and *Rhizoctonia solani* Kuhn. The disease has been produced artificially with the cultures of these fungi under controlled conditions.

Physiology of the Fungi

The linear colony growth of *Macrophomina phaseoli* increased with the quantity of medium used while *Rhizoctonia solani* produces good linear colony growth on all the depths of media tested. *M. phaseoli* grows best on a rich medium while *R. solani* produces the largest colony growth on comparatively poor medium. *M. phaseoli* grows well on normal Richard's agar and its growth is reduced at higher and lower concentrations while *R. solani* does well on lower concentrations such as 0.5, 0.25 and 0.125 N.

The optimum temperature for the growth of both the fungi is 31° C. The maximum and the minimum temperatures are 40° C and 10° C, respectively; for *M. phaseoli* and 43° C and 15° C, respectively; for *R. solani.*

The growth of both the fungi is the highest at pH 4.4-4.8. It declines very sharply in the case of *M. phaseoli* with even a slight change in reaction while in the case of *R. solani* the growth also decreases but not so sharply as it remains quite good up to pH 6.8.

The amount of aerial mycelium of both the fungi is abundant at temperatures varying from 25° -35° C and it decreases at higher and lower temperatures.

Fig. 10.1: Healthy and Root Rot affected Tobacco plants.

In the case of *M. phaseoli*, sclerotial formation is maximum on Richard's agar and in the case of *R. solani* it is maximum on Brown's agar. The sclerotial formation is at its maximum at 31° C in both the fungi while it is quite abundant at temperatures varying from 25-35° C. However, in case of *R. solani* comparatively lower concentrations are suitable for sclerotial formation.

The size of sclerotia of *R. solani* is 110-317μ x 131-236μ and that of *M. phaseoli* is 80-174μ x 76-121μ. Sclerotia of *M. phaseoli* are killed in 0.05 percent mercuric chloride solution when steeped for 10 minutes and in 0.1 per cent if steeped for 5 minutes while the sclerotia of *R. solani* require 10 minutes steeping in 0.2 per cent mercuric chloride solution. The sclerotia of both the fungi do not lose their viability even after 21 months of storage in the laboratory. The thermal death (inactivation) point of *M. phaseoli* lies between 75-80° C and that of *R. solani* between 65°-70° C.

The sclerotial stages of both the fungi, which cause the root and stem rot of tobacco have been identified as *Rhizoctonia bataticola* C strain and *Rhizoctonia solani*; respectively.

M. phaseoli produces sclerotia both on the host and in culture media while *R. solani* has not been observed to produce sclerotia on the host.

Inoculation experiments have been conducted on nearly 104 varieties of tobacco and out of these only Type 244 has shown resistance to both the fungi under all the conditions tried.

The reaction of the soil has been found to have a great influence on the incidence of the disease. Application of lime at 2.5-5 t/ha makes the soil alkaline (generally Pakistan soils are alkaline but they tend to become slightly acidic after growing of tobacco crop for some years) and the attack of the disease is considerably reduced in the case of *R. solani* and is almost checked in the case of *M. phaseoli*.

The host range of the fungi has been worked out. *M. phaseoli* has been found to attack the following plants which are arranged in the descending order of their susceptibility:- *Sesamum indicum* (Sesamum), *Arachis hypogaea* (Groundnut), *Citrullus vulgaris* var. *fistulosus* (Gourd), *Cucumis melo utilissima* (Kabri), *Phaseolus radiatus* (Mung), *Zea mays* (Maize), *Glycine hispida* (Soybean) and *Vigna catiang* (Lobia). *Rhizoctonia solani* attacks the following plants: *Vigna catiang* (Lobia). *Arachis hypogaea* (Groundnut), *Cucumis melo* (Kabri), *Citrullus vulgaris* var. *fistulosus* (Ground), *Zea mays* (Maize) and *Citrullus vulgaris* (Water melon).

Control

The cultivation of resistant varieties constitutes the most suitable control measure. However, in the absence of resistant varieties, phytosanitary measures can greatly help in checking the disease. These include destruction of diseased plant debris, application of lime and long cycle rotation including non host plants. As *M. phaseoli* has wider range of host plants than *R. solani,* and it also produces sclerotia on host plants unlike the latter, it is comparatively more aggressive.

2. Black Shank – *Phytophthora parasitica* Var. *nicotianae* (Breda de Hann) Tucker.

Occurrence and Symptoms

This disease has been reported from most of the tobacco producing areas with varying degrees of infection. It can attack either the seedlings at 2-4 leaf stage or rapidly growing young plants. It makes its appearance on the stems of the seedlings at soil level, invading the outer tissue, developing soft rot and post-emergence death of seedlings. In young growing plants, the bottom leaves turn yellow to brownish, shrivel; droop and appear to be water-soaked. The rotting extends from soil level to about one foot above on the stems or involving the whole stem in case of early infected plants. On up-rooting the plants, the infected parts are found to be brown to black in colour besides decaying and becoming dead. If the stems is split longitudinally, the pith is found to be blackish in colour and divided horizontally into disks. (Fig. 10.2).

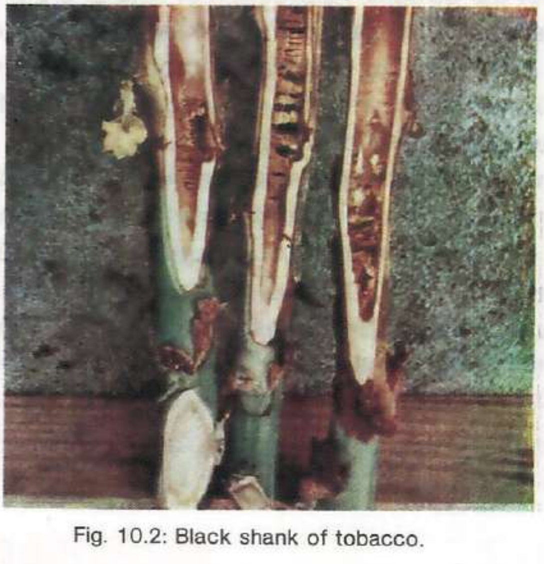

Fig. 10.2: Black shank of tobacco.

Pathogenicity

The isolations have yielded the presence of the fungus, identified as *Phytophthora parasitica*, which can produce the disease within 48 hours on the seedlings under artificial inoculation conditions. Such seedlings when transplanted, developed wilting in 2-3 days and died within a week. There is a variation in varietal reaction, some varieties develop the disease symptoms comparatively more slowly than the most susceptible ones and may therefore escape heavy damage. The cultural studies have shown the optimum temperature at 24.3° C while temperatures above 20° C and a wide range of pH values are very suitable for the growth of the fungus.

Factors Affecting the Incidence

The studies carried out have shown that high temperature and high humidity are conducive to the growth and sporulation of the fungus. Heavy soils are more suited to the fungal attack than the light ones although soil organic content has shown little effect. Addition of compost manure (containing diseased plant debris) accelerates the development of the disease. Spores of the fungus have been found to be transported to healthy fields through irrigation or drainage water and movement of contaminated tools.

Perpetuation

The disease perpetuates through the diseased plant debris lying on the soil or through raising nursery plants in infected soils for transplantation to healthy fields or through irrigation water passing through the infested areas.

Control

In the absence of resistant varieties, sanitary and cultural practices can help in checking the disease. These include 2-3 years rotation including non-host plants, raising of nursery in healthy fields or disinfecting the nursery area with methyl bromide gas (which will also control root knot, black root rot and weeds); destructiion of diseased plant debris and stopping the movement of irrigation or drainage water from the infected fields to the healthy ones.

The other reported fungal diseases are *Alternaria* leaf spot, powdery mildew, wilt and frenching (chlorosis) on which almost no work has been done. The bacterial, viral and nematode diseases are reported in chapters XIV to XVI.

Summary

Tobacco crop is subjected to a number of diseases of fungal, bacterial, nematodal and viral nature. One of the most serious fungal diseases is known by the name of root and stem rot on which investigations have been carried out. Two fungi namely, *Macrophomina phaseoli* (*Rhizoctonia bataticola* C strain) and *Rhizoctonia solani* have been found to cause this disease. Physiology of the fungi as regards growth rate, aerial mycelium and sclerotial formation has been studied. Inoculations have been carried out on many plants and host range has been worked out. Varietal reaction of 104 varieties of tobacco has been tested. Out of them only one variety designated as Type 244 has been found to resist the attack of both the fungi. The application of lime at the rate of 2.5-5 t/ha makes the soil alkaline, reducing the attack of the disease considerably.

The second important disease called black shank (*Phytophthora parasitica*) has been investigated as regards symptoms, pathogenicity, factors affecting the incidence and control measures. It has been found out that the disease attacks either the seedlings or rapidly growing young plants, causing soft rot and post-emergence death of seedlings or rotting of the stems of the adult plants. Temperatures above 20° C and high humidity are conducive to the development of the disease. As the disease perpetuates through infected seedlings and diseased plant debris lying on the soils, methods have been suggested to control these primary sources of infection for checking the disease.

Alternaria leaf spot, powdery mildew, wilt and chlorosis have been recorded in traces but no investigations have been made on these diseases. The diseases caused by bacteria, viruses and nematodes are discussed in chapters XIV to XVI.

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Vegetables

Vegetables constitute an important sector of farming, occupying annually 150,000 hectares with an average production of 1.8 million tons. Vegetable farming is a lucrative industry mostly concentrated in the hinterlands of cities and big towns, which provide an established and easy market. There are a variety of vegetable crops grown during *Kharif* and *Rabi* seasons. Vegetables are also grown on small areas in the villages to satisfy the daily requirements of the individual farmers. If the production is increased, export of vegetables, particularly to the Gulf countries, holds good promise for earning much needed foreign exchange. Although vegetable growing is a profitable business, it involves heavy investment in purchased inputs like seeds, fertilizers (both organic and inorganic), intensive labour, field machinery, irrigation water, fungicides and weedicides along with spraying and dusting equipments. Vegetables also demand careful and timely harvesting, grading, packing, crating and transport to the market. In spite of the heavy investment, the vegetable growers are faced with many destructive diseases and pests, which can cause huge losses even devastating the crops in years of epidemics. Investigations have been carried out on some diseases of a few vegetable crops at various agricultural research institutes in the country. The main results are reproduced below except those on the viral, bacterial and nematodal diseases, given in chapters XIV to XVI.

Potato

1. Tuber Rots

There are three types of tuber rots, which have been found to attack the tubers, causing heavy damage. These include brown rot, wet rot and dry rot.

(a) Brown Rot – *Pseudomonas solanacearum* (E.F.Sm.) Dows.

Occurrence and Symptoms

Brown rot of potatoes which is also called ring rot, has been reported to occur in the districts of Sialkot, Faisalabad, Jhang and Lahore causing 3.6 to 4.1 percent infection of plants and corresponding loss in yield. The causal organism is seed-borne becoming systemic on growth of the plant. Typical symptoms are burning of leaves, reduction in plant height, leaf size and dry weight of tubers as well as discolouration of vascular bundles and exudation of foul smelling liquid in advanced stages. The produce of the infected crop, when stored, develops tuber rot, causing considerable loss. No work has been done on varietal reaction and control measures. Seed disinfection may help in checking the disease. The details are given in chapter XIV.

(b) Wet Rot – and Storage Rot – *Trichurus spiralis* Bassel.

Symptoms and Causal Organisms

The symptoms differ according to temperature conditions under which tubers are stored. At high temperatures (35°-40° C), the rot is always wet due to physiological break down; gradually involving the whole tuber, which becomes soft and can be crushed easily, giving out brown drops of liquid. It emits an offensive smell if rotting is accompanied by the attack of *Pseudomonas solanacearum* and other saprophytic organisms. Storage rot is also caused by different fungi but mainly by *Trichurus spiralis* Bassel. Affected tubers become discoloured, usually brown to black, rupturing later on showing deep cavities. Selection of tubers from a healthy crop and cold storage can help in controlling the rot.

(c) Dry Rot – *Fusarium angustum Sherb and Fusarium oxysporum* Schl.

Symptoms

Dry rot usually occurs at lower temperatures as against wet rot at higher ones. Sunken, shrivelled or concentrically wrinkled areas develop on the surface of tubers. The affected areas are brown to black in appearance with occassional growth of the fungus on the surface. On cutting open such tubers, cavaties are found lined with white fungal mycelium. The tubers exhibiting dry rot symptoms, are finally transformed into dry somewhat hard, shrinked and greyish crumbling masses. (Fig. 11.1).

Pathogen

Two *Fusarium* species have been found to cause the disease. These have been identified as (a) *Fusarium angustum* Sherb. and (b) *Fusarium oxysporum* Schl. These fungi were invariably isolated from the diseased specimens and also produced dry rot symptoms when healthy tubers were inoculated through wounds with the cultures of these fungi. The infections start by producing pockets of decay which gradually develop involving whole tuber. At Tando Jam *Fusarium solani* was also found to be associated with *F. oxysporum*, which was the main causal pathogen.

Physiology

The detailed studies carried out on Richard's agar have given the following results (Table 11.1).

Table 11.1 Physiological characteristics of *Fusarium angustum* and *F. oxysporum*

Characteristic	*Fusarium angustum*	*F. oxysporum*
Maximum temperature	35-40° C	35-40° C
Minimum temperature	5-10° C	5-10° C
Optimum temperature	25-30° C	25-30° C
Aerial mycelium	Abundant	Abundant
Colour of mycelium	Creamy white	Creamy white becoming pinkish on PDA and solman on Richard's agar under constant light.
Sporulation	Abundant	Abundant
Size of macrospores	20.2-26.2µ X 2.1-2.9 µ	29.2-34.0µ x 3.3-6.3µ
Size of microspores	7.9-10.0µ X 2.1-2.9 µ	9.3-10.0µ x 1.8-2.1 µ
Septation	0-4	0-5
Time for spore germination	6 hours	6 hours

Control

A number of cold stores have been constructed both under public and private sectors for storage of table and seed potatoes but they need further extension and functional improvements. On the basis of the studies so far made the following precautions, if taken, can help in reducing the losses. These include (a) selection of those cultivars which are relatively more tolerant to tuber rot (as varieties have been found to differ considerably regarding their reaction); (b) selection of produce of crops free from diseases like early blight, wilt and viruses; (c) selection of healthy, sound and mature tubers without brusis and injuries; (d) surface sterilization of potato tubers with formalin solution in water (1:320 parts); (e) disinfection of store rooms either by spraying with formalin solution or by burning sulphur at the rate of 1 lb./ 1,000 cubic feet space or any other suitable chemicals (Semsan bel, Dithane M 45) and (f) maintaining suitable temperature within range of 12° -15° C and aeration (at which tuber rot is reduced to a negligible proportion). Since potatoes grown in the hilly tracts are harvested late in summer months, the produce can be stored at nearby cooler places and used as seed for growing autumn crop in the plains. This approach may be more economical and needs to be investigated. Production of seed potatoes from certified seed during autumn in the plains under strict controlled conditions (as being done in India) can also help solving the problem.

2. Wilt – *Fusarium oxysporum* Schl. and *F. radicola* (Wr.) Sny. and Hans.

Occurrence

Wilt of potatoes is known to occur in almost all the potato growing countries of the world and is caused by different species of *Fusarium* and *Verticillium*. In Pakistan two species of *Fusarium*; i.e.; *F. oxysporum* and *F. radicola* have been isolated and proved to be pathogenic under artificial conditions of inoculation. The wilt has been found to cause varying degrees of infection depending upon the crop season. Mostly, it is found in the spring-sown crop while very rarely noticed in autumn crop due to lower soil temperatures. The work on the disease was carried out in the undivided Punjab. This disease was found to occur sporadically in all parts of the province but its attack was generally rather serious in Kangra valley from where appreciable quantities of seed potatoes were obtained for sowing the autumn crop in the plains. Pakistan has been confronted with a similar problem as the potato seed supply moves country wide. In the beginning the Punjab (Pakistan) obtained seed potatoes for spring crop from Baluchistan (where this crop had favourable conditions for the development of wilt disease) and Baluchistan in turn depended for her seed supply on the autumn crop of the Punjab. More recently seed supply links have been developed between the provinces of the Punjab and NWFP. This supply system will ultimately help in the production of cheaper and healthy seed potatoes and healthy potato crops.

Symptoms

The first traces of the disease are visible when the plants are about a foot high or nearly 4-6 weeks old. Affected plants show yellowing, wilting, drying and death of the leaves within 2 weeks of first symptoms appearing. In badly affected plants rootlets and root hairs become rotted. A transverse section of the affected rootlets under the microscope shows the presence of delicate filaments of the fungus in the xylem bundles. The disease makes rapid progress in the presence of high humidity and temperature. (Fig. 11.1).

Pathogenicity

It is clear from the pathogenicity tests that the plants cannot be artificially infected in the autumn crop while the disease can be easily produced in the spring crop. Though no definite experiments have been conducted to analyse the meteorological factors affecting the pathogenicity of the fungus, it seems that high soil temperature and dry weather are favourable for the development of the disease in the spring crop. This temperature has been found to correspond with the optimum growth temperature of the fungus in the experiments carried out in the laboratory.

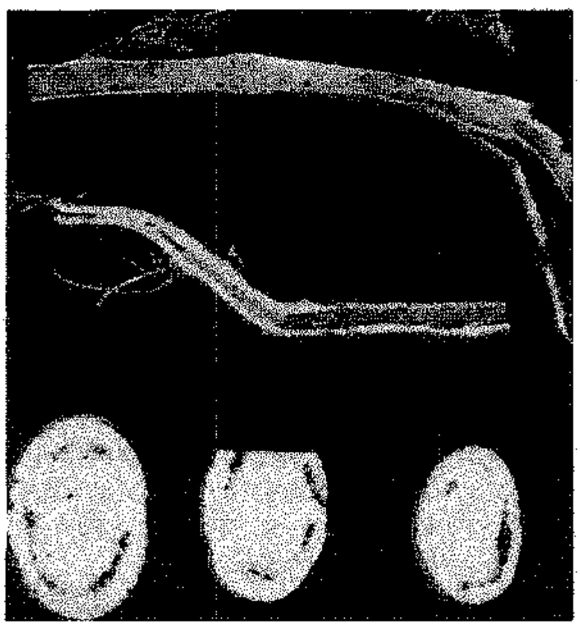
Physiology of the Fungus

The following are some of the main conclusions drawn from the cultural experiments carried out in the laboratory on the fungus (which was identified as *Fusarium oxysporum* Schl.).

The maximum temperature for the growth of the fungus is between 35° C and 40° C, the minimum between 5° C and 10° C and the optimum is 25° C to 30° C.

The linear colony growth of the fungus remains practically unchanged from pH 4.0 to 9.4 and the growth is checked at pH 2.6. The fungus produces abundant linear colony growth from 2N to 0.25N concentrations of Richard's agar while at higher concentrations the growth is very much

(a)



(b)

Fig. 11.1: (a) Dry rot of potato. (b) Wilt of Potato.

reduced. The amount of aerial mycelium is almost the same at temperatures varying from 15° -30° C. It is maximum at pH 4.0 and 4.8 and is fairly good up to 9.4.

Good sporulation occurs between 25 -30° C, becoming scanty at 15° C and 35° C. Abundant sporulation is produced at pH values varying from 4.0 to 6.0.

The macrospores are shorter at 35° C, 15° C and 20° C than at 25° C and 30° C. The size of macrospores is normal at pH 7.4 and 8.0 while at other pH values their length is shorter.

The spores are 0-5 septate. The septation is somewhat less at 35° C. Sixty to seventy percent of spores germinate after six hours at 25° C and the germination can occur at a wide range of pH values.

Control

The following measures, if taken, can help to contain the disease:-

- Selection of wilt-tolerant cultivars, as the varieties have shown varied degree of reaction under artificial conditions of inoculations;
- Selection of seed potatoes from healthy crops grown in healthy areas to minimize disease multiplication effects;
- Selection of seed potatoes from autumn crop and storing them in cold houses for use in raising the next crop;
- Disinfection and surface sterilization of seed potatoes;
- Practising of suitable rotations in infested areas including non-susceptible crops;
- Careful harvesting to avoid bruises and injuries to potato tubers;
- Safe and careful storage of potato tubers.

It may be worth mentioning that one of the methods of solving the seed supply problem is to make the freshly dug out potato tubers suitable for planting by breaking their dormancy. The highlights of the investigations carried out in this direction are that:-

a) Peeling the potato tubers (leaving the eyes intact) and storing them under moist saw dust for 7-10 days can break the dormancy.

b) Cost of peeling can be reduced by 75-80 percent, if potato tubers are rubbed against the wooden cot woven with rough fibers.

c) Potato varieties differ markedly in their dormancy periods. Those with shorter dormancy period also give better response to peeling treatment. Development of such varieties with high yield and other traits may be useful

`Further investigations are needed to be carried out to solve the potato seed supply problem and the private sector should be encouraged in the production and distribution of seed potatoes instead of depending on imported costly supplies.

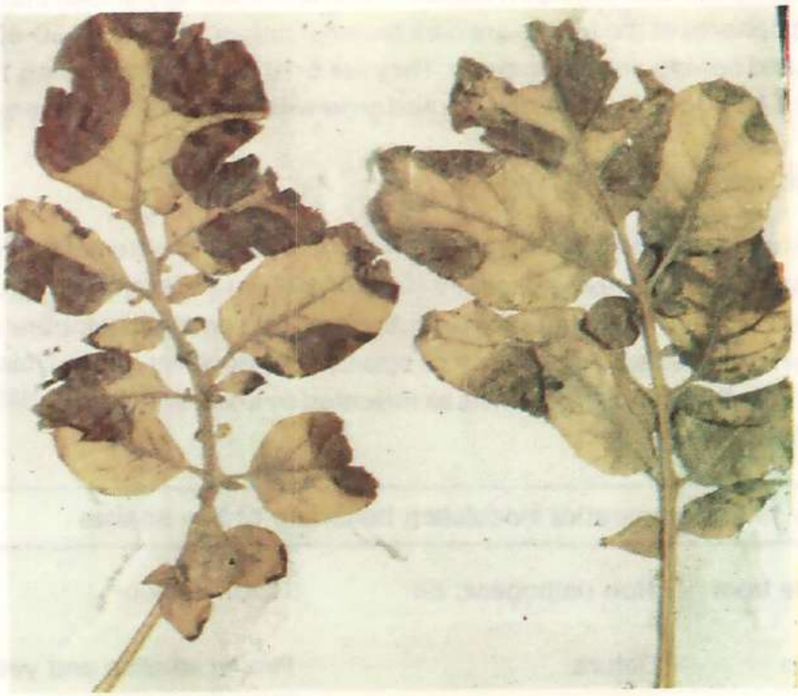


Fig. 11.2: Early blight.

3. Early Blight; *Alternaria solani* (Ell. and Mart.) Jones and Grout.

Occurrence, Symptoms and Perpetuation

Early blight occurs in all the potato growing areas in various degree of infestation; sometimes causing heavy losses. It first appears on the leaf margins as dark brownish lesions, which increase in size with time ultimately causing curling, blighting and drying of leaves. The disease reduces the size of tubers and quantum of yield (Fig. 11.2). The pathogen (*Alternaria solani*) perpetuates through infected seed tubers and/or diseased plant debris lying on the soil. Cultural studies have shown that the conidiophores of the fungus are dark brown in colour, measuring 50-80μ x 8.9 μ and conidia are borne singly. They are 5-10 septate, measuring 130-300μ x 12-20μ and can germinate and grow well on potato dextrose agar.

Physiological Strains

Studies carried out on variation of five isolates of *Alternaria solani* from potato, brinjal, tomato, datura (*D. stramonium*) and mako (*S. nigrum*) have shown very little differences in cultural growth, optimum temperature and pH requirements and in lack of sporulation. However, these isolates constitute five varieties or strains as indicated by comparative inoculation studies (Table 11.2).

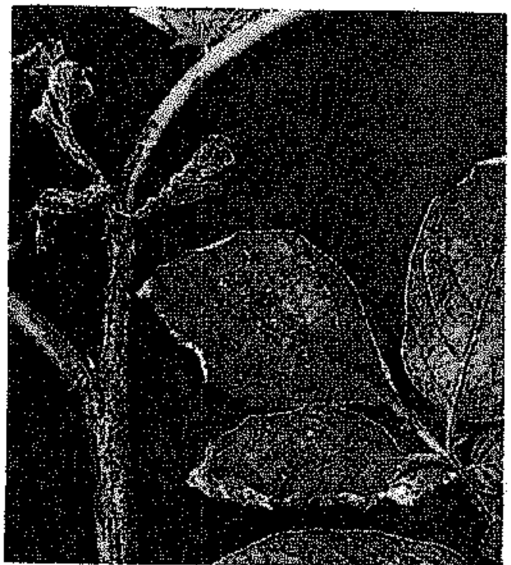
Table 11.2: Comparative inoculation behaviour of five isolates

Isolate from	Non pathogenic on	Colony colour
Potato	Datura	Pink in alkaline and yellow in acidic media.
Brinjal	Datura, Mako and Henbane	-do-
Tomato	Brinjal, Mako and Henbane	-do-
Datura	Tomato, Brinjal and Mako	
Mako	Tomato, Brinjal, Datura and Henbane	–

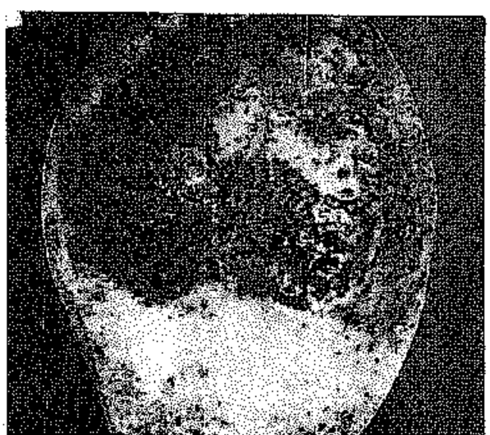
*Pathogenic on the remaining listed plants.

Disease Virulence and Varietal Reaction

Studies carried out on the virulence of isolates from 20 potato varieties demonstrated that isolates could show different levels of virulence. Where the variety/test interaction led to a severe attack, infec-



(a)



(b)

Fig. 11.3: Late blight of potato; (a) Stem & leaves showing infection; (b) tuber rot caused by P. infestans.

tion developed early (6-12 weeks after planting) and where the attack was moderate, infection developed late (12-19 weeks after planting).

In addition, early potato varieties tended to suffer more from the disease; 'Bintje' and 'Multa' being more affected than 'Atlantic' and 'Desiree'. In another study out of 41 varieties tested under artificial conditions of inoculation, none has proved to be totally resistant. One variety ('Benditta') has given 1-10 percent infection, three varieties (11-20 percent), seven varieties (21-30 percent), eleven varieties (31-40 percent), five varieties (41-50 percent) and the others above 50 percent infection. In general high-yielding varieties have proved more susceptible.

Control

In the absence of immune or highly resistant varieties, destruction of diseased plant debris and fungicidal spraying against the spread and control of the disease is the only possible approach. A good deal of work carried out in the country has identified a number of useful chemicals such as Bordeaux mixture, Kocide, Cobox, Vitigran blue, Brestan, Deconil, Duter, Mezene, Lizo Manzeb, Antracol, Cupravit and Dithane; the last two being most effective. Three, 5-day interval timely applications resulted in considerable reduction of disease intensity (upto 90 percent) and yield increased by 30 percent. Large-scale potato growers will need special arrangements for field sprays till suitable resistant varieties are developed. Furthermore, seed tubers should be obtained from healthy crops for controlling the source of primary infection.

4. Leaf Spot – *Cercospora concors* (Caspary) Saccardo.

Occurrence and Symptoms

The disease has been recorded on a potato crop grown in the Murree hills, infesting about 65 percent fields with incidence ranging between traces to 40 per cent. The disease begins to appear after the monsoon with the development of yellowish spots, surrounded by dark fungal growth on the upper surface of the leaflets, while the lower surface becomes fluffy grey due to the profuse mycelial growth in later stages. Laboratory studies have shown that the conidiophores are pale, olivaceous brown in colour, branched with 0-2 septation, often irregular in width and variously curved with conidia measuring 20-100µ x 3.5-6µ. The fungus has proved to be pathogenic when sprayed in water suspension on plants and kept under humid conditions, producing typical symptoms in 12-14 days. No work has been carried out on the other aspects of the disease including control measures.

The other disease recorded, on which no work has been done is *Rhizoctonia* blight of young sprouts, stolons and stems giving rise to cankers and development of sclerotia on tuber surface. It sometimes causes heavy loss of seed potatoes, particularly when seed germination and plant growth are slow (Fig. 11).

Recently in 1984 late blight (*Phytopthora infestans* (Mont.) de Bary) has been recorded in Swat (Malam Jaba, Atrore and Gujar Gabral vallies) causing intensive and extensive infection of leaflets, rachis, petioles and stem, exhibiting brownish to purple black lesions with whitish fungal growth on underside of the leaves, showing conidiophores and conidia (zoosporangia) under the microscope; conidia measuring 20-38μ x 12-23 μ in diameter (Fig 11.3). Conidial and mycelial suspension in water reproduced the typical symptoms of the disease at 20°C. In later stages potato tubers were also found to be infected, being responsible for disease perpetuation. The infected plants produce abundant spores and serve as local sources of infection. High humidity and cool temperatures are condusive to infection. Use of healthy seed tubers and protective fungicides can help in controlling the disease. Detailed studies are now in progress.

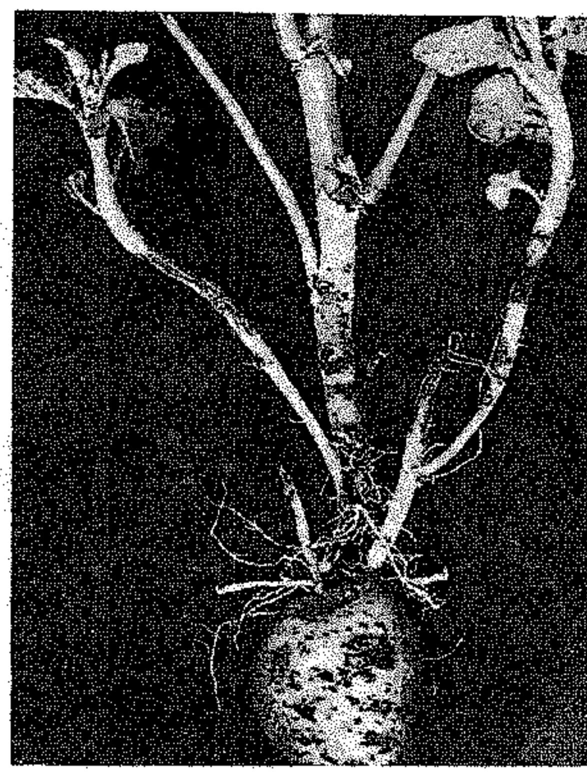


Fig. 11.3 (c) A Potato plant infected by Rhizoctonia canker.

Chillies

1. Die Back –*Vermicularia capsici* (Syd.) Butl. and Bisby and *Gloeosporium piperatum.*

Symptoms

As the name shows, the plants start drying from top downwards. The end branches are affected first, which show yellowing, withering and drying. Gradually the whole plant is involved including pods, which develop partial drying and dead necrotic spots on their surface. In later stages the end branches turn white and silvery in appearance with black dot like structures. These are the fruiting bodies (acervuli) of the fungus containing conidia or spores (Fig. 11.4).

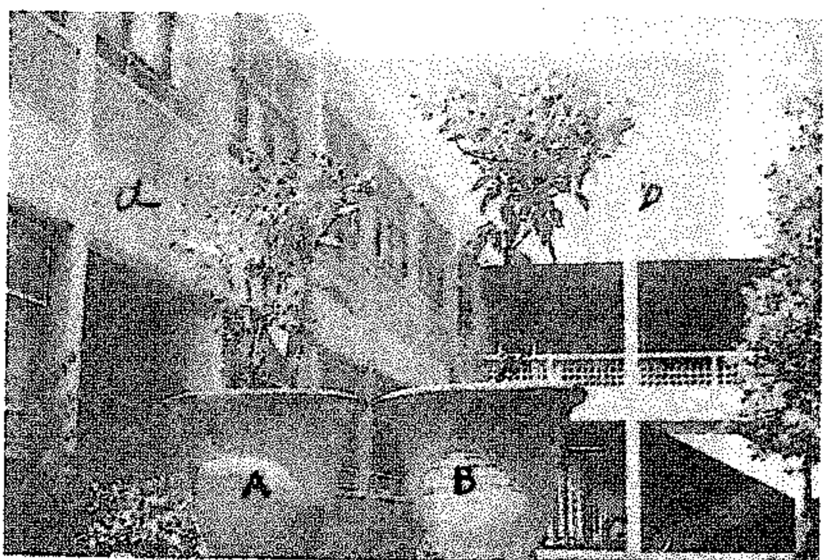


Fig. 11.4: Die-back in chillies (a) infected plant; and (b) healthy plant.

Cause of the Disease

Isolations from diseased material yielded the fungus *Vermicularia capsici.* Artificial inoculations with pure cultures of the fungus have proved that it is strongly parasitic on chillies. Along with *Vermicularia* another fungus *Gloeosporium piperatum* was also isolated from the branches, which showed partial drying and dead necrotic spots on the attached pods. This fungus has also been found to be pathogenic but is comparatively less virulent.

Temperature Relationship

The maximum, optimum and minimum temperatures for spore germination and growth of the fungi have been found to be between 35° -40° C, 25°- 30° C and below 20° C, respectively. The development, spread, incidence and intensity of the disease are very much affected by the prevailing temperatures during the crop season. With the drop in the temperatures the development and the spread of the disease are restricted.

Toxic Effect of Certain Chemicals on the Fungi

Dipping the spores of *Vermicularia capsici* in 0.1 percent copper sulphate solution for one minute or in 1:320 formalin solution for two minutes kills them while the needed toxic strength in five times higher for the spores of *Gloeosporum piperatum.*

Modes of Perpetuation

The disease is perpetuated from year to year by the following methods:-

a) By sowing diseased seed (containing hibernating mycelium) obtained from diseased crop;
b) The fungus remains viable in diseased plant debris till next year initiating infection in the new crop;
c) By sowing seeds contaminated with conidia.

Factors Affecting the Incidence of Disease

The disease is favoured in its attack and development by moist weather and high temperature. With the approach of cold weather the disease ceases to appear. The intensity is very high after rains. *Haroo* crop (sown in March-April from seed) suffers comparatively less than the crop sown in June through transplantation.

Control Measures

The following control measures are effective:-

a) Use of healthy seed. If the seed is contaminated with conidia, it is treated before sowing by steeping it in 2 percent copper sulphate solution for two minutes. If the mycelium of the causal fungus is hibernating in the seed, it is presoaked for 5 hours in water at 18° to 30° C and then immersed in hot water at 46° C for 6 minutes or the unpresoaked seed is steeped in hot water at 49° C for 2 minutes. Germination of the treated seed should be tested before sowing;

b) Spraying the crop with 4:4:50 Bordeaux mixture before the appearance of the disease. If necessary, it should be repeated after about 3 weeks to one month interval;

c) Destruction of diseased plant debris.

2. Fruit Rot – *Alternaria tenuissima*, (Nees ex Fr) Wilt.

Occurrence and Symptoms

The disease has been recorded for the first time in 1961 at Tando Jam with an average incidence of 20 percent and later on in many localities of Hyderabad region in varying intensities. The disease usually occurs on leaves and mature fruits as elevated or sunken spots showing concentric zonation (2-10 mm in diameter); later on covering larger fruit areas, which turn dark brown and rot ultimately (Fig 11.5).

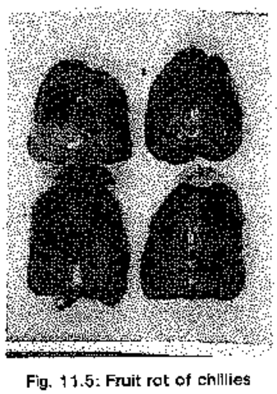


Fig. 11.5: Fruit rot of chillies

Pathogenicity and Perpetuation

The isolated fungus has been identified as *Alternaria tenuissima*, which reproduced the disease under artificial conditions of inoculation (100 percent in injured fruits and 33 percent in uninjured ones). Inoculated fruits, when incubated, have shown complete rotting within a fortnight. The fungus has dark fasiculate conidiophores bearing 1-6 scars, septate and measuring 50-60μ x 4-5.4 μ. Conidia are muriform, borne in short chains, tapering towards beak and measure 23-101μ x 12-20 μ. Potato dextrose agar and Richard's medium are best suited for the growth of the fungus at optimum pH values ranging between 5-6.

The disease has been found to perpetuate from the diseased fruits lying on the surface of the soil.

Control

Collection and destruction of diseased fruits lying on the soil to get rid of inoculum causing primary infection followed by 2-3 repeated sprays at fortnightly interval with any of the copper-based fungicide such as Bordeaux mixture or 0.2 percent Copper Sandoz are recommended. Dithane M-45 can also greatly help in controlling the disease.

3. Powdery Mildew – *Leveillula taurica* (Le'v) Arnd.

Occurrence and Symptoms

The disease has been found to occur in Hyderabad region with an average infection of 50-60 percent in many fields, while its intensity is quite low in other areas. The disease makes its appearance as white powdery spots on the lower surface of the leaves which increase in number and size covering the entire foliage, turning it yellow and resulting into defoliation. The yield is decreased considerably on account of reduction in number and size of fruits, depending upon the disease intensity (Fig.11.5).

Pathogenicity and Perpetuation

The disease has been found to be caused by the fungus *Leveillula taurica*, which has been isolated from the powdery spots. Since this fungus has many host plants, which are probably responsible for its perpetuation, more work needs to be done on this aspect for developing effective control measures.

Control

The disease can be controlled by carrying out timely and repeated dustings with chemicals like sulforon at the rate of 28.5 kg/ha or by spraying with Thiovit or Cosan (0.2 per cent). Destruction of diseased plant debris can help in controlling the primary sources of infection.

Fig. 11.5: Powdery Mildew of Chillies

Okra

Root Rot –*Macrophomina phaseoli* (Maubl.) Ashby.

Occurrence

Okra locally known as Bhindi (*Hibiscus esculentus*) is an important vegetable crop, which is subjected to a very serious fungal disease usually known by the name of root rot. It may be found on individual plants or on a group of plants in patches spreading rapidly under optimum conditions.

Symptoms

The disease begins to make its first appearance in June and it continues till October, while the attack becomes very severe in July. The disease first shows itself in the form of yellowing and wilting of plants, which soon droop and die. On pulling out such plants, they show shredded roots and rootlets, which in advance stage of attack become rotted and when pressed give out offensive smelling drops of liquid. Both sclerotia and pycnidia develop on the attacked portions. Black dots, which are the pycnidia of the causal fungus, become visible in the later stages.

Cause of the Disease

The fungus *Macrophomina phaseoli* has been isolated from the infected roots and it has been possible to reproduce the disease under artificial conditions of inoculation with culture of the fungus or pieces of infected plants.

Cultural Studies

Detailed cultural studies of the fungus were carried out in the laboratory with a view to better understanding its physiology under varied conditions so that the information thus obtained may prove helpful in evolving some suitable control measures to overcome this disease.

Host Range

It was found by inoculation experiments that besides *bhindi*, this fungus could attack important plants like tobacco, sesamum, *mung*, *mash*, groundnut, potato and tomato.

Factors Affecting the Incidence of the Disease

The studies have shown that the incidence of the disease is very high when the soul temperature varies between 25° - 30° C. Similarly, high soul moisture is favourable for the development of the disease because these conditions are conducive to the growth of the fungus.

Control Measures

The following tentative control measures can be suggested at this stage:-

1. A large number of varieties of bhindi have been tried against this disease and it is found that Type 15 can resist the disease to some extent. However, it is necessary to test the reaction of new cultivars, so as to identify resistant or tolerant varieties.

2. Sowings carried out on different dates show that the crop sown from February to 3rd week of March remains comparatively free from the attack of the disease whereas the sowings done after March are prone to heavy attack. Early sowings will help in saving the crop from the attack of the disease.

3. Early application of Chestnut compound near the root zone has been found to be useful.

4. As the causal fungus remains viable for many years in the soil,

proper rotations are required to be worked out and while doing so, care should be taken to exclude alternate host crops such as tobacco, sesamum, *mung*, mash, groundnut, potato and tomato as they are liable to be infected by this fungus. Powdery mildew, caused by *Erysiphe cichoracearum* DC; has also been recorded but no work has been done on this disease.

Tomato

Tomato crop suffers from many diseases like early blight, wilt, root rot, nematodes and mosaics affecting both quantity and quality of the produce. A brief account of two fungal diseases is given below.

1. Fruit Rot – *Alternaria tenuis* Nees and Pers.

Symptoms

The disease commonly appears on leaves as small medium brown lesions and on various parts of the fruits including blossom ends as dark brown to black concentric lesions. The lesions are somewhat flattened, dark brown to black with chlorotic borders, circular in shape and have wrinkled surface. With aging the lesions crack at the centre and the infected fruits drop down. The severity of the disease is at its maximum during January and February, showing upto 50-60 percent infection in many fields. (Fig. 11.6).

Fig. 11.6: Fruit rot of Tomato.

Pathogen and its Physiology

In 1966 some work was reported from Sind on the isolation of the causal organism, its pathogenicity and physiological behaviour. Above 95 percent isolations have given *Alternaria* in association with other organisms like *Helminthosporium* and bacterium. The morphological characters studied, have shown the pathogen to be *Alternaria tenuis*, which has been reconfirmed by the Common wealth Mycological Institute, Kew, England. The pathogenicity tests showed lesser infection (30 percent) by spray of spore suspension and 100 percent when inoculum was applied after needle injury; indicating the weak nature of its parasitism. The physiological studies have shown the optimum growth temperature at 25° C, Richard's medium as the best medium for fungal growth, peptone and manitol as the most suitable nitrogen and carbon sources, respectively; and optimum pH requirements at 5 to 7. The fungus has dark mycelium with septate hyphae while conidia, which are borne in chains, have transversal and longitudinal septations.

Control

No work has been done on varietal reaction. The best disease control approach lies in the development of resistant varieties. However, the possible control measures are destruction of diseased plant debris and repeated copperbased fungicidal sprays. Dithane M-45 and Zerlate have also given good results when repeatedly sprayed on time.

2. Wilt – *Fusarium oxysporum* Schl. *F. lycoperisi* (Sacc.) Snyder and Hansen.

Occurrence and Symptoms

The incidence of wilt disease ranges between traces to as high as more than 50 percent, depending upon the favourable environmental conditions. The initial symptoms of wilt show yellowing of lower leaves, clearing of veinlets, drooping of petioles resulting in leaf shedding. The disease progresses successively to other parts of the plants which remain stunted and finally wilt and die.

Pathogen

Mostly *Fusarium oxysporum* has been isolated from the infected plants and infested soils in NWFP and other places in the country, while *F. lycopersici* has sometime been found to be also associated.

Fig. 11.7: Early blight of tomato

Out of seven chemicals (Dexon, Brassicol, Vapam, Benlate, Brestan-60, Dithane Z-78 and Semsan bel) tested through soil application (2 days before transplantation) reduced the incidence of the disease from 44.4 percent to 7.6 percent. and increased the yield from 6275 to 13109 kg/ha (i.e; by 93 percent); Dexon (2 percent solution) and Brassicol (dry mixed with soil at the rate of 1.5 kg/ha) proved to be the best. Cost: benefit effectivity has not been worked out, but it appears to be favourable.

Early blight caused by *Alternaria solani* (Ell. and Mart) L.R. Jones and Grout has also been recorded infecting tomato plants, producing circular to irregular dark spots on the leaves and cankers on stems, branches and fruit stems (Fig. 11.7). Like early blight of potatoes it can also become serious but unfortunately no work has been reported from Pakistan. The other disease, reported on tomato, is powdery mildew (*Leveillula taurica*).

Cucurbits

1. Downy Mildew – *Pseudoperonospora cubensis* (Berk. and curt.) Rostow.

Occurrence and Symptoms

The disease is found to occur wherever cucurbits are grown in the country. The fungus has a large number of host plants–cucumbers, musk melon, water melon, squash, pumpkin and gourd. The incidence varies from field to field but it can often devastate the whole crop, particularly when the weather is cool and accompanied by rainfall or heavy dew. In Peshawar Division losses upto 57-75 percent have been recorded. At many occassions commercial growers have suffered huge losses while those who carried out timely control measures have reaped high profits. The disease makes its first appearance in the form of pale green irregular spots on the upper side of leaves resembling mosaic mottling symptoms. With time the spots become yellow and increase in number and size, covering large areas of foliage. The lower sides of the leaves are covered with light purplish growth of the causal fungus, containing large lemon-shaped sporangia. Ultimately the leaves become chlorotic, turn brown, shrivel and die. The foliage loss decreases flower setting and fruit development inducing fruit rotting in severe cases. Thus the yield and quality of fruits are reduceu considerably (Fig. 11.8).

Fig. 11.8: Downy mildew of cucurbits.

Pathogenicity and Perpetuation

The fungus *P. cubensis* has been invariably isolated from diseased plants and it has been possible to reproduce the disease through artificial inoculation with cultures of the fungus. Cultural studies have shown that the fungus has coenocytic and intercellular mycelium, giving rise to a group (1-5) of sporangiophores through stomatal openings. Sporangia are greyish to olivaceous, ovoid to elliptical, measuring 14-23μ x 21-39μ. The disease has been shown to perpetuate through diseased plant debris in which the fungus remains viable in the form of mycelium or as oospores (which are sexual fruiting bodies). The secondary infections take place during crop growth period through the zoospores produced in sporangia. High humidity favours the production of spores and disease spread and development.

Control

Sanitary measures consisting of destruction of diseased plant debris and related wild cucurbit weeds before crop sowing or during growth period along with the practice of suitable rotations are recommended. Good results for disease control have also been achieved through 2-3 timely applications of 2:2:50 Bordeaux mixture or any other copper-based fungicide. Dithane M-45 at the rate of 3.3 kg/ha mixed in 100 gallons of water has also given good control. In experimental sprays it reduced the infection by 87 percent and increased the yield of musk melon by 216 percent. In cool and moist weather a greater number of sprays are needed to control the disease. There are many examples of successful control of the disease by large-scale commercial growers leading to high financial gains.

2. Powdery Mildew – *Erysiphe cichoracearum* DC

Occurrence and Symptoms

Like downy mildew, this disease also occurs through out the country affecting various cucurbit plants (and also lady's finger or okra) and doing substantial damage, particularly under dry conditions. Many times the disease has appeared in a severe form causing heavy losses. In the beginning, white superficial spots appear on the leaves and stems and later on the entire surface of the plant is covered with a powdery mass, turning the plants brown and making them dry resulting in defoliation. Usually, the disease greatly affects the plant growth and fruit formation and development. The fruits are generally not attacked but become malformed and sunburnt due to lack of foliage cover. It is more serious in irrigated areas or those localities where heavy dew formation takes place. In severe cases the disease can cause crop failures (Fig. 11.9).

Pathogenicity and Perpetuation

The disease is caused by the fungus *Erysiphe cichoracearum*, which has also been found to cause infection under artificial conditions of inoculations. It perpetuates through the diseased plant debris lying on the surface of soil and spreads by multitude of spores causing secondary infections.

Fig. 11.9: Powdery mildew of cucurbits.

Control

The disease can be controlled through the destruction of diseased plant debris to get rid of the sources of primary infection and by carrying out dusting with any sulphur-based chemical like sulforon at the rate of 22.8-28.3 kg/ha, for checking the secondary infections. The development of resistant varieties can provide more practical control measure.

Two diseases of bottle gourd (*Lagenaria vulgaris* Ser.); i.e.; powdery mildew and leaf spot caused by *Sphaerotheca fuligenea* (Schl.) Poll. and *Cercospora citrullina* Cooke, respectively, have also been reported from South West Pakistan.

Peas

Powdery Mildew –*Erysiphe polygoni* DC

Occurrence and Symptoms

Powdery mildew is found to occur, wherever peas are grown, in various intensities; sometime the incidence is very high, devastating the whole crop. The disease first appears in January on leaves in the form of white powdery spots and later it involves stems and pods and assumes epiphytotic proportion by March. The diseased spots increase in number and size ultimately covering the whole foliage, which becomes pale brown. The plants are defoliated and become withered. In severe cases the vegetative growth rots and gives out an offensive smell. Pod formation is markedly affected, giving fewer and smaller pods and grains. In severe infections total yield and quality are reduced considerably (Fig 11.10).

Fig. 11.10: Powdery mildew of peas

Pathogenicity and Perpetuation

The fungus has been identified as *Erysiphe polygoni*. The disease can be reproduced by inoculation of healthy plants. Studies, carried out on the fungus, have shown the production of ovate to elliptical conidia on conidiophores arising from the mycelial growth, which are responsible for the secondary infection and spread of disease in the standing crop. The disease has been found to perpetuate through infected plant debris containing fruiting bodies (cleistothecia) of the fungus. The fungus has many host plants which render control measures more difficult.

Control

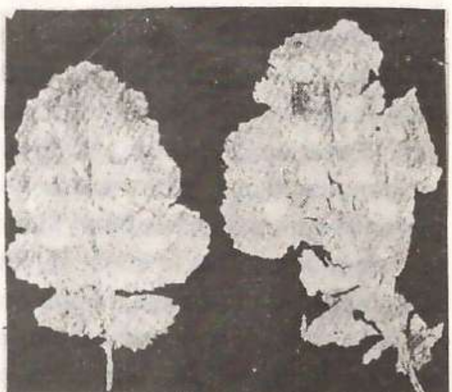
Use of resistant varieties is a practical method of controlling the disease (on which the work should be concentrated). If resistant varieties are not available the cultural control measures (destruction of diseased plant debris and plant parts, rotation) along with fungicidal dusting are recommended. Out of the several fungicides tested, three applications of Sulforon (28.3 kg/ha) or Kumulus (0.2 per cent) have reduced the infection by 20-30 percent and consequently increased the yield in the same proportion. The spraying must be done on time and repeated at fortnightly intervals to check the development and spread of the disease.

The other diseases recorded are leaf and pod blight (*Ascochyta pisi*) Lib. which develops sunken spots on leaves, pods and stems containing black dots (fruiting bodies) filled with spores, which help in the spread of the disease as well as in perpetuation; and root rot (*Rhizoctonia* sp.). No detailed work has been reported to be done on these diseases.

Miscellaneous Crops

A number of diseases on different vegetable crops have been recorded from time to time with preliminary studies on some of them. These include blight or leaf spot and rust of onion (*Alternaria porii* Ell. Cif. and *Puccinia allii* Rud.), wilt of pea (*Fusarium oxysporum* F. *pisi*), downy mildew of radish (*Peronospora parasitica*), powdery mildew of okra, coriander, spinach and carrots and *Cercospora* leaf spot of spinach and okra (*Cercospora beticola*, Sacc. and C. *malayensis*). Some information on the cultural growth studies of the causal pathogens at various temperatures, pH values and nutritional requirements are available but almost no work has been done on the control measures. Infact, there are many other vegetable crops such as cabbage, cauliflower, lettuce, onion, sweet potato, brinjal which are grown in Pakistan and also suffer from many diseases. Unfortunately no work has been done and needs careful planning. (Fig. 11.11).

(a)



(b)

(c)

Fig. 11.11: Diseases of Miscellaneous Crops (a) Cercospora Leaf Spot of Spinach. (b) Downy Mildew of Crucifers (c) Blight of Beans.

Accounts of the diseases caused by bacteria, viruses or nematodes are given in chapters XIV to XVI.

Summary

Vegetables constitute an important sector of farming both for internal consumption and export besides providing cash to the vegetable growers. A large number of vegetables are grown during the *Kharif* and *Rabi* seasons, which are subjected to the attack of many diseases, responsible for reducing both the yield and quality. Investigations have been carried out on some of the diseases of potatoes, chillies, okra (bhindi), tomato, cucurbits(cucumbers, water melon, musk melon, squash, pumpkin, gourd), peas and beans.

Amongst the potato diseases, tuber rots, wilt, early blight and leaf spot have been investigated. Tuber rots are of three types - brown or ring rot (*Pseudomonas solanacearum*), storage rot (*Trichurus spiralis*) and dry rot (*Fusarium* spp.). Detailed studies have been carried on dry rot as regards symptoms, cause of the disease, physiology of the causal pathogens (*Fusarium angustum* and *Fusarium oxysporum*), factors affecting the incidence and control measures. The wilt disease attacks the potato crop grown in spring and has been found to be caused by the fungus *F. oxysporum*, which is able to infect at high temperatures. The physiology of the fungus has been studied in detail and some suggestions have been made on the control of the disease. In the case of early blight caused by *Alternaria*, symptoms, pathogenicity, modes of perpetuation and control measures have been investigated: No variety has been found to be resistant except the indications that the late maturing varieties are less susceptible. A number of copper-based chemicals have been found to control the secondary infection and spread of the disease. These have been enumerated.

Dieback of chillies, which causes heavy damage to the crop has been investigated. Two fungi *Vermicularia capsici* and *Gloeosporium piperatum* have been found to be the causal pathogens of the disease. The physiology of the fungi has been studied along with the weather conditions favourable for the development of the disease. Crops sown in March-April by broadcasting suffer comparatively less than those transplanted in June. The disease has been found to perpetuate through diseased seed and/or diseased plant debris lying on the soil. Fruit rot of chillies has been found to be caused by *Alternaria tenuissima* which affects leaves and mature fruits causing sunken spots with concentric zonation. Pathogenicity and perpetuation have been studied along with possible control measures. The third disease of chillies; i.e.; powdery mildew (*Leveillula taurica*) has been found to cause heavy losses in case of severe infections. It has been found that the disease can be controlled through the destruction of diseased plant debris, followed by timely and repeated dustings with sulforon at the rate of 28.3 kg/ha.

Root rot of okra (*bhindi*) is one of the very destructive diseases of this crop. Symptoms produced are similar to those of cotton root rot. The disease has been found to be caused by *Macrophomina phaseoli*, which has wide host range. Factors affecting the incidence of the disease and control measures have been investigated.

Early blight and fruit rot of tomato (*Alternaria tenuis*) has been found to occur in varying intensities, depending upon the weather conditions. Under artificial inoculations 100 percent infection can be produced on injured fruits compared to 33 percent on un-injured ones. Physiology of the fungus has been studied along with possible control measures including destruction of plant debris and use of fungicidal sprays. Wilt of tomato caused by *Fusarium oxysporum* has been found in traces to as high as more than 50 percent, depending upon the favourable environmental conditions. Work carried out on control has shown the efficacy of some chemicals not only in reducing the incidence but also in increasing the yield by 93 percent over the untreated plots

In case of cucurbits, downy mildew (*Pseudoperonospora cubensis*) and powdery mildew (*Erysiphe cichoracearum*) have been found to be the most destructive diseases of these crops causing heavy damage in commercial plantations. Studies on pathogenicity and modes of perpetuation have shown the diseased plant debris as sources of primary infection while diseased plant parts are responsible for causing secondary infections and spread of the disease. Control measures have been investigated including sanitary measures and fungicidal sprays in the case of downy mildew and dustings for powdery mildew. They have proved highly benificial.

Powdery mildew (*Erysiphe polygoni*) is a serious disease of peas causing losses in large plantations. Pathogenicity and modes of perpetuation of the disease have been studied showing similarity to powdery mildews of cucurbits. Investigations made on control measures have shown the usefulness of destruction of diseased plant debris followed by dusting with Sulforon at the rate of 28.3 kg/ha.

A number of other diseases have been recorded including blight and rust of onion (*Alternaria porii* and *Puccinia allii*), wilt of pea (*Fusarium oxys-*

porum F. *pisi*), downy mildew of radish (*Peronospora parasitica*) and powdery mildew of various crops on which only preliminary studies have been made.

The bacterial, viral and nematodal diseases of vegetable crops are discussed in chapters XIV to XVI

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CHAPTER XII

Fruit Plants

Pakistan due to its varied climatological environment and soil conditions grows a variety of fruits including citrus, mango, banana, apple, guava, apricot, peach, pears, grapes, pomegranate, dates and almonds, covering an area of 263,000 hectares with an average annual production of 2.2 million tons. Orchards being more remunerative, the areas under fruit trees are increasing and efforts are underway to introduce new type of fruits in the country. One of the main reasons for low yield and quality is the damage done by a number of diseases infecting fruit trees in various intensities. The salient features of the investigations carried out at Lyallpur (Faisalabad), Tando Jam, Quetta and Tarnab, on important diseases of citrus, mango, banana, apple, peach, almond, grapes, pomegranate and papaya are given in this chapter.

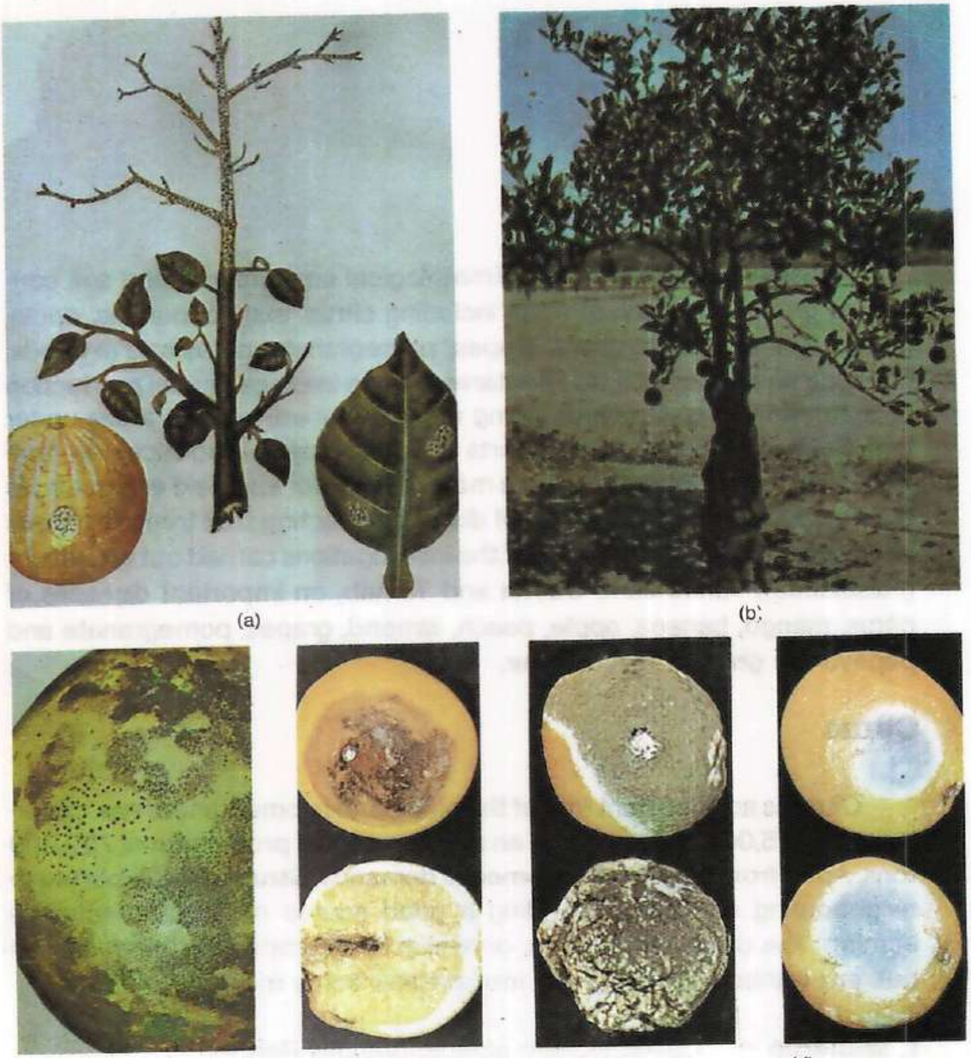
Citrus

Citrus is an important fruit of the plains and submontane areas, covering about 75,000 hectares with an average annual production of 722,000 tons. Apart from meeting the domestic demands, citrus is also exported to neighbouring countries, providing a good source of foreign exchange earning. The diseases of citrus, on which researches have been carried out, are withertip, canker, wilt, root rot and sooty mold.

1. Withertip – *Colletotrichum gloeosporioides* Penz.

Occurrence and Symptoms

Citrus withertip is one of the very serious diseases, causing great damage to citrus plantations throughout the country. The first symptoms of the disease are noticed when the twigs start drying from tip downwards and hence the name dieback is also sometimes used for this disease. Later on, the dried portions become silvery white in appearance and are found to be studded with small, black dots constituting the fruiting bodies of the causal fungus, *Colletotrichum gloeosporioides*. The disease spreads from small twigs to branches and brings about their destruction with the result that if allowed to continue for some years, it kills the plants outright (Fig. 12.1).



(a) (b) (c) (d)

Fig. 12. 1 (a) Withertip of Citrus
(b) Citrus Wilt
(c) Citrus Sooty Mold
(d) Fruit rots

Pathogenicity and Physiology

Initial work has been carried out by Chauduri of the Government College, Lahore, on different aspects of this disease. The main conclusions, which can be derived from the results of his experiments, are given below:-

Colletotrichum gloeosporioides has proved to be pathogenic on citrus plants when inoculated on cut leaves and cut twigs. As a rule the use of cut leaves and twigs in pathogenicity tests should have been avoided as in such cases even a slightly parasitic fungus can become very virulent.

Bordeaux mixture has proved to be most effective spray for the control of the disease. As it is often washed off during rains, Bordeaux mixture with ferrous sulphate can prove better spraying material because it improves the sticking qualities of the spray and also helps in reducing chlorosis, which is frequently found in the orchards.

Application of nitrogenous fertilizers to citrus trees has not helped to prevent the appearance of the disease.

Further studies have been conducted in the Plant Pathology Laboratory, Lyallpur (Faisalabad), in order to clarify the relation between *Colletotrichum gloeosporioides* the fungus occurring on citrus, *Gloeosporium limetticolum* and the fungus causing anthracnose of mango. A comparative study of the three fungi has been made on their respective host plants, as well as in artificial culture media under different environmental conditions. Cross inoculation experiments have also been carried out. The important results obtained are summarized below:

The three fungi produce acervuli on the branches, leaves and fruits of their respective hosts, with no appreciable difference in the size of conidia.

At 30° C the growth of G. *limetticolum* is remarkably slow on all the culture media as compared to the other two fungi.

The optimum temperature for growth of C. *gloeosporiodies*, and G. *limetticolum* is 25° C while it is 30° C for the mango fungus. The growth of the three fungi is restricted below 15° C and there is no growth at 40° C or above.

The three fungi can grow well at pH values from 4.0 to 9.0. The growth of G. *limetticolum* is checked at 2.8 pH while others can tolerate this concentration. However, there is no growth at pH 1.8 in all of them.

The amount of sporulation in the three fungi varies directly with the richness of the culture media.

Setae are always produced on all the culture media in the case of C. *gloeosporioides*, and on majority of culture media in case of the mango fungus. There is no production of setae in the case of G. *limetticolum*.

The size of conidia of the three fungi on different culture media is approximately the same. The conidia of G. *limetticolum* germinate in water after 90 minutes and those of the other two fungi after 120 minutes. Before germination, the conidia swell and become one septate. The germ tubes are given out from ends as well as from sides of the spores. The maximum temperature for germination of spores of the fungi is between 35 to 40° C, while the optimum and the minimum temperatures are 25° C and below 10° C, respectively. The minimum pH for the germination of spores is between 2.0 and 2.8 and their germination is even fair up to pH 9.4. The germination of conidia of the three fungi is identical in 0.25 to 1.0 per cent solutions of potassium nitrate, potassium dihydrogen phosphate, magnesium sulphate and sodium chloride.

The three fungi cause infection on twigs of mango but on twigs of *malta* (orange), *sangtara* (tangerine), rough lemon, jullundri *khatti*, kaghzi lime*, grape fruit and *mokri*, either they do not cause any infection or produce very slight symptoms. They also cause rotting of *malta, sangtra* and mango fruits still attached to the plants, resulting into premature falling. The fungus *C. gloeosporioides* and the mango fungus can also cause rotting of detached fruits of all citrus varieties under test except *kaghzi* lime.

From the results given above, the following conclusions can be drawn:-

(1) The species causing anthracnose of mango is identical with *Colletotrichum gloeosporioides*, which is confirmed to be distinct from *Gloeosporium limetticolum*.

(2) *Colletotrichum gloeosporioides* is actively parasitic on mango leaves, fruits and twigs but it is a weak parasite of citrus, easily attacking fruits and fruit stalks while it may produce a slight infection of twigs and leaves.

These results therefore, show that *Colletotrichum gloeosporioides* is not an active parasite of citrus twigs as earlier stated by Chauduri. Further experiments in this direction have indicated that the infection cannot be produced unless the plants have been pre-disposed to the attack. This is only possible when the plants become weak, either due to high percentage (0.2 percent) of total soluble salts in the root zone, or 8.5 or greater pH values of soil, or other adverse soil factors. Work needs to be done to determine the nature of such soil factors, which are responsible for creating suitable conditions for the fungus to cause infection. This will help in finding out better control measures.

Control

So far the control of the disease consists in pruning and burning of

*Kaghzi lime = *Citrus aurantifolia*; Grape fruit = *Citrus paradisi*; Malta = *Citrus sinesis*; Lemon = *Citrus limonia*; Sangtra = *Citrus nobilis* var. *deliciosa*; Sweet lime = *Citrus aurantifolia* dried branches and the application of ammonium sulphate and farm-yard manure (at 2 1b ammonium sulphate plus 20 1bs of farm-yard manure per plant) in addition to carrying out spraying of the plants with 4:4:50 Bordeaux mixture as detailed under citrus canker. Cupravit, copper A and Perenox (0.2 per cent) have also given promising results.

2. Wilt – *Fusarium* spp.

Occurrence and Symptoms

Citrus wilt is found usually in nurseries although older plants are also affected. The disease prevails more severely in canal irrigated tracts than in sub-montainous area.

Characteristic damping-off symptoms are produced in young plants while in older plants there is a general decline in health with the result that chlorotic leaves appear and the fruits fall down prematurely.

Pathogen and Cultural Studies

About 90 percent of the total isolations have yielded *Fusarium* spp. Two *Fusarium* species designated as (F) and (O) were selected for detailed cultural studies and the important results obtained are as follows:-

The optimum temperatures for maximum linear growth of fungi (F) and (O) are 30° C and 25° C, respectively. The minimum and maximum temperatures for both the fungi range between 5-10° C and 35-40° C, respectively.

Both the fungi grow fairly well from pH 7.0 to pH 9.2 and fail to make any growth below pH 3.0.

The growth of the fungus (F) is adversely affected when any constituent from Richard's agar is omitted but there is no appreciable decrease in the growth of the fungus (O).

Mercuric chloride solutions of 0.05 and 0.025 percent strengths are effective to kill the spores of the fungi (F) and (O), respectively in 5 minutes while 3 percent copper sulphate solution can also kill the spores of the two fungi in 5 and 10 minutes, respectively.

The spore germination in both the fungi is 100 percent at 25° to 30° C.

The specific identity of these fungi was not made.

Both the fungi can cause rotting of seeds and wilt of seedlings in case of *khatti* (*Citrus medica*), *mitha* (*Citrus limetta*) and *kaghzi* lime (*Citrus aurantifolia*).

Control

Although no work has been reported to be carried out on control measures, disinfection of soil with a suitable chemical in nursery beds or growing of nursery plants in tested healthy soils can greatly help to control seed rot and seedling wilt. Similarly, in adult plants the area encircling the stem and its root system can be disinfected with 1 part of formalin mixed in 320 parts of water and then covered with wet sacks for two hours.

3. Root Rot – *Rhizoctonia bataticola* and *rhizoctonia solani* Khan

Occurrence and Symptoms

Root rot of citrus is mainly a disease of young nursery plants. It occurs throughout the country but unlike citrus wilt, it is comparatively more serious in sub-montainus tracts than in canal colonies. In NWFP its incidence has been found to range from 40-58 percent in sweet lime.

The disease causes rotting of the root bark and invades the conducting vessels. It causes damping-off in young seedlings and wilting in grown up seedlings.

In NWFP the symptoms recorded included decay of roots, shrinking and cracking of affected parts of bark near the soil level, exudation of gum, besides yellowing and dropping of leaves from the infected branches.

Pathogens and Cultural Studies

The isolations made from different infected citrus species appeared to fall into five groups. One representative from each group designated as A,B,C,D and E was selected for detailed cultural studies. The isolates A,B, C and D belonged to the species *Rhizoctonia bataticola* and E to the species *R. solani.* In NWFP the pathogen was identified as a *Phytopthora* species.

The fungi A, B, C and D grow fairly well on higher concentrations like 8 N, 4N and 2N of Richard's agar while the fungus E does well on low concentrations like 0.25N.

All the fungi grow fairly well on pH range varying from 4.2-7.2 except the fungus (E) in which case growth falls considerably above pH 5.2.

The size of sclerotia in all the isolates varies greatly with the nature of the medium.

Khatti (*Citrus medica*) seedlings and its seeds are somewhat less susceptible to all the fungi than those of *kaghzi* lime; the temperatures from 30-35° C being optimum for infection.

The thermal death or inactivation point of the fungi A, C, D and E lies between 80-84° C and that of fungus B lies at 62° C.

Formalin solution of 1:320 strength kills the sclerotia of all the fungi in 25 minutes. Mercuric chloride of 0.05 per cent strength can also kill the sclerotia of all the fungi except those of B for which mercuric chloride of 0.1 percent strength is required.

The isolates A, B, C and D belong to the C strain of the species *Rhizoctonia bataticola* and hence are called *Macrophomina phaseoli*. The fungus E has been identified as *Rhizoctonia solani* (sclerotial stage of *Corticium solani* Prill and Delaer). The optimum temperature for growth of all the isolates lies at 30° C.

The minimum temperature for A, B and C is between 15-20° C and for D and E is between 10 and 15° C. The maximum temperature for A, B and D is a little above 40° C and for C and E between 35 and 40° C.

Control

No work has been done on control measures. However, disinfection of soil or raising of seedlings on healthy soil can help to reduce the incidence of the disease considerably.

The studies carried out at Tarnab, where *Phytopthora* sp. has been found to be the causal organism, have shown that:-

- sweet lime, lemon and lime are highly susceptible; grape fruit and rough lime are susceptible; sweet orange and mandarin are moderately susceptible while sour orange is resistant;
- factors affecting incidence are excessive irrigation, faulty drainage, soil salinity and heaping of soil around the plant base; and
- the disease can be controlled to a large extent by avoiding the above mentioned factors besides application of Bordeaux paste to the stems near the ground level and spraying with zinc sulphate solution.

***Comparatsive Studies on Rhizoctonia* spp.**

Since the fungus *Rhizoctonia* causes root rots of many host plants, comparative studies have been carried out on seven isolates from tobacco, okra, sesamum, cotton, citrus, chillies and pigeon peas as regards symptoms, morphological, cultural and pathological behaviour. The main results are:-

- The symptoms produced are more or less similar and the pathogens mostly attack the roots and basal parts of stems, causing shredding, yellowing, wilting and drooping and appearance of black-dotted bodies (sclerotia). The affected plants lose their grip on the soil and can be easily detached. In case of okra and sesamum the fungi also produce pycnidia;

- None of the isolates show specialization of parasitism as they can be made to attack a variety of plants under favourable conditions; groundnut, tobacco and sesamum being attacked by a greater number of isolates;
- On the basis of morphological, cultural and pathological characters these isolates fall into three groups or varieties;

  Group 1 – isolates from tobacco, okra, sesamum, citrus and chillies

  Group 2 – isolate from cotton

  Group 3 – isolate from pigeon pea
- All the isolates be named as *Macrophomina phaseoli*, each group constituting different varieties.

4. Sooty Mold – *Capnodium citri* Berk and Desm.

Occurrence and Symtoms

It is a common disease of citrus and mango trees, appearing on leaves as black velvety coating of the mold. This hinders the normal functioning of the leaves, retarding photosynthesis and giving a set-back to the general growth and fruit development. The disease may also appear on the surface of fruits restricting their development and causing deterioration in their quality and market value. The disease can thus cause heavy losses to the citrus and mango plantations in severe cases of infection, particularly during humid weather. (Fig. 12.1).

Pathogen

The disease appears as a result of feeding activities of insects and its incidence depends upon the population of sucking insects and the amount of honey dew deposits on leaves. These deposits provide an excellent medium for the growth of saprophytic fungi including *Capnodium citri*, which dominates under the local conditions. The disease cannot be produced through artificial inoculations in the absence of honey dew deposits.

Control

As honey dew deposits are pre-requisite to the development of the disease, the control of the sucking insects can also check the development and spread of the disease.

The other diseases recorded are (a) foot rot caused by *Phytopthora* species; (b) greasy spot (*Mycosphaerella horri* Hara); (c) green mold (*Penicillium digitatum* Sacc.) accompanied with blue and pink molds (*P. italicum* Wehmer and *P. roseum* Link.) usually found in markets and stores; and (d) tristeza or quick decline, which is a virus disease. Almost no work has been done on these pathogens and their control.

Mango

Mango occupies a place of great importance and is therefore called the king of fruits, being grown on 58,000 hectares with total annual production of 564,000 tons. It suffers from a number of diseases. The main results of researches carried out on some of the important diseases are given below:-

1. Anthracnose – *Glomerella cingulata* Stonem (S and VS)
Colletotrichum gloeosporioides Penz

Occurrence and Symptoms

Anthracnose is of common occurrence throughout Pakistan, especially in old plantations; sometimes becoming a limiting factor in mango production.

The disease attacks leaves, petioles, twigs and fruits. On leaves it forms numerous oval and irregular brown spots of varying sizes. The spots may begin at the tip or from any other point on the margin or may develop in the centre of a leaf. Under damp conditions the spots grow rapidly, forming elongated necrotic areas, which may sometimes result in the rupture of the affected tissues.

The petioles when affected turn black or grey and the leaves droop, become dry and ultimately fall off.

On the twigs the disease produces elongated black necrotic areas. The tips of very young branches are first attacked and the twigs start drying from top to bottom. When the fruits are attacked, black spots develop on them and rot sets in. Fig 12.2.

Pathogenicity and Cultural Studies

The fungus causing the disease has been identified as *Glomerella cingulata* Stonem, the conidial stage of which is *Colletotrichum gloeos-*

Fig. 12.2: Anthracnose of Mango.

porioides Penz.

Inoculation experiments have shown that the fungus is pathogenic on leaves, petioles, stems and fruits of mango and that the optimum temperature for infection is about 25° C.

The maximum temperature for the growth of the fungus is 35-40° C, while the minimum is between 10-15° C and the optimum between 25-29° C.

The amounts of sporulation and aerial mycelium are quite good on a wide range of temperatures i.e. between 20-35° C.

The growth is about the same at pH 4 and pH 9.0 but it falls considerably at pH 3.5 on the acidic side and at pH 8.2 on the alkaline side.

The maximum temperature for germination of spores is between 35-40° C while optimum is 25° C and the minimum between 10 and 15° C.

Perpetuation

The disease has been found to perpetuate by the following methods:-

1. The fungus remains viable in the detached diseased twigs and leaves which remain lying on the surface of the soil.
2. In the diseased twigs, which remain attached to the trees the fungus remains viable for more than two years. Such twigs are, therefore, responsible for initiating fresh infections.

Control

The following measures for the control of the disease have been suggested:-

i) Removal and burning of all the diseased mango leaves and twigs lying scattered in the garden.

ii) Pruning of all the diseased twigs and burning them. The cut ends of big branches should be coal-tarred or sulphur-pasted.

iii) Spraying of the plants with 3:3:50 Bordeaux mixture three times a year during February, April and September. Cupravit (0.2 per cent), Melprex or Cobox can replace Bordeaux mixture, if needed.

2. Malformation of Inflorescence.

Occurrence

The disease commonly known as malformation of the inflorescence, came into great prominence by mid 1940s. Although it was in existence for many years in the past, the incidence remained generally low. However, the disease has been causing greater damage with the increase in its incidence. The percentage of attack varies greatly from variety to variety and tree to tree. Generally the grafted trees of the same variety show higher intensity of disease than those raised from seedlings.

Symptoms

The symptoms of the disease are very variable. In severe cases the panicle is much reduced in size and thickened. The floral branches are bunched together in the form of a cone, later changing into a black mass. Such masses may continue to hang on the trees for a long time and there is no fruit setting in such inflorescences. In other cases the panicle is only moderately reduced in size so as to allow some of the floral branches to separate out. Instead of a single large cone, a number of smaller compact cones appear. In still others the vegetative leaves appear on the panicle intermingled with the small cones. It is interesting to note that many a time the branches, bearing malformed cones in the previous years, produce both malformed and healthy types of inflorescence next year (Fig. 12.3). The observations made on the diseased flowers have shown that the proportion of staminate and hermaphroditic flowers is greatly disturbed and in many cases unisexual staminate flowers are exclusively found.

Cause

The early investigations carried out at Lyallpur (Faisalabad), have

Fig. 12.3: Malformation of mango inflorescence

shown that the disease is not caused by any insect. Similarly the later studies have failed to prove the association of any fungus or bacterium as the causal agent. Pruning of branches bearing malformed inflorescence, severe heading back or ringing of diseased branches and application of NPK fertilizers alone or in combination have not given any consistent and positive results. No appreciable difference has been found in the carbon: nitrogen ratio of healthy and malformed inflorescence. It has also not been possible to reproduce the disease through inoculation of buds, inflorescence or growing branches and seedlings with the juice extracted from the malformed inflorescence. However, there is some evidence of (a) the presence of eriophyid mites (*Aceria mangifera* syd.) hibernating in bud scales, which may be acting as a vector and (b) transmission of disease through grafting and budding indicating the probable virus nature of the disease. However, the exact nature of the disease is still not clear inspite of thirty five years of research efforts made in Pakistan, India and Egypt. It is still posing a challenging problem to the scientists.

Control

Because of the unsolved nature of mode of disease perpetuation it is not possible to suggest any definite control measures except the following sanitary practices (a) pruning and destruction of branches bearing malformed inflorescence, (b) avoiding the use of material from diseased branches for budding and grafting and (c) following good husbandry practices including fertilization, irrigation, weeding and control of other diseases. Recent experiments have given some indications of control by using antagonistic organisms (*Trichoderma harzianum, Aspergillus flavus* or Arachniotus spp.) with organic soil amendments but it needs thorough testing under varying soil and climatic conditions to refine the treatment and confirm its scientific validity. For more information consult chapter XXI.

The other recorded mango diseases are powdery (*Oidium mangifera*) and fruit rot (*Colletotrichum gloeosporioides* and *Aspergillus niger*). Powdery mildew appears during January - February in Sind and can be controlled by sulforon dusting before flower opening while fruit rot can be checked by spraying Bordeaux mixture or any copper-based fungicide as recommended for the control of mango anthracnose.

Banana

Banana, which was introduced in Pakistan in late 1950s, has now become one of the most remunerative fruits, covering 14,000 hectares with an estimated annual production of 124,000 tons. Pakistan also exports substantial quantities of good-quality banana besides meeting its domestic requirements. As the banana plantations have begun to suffer from many diseases, research work has been initiated to develop suitable control measures. The salient results of such investigations are given below:-

1. Black Tip or Finger Tip – *Botrvodiplodia* sp. and *gloeosporium masarum*

The studies made at Faisalabad have shown that the disease affects the banana fruits on their tips, which turn black and develop rotting symptoms involving the whole fruit or part of it. The fungus *Botryodiplodia* has been found to be responsible for the development of the disease. The incidence of rotting has been studied at different temperatures and found to increase with rise in temperature (Fig. 12.4). It was 10 percent at 15º C, 15 percent, at 20º C and 45, 75 and 90 percent at 25, 30 and 35ºC, respectively.

The increase in the intensity of the disease at higher temperatures explains the prevalence of the disease in plantations situated in hot localities.

According to the recent investigations, carried out at Tando Jam, the disease incidence ranges between 16-22 percent. There it has been noticed that the disease appears as small, black, circular spots on the skin at the end of fingers. Fruits are blackened and the pulp becomes soft and rotten. The causal fungus has been identified as *Gloeosporium musarum* which has 30º C as its optimum temperature. It grows fairly well on potato dextrose agar and Richard's medium with pH range of 4 to 9; pH 6.5 being optimum. The fungus also secretes protopectinase enzyme and toxins, which may be responsible for disease causation. The difference in the causal fungi at the two places may be due to the temperature variation:

Control

The disease has been found to be controlled with the application of 4:4:50 Bordeaux mixture or Zerlate (2 1b/100 gal.). Destruction of diseased plant parts can also prove useful in eliminating the primary source of infection.

2. Pseudo-Stem Rot – Gloeosporium sp. and Botryodiplodia sp.

Two fungi namely, *Gloeosporium* sp. and *Botryodiplodia* sp. which have been found to produce black or finger tip disease are also responsible for causing main stalk rot (Fig. 12.4).

The feasible way of establishing plantations free from the disease is either by selecting young and healthy secondary suckers or by selecting disease free corms, which should be preferably treated with 2 percent copper sulphate solution for 10 minutes and dried before planting.

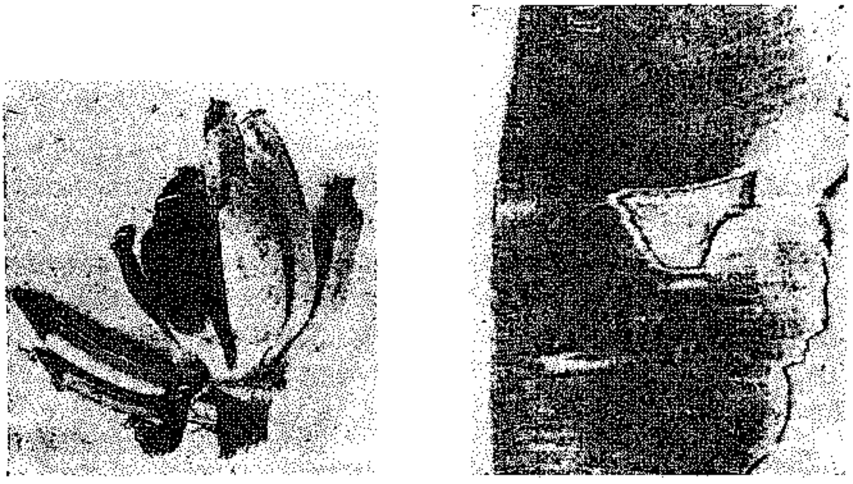


Fig. 12.4 (a) Fingertip of banana and (b) Leaf spot of banana

3. Stem end Rot – Gloeosporium sp.and Botryodiplodia

This is the only serious disease of banana fruits stored in pits for curing. The two responsible fungi are *Gloeosporium* sp. and *Botryodiplodia*, which have been found to be active at 30-40° C. Cultural studies carried out on these fungi have shown that the optimum temperature for both of them is 30° C but the attack is more vigorous at 35° C. (Fig. 12.4).

From the above account it is clear that the two most destructive fungi are *Gloeosporium* sp. and *Botryodiplodia* sp., which cause various types of banana diseases both in the field and in storage. Thus the control of the field diseases will also be effective in protecting the stored fruits. More work needs to be done to find out economical and effective control measures.

The other diseases recorded on banana are leaf spots (*Helminthosporium hawaiiense* and *Alternaria* sp. while *Cercospora musae* Zimm. has been reported as a pathogen from other countries), and those caused by nematodes such as *Rotylenchus juvenile, Hopolaimus, Helicotylenchus* and *Meloidogyne* sp. The latter are discussed in chapter XVI.

Papaya

During the last decade papaya has become an important fruit of the Hyderabad and Karachi regions and its cultivation has spread also to the Punjab plains and sub-montane districts. It is subjected to a number of fungal, nematodal and viral diseases causing heavy losses both in quantity and quality. The salient features of the work carried out on fungal diseases are given below:-

1. Damping-off and Stem Rot – *Pythium aphanidermatum* (Ed.) Fitz.

Occurrence and Symptoms

This disease occurs in low lying areas with standing water and/or in soils with poor drainage conditions. The stems of the infected plants near the ground level become macerated and spongy while the terminal leaves start yellowing, withering and drying. As a result the plants fall down in advanced stages of infection. (Fig. 12.5).

Pathogen

The causal organism has been identified as *Pythium aphanidermatum,* which is sometime also associated with *Rhizoctonia solani.* The high soil moisture contents predispose the plants to the attack of the causal fungus, which is soil-borne in nature.

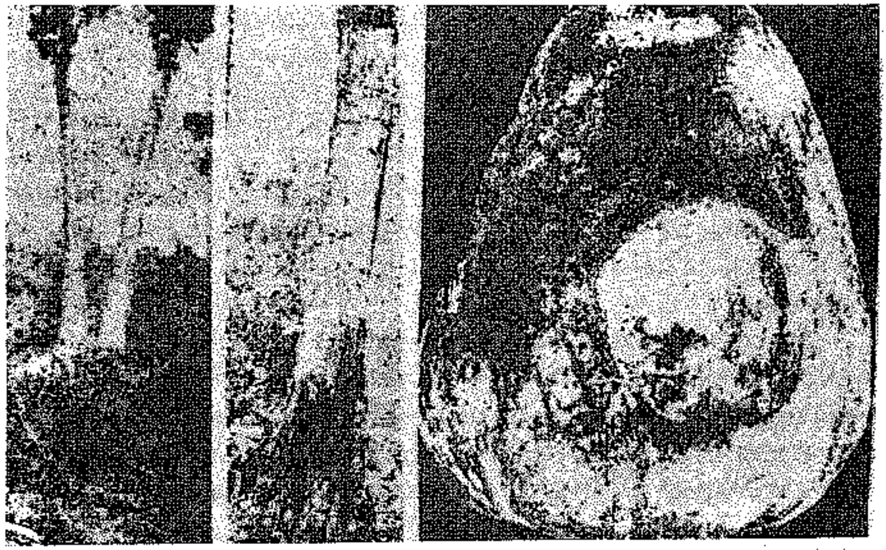


Fig 12.5. Diseases of Papya: (a) Damping off; and (b) Charcoal rot

Control

Uprooting and destruction of diseased plants followed by improvement of the poor soil drainage conditions and avoiding the water stagnation around the stems can greatly help to keep the disease under check. Use of Bordeaux paste or mixture on the affected stems and other plant parts is beneficial in controlling the spread of the disease.

2. Charcoal Rot – *Macrophomina phaseoli* (Maubl.) Ashby.

The disease appears under warm and dry conditions and the characteristic symptoms are breakdown of the parenchymatous tissues of roots and stems, charcoal-like appearance of the affected plant parts, development of carbonaceous fungal structures comprising sclerotia and pycnidia and withering of leaves (Fig. 12.5).

The disease has been found to be caused by *Macrophomina phaseoli*, which is soil-borne fungus and has a wide range of host plants. It, therefore, perpetuates through diseased plant debris. Destruction of diseased plant parts along with use of Bordeaux paste can help in keeping the disease under control.

3. Anthracnose – *Colletotrichum dematium* (Pers. ex. Fr.) Grove

Occurrence and Symptoms

Anthracnose is of common occurrence and mainly attacks the fruits although it can also develop on leaves and stems. It appears as small circular lesions on the surface of the fruits, which on aging become dark brown to black in colour, increase in number and size and involve large areas and cause deformity of fruits.

Pathogen and Cultural Studies

The disease has been found to be caused by *Colletotrichum dematium*, which when inoculated on unripe or ripe fruits can cause typical symptoms of the disease within a fortnight. The fungus produced good linear colony growth on sucrose nitrate-agar and Richard's solution; potassium nitrate and maltose provide good sources of nitrogen and carbon. Optimum, maximum and minimum temperatures have been found to be 28°, 40° and 15° C, respectively while the optimum pH is 6.5.

Control

The experiments carried out on the control measures have shown the beneficial effects of repeated sprayings with Bordeaux mixture or Cupravit at 15-20 days interval.

4. Fruit Rot – *Rhizopus oryzae* Went and Eerl.

Occurrence and Symptoms

This disease is of wide spread nature in the markets and not very common in the papaya plantations because usually the fruits are harvested before ripening. It appears as necrotic spots on the surface of fruits. These spots enlarge and coalesce covering bigger areas, followed by development of whitish fungal growth, which renders the fruits pulpy, watery and unuseable.

Pathogen and Physiology

Three species of *Rhizopus* were isolated from the infected fruits. The unripe or ripe fruits, when inoculated with the isolated cultures and kept at 28° C for 72 hours produced the typical symptoms of the disease; which developed more rapidly on ripe fruits. Rhizopus oryzae being more agressive, produced 100 percent infection while *R. nigricans* and *R. arrhizus*, 75 and 60 percent infections, respectively. Rotting does not take place at 15° C. It starts at 20° C and is more rapid at higher temperatures. The fungi, when grown on nutrient dextrose medium, gave maximum mycelial growth and 3 percent of manitol proved as a good source of carbon. The optimum temperature for the growth of the fungi is 30° C while minimum and maximum temperatures are 15 and 45° C, respectively. They can grow on a wide range of pH values

Control

Studies carrid out on toxicity of some spray fungicide on the cultures have shown that the growth of the fungus is inhibited when copper and zinc based chemicals are added to the medium. The most effective chemicals were Dithane M-45, Polyram-combi, Copper sandoz, Cupravit and 4:4:50 Bordeaux mixture. Large-scale testing of these chemicals has not been done under market conditions, for which methodologies need to be developed. Provision of low temperature storage (10-15° C) can also help to increase the keeping quality of the fruits.

The occurrence of Powdery mildew (*Oidium* sp.) has also been reported.

Diseases caused by nematodes and viruses have been discussed separately.

Apple

Apple occupies an important position among the deciduous fruits in Baluchistan, Punjab, NWFP and Azad Kashmir, covering more than 9,000 hectares with 84,000 tons of annual production. It suffers from the attack of many pests and diseases causing heavy losses to the apple industry. A brief account of the work carried out on apple diseases is given below:-

1. Ripe Rot – *Rhizopus arrhizus* Fisher

Distriybution, Symptoms and Perpetuation

Ripe rot, first recorded in Loralai, Baluchistan in 1946 has become a widely distributed and serious disease in all the apple growing areas of the province; causing an average infection of 15-20 percent. It has been found to be caused by *Rhizopus arrhizus*, while *Botryosphaeria ribis* Gros. and Dug. is the main pathogen reported from USA (which has many host plants such as rose, avocado, currant and gooseberry). It also infects apricot, peach and nectarine. The disease appears on maturing fruits, causing discolouration, disfigurement. rotting, shedding and canker formation on the stalks (Fig. 12.6). Such infected fruits have poor keeping quality and fetch very low price. In some cases mummified fruits remain hanging on the trees, providing primary sources of infection for the perpetuation and spread of the disease. The spores contained in sporangia (fruiting bodies) are carried through wind or rain and cause infection on fruits injured by codling moth or fruit fly. The intensity of the disease has been found to be correlated with the sugar contents of the fruits and higher temperatures. These conditions are usually available when the fruits are nearing maturity (June-September).

Control

Six spray applications during July-September at 15-day interval with 4 fungicides (Zerlate, Dithane M-45, Cupravit, Fermate and Fermate mixed with Malathion at the rate of 2 1bs/100 gallons of water), have reduced the infection by 52 to 93 percent. The best results, have been achieved with Fermate mixed with Malathion (93 per cent reduction) followed by Fermate alone (87 percent reduction). As a result of these and other studies the recommended control measures are (a) pruning of diseased plant parts, picking and burning of mummified fruits and diseased plant debris, and (b) spraying Fermate combined with Malathion; first spray in February followed by 15-day interval sprays during July/September. Although the economics of these control measures has not been worked out, it is presumed that the operations are highly beneficial because of the complete control of the disease.

2. Powdery Mildew – *Podosphaera leucotricha* (Ell.et.Ev) Salmon.

Distribution and Symptoms

Powdery mildew is comparatively less common than ripe rot and die-back diseases of apple in Baluchistan but can become serious under favourable conditions of temperature (19-22° C) and high humidity. It can attack nursery or adult plants, appearing during spring or summer on young shoots, flowers and fruits as small, irregular, white or greyish, coweb-like patches on the under surface (to begin with) and later on covering all the parts. Infected leaves are curled, distorted, browned and shed while diseased branches show stunted growth and are killed forcing emergence of bushy shoots in the following season. Fruits are covered with white mycelial growth distorting their development and quality while infected buds fail to produce flowers and fruits but help in the overwintering of the fungus (Fig. 12.6). As a result the disease can cause quite heavy losses.

Perpetuation

The disease overwinters in buds and the fungus sporulates after opening of buds in the spring. It spreads during the growth period through air-borne conidia of the causal fungus. It perpetuates through ascospores produced in black dotted fruiting bodies (perithecia) of the perfect stage.

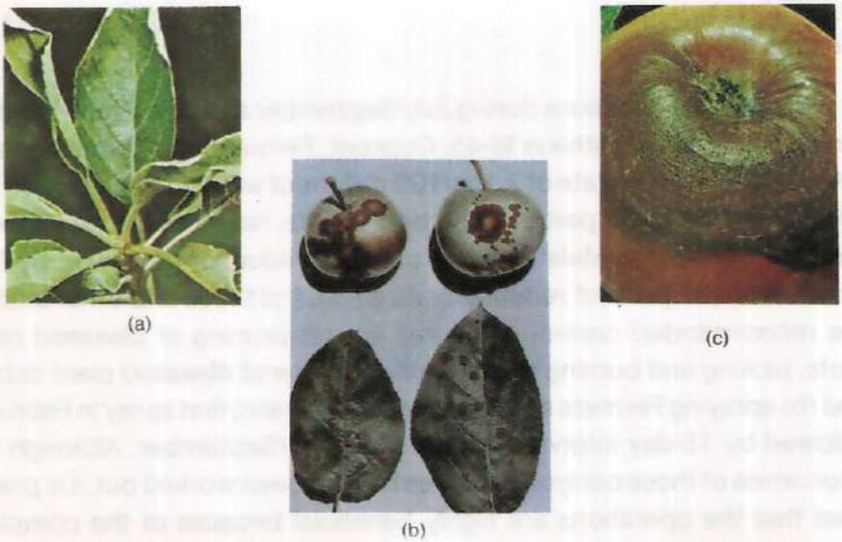


Fig. 12.6: Disease of Apple (a) Powdery mildew; (b) Scab, and (c) Fruit rot

Control

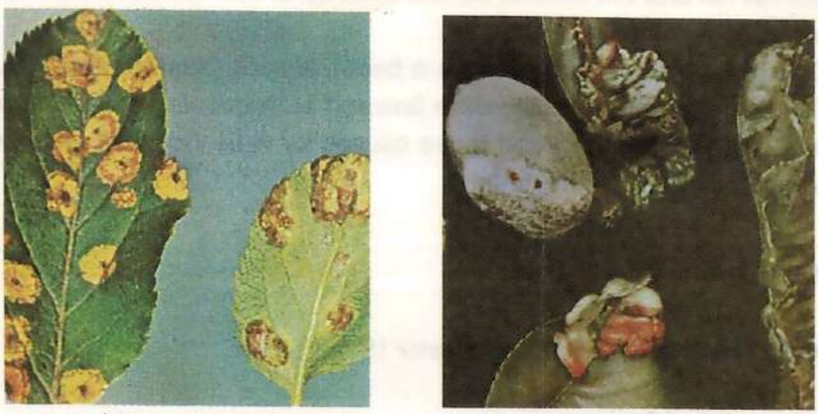
As a result of various experiments the recommended control measures are (a) pruning and burning of all diseased plant parts in winter, and (b) spraying with sulforon (2 1b/100 gallons of water) in February before the buds open followed by second application after the petal - fall stage and third and fourth applications each after 3-week interval. The other equally beneficial chemicals are sulforon dust, lime sulphur (1:40) or Benlate (4 oz/100 gallons of water).

The other reported diseases, on which no work has been done, are sooty blotch or fly speck (*Gloeodes pomigena* Schw.) Colby and *Microthyriella rubi* Petr.) appearing on fruit surface as specks in groups; and scab (*Venturia inaequalis* Cke. Wint.) affecting leaves, petioles, twigs and fruits with olive green spots surrounded by velvety growth which cracks and gives rise to deformed fruits. The fungus overwinters on fallen leaves and spreads through the spores discharged during moist periods; cool and humid spring being conducive to the attack and infections, causing serious losses. Fungicidal sprays scheduled according to rainy and low temperature periods are the most effective means of controlling the disease. The occurrence of leaf spot (*Cercospora mali* Ell and Ev) has also been reported to be present in traces.

Peach and Almond

1. Leaf Rust

As a result of survey in Baluchistan, it has been found that the leaf rust is quite a serious disease of peach and almond (occupying nearly 8000 ha) causing 25 to 30 percent infection on an average and can assume epidemic proportion in favourable climatic years. The infected leaves fall prematurey while peach fruits become disfigured, fetching low price and have poor keeping quality. The infection appears in spring, forming cankers on young wood and spreading the disease through spores formed in sori (Fig. 12.7). Experiments on control using newer fungicides (Captan, Thiram, Zineb, Sulphur) are in progress with promising results.



(a) (b)

Fig. 12.7: Diseases of Peaches (a) Leaf rust; and (b) Leaf curl

2. Leaf Curl – *Taphrina deformans* (Berk.) Tul.

Occurrence and Symptoms

The disease is found in Baluchistan, NWFP and Murree hills in varying intensities, causing considerable damage, particularly in neglected orchards. The incidence may vary from 20-60 percent on leaves of young developing shoots. The typical symptoms include puckering, swelling and discolouration of leaves (young leaves becoming red to purple and older foliage turning yellowish). The affected leaves turn chlorotic, and die followed by defoliation. It also attacks terminal twigs, blossoms and fruits, making the twigs swollen, blossoms wither and fruits are deformed and drop. The fungus also attack nectarines and apricots while its other species produce leaf curling in many stone fruits including almonds and plums.

Perpetuation

The fungus overwinters in bud scales and bark of young twigs and starts infections through opening leaf buds in the following spring. Cool and wet weather favours development and spread of the disease.

Control

Fungicidal sprays after harvest or and before bud swelling can easily control the disease. The number of sprays will depend upon the exact timing, which if well coordinated, will be more remunerative. The first spray before leaves fall and the second before buds swell can control the disease successfully.

The other recorded diseases are bacterial spot (*Xanthomonas pruni* (E.F. Sm) Dows; brown rot (*Monilinia laxa* and *M. fructicola*); scab (*Cladosporium carpophilum* Thiim and those caused by virus. No work has been reported to be done in Pakistan.

Grapes

Powdery Mildew – *Uncinula necator* (Schw.) Burr.

Occurrence and Symptoms

Survey carried out on vineyards in Baluchistan has indicated 10 to 15 percent infection caused by *Uncinula necator*, the causal organism of powdery mildew. It produces the usual symptoms on the leaves, stems, branches and fruits, which are mishapen and cracked (Fig. 12.8). It first appears as greyish - white powdery growth on the growing tips, followed by infection of shoots, stems, flower clusters and berries. Its spread during the summer is rapid at 23 to 32° C and high humidity. It remains dormant in dark coloured spore bodies, which may develop under favourable conditions. The disease may appear in some vineyards every season and becomes potential threat to the crop.

Fig. 12.8: Powdery mildew of grapes.

Control

A number of experiments on checking the disease have indicated the following integrated control schedule. (a)cutting and burning of the diseased plant parts, and (b)spraying with Benlate (4-6 oz/100 gallons of water) first before blossming,second after berry formation and the last one three weeks later. The other equally effective chemical is Afugan. Fungicides tested at Tarnab in descending order of efficiency are Bordeaux mixture, Perenox, Fermate, Orthophalten, Polyram and Cobox. Frequent treatment also helped to increase the yield from 9.80 to 20.20 1b/plant besides improving the quality of the produce.

The other recorded diseases are (a) black rot caused by *Guignardia bidwellii* (Ellis) Viala and Ravaz, attacking the new growths forming red necrotic lesions in groups on leaves followed by on shoots, tendrils, leaf stems and veins; (b) anthracnose or bird eye spot (*Elsinoe ampulina*); and (c) downy mildew (*Plasmopara viticola*)(V & C) Berl. and Det. No research work has been reported from within the country. Leaf spot caused by three different fungi (*Stigmina esfandiarii* Petrak, *Pesudocercospora vitis* Le'v. Speg. and *Dendrophoma* sp.) and grey mold (*Cladosporium roesleri* Cattan.) have also been reported as minor diseases.

Pomegranate

Fruit Rot – *Zythia versoniana*

Distribution, Symptoms and Perpetuation

Pomegranate fruit rot, recorded for the first time in 1946 in Baluchistan, has been found to be gradually increasing and spreading in epidemic proportions, causing upto 25 percent fruit damage. The infected fruits show rotting of internal tissues around the seeds and later on develop cracking and drying (Fig. 12.9).The causal fungus has been isolated,pathogenicity tested and identified as *Zythia versoniana*. The disease perpetuates from year to year through the fallen or hanging infected fruits or fruit stalks. The fungus becomes active in summer and discharge spores, which cause fresh and new infections.

Fig. 12.9: Fruit rot of Pomegranate showing external and internal rots.

Control

The experiments carried out over a number of years have indicated the following control schedule (a) pruning of infected twigs, hanging fruits/fruit stalks and collecting of dry fruits from the ground in January/February followed by burning; and (b) spraying with a suitable copper-based fungicide (Perenox 1.5 - 2 1b/100 gallons of water) in July, August and September.

Summary

Pakistan grows large areas under a variety of fruits, which are subjected to a number of destructive diseases both affecting the quantity and quality of the produce.

Some investigations have been carried out on diseases of citrus, mango, banana, papaya, apple, peach, pear, almond, grapes and pomegranate at various agricultural research institutes in the country. In citrus *Colletotrichum gloeosporioides* is commonly associated with wither tip. It has been found that citrus twigs can only be infected by this fungus in case the plants are poor in health. All factors such as lack of nutrition and high content (0.2 percent) of total soluble salts in the root zone and 8.5 or above pH values of soil, which weaken the plants, are conducive to the development of the disease. The fungus C. *gloeosporioides* is, therefore, a weak parasite on citrus twigs. Physiology and morphology of the pathogen has been studied and compared with the fungus causing anthracnose of mango and *Gloeosporium limetticolum*. On the basis of these results it has been proved that the fungus causing anthracnose of mango ,is identical with *Colletotrichum gloeosporioides,* which is confirmed to be distinct from *G. limetticolum*. The fungus *C. gloeosporioides* is actively parasitic on mango leaves, fruits and twigs but on citrus it can attack fruits and fruit stalks easily, while on leaves and twigs it causes extremely slight or no infection.

Work has also been carried out on citrus wilt caused by *Fusarium* spp. and root-rot disease caused by *Rhizoctonia* sp. In both the cases physiology of the causal fungi, factors affecting the incidence and measures to control have been studied. Morphological, cultural and pathological comparative studies of seven *Rhizoctonia* isolates from tobacco, okra, sesamum, cotton, citrus, chillies and pigeon pea have revealed these isolates as three varieties of *Macrophomina phaseoli.*

Investigations carried out on sooty mold caused by *Canpodium citri* have shown that as the disease appears on account of feeding activities of insects secreting honey dew deposits, the control of insects helps to get rid of the disease.

In the case of mango, studies have been carried out on anthracnose which has been found to be caused by *Glomerella cingulata* (*Colletotrichum gloeosproioides*). The disease attacks leaves, petioles, twigs and fruits. Inoculation experiments have shown that the fungus is highly pathogenic on mango under optimum conditions of temperature and humidity. The disease has been found to perpetuate through diseased plant debris and diseased plant parts, which remain attached to the trees. Suitable

control measures have been suggested.

Investigations have been carried out on malformation of mango inflorescence as regards symptoms and modes of perpetuation. All the results have shown negative association of fungi, insects, bacteria and nutritional deficiencies of major elements with the development of the disease. However, there is some evidence regarding transmission of disease through grafting and budding indicating the possible viral nature of the disease (which needs confirmation). In the absence of definite results some suggestions have been made on the control measures.

Some banana diseases such as black tip or finger tip, pseudo-stem rot and stem end rot have been investigated. In all these diseases *Gloeosporium sp.* and *Botryodiplodia* sp. have been found to be the causal fungi. The pathogenicity of these fungi has been established and control measures devised.

Work has been done on four diseases of papaya (damping-off and stem rot caused by *Pythium* sp., charcoal rot - *Macrophomina phaseoli;* anthracnose - *Colletotrichum dematium;* and fruit rot - *Rhizopus oryzae*) covering symptoms, pathogens, pathogenicity, physiology of the pathogens and control measures.

Investigations carried out on two diseases of apple (ripe rot - *Rhizopus arrhizus* and powdery mildew - *Podosphaera leucotricha*), leaf rust of peach and almond (*Trangschelia pruni - spinosae*), peach leaf curl (*Taphrina deformans*), powdery mildew of grapes (*Uncinula necator*) and fruit rot of pomegranate (*Zythia versoniana*) have covered the various aspects of these diseases with a view to finding out control measures, which have been recommended in each case.

The diseases caused by bacteria, viruses and nematodes have been discussed in separate chapters.

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Forest Trees

Out of 10.4 million hectares classified as forest lands, forest actually occupy only 4.3 million hectares, i.e., 4.8 percent of the total land area (87.8 million hectares) of Pakistan, falling much short of the country's needs. This is evident from the fact that timber and fuel wood produced from local forests and farmlands are not enough to meet the domestic requirements. Total estimated consumption of timber and firewood in Pakistan in 1979-80 was 1.97 and 16.55 million cubic meters, respectively. About 18.5 percent of timber consumed was produced from national forests, 46.3 percent from farmlands and the gap (35.2 percent) was bridged through imports. Similarly, the Government forests produced only 1.8 percent of firewood while the bulk came from the farmlands.

The present situation urgently calls for enhancement of timber and firewood production. This can be done by improving the per unit area productivity, increasing the forest area both under public and private sectors and by reducing losses of vegetative growth. These losses occur due to several causes like destruction by mankind, fire out-breaks, indiscriminate grazing, insect pests and pathogenic diseases.

Forests are one of the most precious gifts of nature for man in meeting his various material needs (timber, firewood, charcoal, grazinglands, wildlife, water, recreation and minor forest products) and affecting environmental and climatic improvements (watershed, soil stabilization and fertility, rainfall, temperature, humidity, wind breaks, oxygen and carbon dioxide balance in the air). Due to varied climatic conditions of Pakistan, ranging from tropical to temperate and alpine, the natural vegetation also varies.

Forests are, therefore, of nine different types. These include:-

i) *Coastal*

Mainly composed of *Avicennia officinalis*, a shrub used for fodder and firewood.

ii) *Riverine*

Situated along the banks of Indus and other rivers; mainly composed of *Acacia arabica* (Kikar), *Populus euphratica* (Bhan), *Prosopis spicigera* (Jand), *Tamarix* spp. (Farash) and *Dalbergia sissoo* (Shisham).

iii) *Tropical Thorn Forests*

The main plant species are *Prosopis spicigera, Capparis aphylla* (Karir), *Acacia modesta* (*Phulai*), *Tamarix articulata* and *Salvadora oleoides* (Pelu), which provide fuel wood and forage.

iv) *Subtropical Broad leaved Evergreen Forests*

Composed of small-sized trees and shrubs such as *Acacia modesta, Olea cuspidata* (Kau), *Zizyphus nummularia* (Ber) and *Dodonaea viscosa* (Sanatha) mainly degraded by over grazing, browsing and lopping resulting into destruction of watershed areas.

v) *Subtropical Conifersious Forests*

Located between 900-1650 m and containing *Pinus roxburghii* (Chir pine) and *Quercus dilatata* (Oak).

vi) *Himalayan Broad-leaved Forests*

Occurring on mountains above 1500 m elevation mainly consisting of *Quercus dilatata; Q. semicarpifolia, Juglans regia* (Walnut), *Aesculus indica* (Horse Chestnut), *Alnus nitida* (Alder), *Prunus cornuta* (Kalakath), *Acer* spp. (Maple), *Pyrus pashia* (Batangi), *Betula* (Bhojpatra) and *Populus ciliata*

vii) *Himalayan Moist Temperate Forests*

Situated at elevations ranging between 1650-3000 m on steep slopes constituting *Cedrus deodara* (Deodar), *Pinus wallichiana* (Blue pine), *Abies pindrow* (Fir) and *Picea smithiana* (Spruce).

viii) *Alpine Forests*

Occurring between 2850 and 3600 m, containing a mixture of conifers and broadleaved trees; and

ix) *Alpine Scrub Forests*

Occurring above 3500 m elevation and mainly composed of *Rhododendron arboreum* and Junipers.

These forests are mostly state-owned, communal or individual property. The conventional forest products are timber, firewood and resin apart from mazri and medicinal plants. The forest plantations fall short of actual requirements, necessitating large-scale expansion and proper utilization of existing forests in the industry (chipboard, hardboard, veneer, plywood, paper and paper board, match, sports goods, crates and packing cases, furniture, buildings and boat making, agricultural implements etc). There are many reasons for low productivity including damages caused by diseases, insect pests and rodents. Some researches have been in progress on diseases of forest trees, firstly at Dehra Dun in British India and later on at Abbotabad and Peshawar after the establishment of Pakistan. These activities resulted in many research findings, which are included in this chapter. The diseases are grouped on the basis of symptoms irrespective of host plants to have general understanding of the pathogens, their modes of perpetuation, predisposing factors and control measures with a view to improving future researches and application of research findings. These diseases constitute several groups such as wood decay and heart rots, powdery mildews, wilts, rusts, damping off, dieback, and leaf spots and blights, while diseases caused by phanerogamic plants are discussed in chapter XVII.

1. Wood Decay and Heart Rots – Polyporaceae, Thelephoraceae and Ascomycetes

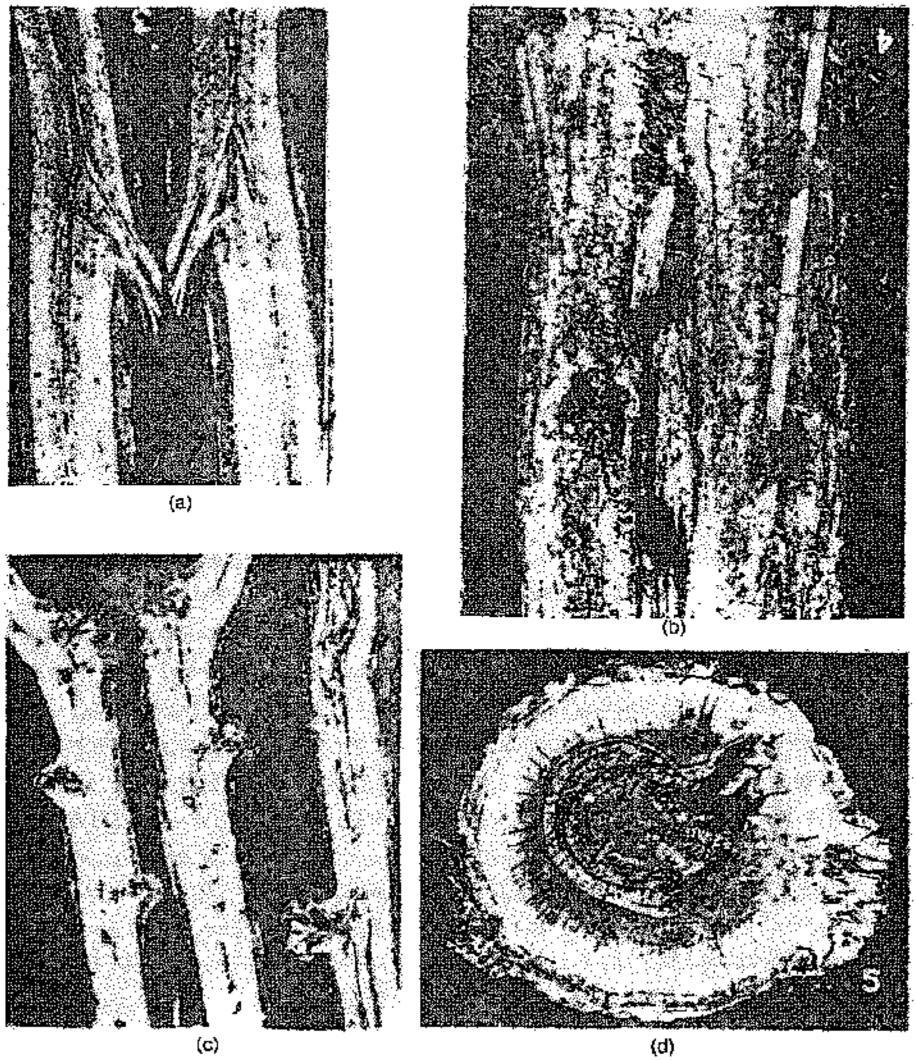
Occurrence and Extent

Timber, constituting a very important item for human use in house building, manufacture of furniture and other industrial goods, is not only in short supply in Pakistan (i.e. 0.6 cu. ft. per capita) but the existing forests also suffer from decay due to moist conditions (prevailing over long periods of the year) favouring the development of wood-rotting organisms. The principal causes of destruction and deterioration of timber are weathering, mechanical wear and tear, chemical hydrolysis of cellulosic material, insect attack, bacterial decomposition and fungal decay. The extent of damage, therefore, varies from place to place, nature of timber trees and the prevalence of different causes. Wood rots not only destroy the timber but also reduce its price and shortens service period resulting in heavy financial losses to the consumers. The protection of timber is, therefore, very important to save such heavy losses and make its use more efficient.

Symptoms

The unsoundness of timber due to fungi falls into three categories (i) wood decays, (ii) dry rots, and (iii) sap stains and other discolourations.

The mycelium of the causal fungus, thriving inside the wood at the cost of the nutrients, produces discolouration and decay reducing the strength of the wood, which becomes unsuitable for construction. Dry rot is a particular type of decay associated with dry, cracked and brownish appearance of rotten wood, which crumbles into powder when rubbed between the fingers. Sap stains (usually bluish grey, pinkish, yellowish or brownish) are caused by specific fungi and can occur very quickly if the wood is stored in warm, damp and ill-ventilated places. The end result is deterioration in timber strength and eventually the destruction of timber.



(a) (b) (c) (d)

Fig. 13.1: Various types of wood decays and heartrots. (a) Decay through a dead branch (b) Infection court in wood; (c) Decay through a branch; and (d) Decay forming a column in wood.

Causal Organisms and Perpetuation

Different types of fungi have been seen growing on timbers, logs and trees and their variation depends either upon the environmental conditions (some being restricted to tropics and others are found in temperate zone) or on timber species (some are restricted to specific hosts and others have wider host range, depending upon the internal wood structure). Since fructifications are nearly stable characters, it is possible to differentiate different groups of fungi as well as individuals. The causal fungi have been divided into two types viz; (a) those producing white rot and (b) others producing brown rot. The survey carried out in Pakistan has shown the presence of 75 fungi belonging to the first group which attack lignin and cellulose and produce white rot and 23 fungi fall in the second group, which attack cellulose and produce brown rot. The white rot causing fungi include many members of *Polyporaceae* (21 *Fomes, 3 Ganoderma,* 22 *Polyporus,* 6 *Trametes* and one species each of *Hexogonia, Daedalea* and *Irpex*), *Thelephoraceae* (18 fungi), and *Ascomycetes* (3 fungi). While brown rot producing fungi mostly belong to *Polyporaceae* (containing 4 *Fomes, 6 Polyporus,* 1 *Polystictus,* 2 *Trametes,* 3 *Lenzites,* 1 *Hexagoniai,* 1 *Poria,* 2 *Daedalea* and 3 *Merulius*). The details of all these fungi alongwith their distribution, characters of rotting produced and morphological features are given in the published literature cited at the end of the chapter. Wood rotting fungi are essentially aerobic and cannot tolerate waterlogged conditions. Once the wood is attacked, the moisture conditions in the wood remain favourable for the continued fungal growth. Most of these fungi produce myriads of spores, which are dispersed by wind, causing new infections under favourable environmental and host conditions. The number of spores produced per fructification is fantastic and runs into millions in a very short period of a few hours. The spores can also remain viable for long periods as they can withstand dry conditions. These two factors are conducive to the longivity and spread of woodrotting pathogens.

Predisposing Factors

Presence of suitable temperatures, which vary for different causal fungi, is essential. On this basis the fungi have been divided into three groups i.e.; those having optimum temperature below 24°C; or between 24°-32°C; or with optima above 32°C. However, many of the woodrotting fungi develop under warm and humid conditions (25.5° - 30°C). Prolonged exposures to temperatures above maximum can prove lethal, which again vary with different fungi.

Similarly, the woodrotting fungi need higher moisture content of wood to initiate infection and usually do not attack at moisture levels of below 20 percent. It has been reported that the woodrotting fungi generally produce considerable quantities of water during their respiration process, and therefore the rot once established, the fungus continues growing inside the wood independently of any external supply of water. Generally 35-50 percent moisture in normal wood is most favourable for the development of woodrotting fungi and this figure may vary with the density and structure of the wood. Since most of the woodrotting fungi are aerobic and require free oxygen, their growth, respiration, sporulation and the metabolic by-products depend upon free supply of oxygen. Requirements may vary with the species because some can also act as facultative anaerobes, particularly brown rot-producing fungi, which destroy cellulose. All the woodrotting fungi produce a certain amount of acid (usually oxalic acid) as a result of their metabolism and, therefore, grow better on acidic medium (between pH 2 and 3). The acidity persists for several months in brown rot fungi but it falls after an initial rise in case of white rots, which usually attack lignin. These fungi also produce enzymes, which help dissolve cell walls and facilitate penetration by he hyphae. Oxidase enzymes are mostly produced by white rotting fungi although in many cases the number of enzymes produced is quite large. All such environmental and nutritional factors, which increase the growth rate of the woodrotting fungi, make them more destructive.

Host Plants

In Pakistan about 75 different fungi have been recorded to cause woodrotting on more than 60 plant species, which include almost all the important trees. However, there are some fungi which are specific only to one plant species. For example, *Fomes caryophylli, F. lamaoensis*, and *F. tricolor attack Polyporus shoreae; Hymenochaete rubiginosa, and Stereum percome* are specifically found on Shorea robusta;while there are others which attack 2-4 host plants and still others which are more aggressive and can infect many hosts such as *Fomes conchatus; F. fastuosus; F. rimosus; F. senex; Ganoderma applanatum; G. lucidum; Polyporus gilvus; P. polystictus; Trametes persooni, T. pini, Irpex flavus; Stereum hirsutum* and *Lenzites betulina*.

Process and Spread of Decay

The fungal growth inside the wood initiates the decay process under favourable conditions of temperature and moisture. This behaviour depends upon the timber species, quality of sap or heartwood, which may or may not contain toxins. The initial or incipient stage is characterized by the presence of fungal mycelium in the wood and its discolouration, ranging between yellowish, brownish or purplish, ultimately resulting in typical decay stage by breaking short of wood fibres when lifted with knife and in some cases zigzag brownish lines appear. In the initial stage brown rot is difficult to distinguish. Later on, all the symptoms of decay develop which include destruction of normal wood colour and structure and its total weakening caused by the production of enzymes that attack lignin-cellulose compounds resulting in the specific pattern of rot (the attack on lignin produces white rot while destruction of cellulose gives rise to brown rot). These rots can be further classified into butt rot, top-rot and root rot, based on the parts of tree attacked. The attack may also be confined to sap or heart wood of living trees or dead timber, producing dry rots. The rots are also classified on the nature and location of the damage done-pocket or patchy rots, mottled rot, ring rot, stringy rot and spongy rot, which are characteristics of specific fungi. The various symptoms produced are also fungal specific and have been classified according to the nature of the pathogens. Studies have also been made on the physical and chemical characteristics of the decaying wood. These may be associated with particular pathogens, type of rots and susceptibility or resistance of different species of timber.

The decay may spread to sound wood in a number of ways, i.e., spore dissemination, vegetative, mycelial contact or through special thread-like structures called rhizomorphs.

Techniques for diagnosis of decay based on morphological and anatomical examination of wood; isolation, culturing and identification of pathogens, maintenance of cultures, fructification and for artificial inoculations have been developed.

Wood decays in conifer trees and hardwood trees have been discussed separately as detailed below:

Wood Decay in Coniferous Trees

Decay of coniferous species both in living trees and felled timbers is quite common in Pakistan and other countries of the world, attracting attention of the research workers. Five important pathogenic fungi (*Fomes pini; F. annosus; F. pinicola; Polyporus schweinitzii;* and *Armillaria mellea*) attack living trees while other fungi such as (*Lenzites saepiaria* and *Fomes roseus*) are associated with decay of felled timbers. These have been studied and their salient features are given in Table 13.1. (Fig.13.1).

Table 13.1: Main types of wood decay in coniferous trees

Fungus	Common name	Symptoms and fungal characteristics
Living Trees		Localized infection through wounds.
1.*Fomes pini* (Thor.ex.Fr) Karst Syn.*Teramte pini*(Thor) Fr.*Xanthochrous pini* Pat	Red Ring or Pocket Rot	Causes heart rot in trees producing large pockets, swollen or punk knots of pinkish or reddish brown colour, dark brown zones and loss of strength. Fruiting bodies appear on trunks, sporophore perennial varying in size, dark rusty coloured turning brown to black. Spores 5.5 x 4.5-5µ, many setae pointed (40µ) and dark brown. Rotted area converted into mass of white fibre. Mycelium coloured yellowish to brown. Optimum tem. 25°C and maximum between 30°-35°C, can remain viable for many years in dead wood but does not spread. Fungus dies out after felling and timber if otherwise suitable can be used.
2.*F. annosus*(Fr) Cooke. Syn.*Ungulina annosa* (Fr.) Pat. *Trametes radiciperda* Hartig. *Herterobasidion annosum* (Fr.) Brefeld	Root Rot or Red Rot or White Pocket Rot	Fungus enters through injured or uninjured roots. Common in Pakistan, causes heart rot. Serious in *deodar* and new plantations. Bracket-shaped fruiting bodies bright and reddish brown in colour appear on stumps of felled trees. White pockets of rot develop with dark resin zones leading to white linted cavities and wood is reduced to a spongy mass. Sporophores vary in size 5-15cm x 4-12cm with whitish pore surface, tubes 4-8mm and basidia hyaline 8 x 6µ and spores colourless 4-6 x 3 µ. It also bears conidia in culture and easy to recognise. Attacks both lignin and cellulose. Fungus continues growing even in felled trees under moist conditions.
3. *F.pinicola* Schwartz ex.Fr. Syn. *Unqulina* .	Red Brown Rot	Found throughout Himalayan range on fir, spruce, tamarack, pines, balsam occasionally on living trees but mostly

marginata (Gill) *F.ungulatus* (Schaeff) Sacc. *Fomes ponderosus*		on felled timbers. Causes heart rot in a few years.
4. *Polyporus schweinitzii* (Fr.) Syn. *Phaeolus schweinitizii* (Fr.) Pat.	Brown Cubical Rot	Attacks both hard wood and conifers. Found on pines, fir, kail, spruce, oak and cherry. Common on kail in Pakistan. Causes reddish brown cubical heart rot. Infection occurs through roots and wounds near the base, producing light yellow to pale reddish brown discolouration leading to cubical rot with thin sheets of palish embedded mycelium. Fungus produces greenish yellow growth at optimum temperature of 28°C. Sporophores are hairy and plush-like. Pore tubes greenish yellow 3-5 mm long to irregular. Spores are 7-8μ x 4 μ. Even a trace of infection makes the wood unusable.
5. *Armillaria mellea* (Vahl ex.Fr.) Quel Syn. *Armillaria mella*(Fr.ex. Vahl)Karst.	Shoe String Rot	Found in tropical and temperate countries attacking large variety of plants (conifers and hardwoods). Some times grows entirely saprophytically in wood humus. Fruiting body is a typical mushroom, fleshy, yellowish to pinkish brown hairy with 5-15 cm diameter. Spores elliptical, colourless 8-9μ x 5-6μ Under favourable conditions become parasitic forming white and firm sheets of mycelium under the bark and can spread from tree to tree through rhizomorphs. Causes fibrous, stringy white rot with zone lines resembling bladder-like swellings of hyphae and produces resinosis in conifers. Also causes decay in felled timbers.

Felled Trees		usually attacks conifer timber structures,buildings and poles under alternating wet and dry conditions. Three types of mycelia are found and have powdery appearance due to formation of oidia in large numbers. Optimum temperatures are 32-34°C while maximum is 40°C.
1. *Lenzites saepiria*(Woulf.)Fr. & *Lenzites subferruginea* Berk	Powdery Rot	
2. *Fomes roseus* (A&S) Fr	Cubical Heart Rot	Infection occurs through wounds and stubs of felled wood, producing discolouration and horizontal cracks. Fruit body perennial 5-30 cm zonate, rough and watery. Spores colourless, round or ovoid, smooth 3-4 u. Optimum temperature 26°C.

ii) *Wood Decay in Hardwood Trees:*

Like conifers, decay of living and felled hardwood trees is also common in Pakistan, causing heavy losses. Twelve types of decay in living trees caused by *Ganoderma, Polyporus* and *Fomes* species and six types in felled trees produced by *Polystictus, Daedalea, Trametes, Stereum, Hymenochaete* and *Xylaria* have been identified and studied. The important results are given in Table 13.2 (Fig. 13.2).

Table 13.2 Main Types of word Decay In hard wood trees

Fungus	Common Mame	Symptoms and fungal characteristics.
Living Trees		A cosmopolitan fungus, found in almost every forest in Pakistan, behaves as a facultative root parasite; commonly enters through wounds or dead roots; mycelium spreads in the wood parenchyma and then through medullary rays, passes into deeper layers. Cellulose and wood gum are dissolved and the wood becomes spongy white. The rot advancing towards centre shows a
1. *Ganoderma lucidum*(Leyss), Karst. syn: *Fomes lucidus*	Spongy white Rot	

dark invasion zone. Severely affected trees are much weakened and can be easily blown down by wind. Sporophore is very characteristic. Pileus reddish to chestnut-brown, orbicular, sometimes flabelliform measuring upto 10-15 x 10-30cm, sessile or stalked. Stalk is ox-blood in colour and smooth. Hyphae either thick-walled, pale yellow, sparsely branched, 2-5 µ broad or thin-walled, hyaline, branched with clamp connections, spores brown thick-walled, minutely verrucose, truncate at the apex 10-12 x 6-8 µ.

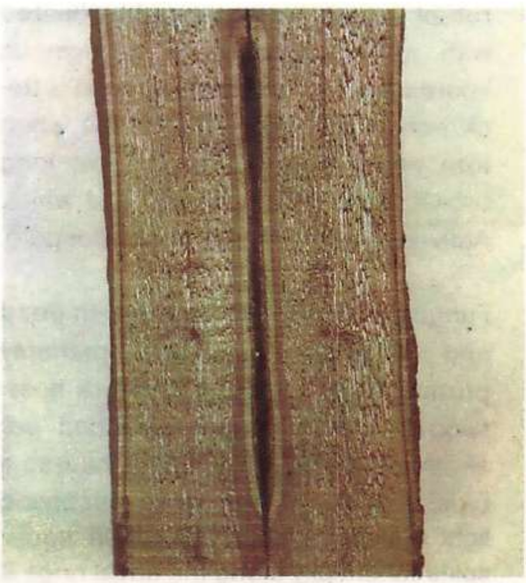


Fig. 13.2: White-pocket rot caused by *Phellinus pini* in blue pine (*Pinus wallichiana*)

2. *Ganoderma applanatum* (Pers.)Pat.Syn: *Fomes applatatus*(Pers.) Gill. *Flacodes applanatus*(Pers.) Quel.	Rectangular White Rot	The fungus is a facultative wood parasite and causes an active heart rot. In early stages, a whitish mottling occurs across the grain, which tends to break the wood into rectangular pieces and ultimately decaying into uniform white, very soft, light and spongy mass. In living wood there is always a narrow, dark brownish invasion zone about 5 mm. wide. The fruit bodies appear on trunks at a point where there was a branch stub or other trunk wound. Sporophore broad, flattened bracket of typical fomes type measuring sometimes upto 40 cm across. Upper surface flat or zoned and raised in lumps. Surface usually rich rusty brown, varying from russet to mars brown, and often dusted with a thick deposit of ferruginous spores. Texture very firm, context is thick rich brown and silky fibrous when torn apart. Pore tubes, 1-5 cm long brown, pore mouth minute and white. Actively growing margin is white or pale.
3. *Polyporus gilvus* (Schew.)Fr.	White Spongy Rot	Fungus is usually associated with dead and decaying trees and primarily produces sap rot but can attack heartwood. In early stages bleached pockets are formed. The fungus causes a typical white rot, the wood becoming light cream in colour. The rotten woodsplits tanentially along the anual rings & radically along the wood rays. Finally the wood is reduced to a whitish spongy mass. Sporophore varies both in size and shape depending upon its position on the host, moisture supply and temperature. Pileus hard, brittle, brown becoming pale yellowish, applanate, often imbricate or even rugulose measuring 6

		x 9 cms. Upper surface coarsely hairy or smooth, often zoned and pustulate. Under surface porous, light yellow to light brown, pore tubes upto 9 mm roundish 2 mm across. Context dark, rusty brown, soft corky when fresh, otherwise woody. Spores hyaline to light brown, minutely verrucose, oval, 4-5 x 3 μ, setae abundant, thick-walled, 1-2 x 6-10 μ.
4. *Polyporus hispidus*(Bull ex.Fr.) Syn.*Xanthochrous hispidus* (Bull).Pat.	Spongy whitish yellow Rot	Fungus enters through branch stubs and wounds due to lopping or other injuries. It spreads up and down the trunk rendering it a hollow shell. The early stage is marked by whitish or yellowish discolouration. It is delimited by a hard brown invasion zone. In typical stage of decay the wood is converted into a spongy whitish yellow mass. The rot generally starts in the heartwood and spreads outwards. Sporophores on living trees usually appear at the point of infection; hooflike or short hemispherical bracket, thick, corky, 10-30 cm across. Context thick, spongy, yellowish or chestnut brown and fibrous. The main body remains soft till quite old when it becomes hard, dark and cracked. Upper surface shaggy with thick soft hair, yellowish to chestnut brown finally changing almost black. Under surface yellowish to snuff brown. Basidia 18-26 x 10 μ and subglobose yellowish spores 6-10 x 7-8 μ. Yellowish brown cystidia sometimes present.
5. *Polyporus shoreae* Wakf.	*White Pocket* Rot	Both sap and heartwood are affected. The wood shows oval or oblong white pockets and is changed into a honey comb like structure. The shallow and oblique pockets become filled with

		creamish yellow hyphael and bleached white fibres. Pockets have walls or partitions of brown colour giving partridge feather effect. In mature trees the white pockets extend to the trunk. Sporophore imbricate, dimidiate, with a narrow tappering base, normally funnel shaped; sometimes applanate or flattened out, hard and brittle in dried condition, big in size, internally yellowish brown. Upper surface very rugulose, with a dark brown to blackish crust. Under surface dark brown. Spores 4-5 µ.
6. *Polyporus Squamosus* Hunds, ca.Fr.Syn.*Melanopus squamosus* (Huds.)Pat.*Ceriporus squamosus* (Huds.)Quel. *Polyporellus squamosus* (Huds.) Karst.	Spongy or Stringy White Rot	Fungus enters through branch wounds and penetrates to the centre of the trunk spreading up and down. The heartwood is consumed from within outwards and the stem ultimately becomes hollow. Produces spongy or stringy white rot. Sporophore rapid growing and fan shaped, varying greatly in size usually with a thick lateral stalk dark coloured at base. At first soft and fleshy and leathery later on. Upper surface pale fawn with numerous dark brown appressed scales or squamules, pore cream coloured, spores colourless, oblong, 10-12 x 4-5 µ.
7. *Polyporus sulphreus* Bull-ex.Fr.	Tan Brown Cubical Rot	In early stages it has insignificant effect on the wood and slowly produces a yellowish or reddish discolouration. In typical decay stage a dark red-brown cubical rot is produced. The cracks often get filled with mycelial felts. Sporophores are annual, bracket shaped with some what wavy margin. Colour is bright pale sulphur yellow to light yellowish orange above and colour fades when old. Flesh soft, cheesy and putrifies soon. On in-

		jury young fructifications exude a pale yellowish juice. Spores white elliptical measuring 7-8 x 5 µ.
8. *Fomes concharus*(Pers.ex.Fr.) Gill	Tan Brown Rot	Fungus enters through wounds. In early stage the area is brownish with a pale centre. As the rot spreads, the brown invasion zone advances irregularly in the wood. Cracks appear longitudinally and become filled with dark brown mycelium. Fruit body sessile, shelving hoof-shaped but more frequently conch-shaped semi-circular, hard corky when young; woody later; size 2-15 x 1.5-9 cm. Colour mouse grey or blackish usually with brownish border, slightly reflexed margin to make it saucer-shaped. Upper surface with rough crust, zoned rugose or rimose, context brown and corky. Spores yellowish brown, ovoid smooth 4-5 x 2-3 µ.
9. *Fomes senex* Nees et.Mont.	Brown Spongy Rot	Fungus enters through wounds and attacks both sap and heart wood. In early stage the wood is changed to light yellowish brown and ultimately to light coloured spongy mass. Fruit bodies, perennial, sessile, somewhat reflexed, corky to woody measuring 10-12 x 5-6 cm. Upper surface rough brown and zoned. Context brown, undersurface brown, spores round and thinwalled with 4 x 3 µ average size.
10. *Fomes lamaoensis*(Murr.) Sacc.et Troff.	Yellow Pocket Rot	In mixed forests young poles growing in wet and shaddy localities are attacked. Fungus sets up active sap rot killing living tissues at the base of young poles and disintegrates sap-wood producing wide oblong pockets. It is an active decomposer of heartwood reducing it to a

			..ney comb structure. A whitish yellow sticky mass is filled in pockets. Fruit body irregular, hard brown, bracket to saucer or funnel shaped, rarely with stalk, single or imbricate and 15-30 cms across in size. Upper surface dark brown to black crusty, zoned startified with radial cracks in the crust. Margin thick rounded, tawny olive to pale brown. Context thick, fibrous zoned, ochraceous tawny to brown with white.
11	*Fomes badius* Beok.	Brown Spongy Rot	Fungus enters through wounds and cuts spreading up and down. In early stages, the rotted wood is mottled reddish to purple with scattered black dots, besides the spongy patches which eventually give rise to holes. Advancing rot shows brown invasion zone. Fruit body thick, woody, sessile, 5 x 6 cm in size, upper surface dull brown, rough, black when old, context rusty or yellowish. Under surface plane or convex, bay-brown dull, rough and ridged. Spores light brown, roundish to oval, thick walled, 6 x 5 μ in size.
12.	*Fomes fomentarius* Linn.ex. Fr.)Fr.Syn.*Ungulina fonentaria* (Linn.)Pat.	White Spongy Rot	Fungus enters through stem wounds or branch stubs and damage is confined to upper parts of trees. It produces a white spongy rot with narrow dark zone. In early stages, a narrow brownish invasion zone is present. Sheets of pale yellowish white mycelium fill the cracks in the decayed wood. Both heart and sap wood are attacked. Fruit body typical hooflike, perennial structure, 40 cm width. Upper smooth, thick, hard and concentrically zoned, grey or greyish-brown to almost black. Context dull, pinky, soft and corky. Spores 15-25 x 5-10 μ in size.

Felled Trees		
1. *Polystictus versicolor* Linn.ex. Fr.Syn.*Coriolus versicolor*(Linn.) Quel.	White Spongy Rot	Common saprophyte of wood under moist conditions. In typical decay, wood is changed to white spongy mass and is light in weight. It consumes entire wood substance. Gregarious in habit, forms imbricate fructifications which are thin and tough brackets, 3-8 cm across. Upper surface greyish or brownish, always velvety with concnric zones of various shades. Under-surface cream coloured. Spores oblong, 6-8 x 3 u cream coloured mass.
2. *Daedalea guercina*(Linn.)Fr. Syn.*Lenzites quercina*(Linn.) Quel.	Red Brown Cubical Rot	Sapwood is attacked much more rapidly than heartwood. Mycelial felts seen in rifts and cracks. Usual rot of oak wood. Sporophore perennial, tough, corky, pale wood coloured brackets. Context concolourous, often irregular and bumpy, occasionally resupinate. Upper surface smooth, rugose and slightly zoned. Spores colourless, thin walled 5-7 x 2-3 u in size.
3. *Trametes lactinea* Berk.	Ring Scale or Ring Shake Rot	Bleaches the timber to light colour, causing ring scale or ring shake and the wood splits along the rings. Affected wood retains its shape but is very light in colour and friable. In advance stages timber is changed to light spongy white mass. Fruit body a shelving bracket, hard, corky, irregular, white to creamy-biscuit colour, may develop singly or in imbricate fashion. Upper surface uneven or undulating, pruinose, sometimes velvety, verrucose to regulose and zoned. Margin regular thin, slightly reflexed; context creamy, white with a silky sheen when torn and spores white in colour.

4. *Stereum hirsutam*(Willd.ex.Fr.) S.F.Grev.	White Fibrous Rot	Wood decay by this fungus is white fibrous and light in colour and soft but retains its shape. Attacks cellulose in addition to lignin.Rot very much like that of Stereum sp., pockets are smaller and narrower. It grows very slowly and is confined to felled trees only. Fruit bodies dark brown, thin, hard and skinny. The spores are hyaline measuring 4-6 x 2-3 μ.
5. *Hymenochaete rubiginosa*(Dicks) Lev.	White Fibrous Rot	Rot very much like that of *Stercum* sp., pockets are smaller and narrower. It grows very slowly and is confined to felled trees only. Fruit bodies dark date brown, thin, hard and skinny. The spores are hyaline measuring 4-6 X 2-3 μ.
6. *Xylaria polymorpha* (Pers.)Grev.	White Spongy Rot	Wood is gradually sottened and changed to greyish white spongy mass. Mycelium at first hyaline, gradually forms a black crust on the surface or between the bark and the wood. In the rotten wood concentric, thin, single or double black zone lines are commonly seen. Affected wood is white, spongy and light in weight. Stroma erect, irregularly finger like, tough, black, 4-8 x 0.5-2 cms. Perithecia present in the upper part of stroma, spores black, one-celled and asci 8 spored.

Thus it may be seen that about seventeen types of wood rots of living and eight types of felled trees have been found to occur in Pakistan, causing considerable losses to timber, which is already in short supply. This situation, therefore, calls for the establishment of a special research unit to carryout detailed studies on woodrotting fungi and their control.

Control

As most of the woodrotting pathogens are soil-borne or host-borne, remaining viable over a number of years, the most effective control consists in preventive measures. These include removal, collection and burning of the diseased plant parts and stumps followed by painting of cut parts or wounds with copper-based fungicides. Further spread of the disease can be checked by trenching and liming for the isolation of the infected plants. The durability of the felled timber can also be increased by special chemical treatments to enhance its resistance to the attack of fungi. It has been seen that some plant species such as mango, simul and poplars are more prone to the attack of fungi than trees like teak, shisham and babul, which have higher concentration of tannin or other toxic substances in the heartwood. Similarly, there is a good deal of variation in resistance within the same species and different parts of the same log, depending upon the internal structure of the wood and its moisture contents.

Generally speaking, more dense and dark coloured wood has greater resistance than light or pale-coloured one with a few exceptions. There are many methods by which the timber can be made resistant to the attack of the fungi rendering it more durable. These include application of lethal temperatures upto 65°C to kill the pathogens; reducing the moisture contents below 20 percent of dry weight during seasoning which prevents the growth of the fungus; steaming and seasoning, which includes steam sterilization and then subjecting the wood to chemical preservative treatment. The chemical treatments include the use of many kinds of preservatives for different timber types. However, the selected preservatives should essentially be toxic to the fungi and must penetrate the wood readily and deeply. Moreover, the preservatives should be odourless, colourless and economical in application besides being stable, resistant to leaching and safe to handle. The recognised and economical preservatives are divided into three categories i.e., (a) preservative oils or mixtures of oils of low volatility and slightly soluble in water; (b) inorganic salts used as water solutions; and (c) toxic chemicals dissolved in some colourless and usually volatile solvents other than water. The important preservatives are zinc and copper napthenates, creosote, pentachlorophenol, zinc meta-arsenite, copper chrom-arsenic preparations and similar other chemicals. Of them creosote is perhaps most commonly used for outdoor timber. These chemicals are usually applied either without any pressure through diffusion or impregnated under pressure into the wood cells. A good deal of work has been done on methods of preservation as well as on the reaction of different preservatives on the growth of various pathogens. Similarly, special treatments have been developed for checking the growth of molds on timber, which are usually recommended for humid conditions.

Other Important Groups of Diseases

Powdery Mildews

They constitute an important group of diseases in Pakistan. Apart from field and fruit plants, they also infect many forest trees in the temperate, tropical and subtropical areas of the country. Powdery mildew fungi, which comprise the family Erysiphaceae are generally obligate ectoparasites growing on the surface of the host and invading the cells through haustoria. The economic significance of these diseases seems to be slight and are therefore, generally ignored. Although, magnitude of damage inflicted in the forest trees has not been estimated the disease intensity is quite high.

Occurrence and Distribution

The forest trees attacked by the powdery mildews and their causal organisms are summarized in Table 13.3.

Table 13.3. Powdery mildews of forest trees in Pakistan

Host	Botanical Name	Causal Organism	Distribution
Teak	*Tectona grandis*	*Uncinula tectone*	East Pakistan (Now Bangladesh)
Shisham	*Dalbergia sissoo*	*Phyllactinia dalbergiae*	Throughout Pakistan
Mulberry	*Morus alba*	*P.corylae*	-"-
Willow	*Salix tetrasperma* and *Salix* sp.	*P. suffulta* and *Uncinula salicis*	Punjab
Siris	*Albizzia labbek*	*Leveillula taurica*	Sind
Ber	*Zizyphus nummlaria*	*Oidium* sp.	Sind
Devi Kandi(Walayati Kiker or Walayati Jand)	*Prosopis glandulosa*	*Oidium* sp.	Sind

Symptoms

In early stages, scattered and diffused spots appear on young aerial parts of the plants. These spots later on enlarge and coalesce involving most of the foliage surface. In teak and shisham, the leaves are completely covered with dirty whitish powdery mass of mycelium on both sides. In other plants infection remains mild. Isolated trees at long distances are also found affected. Leaves of young and old trees are equally attacked but the fungus is more destructive to younger plants. Under severe condition of infection, shedding of leaves takes place resulting in serious damage. The infection interferes with the process of photosynthesis by cutting off the light and assimilating laminar surface. Low lying areas and damp places are more conducive for the development of powdery mildews (Fig. 13.3).

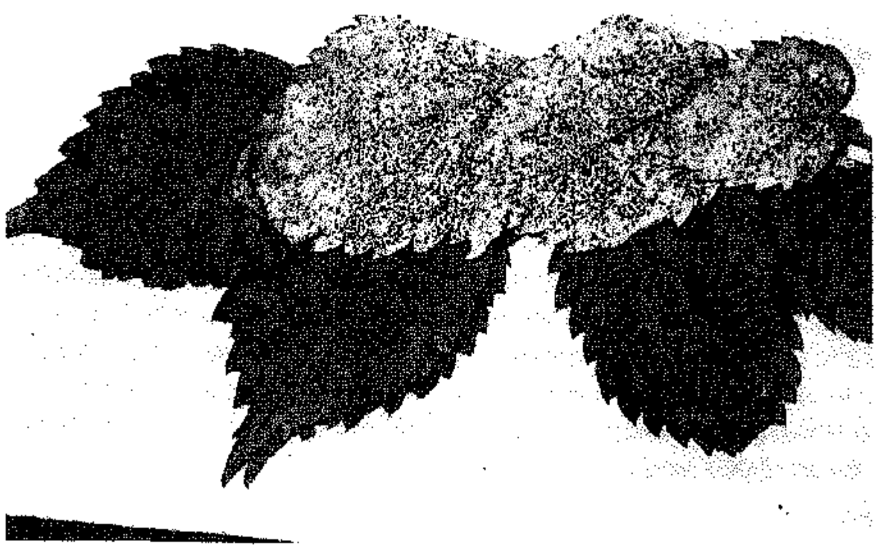


Fig. 13.3: Powdery mildew caused by *Unicula polychaeta* on *Caltis australis* leaves.

Pathogen

Several genera of powdery mildew occur and can be recognized by two characteristics i.e. kind of cleistothecial appendages and the number of asci in each cleistothecium. Majority of the powdery mildew fungi have an asexual stage belonging to the genus *Oidium*.

Uncinula is widespread genus with a number of species attacking many plants. According to Chatterji (1962), the fungus has been known in the Indo-Pak sub continent since 1896. *U. tectonae* forms mycelium on both sides of leaves of teak, giving rise to 2-3 conidia on each conidiophore. Cleistothecia are small, orange to black, subgregarious, hemi-spherical, appendages numerous measuring 75-100 µ in diameter, hyaline, aseptate, usually thin-walled and opaque, apex closely uncinate and some time helicoid, asci 4-9, small, ovate with short distinct stalk, ascospores 6–8 and rarely 4.

Another important pathogen is *Phyllactinia dalbergiae*. It produces superficial hyphae on fallen leaves, give rise to hard reddish to black round cleistothecia with 5–18 appendages. The tips of the appendages are mucilaginous which help in sticking to the leaf surface. In each fruiting body there are 4-5 asci with thin, weak, and short stalks, each producing 2-3 mature spores ultimately.

Perpetuation

During active growth period, the conidia of the fungi, causing powdery mildews, are easily dislodged and disseminated by wind over long distances. The conidia, which settle down on the lower surface of the leaves, give rise to superficial mycelium. Later on short, sunken hyphae are produced, which pass through stomata entering into the air cavities below. Fine haustoria are given out for absorbing nutrients to support the fungal growth. Cleistothecia are formed on perennial plants. The fungus over winters in different ways either in the form of dormant mycelium on the surface of living tissues especially in the buds or as ascospores in cleistothecia on the fallen leaves in the soil.

Control

Generally no treatment against powdery mildew diseases is advocated as the damage is not considered serious. If the infection becomes severe, dusting with sulphur or spraying with 4:4:50 Bordeaux mixture or Potassium sulphate at 15 g/gal of water can provide adequate control. Powdery mildew of mulberry can be controlled by spraying with 0.3 percent Karathane or dusting with 1 percent colloidal sulphur, two times at 10-15 days intervals. Cultural practices and sanitary measures such as growing of nurseries in drier and exposed areas, maintenance of proper plant density and collection and burning of infected leaves and other plant parts can help containing the disease.

3. Wilts

Fusariosis or wilting is a common problem of nurseries and growing trees of many plant species in Pakistan. As a matter of fact, soils of Pakistan are rich in *Fusarium* spp. which become active under favourable high temperature and moist conditions, causing tangible losses. Wilts are usually noticed during March-April and/or July-October becoming serious during and after rainy periods, particularly in low lying areas. The disease is quite serious in *shisham* nurseries or plantations, while a number of other plants are also affected. The commonly found wilt diseases of forest trees and the associated pathogens are given in Table 13.4.

Table 13.4: Wilt diseases of forest trees and causal organisms

Local name	Botanical name	Pathogen	Distribution
Teak	*Tectona grandis*	*Fusarium oxysporum*	Bangladesh
Shisham	*Dalbergia sissoo*	*F. oxysporum*	Sind and Punjab
Babul	*Acacia arabica*	*Fusarium* sp.	-
Khair	*A. catechu*	*Fusarium* sp.	Punjab
Siris	*Albizzia* sp.	F. solani var. *albizziae*	Punjab
Sal	*Shorea robusta*	*Fusarium* sp.	Punjab

Symptoms

There is a sudden withering and wilting of plants as if produced by drought but actually such conditions are absent. The disease is manifested in the seedling stage by simultaneous withering of the entire top, but it may be prolonged with the growing plant giving rise to top wilting. Flagging, hanging, yellowing and drooping of leaves is also quite common. These symptoms are followed by thinning of crown, bark peeling and fermentation of rotted tissues. Pinkish brown discolourations are noticed in the bark and peripheral sap wood. The fungus attacks the collars of 1-2 year old plants, which are ultimately killed. The disease may affect individual trees or may cause sporadic killing of the trees in small groups growing in marshy water logged tracts in depressions along the road sides or in low lying forest patches (Fig. 13.4).

Pathogen

Fusarium oxysporum is generally found to be associated with the wilt diseases. It is an active parasite, especially during and after the monsoon rains when the temperatures and humidities are quite high, favouring its development and growth. It is a vascular pathogen with fruiting bodies as

Sporodochia bearing microconidia and macroconidia. *F. solani* and other *Fusarium* spp. have also been isolated from wilted plants, but to a lesser extent. The other pathogens involved in wilt complex are species of *Phytophthora, Verticillium* and *Rhizoctonia*.

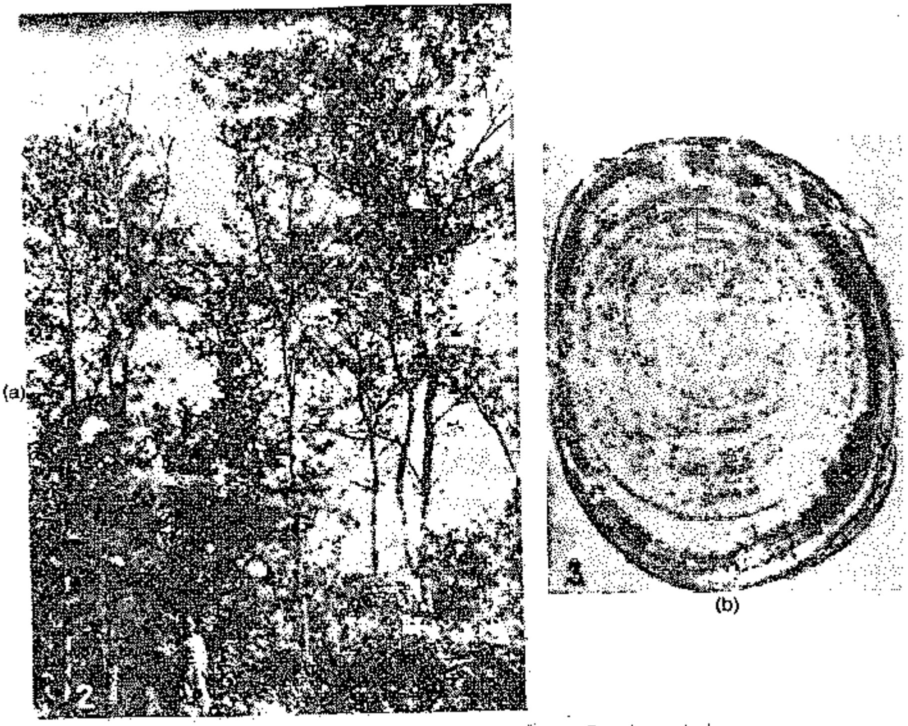


Fig. 13.4: (a) Wilt of Sisso; (b) Discolouration of wood due to *Fusarium solani*

Mode of Perpetuation

The fungus enters the plants through injured roots. The infection spreads through fibro-vascular bundles and ascends with the sap stream, finally plugging the vessels with gummy substances, produced during the attack. Soil-borne infection, through spores and mycelial mats is a general rule, but air-borne conidia can also enter through plant injuries infecting neighbouring trees.

Control

The following cultural practices, if carried out, can help to contain the disease:

- Avoid plantations in marshy waterlogged and low lying areas;
- Before plantation disinfect the soil with formalin solution (1 part

in 300 parts of water) or any other appropriate available chemical;

- In early stages of infection (a) prune the diseased plant parts and apply creosote, coal tar or Bordeaux paste to the stubs, if possible, preceded by a coat of shellac to protect the living tissues from injury, and (b) disinfect the soil around the root zone by drenching with formalin solution in water, carefully covering it for two hours;
- Discourage such cultural practices which cause root injury to the plants;
- Raise healthy nursery plants on healthy sites;
- In advanced stages of infection remove the dead trees and replace them with healthy young seedlings, after disinfecting the soil and leaving it fallow for sometime.

4. Rusts

Occurrence and Distribution

The rusts are obligate parasites and cause considerable damage either by reducing photosynthesis or dwarfing and killing the plants. With the exception of some important cereal rusts, little is known about the others beyond their taxonomy and life cycles of some of them. The sub-continent of Indo-Pakistan is believed to be particularly rich in rust diseases. By 1954 about 21 genera comprising 53 species had been collected from various forest trees or alternate hosts in India and Pakistan. The rusts are found on many types of forest trees including hardwood trees, conifers and bamboos inflicting varied intensities of infection and damage. An overwhelming majority of the rusts attack the leaves and sometimes twigs and fruits. Some of the salient features of the important rusts are given below:-

(a) Rusts of Hardwoods

Rusts of hardwoods are quite common, mostly affecting leaves and sometimes twigs and fruits, causing defoliation. They are usually of no serious consequence excepting when appearing in an epidemic form. The rusts, however, have devitalizing effect on the host rendering it susceptible to other pathogens. Nearly 19 genera have been recorded on 57 plant species, showing their widespread occurrence in the country (Table 13.5).

Table 13.5: Recorded rusts of various hardwoods.

Host	Parts affected	Name of rust
1. LEGUMINOSEAE		
Acacia catechu	Leaves	*Ravenelia tandoni*
Acacia eburnea	"	*Aecidium esculentum Barcl*
Acacia leucophloea	Twigs	*Hapalophragmium ponderosum.*
Albizzia lebbek	Leaves & Pods	*Ravenelia sessilis Sphaerophragmium acaciae*
A. procera	Leaves	*Ravenelia indica Berk*
Dalbergia sisso	"	*Uredo sissoo*
	"	*Uromyces achrous*
Pongamia glabra	"	*Ravenelia hobsoni*
Erythrina sp.	"	*Uromyces erythrinae*
Acacia modesta	Leaves & Twigs	*Ravenelia taslimii.*
Desmodium tiliaefolium	Leaves	*Aecium callianthum*
Bauhinia acuminata & *B. tomentosa*	"	*Uromyces vestergreni*
Pterocarpus marsupium	"	*Mainsia pterocarpi*
Caesalpinia sepiaria	"	*Ravenelia indica*
2. SAPOTACEAE		
Madhuca latifolia	"	*Uromyces echinulatus*
Mimusops elengi	"	*U. mimusops.*
3. EBENACEAE		
Diospyros tomentosa	"	*Aecidium rhytismoideum*
4. OLEACEAE.		
Olea dioica	Leaves	*Cystopsora oleae*
5. APOCYANACEAE		
Holarrhena antidysenterica	"	*Hemileia canthii*
Wrightia tinctoria	"	*H. wrighti*
6. BORAGINACEAE		
Cordia sp.	"	*Aecidium brasilieuse*
Eheretia accuminata	Leaves & petioles	*Uredo ehretiae*

7 CELASTRACEAE		
Celastrus panniculatus	*Leaves & petioles*	*Pucciniastrum celastri*
8. MYRTACEAE		
Eucalyptus globulatus	Leaves & petioles	*Melampsora eucalypti*
9. VERBENACEAE		
Tectona grandis	"	*Olivea tectonae*
10. EUPHORBIACEAE		
Bridelia tomentosa	Leaves	*Bubakia cingens*
Phyllanthus emblica	"	*Ravenelia emblicae*
P. distichus	"	*Phakopsora phyllanthi*
Buxus sempervirens	"	*Uromyces ambiens*
11. MORACEAE		
Ficus glomerata	"	*Cerotellum fici*
F. religiosa	"	
Morus indica		
M. alba		
M. serrata	"	*Aecidium mori*
12. FAGACEAE		
Quercus sp.	"	*Cronartium quercuum*
Castanopsis sp.	"	*Pucciniastrum castanae*
13. SALICACEAE		
Populus ciliata	"	*Melampsora aecidioides*
P. alba	"	
Salix daphnoides	"	*M. salicis - capreae*
S. alba	"	*M. salicis-albae*
14. CAPPARIDEAE		
Crataeva religiosa	"	*Aecidium carlaeviae*
15. RHAMNACEAE		
Zizyphus rugosa	"	*Crossopsora zizyphi*
Z. oenoplia	"	*Phakopsora zizyphi*
Z. jujuba	"	*P. vulgaris*
Rhamnus procumbens	"	*Puccinia coronata*
R. purpurea		

R. dahurica	Leaves	*Puccinia himalensis*
R. virgata		
16. SAPINDACEAE		
Acer caesium	Leaves	*Pucciniastrum aceris*
A. cultratum		
17. ANACARDIACEAE		*Phakopsora odinae*
Odina wodier	Leaves	*Cerotelium lamnae,*
18. ROSACEAE		
Pyrus pashia	"	*Thekopsora areolata*
		Gymnosporangium cunninghamianum
19. BAMBUSEAE		
Bambusa sp.	"	*Puccinia gracilenta*
Bambusa metake	Culms	*P. xanthosperma*
		Stereostratum corticioidae
Bambusa sp.	Leaves	*Dasturella bambusina*
Phyllostachys bambusoides	"	*Stereostratum corticioides*
Dendrocalamus strictus	"	*Dasturella divina.*

Out of the above mentioned rusts, six have been studied, which are described in Table 13.6.

Table 13.6: Description of some important rusts of hardwood

Host	Pathogen	Description
1. *Tectona grandis*	*Olivea tectonae*	Found and present throughout the year in Bangladesh. Causes defoliation and affects growth and vigour of plants. Quite common and serious in nurseries. Uredial stage is common but also produces teliospores in sori.
2. *Dalbergia sissoo*	*Uredo sissoo*	Attacks young tender leaves

			throughout the country, causing serious losses occasionally.
3.	*Wrightia tinctoria*	*Hemileia wrighti*	First reported in 1950. Develops hypophyllus sori. It is not autoecious.
4.	*Pterocarpus marsupium*	*Mainsia pterocarpi*	Found in Bangladesh on leaves and causes defoliation. Uredia and telia are produced, the latter stage being intraepidermal.
5.	*Acacia modesta*	*Ravenella taslimii*	Found in salt range and Changa Manga, present on leaves and stems. One-celled, held in oval-heads by pendant cysts equal in number to teliospores.
6.	*Populus alba*	*Melampsora aecidioides*	Found in Abbottabad and quite serious on young plants causing defoliation and distortion of young shoots. Sori are hypophyllus, yellow with crimson centres. Petioles and twigs are also attacked. Prevalent throughout the year, subsiding in winter. Teliospores either intermixed or separate measuring 25 x 35µ while uredospores measure 21 x 21µ.

(b) Rusts of Bamboo

Two rusts have been recorded on bamboo, (i) *Stereostratum corticioides* previously identified as *Puccinia corticioides* and (ii) *Dasturella divina*. The fungus *S. corticioides* produces two-celled teliospores grouped in sori forming corticium like crusts measuring up to 10 cm. The uredia are also produced but are sterile. In case of *D. divina* the sori are hypophyllus, uredia erumpent, light brown, paraphysate, incurved paraphyses.

(c) Rusts of Conifers

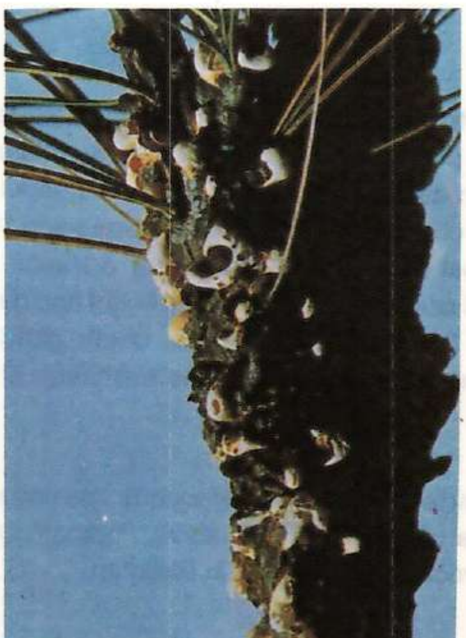
The conifer rusts are quite common and when attacking produce a characteristic disagreeable odour, clouds of orange yellow spores, browning of needless, witches' broom, cankers and galls. The rusts include about 15 species distributed on elevations ranging 5,000 to 9,000 feet; five are teleutoforms and seven aecidial (Table 13.7).

Table 13.7: Rusts on conifers and their alternate hosts.

Conifer	Rust stage	Alternate host	Rust stage
1. *Pinus longifolia*	*Peridermium himalayense.*	*Swertia angustifolia*	*Cronartium himalayense*
		S. alata	
		S. cordata.	
	Peridermium orientale Cke.	*Campanula colorata*	*Coleosporium complanatum*
2. *Pinus excelsa*	*Peridermium indicum*	*Ribes ruburum* *R. orientale*	*Cronartium ribicola*
	P. brevius Barcl.	*Senecio rufinervis*	*Coleosporium barclayense.*
3. *Abies*	*Peridermium abies-pindrowina.*	*Lastrea filixmas*	*Uredinopsis* sp.
4. *Picea smithiana*	*Peridermium piceae* Barcl.	*Rhododendrum aroreum*	*Chrysomyxa himalensis*
	P. thomsoni Berk.		
	Chrysomyxa deformans.		
	Thekopsora areolata (Wall.) Magn.		
5. *Cedrus deodara*	*Peridermium cedri* Barcl.		
6. *Cupressus torulosa*	*Gymnosporangium cunninghamianum* Barcl.	*Pyrsu pashia*	*Roestelia*

The important ones are *Cronaritum himalayense* (attacking *Pinus*

(a)



(b)

Fig. 13.5: Rusts: (a) *Chrysomyxa deformans* on spruce (*Picea smithiana*) needles
(b) *Cronartium ribicola* on blue pine (*Pinus Wallichiana*) stem/branches.

longifolia; being more serious in India), *Cronartium ribicola* (attacking *Pinus excelsa* of 3-10 years age), *Peridermium cedri* (produces witche's broom in deodar) and *Chrysomyxa deformans* which attacks spruce (Fig. 13.5).

Control

In the absence of resistant plant clones the sanitary and cultural practices can help to contain rust diseases. These include collection and burning of diseased plant parts and alternate host plants to get rid of primary sources of infection, avoiding plantations in water logged and low lying areas, as well as congestion (specially in nurseries) to check the spread of rusts and improving general health of plants. Repeated spraying with copper-based fungicides can also help to control the rusts in individual trees or in small plantations as large-scale application is both laboureous and costly.

Nursery Diseases

Symptoms

Damping-off is the most serious of all the nursery diseases, attacking many broad leaved plant species but primarily the incidence is serious in conifers, resulting in destruction of nursery stocks under favourable soil and environmental conditions. The disease appears in three stages viz. pre-emergence, post-emergence and during advance growing stage, attacking hypocotyl or roots or both causing blight and death of the seedlings. The damage becomes more serious under either excessive soil moisture or drought which discourage the formation of new roots and revival of plants.

Pathogens

The most important soil-borne pathogens causing damping-off are found in the genera of *Pythium, Rhizoctonia, Phytopthora* and *Fusarium; Rhizoctonia* being more predominant in Pakistan.

Control

Modifications in cultural practices can help to control the disease. These include (a) growing of nurseries on well drained sites with minimum regime of watering, (b) partial sterilization of soil by steaming or with fumigants like formalin and methyl bromide before seeding, (c) spraying or dusting with chemicals like Captan, Thiride, Cuman or Zineb and (d) seed disinfection with a suitable chemical which may or may not be useful for conifers, because of epigenous type of seed germination.

Root Rots

Symptoms

Root rot diesases remain unnoticed until manifested by symptoms on the above ground plant parts. They attack the roots in different stages of growth resulting in peeling off the bark, withering and death of the plants. The fungi attack a wide range of host plants including conifers and hardwood species (Fig 13.6).

Fig. 13.6: *Gonoderma lucidem*, a destructive root-rot pathogen on Shisham (*Dalbergia sissoo*) growing at the base of affected tree.

Pathogens

There are many soil-borne fungi, which have both saprophytic and parasitic phases and attack the specific hosts under favourable environmental conditions. Many of them belong to the woodrotting group of fungi (discussed separately) and the others are *Fusarium*, *Verticillium* and *Rhi-*

zoctonia species, which remain viable in the soil or on diseased plants parts for long periods.

Control

In the absence of resistant plant species the possible control measures are: (a) soil fumigation prior to sowing, (b) crop rotation or fallowing, (c) mixed plantation of host and non-host plants, (d) burning of diseased plant parts, (e) construction of isolation trenches, and (f) use of chemical and biological control measures.

7. Diebacks

Symptoms

Dieback diseases are quite common in many plant species like mulberry, semul, safaida, salix and bankhor (Indian horse chestnut), producing different types of symptoms, the general feature being the infection of the upper plant parts resulting in drying of the plant from top to downwards. The infections ultimately produce girdling of stems causing slow-death of the plants. The high incidence of disease is favoured by greater humid conditions and close canopy of plants (Fig 13.7).

Fig. 13.7: Die-back in Chinar (*Platanus orientalis*).

Pathogen

The pathogens causing dieback in Pakistan are given in Table 13.8

Table 13.8: Dieback diseases in Pakistan

H o s t	Botanical Name	Causal Organisms
Mulberry	*Morus alb*	*Hendersonula toruloidea*
Semul	*Bombax malabaricum* *Salamalia malabarica*	*Phomopsis salamalica*
Safaida	*Populus nigra*	*Botryosphaeria ribes*
Casuarina	*Casuarina equisetifolia*	*Trichosporium vesiculosum*
Bankhor	*Aesculus indica*	*Botryosphaeria ribes*

Control

In the absence of resistant tree varieties those cultural practices can help to contain the disease, which do not predispose the plants to the attack of the pathogen. These include sanitary measures like collection and burning of the diseased plant parts followed by application of Bordeaux paste or coal tar to the cut ends, and retaining of open stands of mixed plantations.

Witches'-Broom

Symptoms

The disease has been reported in deodar and casuarina. In case of deodar the affected needles remain short and curved backwards, giving rise to yellow fruiting bodies on their surface which subsequently burst, yielding clouds of yellow spores. Similarly, in case of casuarina, the plants show bunchy growth of leaves and presence of thickened needles on which the pycnidia of the fungus develop. However, in both cases the disease produces witches' broom, which are more conspicuous outward sign of the attack (Fig. 13.8).

Pathogen

The two pathogens responsible for causing the disease are (a)

Peridermium cederi in case of deodar and (b) *Phoma casuarinae* in case of casuarina.

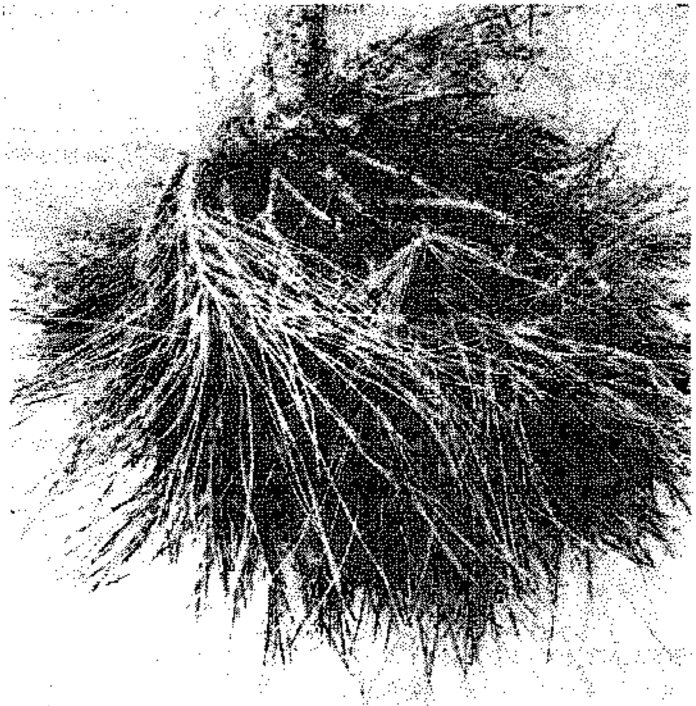


Fig. 13.8: Witches' - broom caused by Himalayan dwarf mistletoe (*Arceathobium minutissimum*) in blue pine.

Control

The disease can be kept under control by (a) removal and burning of diseased and dead plant parts; (b) avoiding injury to the healthy plants and (c) planting mixtures of species and avoiding use of damp valleys.

Leaf Spots and Blights

Occurrence and Distribution

Leaf spots and blights constitute an important group amongst the foliage diseases of forest trees, being found on all types of trees through out the year. Some of them cause great damage through reduction in photosynthetic area and normal growth, besides partial or complete defoliation and wood quality deterioration, depending upon the magnitude of predisposing factors. So far 17 such diseases have been recorded on ten different host plants in varying degrees of infensity.

Symptoms

The symptoms differ slightly from one disease to another but generally speaking diseased lesions or spots of varying size and colour develop on the leaves, sometimes becoming necrotic, producing shot holes or reduction in leaf size, causing partial or complete defoliation or dieback of tree branches or appearance of cankers or even total killing of the young plants. The predisposing factors like favourable temperature and humidity, nutrition deficiency or imbalance, plantations in depressions or low lying areas or presence of growth stress conditions greatly influence the appearance, development, incidence and damage caused by these diseases (Fig. 13.9).

Fig. 13.9: *Dothistroma pini*, causing serious blight disease in blue pine (growing in Swat Forests).

Pathogens and Perpetuation

The pathogens are the universal fungi or bacteria, most frequently living as saprophytes on dead leaves, twigs or other plant parts, becoming aggressively active under favourable conditions. Some are weak parasites needing injured or bruised areas for attack while the others are active parasites. The pathogens produce different types of fruiting bodies to help overcome adverse climatic conditions or overwinter as mycelium in dead plant parts. The disease appear as soon as favourable conditions become available and continue spreading through spores dispersed by wind or rain splashings. A list of ten recorded leaf spot and blight diseases is given in Table 13.9.

Table 13.9: Recorded leaf spot and blight diseases of forest trees

Host	Disease	Pathogen
1. Sal		
Shorea robusta	Sooty molds	*Cercospora* spp.
	Sooty moulds	*Meliola* spp.
	Thread blight	*Marasimus sarmentosus* Berk.
2. Shisham		
Dalbergia sissoo	Leaf blight	*Glomerella cingulata* (*Colletotrichum gleosporioides*)
3. Mulberry		
Morus alba	Leaf spots	*Septogloeum mori*
4. Siris		
Albizzia odoratissima	Leaf spots	*Endothella albizziae* 1Svdow)
5. Walnut		
Juglans regia	Leaf spots	*Melanconium juglandinum* (*Melaconis juglandis*)
	White spots	*Microstroma juglandis*
	Foliage spots	*Exo'porium tiliae*
	Bacterial blight	*Xanthomonas juglandis*
6. Kalakanth		
Prunus cornuta *P. padus*	Leaf spots	*Polystigma ochracenm* (*P. pallescens*)
7. Bed willow		
Salix sp.	Twig blight	*Cryptodiaporthe salicina*

		(*Discella carbonacea*)
	Canker	*Dothichiza populea*
8. Sufaida		
Poplar sp.	Die back	*Botyrosphaeria ribis*
	Leaf blight	*Marssonia* spp.
9. Casurina		
Casurina equlsetifolia	Die back	*Trichosporium vesiculosum*
10.Ban		
Bamboos	Culm spots	*Apiospora montagnei* Sacc.

Control

Unless serious, these diseases do not need special control measures. However, the following steps if taken will help to contain the diseases:

- Maintenance of proper distances between plants to ensure adeququate aeration and sunlight;
- Pruning of diseased or dead branches and infected parts of the tree followed by burning. Pruned branches should be painted with Bordeaux paste or any other antiseptic material;
- Removal and burning of fallen leaves and ground spraying with Arbo-
- rol or Nitrosan (0.5 per cent) at 2 litre/m^2 on commercial trees;
- Maintenance of normal growth and vigour of plants through better nutrition and management;
- Spraying of the commercial trees like walnut and mulberry with 1-2 per cent Kuprikol or 5:5:50 Bordeaux mixture (containing streptomycin) before flowering.

Summary

The chapter describes the great importance of forests in meeting not only the material needs of people but also in improving the environmental and climatic conditions of the country. The forests occupying only 4.8 percent of the total land area, cannot meet the minimum requirements of the country, necessitating big imports of timber at a heavy cost. Due to varied climatic conditions, ranging from tropical to temperate and alpine, there are nine forest zones in the country containing many of the well known tree species meant for human use. Not only are the forest plantations small and the per unit area productivity low, the forests are subject to the attack of many insect pests & diseases.The salient features of the researches carried out on tree pathology before & after the independence of Pakistan are embodied in the chapter.These include groups of allied diseases discussed together in separate sections.Detailed account of the most discussed together in separate sections. Detailed account of the most damaging group of diseases, causing wood decays and heart rots is given. The chapter deals with their occurrence and extent, symptoms, causal pathogens, predisposing factors, host plants, spread of decay along with description of 17 heart rots of living and eight of felled trees. These are caused by various groups of fungi (*Polyporaceae*, *Thelephoraceae* and *Ascomycetes*) producing both white and brown rots. The principles governing control measures have been discussed, highlighting the need for large-scale adoption of recommended methods to prevent heavy losses. The other groups of diseases discussed include powdery mildews, wilts, rusts, nursery diseases, root rots, die back, witche's brooms and leaf spots and blights. In each group symptoms, pathogens, perpetuation and possible control measures have been described. These include sanitary measures, chemical sprays for special situations and soil disinfection or sterilization for soil-borne pathogens. As prevention is better than cure, the methods, which can eliminate primary sources of infection, will be most practical and economically feasible. This will need development of forest management package practices to be followed for the control of important diseases along with scientific treatment of timber to prevent wood rots for increasing their service span.

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Chapter XIV

Diseases Caused by Bacteria

Like, fungi, bacteria constitute an important group of disease causing pathogens. They are achlorophyllous organisms with saprophytic or parasitic mode of life. They are unicellular and multiply in liquid medium with considerable rapidity and dispersed by contaminated water, insects, seeds, plant parts and farm implements but infrequently by wind. Bacterial cells make their entry into host through natural openings or wounds and multiply intercellularly, producing characteristic symptoms. Rainy and humid conditions are conducive to the development and spread of bacterial diseases.

Bacteria cause three types of diseases in plants:

i) *Vascular diseases:* where the xylem vessels are clogged, promoting wilting symptoms and development of diseases such as blight of cotton, common blight of bean and ring rot of potato.

ii) *Parenchymatous diseases:* where soft and succulent plant tissues are invaded, causing necrosis and rotting sometimes giving out offensive smelling liquid e.g., soft rots and blights.

iii) *Hyperplastic diseases:* which are characterized by the formation of tubercles, tumours or galls e.g., crown galls.

All the three types of the bacterial diseases are found in Pakistan and cause substantial losses in field and fruit crops ranging between 5-7 percent. However, unlike fungal maladies, bacterial diseases of plants have received little attention so far, due to non-availability of trained scientists and the necessary laboratory facilities besides lack of detailed surveys. The information available on the occurrence and distribution of bacterial diseases, according to the investigations carried out so for, is summarised below:

1. Tundo of Wheat – *Corynebacterium tritici* (Hutch) Burk.

Occurrence and Importance

Tundo yellow ear or spike blight was regarded as an unimportant disease until 1966 when it appeared in an epipthytotic form in certain areas of Pakistan, particularly in upper Sind with an averge incidence of 25 percent. Since then the disease has been found to be distributed throughout Pakistan with varying degrees of intensity.

Symptoms

In early stages, the disease usually goes unchecked because of delayed visible symptoms. Initially, leaves may be wrinkled or misshappen as they emerge from the whorls. When the heads eventually emerge, they are also misshappen and twisted, covered with sticky, yellowish exudate of the bacteria. Later on dried white exudate appear which distort the head, neck and upper leaves and also inhibit their elongation (Fig. 14.1).

Pathogen

The disease is caused by a bacterium, which is seed-borne and survives in the organic matter under wet conditions in low lying areas. Dissemination within the field primarily takes place through seed gall nematodes - *Anguina tricitci* (Steinbuch) Chit. The nematodes larvae become contaminated with bacteria in the soil and carry them up the stem to the plant apex.

Control

The disease can be kept under control by sowing gall-free seed besides following 2-3 years crop rotation and keeping the soil well drained.

2. Bacterial Stripe of Sorghum – *Pseudomonas andropogonis* (E.F.Sm.) **Stapp**

Occurrence and Importance

Bacterial stripe, also known as leaf stripe is found in all the sorghum cultivars grown in Pakistan. It usually makes its appearance in June and July and continues upto September. Disease development is favoured by warm conditions and cloudly days followed by frequent rains.

Symptoms

Stripes which are light red to brick red in colour develop on the leaves (Fig. 14.1). These are restricted to the interveinal areas of apical portions of the lower leaves and range in length from 25 mm to the entire length of the leaf blade. Large areas of the leaves may be covered by numerous stripes when they coalesce. Bacterial exudate may be observed on the underside of affected portion of leaves forming red crusts until washed off by the rains.

Pathogen

The disease is caused by a bacterium, which is seed-borne and also survives in the plant residues, soil and infected debris. Dissemination of the pathogen takes place by wind, water and insects. The new infections occur through stomatas and wounds caused by high wind velocities and insects.

Control

Cultural practices are very effective in minimizing the infection. These include rotation of sorghum with non-susceptible crops, delayed sowing to avoid wet conditions, destruction of diseased plant debris and removal and burning of residues. Sowing of healthy seed or treated with copper or mercury based fungicides is useful in controlling the seed-borne infection. Some varieties of sorghum e.g. H-4-2 , Acho Kartuho , Acho Kodri and Altakh , have shown a high degree of resistance to the disease even under artificial conditions of inoculation in Sind.

3. Bacterial Blight of Rice – *Xanthomonas oryzae* (Uyeda and Ishiyama) Dow

Occurrence and Importance

Bacterial blight has been found to occur in all the rice cultivars throughout Pakistan. The disease begins to appear in June and assumes maximum intensity in October. An extensive survey carried out during 1983 indicated that the disease was prevalent in 21 rice varieties grown in the Punjab, NWFP and Sind, showing a wide range of genotypic reaction.

Symptoms

Water-soaked stripes appear along the margins of leaf blades, which later on turn yellow. Eventually, the stripes cover the entire blade and may even extend to the lower end of the leaf sheath (Fig. 14.1). With the advancement of the disease, water-soaked areas also appear on the glumes of green grains. The affected leaves turn grey or light yellow while in older plants they become conspicuously pale yellow.

Pathogen

The pathogen survives in rhizosphere of weed hosts, piles of infected straw and root stubbles. Although glumes also become infected, seed-borne infection has not been reported so far. Local dissemination takes place by wind and water, which are also responsible for long-range transmission.

The bacteria enter the plant through hydathodes or wounds produced by implements, insects and strong winds. Bacteria affect the vascular tissue and under high moisture conditions, bacterial masses ooze out from the lesions. These masses on drying fall into the water standing in the paddy fields.

Control

Cultivation of resistant varieties is the only possible control measure. Varieties like Basmati 370 , IRRI-6, and Lateefy have shown a good degree of resistance against the diease, which, can also be used in the breeding programmes.

4. Red Stripe of Sugarcane – *Xanthomonas rubrlieans* (Lee et al.)

Occurrence and Importance

Red strip or top rot disease is widely distributed in the country wher-ever sugarcane is grown,but it has received little attention.The incidence of bacterial stripe varies from place to place and from variety to variety because it is greatly influenced by the environmental conditions and the amount of inoculum present. However, 2-5 percent incidence has been generally recorded in the Punjab.

Symptoms

All parts of the plant may be infected including the leaves, stalks and roots, but leaf infection is very common in Pakistan. Initially, water-soaked stripes surrounded by chlorotic zones develop on the leaves, but later on the stripes become dark red in colour Stripes are 15-40 cm in length and 1-5mm in width, but may extend down to the leaf sheath. They usually appear midway in the leaf and near the midrib, but sometimes become concentrated toward the leaf base. Eventually, stripes coalesce forming bands of chlorotic areas and the vascular bundles of the stalks become slightly red. Under severe conditions of infection, terminal buds and spindle leaves may die causing top rot while lateral buds may also show reddening. Detection of foul and nauseating odour due to decomposition of stalks in advanced stage is a good indication of the presence of the disease.

Pathogen

The disease is caused by *X. rubrileans*, which persists in the older withered leaves and the soil. Bacterial exudate may ooze out under warm and wet conditions. The disease is disseminated through implements, wind and rain as well as by sugarcane cuttings. Bacteria enter the plant through wounds or stomatas.

Control

Diseased stools should be rogued out. Sugarcane varieties which are resistant or tolerant to the disease should be planted. The present commercial varieties have shown a good degree of tolerance. Some of the tolerant varieties are L-116 , L-113 , Triton , BF-133 and HF-146 while BF-134 is highly susceptible (30 percent infection).

5. Bacterial Blight of Cotton – *Xanthomonas malvacearum* (E.F.Sm)

Occurrence and Symptoms

Bacterial blight (also known as angular leaf spot) first recorded in early fifteees,is now spreading and causing appreciable losses (sometimes up to 50 percent) in severely affected fields. Its incidence has been recently recorded as 20-37 percent in Lyallpur (Faisalabad) district. In early infections under artificially inoculated conditions, it has caused 38.2 percent flower shedding with 8.4 percent reduction in yield, which has gone upto 16.8 percent under combined early and late infections.

Symptoms

The disease attacks the cotton plant at all stages, causing seedling

Fig. 14.1: (a) Tundo of Wheat; (b) Bacterial Stripe of Sorghum, (c) Bacterial blight of Rice, (d) Bacterial blight of Cotton (*Top* - on stem branches; and *bottom* - on bolls).

rot, angular spots on leaves (with greater involvement of veins particularly under drier conditions) and stems (called blackarm disease) and boll rot. The disease lesions on leaves are first water-soaked, later on becoming necrotic and angular. They vary in size and then coalesce forming irregular patches and giving rise to gummy bacterial exudate. On stems, branches and petioles, black lesions are produced, the former showing cracking and gummosis. While water-soaked lesions, which are dark brown to black and invariably sunken, are produced on the bolls. The bacterium after entering through natural openings and wounds, destroys succulent plants parts, also infecting bolls and seeds besides causing staning and weakening of the fibre (Fig. 14.1).

Causal Organism

The disease is caused by the bacterium, which grows well at 36°C and 85 percent R.H. It forms pale yellow colonies on culture medium with glistening, convex and irregular margins. In Pakistan three races (8, 12 and 18) have been identified on the basis of host differentials; race 18 being highly virulent and widely prevalent while the other two races are rarely found on indigenous cotton varieties. The disease is mainly carried over through seed and plant debris; the seed-borne infection varying between 1-7 percent.

Isolation Method

As in early experiments the isolation of the bacterium was prohibited by the associated quick growing fungi, which had low incubation temperatures and a favourable type of solid media used, a suitable technique was developed. It consists of using old seeds which are soaked in 0.2 percent Usploan for 8 hours at 20°C before their incubation at 32-33°C, preferably in semi-solid medium (using 1 percent instead of 2 percent agar). The bacterium can also be isolated by using dilution plate technique or by plate streak method.

Perpetuation

The disease is mainly carried over through infected seed and plant debris but can also spread through irrigation water, rain splashes, wind, insects and contaminated field implements.

Control

Removal and destruction of diseased plant debris is generally recommended. Delinting of cotton seed with commercial sulphuric acid (1 kg acid/8 kg seed) and fungicidal seed treatment with Agrosan or Ceresan can reduce primary source of infection.It does not provide any protection against secondary infection for which chemical sprays with copper fungicides are found to be partially effective but uneconomical.In recent experiments Agrimycin (an antibiotic)has given promising results in controlling both local and systemic infections, when used as a foliar spray.

Under conditions of artificial inoculation *desi* cultivars D-9 and R-231 have been found to be resistant while AC-134, AU-59 and B 557 are highly suceptible. In experiments at UAF the indigenous varieties have shown comparatively lower degree of seed-borne infection than found in exotic varieties.

Development of blight resistant varieties will be the most economical and lasting control of the diease. As a result of large-scale varietal screening (92 entries from USA, Africa and Pakistan) at the Cotton Research Institute, Multan, all the local cultivars have proved to be susceptible, while some exotic varieties have shown immunity; controlled by different genes. It shows that multiple resistance combining different genes will help in the development of resistant varieties in Pakistan, on which work is in progress.

6. Brown Rot of Potato – *Pseudomonas solanacearum* (E.F.Sm.) Dows.

Occurrence and Importance

Brown rot or bacterial wilt of potato is an important and serious disease attacking potatoes worldwide, especially affecting seed potato production (Martin, 1981). In Pakistan, the disease, first reported in 1968, has been recently identified to be quite important. International Potato Centre (CIP) in collaboration with Pakistan Agricultural Research Council, conducted an extensive survey of potato fields in the Punjab and NWFP in 1980. Bacterial wilt was found to be prevalent in the Punjab, varying from 0.1-0.5 percent in four potato varieties (Desiree, Ultimus, Patronese and Cardinal) but the northern areas were found to be free from the disease. Later studies, have also confirmed the existence and prevalence of this disease mostly in the Punjab. According to 1984 survey, its incidence has been reported from 4-6 percent in the districts of Jhang, Faisalabad, Sialkot and Lahore, reducing yield by about 5.5 percent. It is likely that the disease is also present in other provinces.

Symptoms

The disease produces two types of symptoms viz., above ground and below-ground. Above ground symptoms include wilting, stunting and yellowing of the foliage, resembling to the symptoms produced under water stress conditions or to those produced by *Rhizoctonia* or *Fusarium* sp. However, wilting of a part of the plant is characteristic of brown rot, but it finally leads to wilting of the entire plant (Fig. 14.2). The most conspicuous below-ground symptoms are associated with the tubers, which on cutting show brown discolouration of the vascular system. A slight squeezing of tubers forces a typical greyish-white bacterial slime out of the vascular ring.

Pathogen

It is caused by *Pseudomonas solanacearum*, which seems to have three races. Cultural studies of the pathogen need to be carried out to differentiate its races or biotypes present in Pakistan. Preliminary observations have indicated the occurrence of race 1, which has host range of solanaceous crops and is more adaptable to warmer areas and lower elevations. Optimum temperature for bacterial growth has been from 30^0 to 32^0C. The bacterium loses its virulence when grown for a long time on a synthetic medium.

Disease Development

Infected seed tubers and infested soils are the two main sources of primary inoculum. Although infected tubers may escape detection, but when they are planted in warmer locations they give rise to disease causing severe losses. The pathogen survives in the soil for long periods and infection takes place through wounds on roots that may occur during cultural operations. Once the bacterium penetrates the roots, it multiplies and spreads throughout the xylem vessels of stems and petioles. This results in cutting off the water supply due to accumulation of bacterial slime and causes wilting. The disease development is mainly influenced by temperature and humidity, while infection can spread through irrigation water, insects or by using soil-contaminated implements.

Control

An integrated combination of various measures provides possibilities of successful control of the disease; use of healthy seed tubers; careful crop management which ensure good tillage, growth and minimal injury;

crop rotation and cultivation of resistant varieties are highly effective. Strict quarantine measures are required to inhibit the entry of the pathogen in seed stocks to eliminate seed-borne infection.

7. Soft Rot of Vegetables

—*Erwinia carotovora* (*Jones*) *Holland*
E. avoideae (Townnend) Holland
E. atroseptica (V.Hall) Jennison

Occurrence and Importance

Bacterial soft rot is one of the most common and destructive diseases of vegetables and fruits including potato, sweet potato, tomato, onion, carrot, turnip, raddish, peas, mango, pomes and stone fruits. It reduces germination of seed potatoes considerably. It is widely distributed and causes serious losses in the field, in transit and in storage of nearly all fleshy vegetables and fruits. Soft rot causes economic losses by reducing both the quantity and quality of the produce and lowering its market value. Recent trend of cellophane- packing for marketing of vegetables provides ideal conditions for the disease development, resulting into greater losses compared to unbagged marketing of the produce. The recent trend in packing has increased the need for developing practical control measures.

Symptoms

The symptoms produced by bacterial soft rot in all the hosts are almost similar. These include appearance of slimy, soft, depressed areas, which rapidly enlarge especially when the diseased material is stored under humid conditions. Some vegetables, when stored for 3-5 days under high humidity are converted into soft, watery, colourless, decayed masses with a distinctive foul odour. If infected vegetables are transferred in early stages to dry stroage conditions, the rotting areas usually dry up and further development of the disease is halted. Potato plants can become infected from the soil, leading to wilting and death of the above ground parts. Shoots from infected potato tubers are stunted and often appear blackened at the base-a condition known as black leg. (Fig. 14.2). The disease has been found to be more frequent in the districts of Sialkot, Gujranwala and Lyallpur (Faisalabad) with an incidence ranging between 0.2-2.9 percent in Desiree, Ultimus, Multa, Patrones and Cardinal varieties.

Pathogen

As mentioned earlier the disease is caused by three species of

Erwinia. The bacteria are gram negative, motile and opalescent. Colonies on the agar media are smooth with irregular margins. Optimal growth of the bacteria take place at 35-40°C.

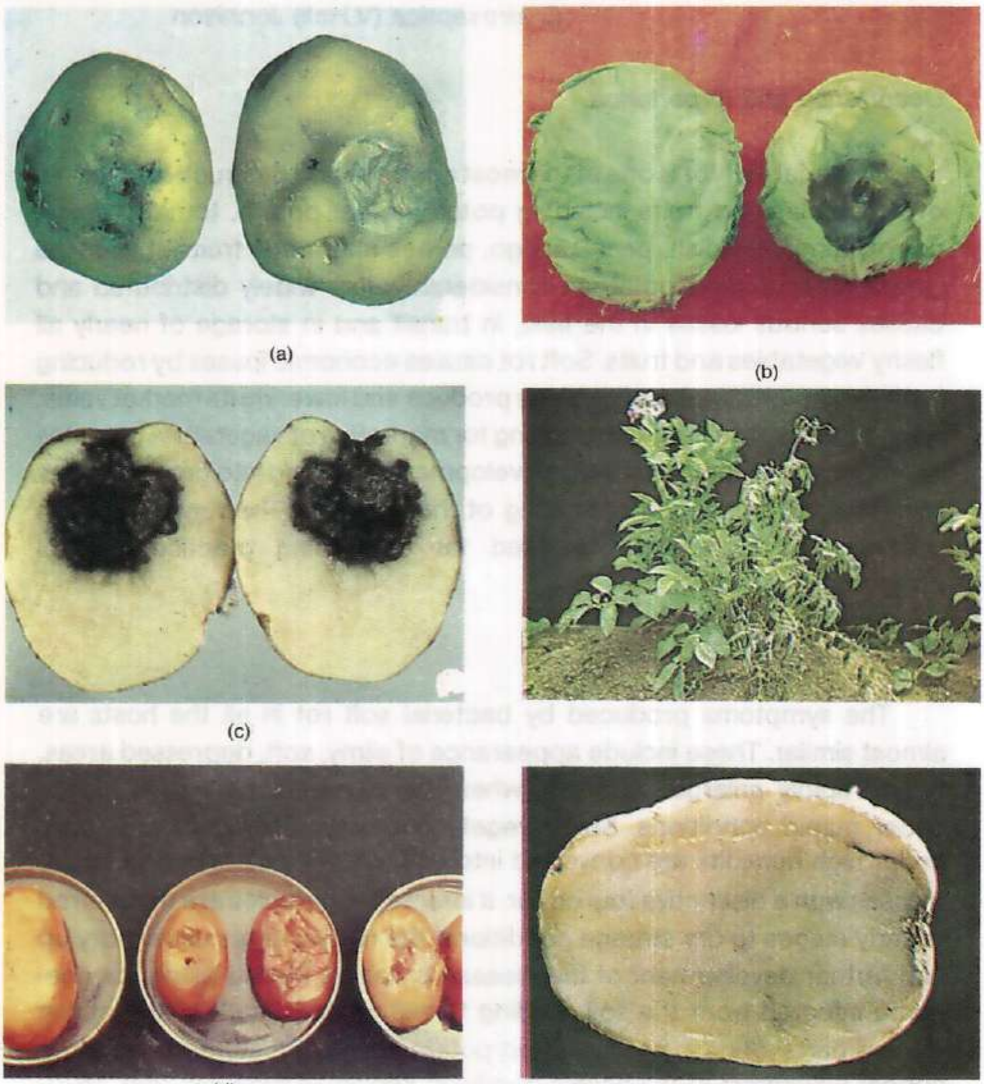

Fig. 14.2: (a) Brown rot of potato, (b) Soft rot of vegetables; (c) Black leg of potato (d)Soft rot of tomato; (e) Bacterial wilt of potato showing an infected plant and a tuber.

Disease Development

The bacteria, causing soft rot, are present in the field in most of the soils and also in decaying plant refuse, which are responsible for the seasonal carry over of the disease. The pathogen is also found in store houses and sometime in seed potatoes. The bacteria cannot directly attack plants as they can only enter through wounds, caused by mechanical injuries, bruises, growth cracks and insects. The presence of abundant moisture around the wounded areas is necessary for the development and spread of infection. Bacteria multiply and break down the surrounding vegetative tissues. The slimy mass, produced in decayed tissues, consists of innumberable bacteria, which can cause reinfections on contact with wounded vegetables. Warm (25°-37°C) and humid conditions favour disease development.

Control

Careful handling of the produce in the field, store house and transit, (which reduces the extent of mechanical injuries, wounds and bruises) can minimize the degree of infection. Avoiding over-irregation in the field and harvesting during warm rainy periods can also help protecting the produce. If the vegetables are washed after harvesting, provision should be made for rapid drainage of water and drying before these are packed and stored. Store houses should always be thoroughly cleaned and fumigated and provided with adequate ventillation to prevent humidity build-up. Affected field areas should be rotated with crops such as cereals, corn or legumes. In case of potatoes, tubers should be allowed to fully mature after harvest.

8. Crown Gall – *Agrobacterium tumefaciens* (Riker et al.) Conn.

Occurrence and Importance

Crown gall is an important bacterial disease, which is widely distributed but is usually overlooked. It affects many woody and herbaceous plants, including fruits and ornamentals, belonging to diverse botanical families. The common host plants include species of *Zizyphus, Acacia,* apple, peach and pear. Tomato is also very well known to be infected by the pathogen, besides many cultivated fruit trees, which fall prey to the infection. Formation of tumors or galls of varying size and shape on either roots, shoots or other plant parts, affect the growth, quality and productivity of the host plants.

Symptoms

The disease can be recognized from the small overgrowth or excrescences and protuberances on the stems and roots near the ground level. Initially, tumors are more or less spherical in shape and soft in texture and continue their growth till the tissue becomes dark brown or black in colour due to the death of peripheral cells. The outer surface of the tumors also becomes more or less convoluted. Sometimes, there is no distinct line of demarcation between the tumor and the plant surface. Ultimately, tumors appear as irregular swellings of the tissues surrounding the stem, a condition commonly observed in Pakistan (Fig. 14.3). The tumor is connected by a narrow neck, and it becomes woody and hard, looking knobby or knotty and grows big in size up to 30 cm in diameter. Affected plants become stunted in growth, producing small, chlorotic leaves and are generally more susceptible to the adverse environmental conditions.

Pathogen

The disease is caused by a rod shaped (1-3 x 0.4-0.8 μ) bacterium known as *Agrobacterium tumefaciens*. It occurs singly or in short chains, with two flagella at the same pole. The most characteristic property of the bacterium is its ability to transform normal plant cells into tumor cells in a short period of time. Once the transformation to tumor cells has been completed, these cells become independent of the bacterium and continue to divide and grow abnormally.

Disease Development

Bacteria generally over-winter in soil and enter the roots or stems near the ground level through wounds developed during cultural operations, grafting or by high wind velocity and insects. Bacteria become established between the cells of the tissue, stimulating accelerated division of the surrounding cells. Whorls or hyperplastic cells appear in the cortex or cambial layer, depending upon the depth of the wounds. Swellings appear 10-14 days after the bacterial penetration. With the continued irregular division and enlargement of the cells, the tumor formation becomes apparent. Tumor cells exert a great pressure on the surrounding and underlying normal plant tissues, which ultimately become distorted or crushed. This condition reduces the supply of water to the upper parts of the plants, producing hypertrophy and hyperplasia which affects photosynthesis. This results in overall stunted growth of the plants.

Control

Control measures against crown gall are based on cultural practices, phytosanitary field conditions and avoiding budding or grafting from the infected scion plants. Physical removal of galls or tumors from the trees and their treatment with certain antibiotics such as Terramycin and Vancomycin have proved quite effective against tumor formation.

9. Fire Blight – *Erwinia amylovora* (Burrill) Bergy et al.

Occurrence and Importance

The disease has been found to be confined to the specific localities in NWFP. It is a quite destructive disease causing damage to pear and apple orchards. Many members of the Rosaceae family and other host plants including stone fruits and some wild ornamental species are also infected, and provide hosts for the causal pathogen to over-winter. Fire blight damages flowers, twigs and girdles of large branches resulting into their death in case of severe infections.

Symptoms

Initially, symptoms of fire blight appear on the flowers, which become water-soaked, shrivelled and brownish in colour. Later on, infection takes place on foliage and twigs, which develop black blotches resulting in curling and death of affected parts. Terminal twigs start wilting from the tip downwards. The bark of the branches around the infected twigs appear water-soaked, and turn darker, becoming sunken and dry. Fruits are not infected directly but through twigs. They become water-soaked, and turn brown ultimately shrivelling and mummifying (Fig. 14.3).

Pathogen

The fire blight pathogen has not been characterized adequately in Pakistan. It over-winters on pear trees and other susceptible hosts. In spring due to favourable conditions of temperature, the bacteria become active, multiply and spread in the adjoining healthy bark. During humid or wet weather, sticky exudate of bacteria develops, attracting many insects, which disseminate the infection under natural conditions. Infection takes place through nectaries, stomata and hydathodes as well as through wounds caused by insects and hailstorms. Young tender twigs may be infected through lenticles. The bacteria after becoming established intercellulary, cause break down of the cortical cells. Invasion of the large twigs and branches is restricted primarily to the cortex. Progress of the disease depends upon the succulence of the tissues and favourable environmental conditions including presence of high concentration of salts and deficiency of nitrogen and phosphorus in the soils.

Control

Amelioration of soil conditions and correction of nitrogen and phosphorus deficiencies along with phytosanitary measures are essential for controlling the disease in the long run. Pruning of blighted twigs, branches and cankers in winter can prove useful. Cutting of blighted twigs, suckers and root sprouts in the summer can reduce the quantity of inoculum. Satisfactory control of fire blight with chemicals can be obtained only in combination with the above mentioned measures. Use of Bordeaux mixture (5:5:50), copper sulphate (0.4 percent), or any other suitable copper-based fungicide is highly effective in combating the disease. Spraying with 100 ppm of Streptomycin, which acts as a systemic antibiotic, is also highly useful.

10. Citrus Canker – *Xanthomonas citri* (Hasse) Dows*

Occurrence and Symptoms

Citrus canker occurs commonly throughout the country and ranks as one of the major diseases of citrus plants in Pakistan. The disease affects leaves, stems and fruits. On young leaves, it is first visible generally on the lower surface as small yellowish spots. The lesions with age become brown, corky and hard. They are circular when young and become irregular when old. The size of the lesions varies with the species of the host attacked and the conditions prevailing during the disease development period. The lesions, which are scattered in the beginning join up later on. The canker spots are similar on twigs and fruits which become dry and disfigured (Fig. 14.3).

Causal Organism and Pathogenicity

The disease has been found to be caused by a bacterium called *Xanthomonas citri*, which is carried over through infected plant parts. The following citrus varieties have been found to be infected by the disease in the descending order of incidence *Kaghzi* and sweet lime (*Citrus aurantifolia*), Grape fruit (*C. paradisi*) and Malta orange (*C. sinesis*). However, mandarin (*C. nobilis* var *deliciosa*) is not attacked.

*Recently changed to *Xanthomones campestris pv citri.*

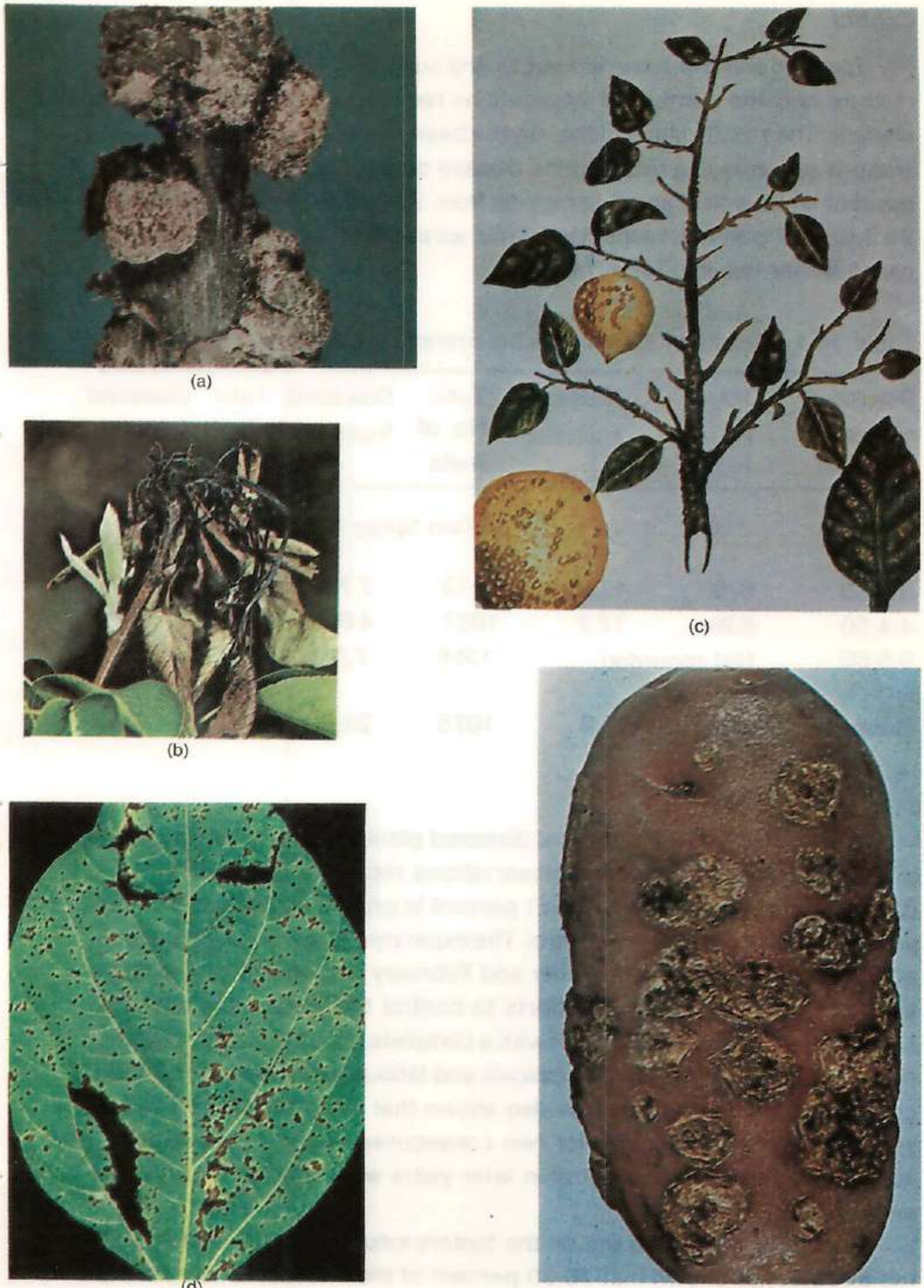

Fig 14.3: (a) Crown gall, (b) Fire blight, (c) Citrus canker, (d) Bacterial blight of legume. (e) Potato scab.

Control

Experiments were carried out to find suitable strengths of Bordeaux mixture and the number of applications required for the control of the disease. The results showed that on the basis of average of three concentrations one spraying reduced the disease on the fruits from 27.9 to 17.2 percent while with 2 and 3 sprayings from 24.8 to 6.7 percent and from 25.2 to 10.7 percent, respectively, two sprays with 4:4:50 concentration giving better results (Table 14.1).

Table 14.1: Results of spraying experiments

Bordeaux mixture Strength	Total No. of fruits	Diseased fruits(%)	Total No. of fruits	Diseased fruits(%)	Total fruits(%)	diseased fruits(%)
	One Spray		Two Sprays		Three Sprays	
3:3:50	879	17.2	913	7.7	2300	13.2
4:4:50	836	17.2	1027	4.8	3578	8.2
5:5:50	Not recorded		1365	7.8	2477	10.8
Control	645	27.9	1075	24.8	2120	25.2

In later studies the pruning of diseased plant parts was also included in the spraying schedule. The observations recorded showed that the disease was reduced to less than 1 percent in pruned and sprayed plants as against 25 percent in the control. The experiments also proved that one additional spray during December and February helped in further reducing the amount of infection. Efforts to control the disease on affected *kaghzi* lemon plants did not meet with a complete success. The calculated cost of operations including chemicals and labour indicated high benefit: cost effectivity. Experience has also shown that if the infected trees are sprayed four times annually for two consecutive years, it is possible to keep the disease under control in later years with only two sprays per annum.

Recent work, carried out on the factors influencing the incidence of the disease, has shown that 70-90 percent of the infection occurs in the rainy months of July and August. Thus, the spraying of the plants in the rainy months is helpful in controlling the disease. To avoid the removal of the spraying material by rains, rosin is added to Bordeaux mixture. Two lbs.

of rosin and 1 lb of washing soda are thoroughly boiled in 1 gallon of water till the rosin is dissolved. This solution is then added to 25 gallons of Bordeaux mixture. The latest experiments have indicated that spraying with Streptomycin mixed in water can effectively control the disease. The antibiotic approach for the control of bacterial diseases is worth exploring because it will be cheaper and more practical.

11. Bacterial Leaf Spot of Mango – *Erwinia mangiferae* (Doidge) Bergey et al.

Symptoms

The disease appears on mango leaves after the monsoon rains in September, producing water-soaked spots, which later on turn dark brown and blackish in colour and are bounded by veins and veinlets of the leaf. With aging, bacterial exudate starts depositing on the necrotic portions, which become some what raised, hard and corky surrounded by clear haloes. Petioles are also sometimes infected developing longitudinal cracks.

Pathogen

The disease was recorded for the first time in 1961 in Sind. Some studies have been carried out on the pathogen including its nutritional requirements, pathogenicity and morphological characters. The results have shown that the pathogen (a bacterium) is a wound parasite having optimum growth temperature of 35°C with thermal death point at 55°C (which is 5° lower than that reported by Elliot). The bacterium is gram negative, measuring 1.5-2.0 x 0.4-0.6 μ. It is mostly single celled and rarely 2-3 celled occurring in chains. It is non-sporing, non-capsulated and motile with peritrichous flagella. It forms mucoid yellowish round colonies on nutrient agar with undulated, smooth, glistening and raised margins. It prefers ammonia as a source of nitrogen and sucrose as a source of carbon. It is aerobic to micro-aerophilic and grows well on pH range of 4.4 to 6.8 with no growth at pH 3.6. The pathogen has been identified and its identity confirmed by the Commonwealth Mycological Institute, Kew, England as *Erwinia mangiferae* and not *Pseudomonas mangiferae* as reported by Patel et al. from India.

No work has been done on factors affecting the spread of the disease, its incidence and varietal reaction.

Control

Since the causal bacterium is a wound parasite, all efforts should be made to minimize chances of injuries. Destruction of diseased plant debris will help to get rid of the primary source of infection while spraying with 4:4:50 Bordeaux mixture or any other suitable copper-based fungicide will reduce the chances of secondary infection and spread of the disease. Spraying with Streptomycin or other appropriate antibiotics may also prove useful. Work needs to be done on bactericidal antibiotics.

Some Minor Bacterial Diseases

A. Bacterial Blight of Legumes – *Xanthomonas phaseoli* (E.F.Sm)Dows*

Bacterial blight is frequently observed in several summer legumes including mung beans and cowpeas. However, detailed investigations and yield losses from field infections have not been made. The initial symptoms of bacterial blight are the development of tiny, water-soaked spots on leaves. With the death of surrounding tissue, tan to orange colouration develops. Under heavy conditions of infection, dead spots emerge and large areas of leaf are affected including stems, which develop cracking (Fig. 14.3)

The disease spreads rapidly during warm and heavy rainy periods. High disease incidence is generally attributed to seed-borne infection and inadequate cultural practices like suitable rotation and clean culture. Control measures include use of clean and healthy seed, destruction of diseased plant debris, rotation with non-host plants and cultivation of resistant or tolerant varieties, if available.

B. Potato Scab – *Streptomyces scabies* (Thaxt.) Waks. and Henrici

The disease is prevalent in Murree, Balakot and Kaghan hills where the soils have acidic reaction and causes substantial losses due to blemishing of tubers with subsequent reduction in commercial value.

There are two types of scabs i.e. shallow or superficial and deep. Shallow scab consists of corky tissues which arise from abnormal proliferation of cells of the periderm layer of tubers. Deep scab or pitted scab comprises of lesions, which are 1-3 mm deep and are darker than those of shal-

*Recently changed to *Xanthomones campestris pv. phaseoli* low scab. The pathogen inciting scab (*Streptomyces scabies*) survives in the soil for an indefinite period under favourable conditions. Young potato tubers are comparatively more susceptible than the matured ones. Potato varieties with thick or russet skin have shown higher degree of susceptibility than the smooth-skinned varieties like Cardinal, Desiree and Favourita. It has not been possible to achieve complete control of potato scab. However, preventive measures can help in reducing the introduction and amount of inoculum. Tuber treatment with mercuric chloride (0.1 percent) or 5 percent formaldehyde have also proved to be effective.

C. Stalk Rot of Corn – *Erwinia carotovora* f.sp. Zeae Sabet

Although stalk rot of corn is a complex problem caused by a number of fungi, a bacterial pathogen (*E. carotovora* f. sp. *zeae*) has also been found to be associated with the disease. The disease is favoured by high temperature (30°-35°C) and prolonged wet conditions. Bacteria are also blown or splashed on to the plants where they enter through hydathodes, stomates or wounds. Affected plants fall down on the ground with collapsed and twisted stalks. Vascular strands of the stalks are slowly decomposed. The affected nodes turn dark brown to black in colour and become water-soaked, soft and slimy giving out a disagreeable odour. There is no satisfactory control of the stalk rot except the use of resistant hybrids.

D. Bacterial Specks of Tomato – *Pseudomonas syringae* Van Hall

The disease is found in traces in some localities. Light yellow necrotic spots of varying size without water-soaked haloes occur on leaves. Marginal chlorosis is also observed. Fruits show various colourations. The causal pathogen (*P. syringae*) over-winters in infected residues. Control measures include use of fungicide - treated seed, removal of diseased plant debris and practising of suitable crop rotations.

E. Bacterial Blight of Beans – *Xanthomonas phaseoli* (E.F.Smith) Dowson

Inoculations of unifoliate or trifoliate leaves of dwarf beans (*Phaseolus vulgaris*) with *Xanthomonas phaseoli* have produced necrosis, with severe effects of partial wilting at cotyledonary stage due to reduction in water supply nutrients and photosynthates. Damage is greater at high infection intensity and in the early stage of crop growth Studies carried out on the distribution of 14C - labelled assimilates have shown marked effects on systemically infected plants (in comparison to localized infections) due to modified source-sink relationships because of the interference of vascular function in such plants. *Fusarium* root rot caused by *F. solani* has also been reported but no work has been done on this disease.

F. Bacterial Leaf Spot of Pepper – (*Xanthomonas campestris* pv *vesicatoria*)

Recently two isolates namely XCV1 and XCV2 have been isolated at NARC, Islamabad from bell pepper and ornamental pepper, respectively; XCV1 producing more copious yellow salime on yeast extract dextrose $CaCo_3$ medium (YDC) at 25°C after 48 hour incubation. The cultures have been found to be pathogenic in cross inoculations to both the hosts, giving hypersensitive reactions in tobacco plants but are similar biochemically and physiologically. Disease becomes serious during humid period of monsoons.

Summary

After describing the three types of diseases (vascular, parenchyatous and hyperplastic) caused by bacteria, which are usually wound parasites disseminated through water, insects, seeds, plant parts and farm implements, a brief account of 11 major and 6 minor diseases has been given.

In case of each disease its importance, symptoms, pathogen and control measures have been described. Out of them spike blight of wheat (*Corynebacterium tritici*), bacterial blight of rice (*Xanthomonas oryzae*), cotton blight (*Xanthomonas malvacearum*) and brown rot of potatoes (*Pseudomonas solanacearum*), are seed-borne in addition to soil-borne while red blight of sugarcane (*Xanthomonas rubriieans*), soft rot of vegetables (*Erwinia* spp.), crown gall (*Agrobacterium tumefaciens*), fire blight (*Erwinia amylovora*), citrus canker (*Xanthomonas citri*) and bacterial leaf spot of mango (*Erwinia mangiferae*) are carried over through soil and/or diseased plant debris, usually attacking the hosts through wounds, bruises or injuries including stomatas, hydathodes and in certain cases through roots. Mostly the bacterial diseases are favoured by high temperatures and humidities. In the absence of resistant varieties, careful cultural operations avoiding wounds and injuries, sanitary measures comprising destruction of diseased plant parts or debris are recommended for the control of bacterial diseases. Spraying with a bactericidal chemicals has also proved useful in some diseases such as citrus canker and mango leaf spot. However, investigations in this specialized field need to be strnegthened and improved by establishing a well-equipped and staffed research unit in the country. This unit should also take up studies on the production and use of antibiotics as well as on the production of rhizobium cultures for the selected legume crops.

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Diseases Caused by Viruses

Despite over fifty years of recorded occurrence of virus or virus-like diseases on some cultivated crops in the area now constituting Pakistan, very little systematic study has been carried out till recently. Field observations were initiated on sugarcane mosaic virus, potato viruses and leaf curl viruses during the pre-partition period. Since the creation of Pakistan, about 20 virus diseases have been reported from different regions, mainly based on symptom expression under natural field conditions.Research work on plant viruses has not been undertaken in a systematic way due to dearth of trained and qualified manpower in the universities and the research organizations, non-availability of appropriate and adequate laboratory facilities, and underestimation of the magnitude of losses caused by these diseases. In fact, none of virus diseases has been studied thoroughly with respect to symptomatology, host range, transmission and biological properties as well as control measures. This scientific negligence has resulted in (i) continuous spread of virus diseases through various agencies, (ii) build up of inoculum potential and development of severe virus strains, (iii) increase in population of viruliferous vectors (aphids, whiteflies and hoppers), (iv) progressive decline in yield and quality of produce and (v) gradual deterioration and degeneration of crop varieties especially those grown vegetatively.

Present Status of Virus Diseases

Virus diseases are prevalent and widely distributed in many field crops, vegetables, fruit plants and ornamentals throughout the country. A

*Contributed by Dr. S. M. Moghal, Coordinator Plant Virology, PARC, Islamabad.

casual survey of sugarcane, potato and tomato fields can reveal the occurrence of a large number of virus diseases showing manifold symptoms mostly of complex nature. It is not an exaggeration to state that in crops like sugarcane, tomato and tobacco, even one healthy plant may hardly be traced.

Virus diseases like fungal pathogens are often serious with regard to their intensity and nature of damage. Indeed, substantial and quantitative information on the extent of virus diseases loss is not yet available. However, normal losses due to virus diseases can be roughly estimated at 10-15 percent of the potential yields and may go as high as 50-70 percent under severe conditions of infection in certain crops.

Beginning of Research on Plant Viruses

The Governments of Sind and the Punjab provided a small staff and limited facilities at Tandojam and Lyallpur (Faisalabad) in 1965 to study virus diseases. A full-fledged section of Plant Virology was established in 1973 at the Ayub Agricultural Research Institute, Lyallpur (Faisalabad). Work was initially confined to surveys and distribution of virus diseases followed by studies on host range, symptomatology, epidemiology, transmission, insect vectors and control measures. Virus diseases of sugarcane, potato and tomato received more attention than others.

The importance of virology was further emphasised by the Pakistan Government in the fourth and fifth 5-year plans and later on in the tenth meeting of the Pakistan Agricultural Research Council, in 1981. As a result of these recommendations, a Plant Virus Research Laboratory has been established at the NARC, Islamabad. In collaboration with virology units at Tandojam, Faisalabad and other suitable places, NARC will carry out scientific studies on problems relating to virus diseases. The knowledge in plant virology has grown rapidly and remarkably in the advanced countries of the world and it is hoped that with continuous and strenuous efforts in Pakistan it will be possible to save agricultural crops from the ravages of this important group of pathogens.

Review of Work

The work so far carried out on different aspects of viral diseases in the country is summarized below under six groups of viruses (Mosaics; Yellows; Leaf Curls; Leaf Rolls and Chlorotic Streaks) including miscellaneous.

A. Mosaic Viruses

1. Sugarcane Mosaic Virus (SCMV)

Occurrence

The sugarcane mosaic virus was recorded for the first time in the Punjab during 1926-27, which happened to be an epidemic year. There is strong evidence that the disease was originally introduced through two susceptible varieties i.e., P.O.J 213 and Java 213 from Java, where it had been reported as early as in 1892. It is also suspected that spread of sugarcane mosaic in other parts of India was from Lyallpur (Faisalabad) through Co-223-a highly susceptible variety - (Mc Rae and Subramanian, 1968). At present, SCMV is prevalent and distributed in all the cane growing areas of Pakistan.

Dean (1974) after surveying the sugarcane crop in Pakistan has reported that practically every shoot of commercial cane in Pakistan is infected with SCMV. Only two varieties viz; CP-48-143 and PR-1000 showed a little less than 100 percent infection at a few places.

Losses

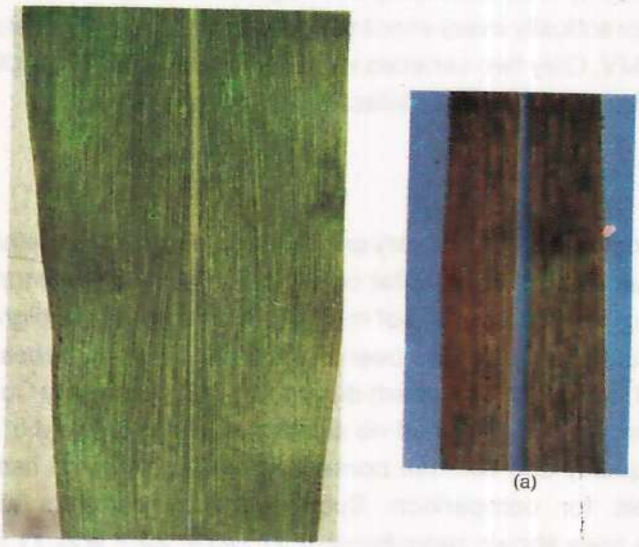
Losses caused by SCMV vary greatly and depend on varietal reaction, strain of virus and environmental conditions affecting symptom expression, growth of plants and rate of multiplication of virus. As high as 30-40 percent reduction in yield has been reported from many areas. Field experiments at Lyallpur (Faisalabad) during 1930-33 on variety Co. 223 indicated that ordinary mosaic had no significant effect on yield of cane and juice, juice quality and sucrose content; most probably no healthy cane was available for comparison. Subsequent experiments at Lyallpur (Faisalabad) have shown reductions of 27, 25.9, 29.1 and 11 percent in case of stripped cane, jaggery, juice, and sucrose, respectively. In the absence of biological and serological confirmation of virus status, these losses appear to be comparatively high. According to Dean (1974), Pakistan cultivars usually show mild symptoms with crop losses ranging from 1-3 percent but causing heavy damage on total acreage basis.

Symptoms

The characteristic symptom of the disease is mottling of the young crown leaves showing a definite pattern of alternating dark and light green coloured patches, becoming progressively fainter with age of the leaves. The patches are of varying size and run parallel to the midrib of the leaf while the infection intensity varies with the variety, season and the virus strain. The disease symptoms may appear early in some varieties and late in others and in still others they may disappear soon. The length of time and extent of chlorophyll destruction determine the severity of damage caused by the disease. (Figure 15.1).

Cause

The disease is caused by a virus belonging to the potyvirus group. The



(b) (a)

Fig. 15.1: (a) Mosaic in sugarcane; (b) Propagation of ScMV in Sweet Corn.

virus particles are flexuous rods measuring 750nm x 15 nm, with 60°C thermal inactivation point, 1×10^{-2} - 1×10^{-4} as dilution end point, and longevity in vitro for 12-18 hours at 25°C.

Host range of SCMV is restricted to a few members of Gramineae. The virus is propagated in sweet corn (*Zea mays*) (Fig. 15.1) and sorghum (*Sorghum bicolor*). In the infected cells it induces the formation of inclusion bodies, pinwheels, bundles, laminated aggregates or loops. The virus has been detected with imported antisera as well as by electron micros. (Fig. 15.2).

Fig. 15.2: Electron micrograph of ScMV.

Transmission

The disease has been found to be transmitted through mosaic infected setts and it continues spreading in the field, most probably through aphids (which has not been studied experimentally). There is so far no evidence of seed transmission of the mosaic.

Control

Use of virus-free sugarcane setts is a satisfactory method of combating the disease. It is possible to raise a nursery from disease-free setts and use it for planting over a period of 3-5 years by controlling the recontamination.

Successful attempts have been made at Lyallpur (Faisalabad) to free setts of Triton from ScMV by serial thermotherapy consisting of four, 7-10 minutes heat treatments at 55, 56.5, 57.5 and 57.5°C each at 24-hour interval. Plants raised from the virus-free setts are comparatively taller and have greater length of internodes and more weight.

Varietal resistance may prove to be of practical value if work is concentrated on identification of strain of ScMV and varietal screening carried out under artificial conditions of inoculation.

2. Potato Virus Y (PVY)

Occurrence

The disease has been present in the Punjab and NWFP since 1944 on the two cultivated varieties of Katwa and Phulwa, showing milder symptoms. With the introduction of severe strains of PVY through the imported European seeds the disease spreaded in all the provinces and its incidence now ranges from 1.5-5.7 percent, being greater in the Punjab. At present it is the second major potato disease depressing the yield considerably depending upon the nature of virus strains. It can destroy the entire crop if it occurs along with potato virus X and potato virus S. In Sind the leaf drop streak strain has been found to retard the entire plant growth as well as the size and yield of tubers by about 40 percent, besides rendering the crop more susceptible to *Alternaria* blight and *Fusarium* wilt.

Symptoms

The symptoms are variable depending upon the variety and strain of virus, ranging from weak mosaic to severe necrosis and even to plant kill. Initially, mild mosaic appears followed by rugosity, severe mosaic and crinkling and veinal necrosis resulting into collapsing and dropping down of older leaves. The infected crops can be easily recognized in the field and give much reduced yield (Fig. 15.3).

Fig. 15.3: Potato plants infected with potato virus.

Pathogen

The virus causing the disease has long flexuous particles measuring 750 nm with 56°-64°C as thermal inactivation point, 1×10^{-2} - 1×10^{-3} as dilution end point and longevity in vitro for 24 hours at 25°C. It can retain infectivity at pH 3-11 with optimum being 7-8.5 for 24 hours at room temperature.

Host range of PVY is restricted to tobacco, *Nicotiana tabacum, N. glutinosa* and *N. clevelandii*, tomato - *Lycopersicum esculentum* and chillies - *Capsicum frutescens* while localized lesions are found on *Chenopodium* spp.; *Datura stramonium* being immune to PVY. The virus reaches maximum concentration in tobacco plant 15 days after inoculation. The virus could be partially purified by homogenizing infected tissue in 0.5 M borate buffer, pH 8.1, containing 1.5 percent thioglycollic acid and choloroform (1 gm: 1 ml:1 ml) followed by two cycles of differential centrifugations. (Fig. 15.4).

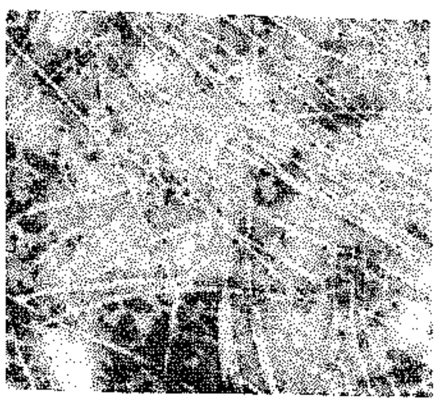


Fig. 15.4: Electron Micrograph of Potato virus y.

Transmission

Virus can be transmitted through the sap extracted from the infected plant parts and by grafting while the natural spread occurs through aphids; *Myzus persicae* being an effective vector. The virus is transmitted in a non-persistant manner.

Control

Use of resistant varieties is the most economical way of controlling the disease. Out of the present cultivars none is resistant but Desiree, Patrones and Vekaro are comparatively less susceptible.

Use of virus-free seed provides best control while the spread of the disease can be partially checked by controlling aphids through systemic insecticides.

3. Potato Virus X (PVX)

Occurrence

The disease, also known as simple, mild or common mosaic, is distributed throughout Pakistan as indicated by 1980 survey on five potato varieties (Ultimus, Patrones, Multa, Spunta and Cardinal) ranging between 1.5-6.2 percent, being more in Punjab. Even imported seeds have shown 0.7-3.8 percent infection indicating its continuous introduction in the country. Initially from its mild status, the disease has now become a potential danger with the detection of severe strains of PVX (which can reduce the yield by more than 10 percent). Due to high aphid activity multiple infections with PVY and PVA can prove more harmful than single strain infections of PVX.

Symptoms

The type of symptoms depend on the cultivars, nature of the virus and environmental conditions. Most of the varieties are simple carriers of PVX; some showing mild mosaic (scarcely visible on upper and older leaves) but interveinal mosaic is a common symptom. Virulent strains may cause rugosity and sometimes top necrosis. However, affected plants produce a small number of small-sized tubers (Fig. 15.5).

Pathogen

The disease is caused by virus X (PVX) which can be detected on indicator plants like *Nicotiana tabacum* (White Burley) and *Datura stramonium* (which are infected systemically). It can also produce local lesions on *Gomphrena globosa*. The virus has been confirmed with the help of imported antisera. Attempts made to produce virus X-free tubers by treating nodal segments, growing tips or sprout discs from infected tubers with antiviral chemicals like thiouracil and malachite green (incorporated in medium or used as a dip) arrested the virus multiplication and its infective capacity to produce disease symptom on an indicator plant of *G. globosa*.

Transmission

The disease mainly develops through infected seed tubers and spread by contact while the aphids do not play any part.

(a)

(b)

Fig. 15.5: Symptoms of PVX in (a) Potato plants and (b) Datura plant.

Control

The disease can be controlled by using virus-free seed tubers, certified by the Virological Station. Roguing of the infected plants without touching the healthy ones can help in reducing the spread and damaging effects of the disease.

4. Calico Virus of Potato (AMV)

The disease has been reported from the Punjab only in the imported seed in 1978, but on the whole it is not so widely distributed as other viruses. It is caused by a strain of alfalfa mosaic virus (AMV) and can be artificially transmitted to potato and several indicator plants by mechanical inoculation and by aphids (*Myzus persicae*) in nature. It produces large yellow spots on leaves, which when severely infected turn chlorotic and develop black necrotic lesions. The virus can also infect *Phaseolus vulgaris*, producing characteristic symptoms of reddish brown local lesions on the leaves, and *Vicia faba* with characteristic blackening of the leaves and stems. While *Nicotiana tabacum* is infected systemically (Fig. 15.6)

Fig. 15.6: Calico virus in potato.

5. Potato Virus A (PVA)

The disease occurs in the Punjab with noticeable incidence, producing mild symptoms and showing irregular mosaic patches of green and dark green colour while in some varieties it produced typical veinal mosaic. The infected leaves look shiny with crinkled margins, particularly when the virus is mixed with PVX strain. The virus can infect *Nicotiana* spp. producing vein clearing, followed by mottling and vein banding. It develops dark lesions on the leaves of A6 plant which is a cross of *Solanum demissum* X *Solanum tuberosum*. Its host range is limited and the aphid (*Myzus persicae*) is mainly responsible for the spread of the disease.

6. Potato Virus S (PVS)

The disease is reported to occur in the Punjab,but it does not seem to be widespread on the commercial varieties. The presence of PVS has been identified on the basis of symptomatology and its reaction on differential hosts and on serology tests.

Typical symptoms include deepening of veins on upper surface of leaves, rugosity and roughness of leaf surface and slight mottling and faint banding of veins. Sensitive varieties turn bronze and may develop necrotic spots. Symptoms are conspicuous only under cloudy weather. The virus has a narrow host range. It develops local lesions on *Chenopodium quinoa*, *C. amaranticolor* and *Gomphrena globosa* while it causes vein clearing and vein banding on *Nicotiana debneyi*, which is a good indicator plant for PVS. It does not infect *Nicotiana tabacum*, *N. glutinosa* and *Lycopersicum esculentum* (Fig. 15.7).

Fig. 15.7: Potato virus S.

7. Cucumber Mosaic Virus (CMV)

Occurrence

Cucumber mosaic virus has been detected on chillies and tomato in the Punjab, on virginia tobacco in NWFP and on bottle gourd and other cucurbits in Sind. The presence of this virus is expected throughout Pakistan because of its wide host range and transmissibility through aphids under natural conditions.

Symptoms

Affected plants develop conspicuous mosaic pattern of dark green and yellow areas on the foliage and the symptoms tend to disappear during warm weather. Diseased tomato plants usually produce filiform leaves while deformed fruits are commonly found in cucumber.

Transmission

The disease is sap transmissible by mechanical inoculation and natural spread takes place through aphids (*Myzus persicae*) in non-persistant manner. No work has been done on host range and physico-chemical properties of the virus while none of the tested varieties of chillies and tomato has shown any resistance against the disease.

8. Tomato Mosaic Virus (TMV, ToMV)

Occurrence

The virus which is a strain of tobacco mosaic virus is present throughout Pakistan, sometimes assuming epiphytotic conditions and causing heavy losses even upto 50 percent.

Symptoms

The infected plants are stunted in growth with young leaves remaining small and dwarf becoming crinkled, turning pale yellow to light green in colour and are commonly distorted. The diseased plants produce a few but small fruits, which may also show mottling. The extent of damage depends upon disease intensity which is influenced by temperature, stage of infection, virus strain and tomato cultivars (Fig. 15.8).

Pathogen

The disease is caused by a virus, which is resistant to adverse conditions and can remain infectious over a long period.

The virus has been detected in Sind and Punjab and can infect several indicator plants like *Nicotiana tabacum*, *Chenopodium amaranticolor*, *C. album*, *Lycopersicon esculentum* and *Capsicum frutescens* producing characteristic viral symptoms. It has also been confirmed by serological tests. Virus remain infectious at dilutions between 1×10^{-4} to $1\text{-}10^{-5}$ with thermal inactivation point at 70°-75°C and longevity in *vitro* for 4 days at 25°C (Fig. 15.9,10,11).

Fig. 15.8: Tomato plant infected with tobacco mosaic virus.

Fig. 15.9: Masaic symptoms in tobaco caused by TMV.

Transmission

Preliminary work done in Sind has shown that the virus is seed-borne, producing upto 60 percent infection in seedlings and has also been detected from imported seeds (15 percent) and upto 70 percent in seeds obtained from diseased plants and 20 percent in seeds from apparently healthy plants. The infection spreads through seedlings during transplantation, manual handling and contact with contaminated soil and farm implements.

Control

Cultivation of resistant varieties is the best method of controlling the disease. Out of 30 cultivars screened at Lyallpur (Faisalabad) none has shown resistance.

Seed treatment through 15-20 minutes soaking in 10 percent H_3PO_4 solution can get rid of surface contamination while for elimination of inter-nal infection seed is heated at 70°C for 2-3 days.

Phytosanitary measures like clean cultivation, avoiding manual con-tamination and rogueing of infected plants can help in reducing the disease incidence.

Fig. 15.10: Necrotic reaction of TMV in *Nicotiana glutinosa*

9. Papaya Mosaic Virus (Pa MV and Pa RSY)

Occurrence

This disease of papaya, first recorded in Sind during 1972 has now been experimentally found to be caused by a virus. It has been increasing progressively and produces as high as 20-30 percent infection at present.

Symptoms

The disease makes its first appearance on about 6-month old plants in the field. Initially, young leaves show vein clearing followed by crinkling, rolling, blistering and distortion. Old leaves develop yellow spots. On the whole the affected plants remain stunted in growth, producing fewer leaves of reduced size and small-sized or deformed fruits. The virus has been found to infect *Nicotiana tabacum, Cucumis sativus, Glycine max, Chenopodium quinoa, Vigna sinensis* and *Phaseolus vulgaris*, producing more or less similar symptoms (Fig. 15.12).

Fig. 15.11: Electron micrograph of TMV (80,000X)

Transmission:

The virus is sap-transmissible and can produce typical symptoms in young seedlings in 15 days after inoculation. The virus is inactivated at 55°C in 10 minutes or after 3 days storage at 25°C and can stand dilution of 1×10^{-3}, remaining infective at pH ranging between 3.7-9; optimum pH being 7.5. It shows flexuous type of virus particles in leaf dip preparations under an electron microscope. The virus resembles that of papaya ring-spot on the basis of its physical and biological properties.

Control:

In the absence of resistant varieties, eradication and destruction of infected papaya plants and other alternate hosts may help to keep the disease under check.

10. Mosaic of Cowpea (CPMV)

The disease was first observed at Lyallpur (Faisalabad) in 1942, affecting cowpeas grown mixed with cotton showing three types of symptoms (a) stunting of upper parts with thick foliage, vein clearing, mottling and alternating areas of dark and light green colour and sometimes presence of raised blister-like undulations, (b) foliage chlorosis and distortion and (c) conspicuous mottling with pale to vivid yellow areas finally turning into reddish brown spots (Fig. 15.13).

Anatomical studies have revealed advanced fusion of epidermis with cuticle, paucity of palisade and chloroplasts, discontinuous and irregular tissue thickening and elongation of xylem vessels and spongy sclerenchyma and disorganized vascular bundles.

Later studies, have shown the presence of the virus which is found to be seed-borne, sap and aphid transmissible and can also infect other legume crops. Successful transmission by the cowpea aphid (*Aphis craccivora*) was done at Lyallpur (Faisalabad) in 1979.

Fig. 15.12: Symptoms of papaya mosaic virus.

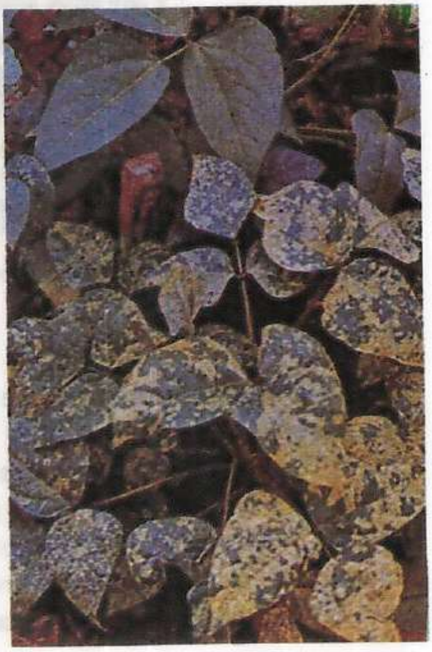


Fig. 15.13: Symptoms of mosaic in cowpeas.

B. Yellow Viruses

1. Yellow Mosaic of Soybean

Occurrence

Soybean in the Punjab and Sind suffers from a yellow mosaic disease, which is sporadic in nature usually causing inappreciable damage except in years of high temperatures and humidity. The disease is a limiting factor in the cultivation of soybean in the Punjab as a summer crop.

Symptoms

Affected plants develop typical yellow patches on leaves which turn chlorotic to brownish, remain stunted in growth and do not flower in case of early infections.

Transmission

The virus is not transmissible by sap but it spreads in the field through white fly (*Bemisia tabaci*). It can also produce similar symptoms on mung (*Phaseolus mungo*) and moth (*Phaseolus actinofolius*). The identity of the virus has not been confirmed so far.
Out of 111 soybean lines, none has shown any resistance to the virus.

2. Yellow Mosaic of Cowpea

Occurrence and Symptoms

The disease is widely distributed in the Punjab and Sind on almost all the cultivars grown in the region. It is characterized by the appearance of irregular, bright yellow patches over the laminae of leaflets which in severe cases turn yellow and the disease continues appearing on new growths. The pods also develop yellow mottling. High temperatures are conducive to the development of severe infections.

Transmission

The disease cannot be transmitted through sap, seed, soil or nematodes but by grafting and through whitefly (*Bemisia tabaci*) and it appears to be distinct from yellow disease of mung beans (*Phaseolus mungo*).

3. Yellow Mosaic Virus of Jute

Occurrence and Symptoms

The disease was first time recorded in 1978 on Jute (*Corchorus capsularis*) crop in the Punjab, occurring from May to September. The symptoms develop on young leaves showing conspicuous light yellow mottling followed by bright yellow irregular areas interspaced with green. The early sown crop is less affected because of its advanced growth before the appearance of the disease.

Transmission

The virus is transmitted through grafting and whitefly (*Bemisia tabaci*) and not transmitted by mechanical means, dodder, seeds, soil or nematodes. Whitefly acquires virus in 3-hr feeding period and the symptoms develop in 20-25 days after inoculation feeding. It cannot be transferred to *Corchorus olitorius*. Viruses of wild jute (*Corchorus tricularis*) and beans have failed to produce symptoms in cross inoculations. The virus survives on off-season host plants.

4. Yellow Mosaic of Mung

Occurrence and Symptoms

The disease is present throughout the country on mung (*Phaseolus mungo*) crop in varying intensities. It develops broad and bright yellow scattered patches on the foliage, coalescing to form larger yellow areas and later on turning chlorotic and whitish in appearance. The damage caused depends upon the intensity and severity of symptoms.

Transmission

The virus is transmitted through grafting and whitefly (*Bemisia tabaci*) and is not transmissible by mechanical means, seeds, soil, dodder or nematodes. The virus can also infect mash (*Phaseolus aureus*), moth (*Phaseolus actinofolius*) and soybean (*Glycine max*). Some varieties of mung have shown partial resistance.

5. Yellow Vein Mosaic of Okra (OYVM)

Occurrence

It is an important disease of okra or bhindi(*Hibiscus esculentus*)found throughout Pakistan in various intensities, causing considerable damage ranging as high as 25 percent in Sind.

Symptoms

The disease can appear in all stages of plants showing vein clearing followed by development of irregular yellow green to plae green areas on leaves, which are reduced in size. The petioles are shortened, flowering is sparse and the fruits are limited in number and size. Severity of symptoms is generally associated with stage of infection and population of vector.

Transmission

Roguing of diseased plants and eradication of malvaceous weeds can greatly help to check the spread of the disease. Control of whitefly through insecticidal spraying can protect the crop, if done by all the farmers.

C. Leaf Curl Viruses

1. Leaf Curl Virus of Tobacco (TLCV)

Occurrence

The disease is found throughout Pakistan mainly in Sind and is responsible for limiting the cultivation of cigarette tobacco in the province. It is highly destructive disease and can wipe out entire crop in case of severe infections. The extent of damage varies with the vector population which increases in summer, falls down in winter and again starts increasing in spring.

Symptoms

The disease may appear in the nursery beds but it mainly develops after transplantation. General symptoms include reduction in leaf surface and size, vein banding, thickening and curling of leaves which become dark green in colour and brittle in texture. Additional symptoms are condensation of inflorescence, abnormal opening of flowers and overall dwarfing of the plants. The yield is reduced and the produce is of low quality and unfit for curing.

Pathogen

Although the disease is presumed to be caused by tobacco leaf curl virus, the expression of varied symptoms indicate combination of many strains of virus infecting several hosts belonging to family Solanaceae. No special studies have been made to identify the exact nature of the pathogen(s).

Transmissin

The disease is transmitted by grafting as well as by dodder but not by seed, sap or soil. In nature it is transmitted and quickly spreads by whitefly (*Bemisia tabaci*), which has proved to be an efficient vector even at low populations. The vector can acquire the virus in 1-2 hours feeding and reproduces symptoms in healthy plants in 25 days after inoculation feeding. The vector population build-up is quite persistent except in winter and therefore makes its eradication difficult.

Control

As no resistant varieties of tobacco are available, only the alternate control measures can be practised. These include roguing of infected plants, eradication of volunteer tobacco plants and alternate Solanaceous hosts and control of whitefly through repeated chemical sprays.

2. Leaf Curl of Tomato (TLCV)

Occurrence

It is one of the major disease of tomato and is distributed throughout the country in varying intensities. Its high incidence limits the tomato cultivation in the provinces of Sind and the Punjab. The damaging effects of the disease are quite high, depending upon the time and the degree of infection.

Symptoms

The disease shows a variety of symptoms comprising curling, rolling and puckering of leaves, vein clearing, branching and partial to complete sterility of flowers. On the whole plants remain underdeveloped and fruit setting is greatly reduced; with greater losses in cases of early infections (Fig. 15.14).

Fig. 15.4: Tomato plant infected with leaf curl virus.

Pathogen

The disease causing pathogen is a virus which has small isometric particles measuring 15-20 nm in diameter. No studies have been carried out on physical and biological characteristics of the virus.

Transmission

Except grafting, the other attempts to produce the disease through sap, seed, soil or nematodes have failed. In nature the disease is transmitted through whitefly (*Bemisia tabaci*), which is present throughout the year on various host plants (tobacco, chillies and other solanaceous plants). The vector can acquire virus in 2-hour feeding and produces infection in 24 days after inoculation feeding of 24 hours (Fig. 15.15).

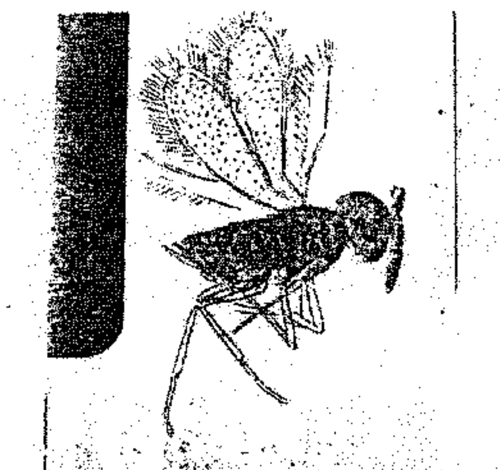


Fig. 15.15: White fly vector of leaf curl virus.

Control

Raising of protected nursery under muslin cloth can provide healthy plants for transplantation. Early roguing of infected plants can help in removing foci of infection and checking the spread of the disease. Early rogueing followed by chemical sprays to eradicate whitefly are helpful in achieving effective control of the disease. First spray with Anthio 25 percent EC at 1/2 litre in 50 gallons of water and subsequent two sprays with Orthene 75 percent W.P (300-400 g/20-25 gallons of water) have given good results. No spraying should be done 25 days before fruit picking.

3. Leaf Curl of Papaya (PLCV)

Occurrence

The disease has been reported from the papaya growing areas of Karachi and Hyderabad divisions in various intensities averaging 20-30 percent incidence. It is steadily increasing and threatening the cultivation of papya due to persistent and heavy losses caused to the plantations.

Symptoms

The initial symptoms appear on the leaves which comprise curling, crinkling, vein clearing, thickening, reduction in size and distortion. Later on, the leaf margins are inwardly rolled down becoming leathery and brittle in texture with interveinal areas showing rugosity due to hypertrophy. On the whole the affected plants show arrested growth and either fail to flower and fruit or produce deformed fruits (Fig. 15.16).

Fig. 15.16: Leaf curl of papaya

Transmission

No systematic work has been done on the modes of transmission except that the disease is transmissible through whitefly (*Bemisia tabaci*) under natural conditions. However, the studies carried out in India have shown that the virus is transmissible through sap, grafting, nematodes and whitefly. The causal agent has been identified as tobacco leaf curl virus, transmissible to white Burley tobacco. Similar symptoms are produced in crop growing in waterlogged areas, independent of virus infection.

Control

In the absence of resistant varieties, eradication and destruction of infected plants combined with other sanitary measures and control of whitefly through chemical sprays are the only possible means of keeping the disease under check.

4. Leaf Curl of Cotton

Occurrence

The disease was first recorded in 1967 at Multan and was not reported from other places by that time. Later on, it has been spreading in the Punjab and increasing in intensity steadily and now causes substantial losses in the form of a reduced number of effective bolls.

Symptoms

The extent of damage depends upon the time of infection and population of whitefly, which acts as a vector for the virus. The symptoms comprise twisting, elongation and deformation of leaves accompanied by vein clearing and necrosis. The symptoms may vary according to the varietal differences and application of chemical sprays, if any.

Transmission

The virus causing the disease can be transmitted through grafting and whitefly (*Bemisia tabaci*), which spreads the disease under natural conditions. It has many alternate host plants like *Hibiscus esculentus, H. rosachinensis, Altheae rosa, Zinnia elegans, Gossypium raimodii,* and *Poinsettia* spp.; many of which grow in or around the cotton fields, serving as alternate sources of infection.

Control

There is a varietal difference to disease reaction, *Gossypium arboreum* has been found to be immune, local cultivars have medium resistance while varieties like Stoneville 731 NL, 247-1 and H.A.12 are susceptible. Cultivation of resistant varieties can provide a reasonable control measure. Adoption of suitable cultural practices for eradication of alternate host plants, volunteer cotton plants combined with vector control through insecticidal sprays can further ensure the crop protection from the disease.

D. Leaf Roll Viruses

1. Potato Leaf Roll Virus (PLRV)

Occurrence

The disease is fairly common throughout the country being more serious in the plains of the Punjab and Sind with incidence ranging between 20-60 percent, depending upon source of seed, vector population and weather conditions. The average intensity of infection varies between 10-15 percent and therefore, it is one of the most destructive diseases of potatoes, considerably reducing both the quantity and quality of the produce.

Symptoms

The symptoms are of a variable nature mainly depending upon the source of seed, varieties under cultivation, virus strain and environmental condition. Primary infection usually does not show symptoms in early stages of plant growth. Plants growing from infected seed tubers show secondary infection (Fig. 15.17).

Fig. 15.17: Potato plant infected with leaf roll virus.

Leaves show inward and upward curling, become stiff, brittle, thick, leathery and rough in texture with the upper leaves remaining erect and palish in colour. On the whole, the infected plants remain stunted in growth producing reduced number and size of tubers of low quality. Anatomical studies reveal presence of necrosis in the phloem when stained with anailine blue or resorcin. The infection can be inherited through tubers from generation to generation intensifying the degree of infestation, resulting into complete seed degeneration, which is more rapid in the presence of other aphid-borne viruses like PVA and PVY.

Seed degeneration studies made in the Punjab and Sind have shown considerable increase in leaf roll virus from year to year. In four varieties (-

Desiree, Multa, Patrones and Wilja) studied in the Punjab, the virus increased, from 0 to 0.2, 9.2, 13.1, 16.1 and 52.5 percent respectively, in a five year period. At Mirpurkhas, Sind, the viral increase has been 5.1 to 24.2 and 38.7 percent in three years, while the yield reduction in 27 varieties has averaged 17, 37.4 and 56.5 percent in this period, yearwise; showing the highly increasing rates of virus infection and damaging effects of the disease on yield through the repeated use of the same source of seed.

Pathogen and Transmission

The disease is caused by a polyhedral virus, which cannot be transmitted mechanically. Under natural conditions it spreads through aphid (*Myzus persicae*) which is the most efficient vector acquiring virus through feeding on a number of hosts and transmitting the disease to healthy plants. Van Harten (1977) has reported two species of aphids in Pakistan (*Aphis gossypii* and *Myzus persicae*); the latter being more common on potato, okra and other host plants. The studies carried out at Lyallpur (Faisalabad) have shown that *Myzus persicae* appears from October to May with a peak period from February to April (53 aphids trapped in 24 hours) resulting into heavy infestation of spring potato crop. Similar results have been reported at Tandojam. The aphid also survives and multiplies on many weed plants (*Convolvulus arvensis, Euphorbia heliscopia* etc). adding to the build up of the vector population and greatly increasing the chances of infection in the spring potato crop. However, systematic studies are needed to be carried out on the ecology and population density of aphids, disease spread and incidence for identifying safer seed production areas in the country (Fig. 15.18).

Control

As no potato variety resistant to leaf curl virus has been found, use of certified seed or seed from the autumn planted crop (when the aphid population is very low) can greatly help in producing a healthy crop. Defoliation of the autumn crop in late seasons can further ensure healthy seed production as successfully practised on a large-scale in Jullunder, India. Hot water treatment of seed tubers at 53°-55°C for 15-20 minutes is useful in checking infection. Sanitary measures such as roguing of infected plants and control of aphids through soil application of Furodan 25kg/ha at planting time followed by foliage spray with Malathion 0.25 percent can control secondary infection and reduce the aphid population.

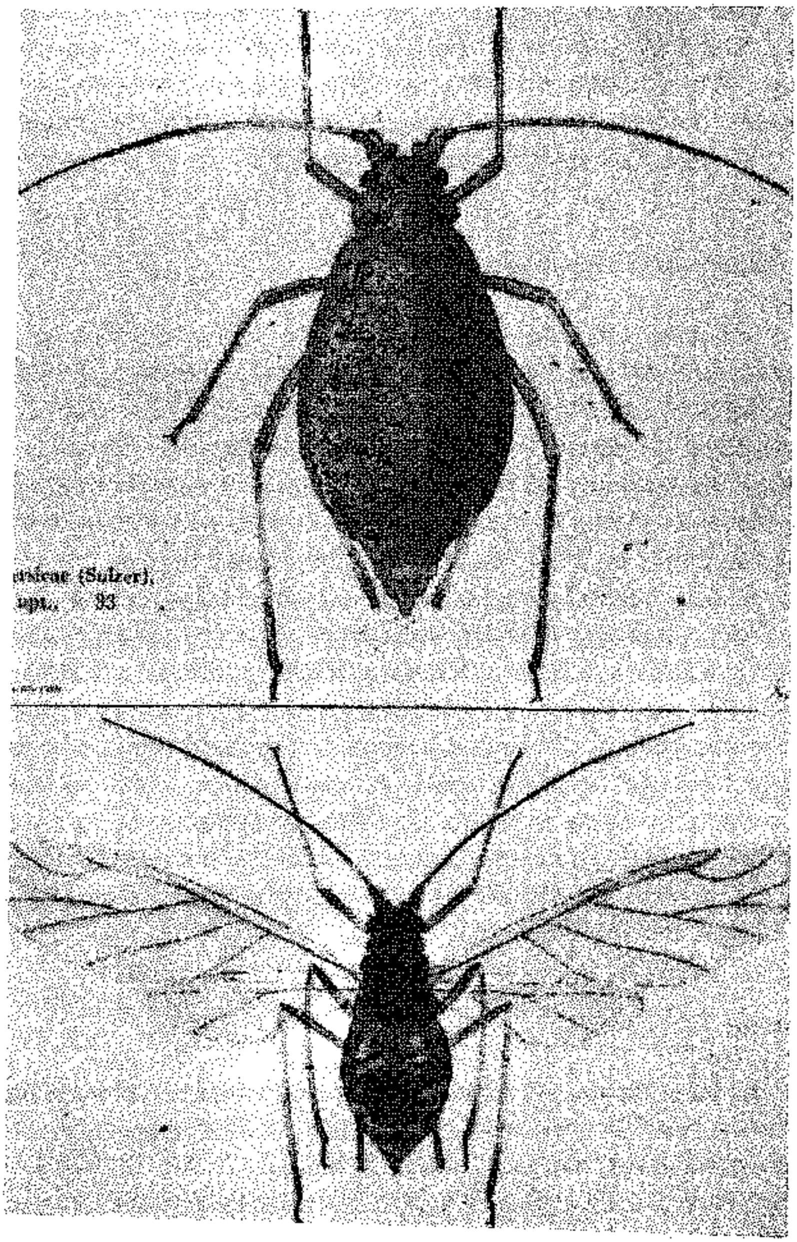


Fig. 15.18: Green peach aphids (*Myzus persicae*) vector of PVY and PLRV.

E. Chlorotic Streak Viruses

1. Chlorotic Streak of Sugarcane

Occurrence

The disease, first reported from Sind and the Punjab in 1968 and 1976, respectively, is now prevalent in most of the commercial sugarcane varieties throughout the country. Its incidence is generally low causing negligible losses.

Symptoms

The virus produces on leaves of all ages, a number of transparent or bright green to yellowish streaks of varied lengths with widths ranging between 0.25 mm to 10 cm, running parallel to the veins. Under severe infection conditions the leaves become crinkled, stiff and erect giving an abnormal appearance to the infected plants.

Transmission

It has not been possible to reproduce the disease mechanically, suggesting involvement of a vector (which has not been investigated). Similarly, no studies have been made on the nature of virus, secondary infection, damaging effects of the disease and control measures.

F. Miscellaneous Viruses

1. Rosette of Peanut

Occurrence

The disease has been reported to be present in Sind while it is likely to be found in other peanut growing area of the country.

Symptoms

The symptoms include malformed and leafy growth, pronounced stunting, shortened internodes, general chlorosis, sterile flowers and poor production of blossoms and pods. On the whole the infected plants are severely stunted with flattened tops or disks of foliage (suggesting "rosette" as the name of the disease).

Transmission and Control

No systematic work has been done on the specific nature and biological properties of the virus, transmission, vector, alternate host plants, extent of damage and control measures. However, eradication and destruction of infected plants may be useful in checking the disease spread.

2. Sterility Mosaic of Pigeon Pea

Occurrence

The disease has been recently reported from the Punjab and is likely to be present in comparatively drier parts of the country, particularly where mites are posing a problem.

Symptoms

Leaves and branches become pale green in colour and are reduced is size, causing stunted growth with partial or complete sterility. The whole plant puts up stunted growth and reduced production of flowers and pods.

Transmission

So far it has not been possible to reproduce the disease through seed, sap, soil or vectors like whitefly and aphids. The work done in India has shown Eriophyd mites as vectors of the disease. However, detailed studies are in progress.

3. Stenosis of Cotton

Occurrence

This malady, also called small-leaf disease of cotton , was first recorded in 1933 from the Punjab, mainly on American varieties and is now present in many parts of the country to a lesser degree causing inappreciable damage.

Symptoms

The symptoms comprise formation of yellow patches on leaves which are reduced in size, crinkled and deformed. The other symptoms are stunting of aerial parts, reduced development of root system, shedding of bolls and poor fibre quality.

Transmission

The viral nature of the disease has not been established as it has not been found to be transmitted through seed or sap. However, possibility of a vector is strongly suspected.

4. Rice Virus Diseases

Virus-like diseases were reported from East Pakistan (now Bangladesh), where the warm and humid climatic conditions are conducive to the survival and proliferation of many insect species, serving as vectors. In a sample survey carried out in 1967 at Isherde, 24 species of leaf hoppers belonging to 9 families and 22 genera were collected, out of which two species of *Nephotetix* (green leaf hopper) are important. The reported virus diseases are:

a) *Tungro Virus*

The incidence of Tungro virus increased steadily with the introduction of IRRI varieties and by 1969 it reached the figures of 4 and 20 percent in *aus* (summer) and amon (autumn) crops, respectively. The disease symptoms vary considerably. The infected plants are stunted in growth, develop interveinal mottling on leaves, which turn yellow and orange in colour, and show rusty spots. Tillering is limited and panicle formation is poor. Symptoms may also resemble those of certain physiological diseases caused by unfavourable soil conditions. The extent of damage varies with the crop growth stage, being less in late infections.

The disease is transmitted by the green leaf hopper (*Nephotetix imicticeps*) which can acquire virus in 15 minutes of feeding period and transfer it to healthy plants immediately within 5 minutes, incubation period within the insect is about one day.

b) *Yellow Dwarf*

It is a minor disease causing plant stunting, excessive tillering and chlorosis of leaves. It is transmitted by the green leaf hopper, which can incubate the virus upto 30 days.

c) *Orange Leaf*

The main disease symptoms include stunted growth, orange discolouration and rolling of leaves, reduced tillering and premature death of plants. It is transmitted by zigzag leaf hoppers (*Recilia dorsalis*) with incubation periods of 6 and 14 days in insects and plants, respectively.

d) Grassy Stunt

The disease produces profuse tillering, stunting and conspicuous narrowing of leaf blades. It is caused by brown leaf hoppers (*Nitaparvata lugens*) which can incubate the virus for 7 days while the new symptoms appear 13 days after inoculation feeding.

Control

Although preventive measures including spraying organophosphates can provide a satisfactory control of leaf hoppers, the virus diseases are not controlled due to quicker virus transmission and lag of time between transmission and vector killing. The best solution lies in the development of virus resistant varieties. Lately, varieties like IR-20 , IR26, resistant to *Tungro* and IR-28 , IR-29 and IR-30 , resistant to grassy stunt have been developed at the International Rice Research Institute.

5. Tobacco Ringspot Virus (TRSV)

The disease has been recently reported from tobacco crops in NWFP but no sysmtematic work has been carried out except frequent recording of nematode vector *Xiphenema* in diseased fields. It is reported to have many host plants.

6. Citrus Tristeza Virus

The disease seems to be of frequent occurrence in citrus plantations, especially in the Punjab. It produces various types of symptoms including greening, yellowing, chlorosis, withering and cracking of bark and reducing considerably the productive life of plants. No systematic studies have been made on the various aspects of the disease.

Summary

This chapter presents an evidence on the occurrence of a number of virus diseases affecting field crops, vegetables and fruit plants. Twenty seven diseases have been described, mainly on the basis of the symptomatology of five groups of viruses (Mosaics; Yellows; Leaf Curls; Leaf Rolls; and Streaks). Some of the diseases may not be distinct due to lack of detailed studies on host range, transmission, serological testing and physical and biological properties. The present number of diseases is likely to increase in the future with the intensification of work including virus identification. However, it is imperative to carry out work on complete

characterization and description of individual diseases and the causal viruses in order to assign or place them in particular taxonomic virus groups, recognized in the scientific world. On the basis of epidemiology of virus diseases, it appears that leaf curl viruses, transmitted by a common vector whitefly (*Bemisia tabaci*), are predominantly present in this part of the world. However, the most serious viral diseases include sugarcane mosaic virus, potato viruses, rice viruses, leaf curl viruses of tobacco, potato, tomato, chillies, okra and papaya, yellow viruses of leguminous hosts and citrus tristeza virus. These diseases take heavy toll by decreasing production. The damaging effects on yield and quality become intensified where there is a mixed infection of different viruses, particularly in several solanaceous and leguminous hosts.

Investigations on various diseases made so far are of preliminary nature as the available finance and facilities for systematic investigations do not match with the total losses caused to agricultural and horticultural crops. Since plant virology has remained a neglected field in the past due to lack of trained manpower and appropriate facilities, it is essential to intensify researches on virus diseases of host plants of economic importance through concerted efforts. The studies should include virus transmission, virus-vector relationship, serology and more specifically on evolution of resistant varieties,production of virus-free seeds and nursery plants and development of practical control measures against major diseases. With the establishment of Plant Virus Research Laboratory at NARC and cooperative units in various provinces, it will now become possible to strengthen and streamline research activities in this important discipline for producing visible impact on productivity and profitability of the crops.

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Chapter XVI

Diseases Caused by Nematodes

During pre-partition period, the diseases caused by nematodes received very little attention due to lack of trained manpower, appropriate laboratory facilities and information on the magnitude of crop losses besides scientist's pre-occupation in research on fungal diseases. The only work done was on Ear Cockle of wheat caused by *Tylenchus tritici* (described in chapter II). With the establishment of Pakistan, some systematic studies were initiated in East Pakistan (now Bangladesh) from 1955 to 1963 on plant and soil nematodes. In West Pakistan (now Pakistan) the work on nematodes received some attention of a few scientists from 1958 onward; mostly on soil analysis leading to the recording and identification of plant parasitic nematodes and compilations of systematic lists. Some studies have also been reported to be conducted on the known nematicides and on nematicidal properties of aromatic fractions of petroleum or new nematicides for controlling the pathogens.

The other studies carried out relate to survey of nematodes of important crop plants, intensity of infestation, factors affecting the incidence, varietal reactions, fungal and nematodal association, pathogenicity trials and spread of nematodes through lack of quarantine regulations. All this work has emphasized the growing importance of the damage caused by

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nematological diseases to agricultural crops, necessitating an urgent need for the establishment of a specialized centre on Nematological research in the country. The foundation of a working centre was laid down in 1967 at PCSIR Laboratories, Karachi and later on at the University of Karachi in 1974. The main objective was to develop a well-equipped laboratory for conducting a survey of important plant diseases caused by nematodes in the country and to carry out experimental work on their various aspects. This centre was also to provide training to the scientists in the neglected but very important discipline of nematology. Since then the research work on nematodes has been in the process of being strengthened, improved and streamlined to meet the national objectives.

Review of Work

East Pakistan (Bangladesh)

The investigations on nematodes covering the period of 1955-63 have been limited to survey of plant and soil nematodes in 8 important crops, namely, rice, broad bean, jute, banana, cotton, sugarcane, maize and potato. The main results are given in Table 16.1.

Table 16.1: List of nematodes of some important crops.

Name of Nematodes	Crops
Aphelenchoides besseyi	All crops
Aphelenchoides bicaudatus	All crops except cotton and broad bean
Criconemoides rusticum	Rice, jute and cotton
Ditylenchus angustus	Rice
Ditylenchus destructor	Potato
Helicotylenchus multicinctus	Jute
Helicotylenchus dihystera	Maize
Hemicriconemoides spp.	Sugarcane
Hoplolaimus spp.	All crops
Longidorus spp.	Sugarcane
Meloidogyne arenaria	Banana and sugarcane
Meloidogyne incognita acrita	Broad bean and jute
Meoloidogyne javanica	Broad bean
Pratylenchus spp.	Rice, banana, sugarcane and cotton
Pratylenchus zeae	Maize
Radopholus oryzae	Rice
Rotylenchus spp.	Rice and sugarcane

Rotylenchus reniformis	Broad bean, banana and maize
Trichodorus spp.	Sugarcane
Tylenchorhynchus martini	Rice, jute and maize
Xiphinema indicum	All crops except potato

In all; 14 genera of nematodes have been recorded, out of which two nematodes (*Aphelenchoides besseyi* and *Hoplolaimus* spp.) have much wider pathogenicity infecting all the 8 crops followed by *Xiphinema indicum* (7 crops), *Aphelenchoides bicaudatus* (6 crops), *Pratylenchus* spp. (4 crops), and *Criconemoides rusticum*, *Rotylenchus reniformis* and *Tylenchorhynchus annulatus* (3 crops each) while others are more specific in infecting 2 or 1 crop only. As regards their status, it is low in broad bean, maize and sugarcane while in other crops high infestations have been recorded. However, this pioneering work highlighted the importance of plant nematodes giving impetus to nematological researches in the country.

West Pakistan (Now Pakistan).

The preliminary work, initiated in 1958, has been steadily expanding and gaining importance over a period of twenty seven years. It includes survey of nematodes of important field crops, vegetables and fruits and other related studies.Apart from development of suitable laboratory and field techniques, emphasis has been laid on strengthening of laboratories library and training facilities and institution of advisory service for soil analysis and control of nematodes. The work, so far carried out, has been summarized below.

Survey

The occasional surveys carried out from time to time in various parts of the country have shown the occurrence of nematodes on 14 field crops and 13 fruit trees. A large number of species have been recorded on 6 important crops (wheat, rice, maize, sugarcane, tobacco and potato) and 3 important fruit plants (apple, citrus and mango) Table 16.2.

Table 16.2: List of nematodes of important crops in Pakistan.

Name of Nematode	Crop	Location
1. *Aglenchus agricola*	Apple, Potato, Tobacco	Sind, Punjab and Baluchistan

	Name of Nematode	Crop	Location
2.	*Anguina tritici*	Wheat,Oat,Barley	All Provinces
3.	*Aphelenchus avenae**	Citrus, Rice, Wheat, Maize, Tobacco, Potato	All Provinces
	Aphelenchus spp.	Mango, Tobacco, Potato	Punjab & Sind
4.	*Aphelenchoides besseyi*	Maize, Potato, Rice	Sind & Baluchistan
5.	*A. bicaudatus*	Maize, Bean, Banana, Sugarcane, Rice	Sind
6.	*A. blastophthorus*	Sugarcane	Punjab & Sind
7.	*A. caprifica*	Sugarcane	Punjab & Sind
8.	*A. parictinus*	Sugarcane	Punjab & Sind
9.	*A. winchesi*	Sugarcane	Punjab & Sind
	Aphelenchoides spp.	Mango, Potato	Punjab & Sind
10.	*Basiria graminophila**	Mango, Rice, Banana	Punjab & Sind
11.	*B. india*	Pear,Wheat	NWFP
12.	*B. minor*	Pear,Wheat	NWFP
13.	*Boleodorus acutus*	Oat, Rice, Mango, Citrus	Sind
14.	*B. oakistanensis**	Mango	Punjab
15.	*B. Zinia**	Citrus	Punjab
16.	*Criconemella curvata*	Maize, Mango, Pear, Apple	Sind
17.	*C. lobatum*	Wheat	Sind
18.	*C. onoensis**	Mango, Citrus	Punjab
19.	*C. sphaerocephalum**	Mango, Banana	Punjab & Sind
20.	*C. xenoplax**	Plum, Datepalm, Citrus, Barley, Rice, Pear, Grape	
21.	*Ditylenchus angustus*	Rice	Punjab & Sind
22.	*D. clarus**	Rice, Mango	Punjab & Sind
23.	*D. destructor*	Potato	Punjab & Sind
24.	*D. dipsaci*	Citrus, Barley, Oat, Wheat, Maize, Sugarcane, Grape	All Provinces
25.	*Globodera rostochiensis**	Potato	Punjab

	Name of Nematode	Crop	Location
26.	G. *tabacum*	Tobacco	NWFP
27.	*Helicotylenchus californicus*	Citrus	Punjab & Sind
28.	H. *conicephalus**	Citrus, Banana	Punjab & Sind
29.	H. *digonicus**	Oat,Barley,Plum, Pear,Wheat,Maize, Mango, Citrus, Sorghum, Grape	Punjab & Sind
30.	H. *dihystera**	Oat, Barley, Sorghum, Pear, Plum, Wheat, Rice, Maize, Sugarcane, Potato, Citrus	Punjab & Sind
31.	H. *erythrinae**	Citrus, Oat	Punjab & Sind
32.	H. *indicus*	Datepalm, Wa-	Punjab & Sind
32.	H. *indicus*	Datepalm, Watermelon, Rice, Mango, Citrus, Cotton, Chillies	Punjab & Sind
33.	H. *microdorus**	Apple, Wheat, Citrus, Banana	Punjab & Sind
34.	H. *multicinctus**	Papaya, Banana, Wheat, Rice, Citrus, Pear	Punjab & Sind
35.	H. *parvus*	Sugarcane	Punjab & Sind
36.	H. *pseudorobustus**	Rice, Grape	Punjab
37.	H. *egyptiensis*	Pear, Sugarcane, Wheat	Sind
38.	H. *crenecauda**	Mango	Punjab
39.	H. *thornei*	Mango, Citrus	Punjab, Sind & NWFP
40.	*Hirschmaniella caudacrena**	Rice	Punjab
41.	H. *gracilis*	Wheat, Rice	Sind
42.	H. *mucronata*	Rice	Punjab
43.	H. *oryzae*	Wheat, Rice	Punjab & Sind
44.	H. *spinicaudatus*	Rice	Punjab & Sind
45.	*Hemicriconemoides cocophilus*	Sugarcane, Plum, Wheat, Pineapple, Apple, Grape	Punjab & Sind

Name of Nematode			Crop	Location
46.	*H.*	*strictathecatus*	Citrus	Punjab
47.	*H.*	*gaddi*	Mango, Oat, Pear, Sugarcane	Punjab & Sind
48.	*H.*	*mangiferae*	Mango, Pineapple, Papaya, Banana	Punjab & Sind
49.	*H.*	*ghaffari**	Citrus	Punjab
50.	*Heterodera avenae**		Wheat, Maize	NWFP
51.	*H.*	*zeae**	Garlic, Pear, Gram, Citrus, Maize, Wheat, Sugarcane, Chillies	Punjab & NWFP
52.	*H.*	*mani**	Wheat	NWFP
53.	*H.*	*mothi**	Eggplant,Wheat, Sugarcane, Pear, Plum	NWFP
54.	*H.*	*oryzae*	Rice	Punjab
55.	*H.*	*sacchari*	Sugarcane	Punjab
56.	*H.*	*schachtii*	Sugarcane, Cauliflower, Maize	Punjab & Sind
57.	*H.*	*vigni*	Cowpea	NWFP
58.	*Hoplolaimus galeatus**		Banana, Rice, Sugarcane, Maize	Punjab
59.	*H.*	*californicus*	Mango	Punjab
60.	*Hoplolaimus indicus**		Rice, Oat, Pineapple, Papaya, Wheat, Sugarcane, Banana, Grape, Sorghum, Potato, Tobacco	NWFP, Punjab
61.	*H.*	*pararobustus**	Rice	Punjab
62.	*H.*	*seinhorsti**	Wheat	NWFP, Punjab
63.	*H.*	*columbus*	Sugarcane	Sind
64.	*H.*	*stephanus*	Mango	NWFP, Punjab
65.	*Longidorus meyli**		Apple	Punjab, Baluchistan

Name of Nematode	Crop	Location
66. *Meloidogyne arenaria*	Tomato, Sugarcane, Tobacco, Potato	Punjab, NWFP
67. *M. hapla*	Tobacco, Potato. Tomato, Pyretnrum, Chillies, Bean.	NWFP, Sind, Punjab
68. *M. incognita*	Banana, Beetal, Bean, Sugarcane, Tobacco, Black-night shade, Eggplant, Cabbage, Cauliflower, Chenopodium, Chillies, Cotton, Ginger, Maize, Okra, Papaya, Pyrethrum, Sugarbeet, Tomato, Amaranthus sp. Masoor, Sponge gourd	All Provinces
69. *M. javanica*	Banana, Bean, Beetal, Eggplant, Chenopodium, Ginger, Papaya, Potato, Sponge gourd, Sugarbeet, Sugarcane, Maize, Tobacco	Punjab, NWFP
70. *Malenchus andrassy*	Wheat, Mango	Sind, Punjab
71. *M. pakistanensis**	Pear	NWFP
72. *M. platycephalus*	Citrus, Apple	Sind, Punjab, NWFP
73. *M. nausheri**	Apple	NWFP
74. *M. fusiformis**	Oat, Papaya, Banana, Wheat, Citrus, Pear	Punjab, Sind
75. *Merlinius brevidens**	Maize, Oat, Barley, Rice, Mango, Potato, Sorghum,	Punjab, Sind & Baluchistan

	Name of Nematode	Crop	Location
		Citrus, Wheat, Fig, Plum, Pear	
76.	*M. microdorus**	Sugarcane,Wheat, Pear	Punjab , NWFP & Baluchistan
77.	*M. nanus**	Maize, Pear	Punjab
78.	*Metaphelenchus sacchari*	Sugarcane	Punjab
79.	*Nothotylenchus goldeni**	Apple	Baluchistan
80.	*Orientylus siddiqii**	Citrus	Punjab
81.	*Paktylenchus tuberosus**	Potato	NWFP
82.	*Paratrichodorus mirzai**	Sugarcane	Punjab
	Paratylenchus spp.	Sugarcane	Punjab
83.	*Paratylenchus nanus*	Apple, Pear	NWFP, Baluchistan
84.	*P. hamatus**	Barley, Rice, Potato, Fig, Date-palm, Pear	Punjab
85.	*P. projectus*	Barley, Sorghum, Apple, Citrus, Rice, Maize	Punjab, Sind, Baluchistan
86.	*Pratylenchus brachyurus**	Barley, Rice, Sorghum, Mango, Wheat, Maize, Sugarcane,Citrus	Punjab, Sind
87.	*P. crenatus**	Maize, Sugarcane, Barley, Waterlemon	Punjab, NWFP
88.	*P. coffeae**	Rice, Papaya, Banana, Apple, Potato, Pear	Punjab, Sind
89.	*P. neglectus*	Citrus, Tobacco	Punjab
90.	*P. penetrans**	Oat, Barley, Watermelon, Wheat, Maize, Citrus, Tobacco, Plum, Apple	NWFP, Punjab,
91.	*P. pratensis*	Rice, Fig, Maize, Citrus, Plum	Punjab, Sind
92.	*Pratylenchus sacchari*	Sugarcane	Punjab

Name of Nematode	Crop	Location
93. *P. similis*	Wheat	Punjab
94. *P. scribneri*	Sugarcane	Punjab
95. *P. thornei*	Oat, Barley,Rice, Maize, Wheat,Sugarcane, Tobacco, Sorghum, Citrus, Watermelon, Fig, Mango, Banana, Pear	Punjab, NWFP,
96. *P. safeaensis**	Rice	Sind, Punjab
97. *P. vulnus*	Fig, Pear, Citrus, Plum	Punjab, Sind
98. *P. zeae*	Oat, Sorghum, Wheat, Sugarcane, Maize, Mango	Punjab, NWFP, Sind, Punjab
99. *P. hexincisus*	Oat	Punjab
100. *Paurodontella sohailai**	Sugarcane	Sind
Psilenchus spp.	Wheat, Maize	Punjab
101. *P. hilarulus**	Barley, Papaya, Rice, Potato, Sugarcane,Wheat	Sind, Punjab, NWFP
102. *Quinisulcius acutus**	Sorghum, Pear, Citrus	Punjab, Sind
103. *Q. capitatus**	Oat, Barley,Maize, Mango,Potato, Citrus, Fig, Pear, Plum	Punjab, NWFP,Sind
104. *Q. solani**	Potato	Punjab
105. *Rodopholus gracilis*	Wheat, Maize	Punjab
106. *R. similis*	Maize, Watermelon, Banana	Punjab, Sind
107. *Rotylenchulus reniformis*	Oat, Sorghum, Potato, Citrus, Wheat, Maize, Pineapple,Papaya, Watermelon, Fig, Mango, Banana, Pear	Punjab, NWFP, Sind
108 *Rotylenchus robustus*	Wheat, Sugar-	Punjab, Sind

Name of Nematode	Crop	Location
	cane, Potato, Apple	
109. *R. buxophilus*	Sugarcane, Banana, Pear	Sind
110. *Scutylenchus koreanus**	Wheat	Punjab, NWFP
111. *Trichodorus pakistanensis*	Mulberry, Maize, Citrus	NWFP, Sind
112. *T. obtusus*	Sugarcane	Punjab
113. *Trilineellus triglyphus**	Cotton	Sind
114. *Tylenchus avenae*	Maize	Punjab
Tylenchus spp.	Sugarcane, Tobacco, Potato, Apple	Punjab, NWFP
115. *Tylenchulus semipenetrans*	Citrus	Punjab
116. *Tylenchorhynchus annulatus*	Barley, Rice, Wheat, Mango, Citrus, Pear, Plum	Punjab, NWFP, Sind
117. *T. brassicae*	Oat, Barley, Wheat, Maize, Rice, Sorghum, Date-palm, Pear	Punjab, NWFP, Sind
118. *T. claytoni*	Potato	Punjab, NWFP
119. *T. clarus*	Rice, Sugarcane, Tobacco, Maize, Citrus	Punjab, NWFP
120. *T. cylindricus*	Wheat, Maize, Sugarcane, Potato	Punjab, NWFP
121. *T. manubriatus*	Sugarcane	Punjab
122. *T. mashhoodi**	Oat, Barley, Wheat, Maize, Tobacco, Citrus, Rice, Sorghum, Banana, Pear, Plum	Punjab, Sind
123. *T. parvus**	Potato	Punjab, NWFP
124. *T. striatus*	Sugarcane	Punjab
125. *T. tritici**	Wheat	NWFP
126. *T. nudus*	Sugarcane, Sorghum	Sind
127. *T. clavicauda*	Banana	Sind

Name of Nematode	Crop	Location
128. *Xiphinema ornatum*	Oat	Punjab
129. *X. insigne*	Wheat, Sugar-cane, Mango	NWFP, Punjab
130. *X. intermedium*	Wheat	Sind
131. *X. brevicolle*	Apple, Banana, Pear	Baluchistan, Sind
132. *X. revesi*	Citrus	Punjab
133. *X. mediterraneum*	Mango	Punjab
134. *Xiphinema americanum*	Apple, Mango, Sugarcane, Whe-at, Rice	Punjab, NWFP
135. *X. basiri* *	Citrus	Punjab
136. *X. indicum* *	Rice, Sugarcane	Punjab
137. *X. index*	Maize, Citrus, Fig	Punjab, Sind
138. *X. pratense* *	Sugarcane	Punjab
139. *X. radicicola**	*Sugarcane,*	*Punjab*
139. *X. radicicola* *	Sugarcane,Mango	Punjab

In all 37 genera with 139 species of nematodes have been recorded including 59 new records from Pakistan. The most important genera are *Pratylenchus* (14 species). *Hoplolaimus* (7 species) *Helicotylenchus* (13 species). *Tylenchorhynchus* (13 species), *Xiphinema* (12 species) and *Heterodera* and *Globodera* (10 species each) while the others have fewer number of species. Some of the nematodes are specific to 1, 2 or 3 crops and others have wider pathogenicity affecting a greater number of crops.

The distribution is wide and the incidence varies hostwise. The important nematodes for different crops are *Anguina, Aphelenchus, Ditylenchus. Helicotylenchus, Heterodera, Pratylenchus* and *Tylenchorhy nchus* (wheat): *Aphelenchoides. Helicotylenchus* and *Hirschmaniella* (rice); *Heterodera* and *Pratylenchus* (maize); *Helicotylenchus, Paratrichodorus, Pratylenchus, Rotylenchus* and *Tylenchorhynchus* (sugar cane); *Aphelenchus, Heterodera, Pratylenchus* and *Tylenchorhynchus* (tobacco); *Hemicriconemoides* and *Hoplolaimus* (mango): *Aphelenchus* and *Hoplolaimus* (potato) and *Criconemella, Helicotylenchus. Heterodera, Hoplolaimus, Tylenchorhynchus* and *Tylenchus* (citrus); many of them having common hosts. However, the serious diseases caused by nematodes are ear cockle of wheat, white tip of rice, root-knot, root lesion, slow de cline of citrus, tuber rot and stem diseases.

The list of nematodes isolated from Pakistan and recorded for the first time in the world (Table 16.3) shows isolation of one new genus of *Paktylenchus*; 3 new species of *Nothotylenchus, Boleodorus* and *Paurodontella* belonging to super-family Neotylenchoidea and 2 new species of *Malenchus* of sub-family Dousalcinae and one new species of *Hemicriconemoides* belonging to sub-family Hemicriconemoidinae. These have been fully described and creation of a new sub-family (Triliniinae) under Tylenchorhynchinae family has been suggested and supported by a key to the sub-family.

Table 16.3: New world records of nematodes isolated in Pakistan

Crop	Location	Nematode	Status
Citrus	Punjab	*Boleodorus zaini*	M
	Punjab	*Hemicriconemoides ghaffari*	H
Pyrus communis	Baluchistan	*Malenchus pakistanensis*	M
Pyrus malus	Baluchistan	*Malenchus nausheri*	M
		Nothocylenchus goldeni	M
Saccharum officinarum	*Sind*	*Paurodontella sohailai*	M
solanum tuberosum	Baluchistan	*Paktylenchus tuberosus*	M
	Punjab	*Quinisulcius solani*	H
Triticum vulgare	NWFP, Sind and Baluchistan	*Tylenchorhynchus tritici*	H

M = Medium (51-500 nematode population per 200g of soil).
H = High (above 500 nematode population per 200g of soil).

The work, so far carried out, has further shown that the majority of the plant parasitic nematodes belong to Phylum - Nemata; class - Secernenta; and order - Tylenchida and a few to order - Dorylaimida. Although the order Tylenchida is very large and of diverse groups representing world wide distribution, only less than 10 percent of its total species thought to exist, have so far been described. The proposed chart on the classification of the order - Tylenchida shows the vastness of this order comprising 2 sub-orders, 6 super-families, 23 families, 46 sub-families, 136 genera and numerous species.

Fig. 16.1: Tobacco nursery showing severe attack of nematode.

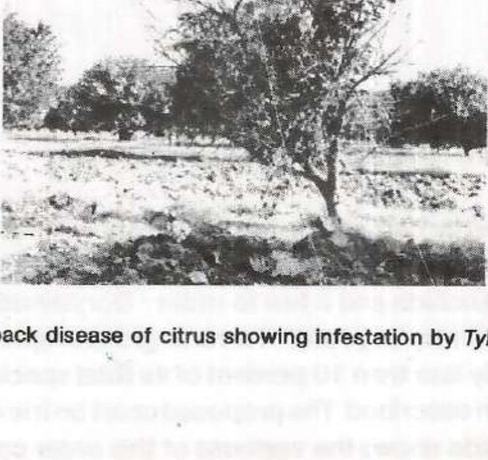


Fig. 16.2: Die-back disease of citrus showing infestation by *Tylenchalus* sp.

General Symptoms and Nature of Damage

During surveys, varying types of symptoms and degrees of damage, depending upon the intensity of infestation, have been recorded on different crops. The symptoms vary according to the nematodes. In case of *Anguina tritici*, which causes ear cockle of wheat, the main symptoms in clude wrinkling, rolling and distortion of leaves, thickening of stems, twisting, yellowing and shortening of ears which are filled with black round galls containing a large number of eelworms while *Heterodera* spp. produce permanent patches of stunted plants along with growth reduction and discolouration of leaves. *Ditylenchus* spp. manifest distorted top growth and tuber rot of potatoes while *Meloidogyne* spp. and *Globodera* spp. produce galls on roots and tubers, growth reduction and wilting with shortening and browning of roots. *Aphelenchoides* spp. cause white tip of rice and shortening and twisting of leaves while *Ditylenchus angustus* produces ufra disease with chlorosis or streaks in upper leaves or swelling of panicles with a tendency to branching. *Hirschmanniella* spp., commonly infect roots, producing discolouration and rotting. The sugarcane-infecting nematodes produce various symptoms. *Meloidogyne* spp. give rise to galls or knots of varying size near the tips of roots and cause chlorosis of the above ground parts, *Helicotylenchus* spp. produce rotting of roots, *Tylenchorhynchus* spp. give rise to stunted growth while other (*Xiphinema* spp.; *Longidorus* spp., *Trichodorus* spp.; *Criconemella* spp.; *Hemicriconnemoides* spp., and *Paratylenchus* spp.) cause root stunting, discolouration and poor plant development. More or less similar types of symptoms are produced by various nematodes affecting tobacco, citrus, apple and maize. In brief the nematode-affected crops produce stunting growth of roots and plants resulting in decreased yield, depending upon the degree of infestation (Fig. 16.1 and 16.2).

General Modes of Perpetuation

The modes of perpetuation vary according to the types of nematodes. In some cases (*Anguina tritici, Aphelenchoides besseyi* and *A. ritzemabosi*) the nematodes live as larvae in a long dormant or anhydrobiotic stage in the seeds, or attached to the roots as cyst (*Heterodera* spp.); or in the host tissue and in the surrounding soil (*Ditylenchus* spp.); or in hard egg mass deposits (root-knot nematodes - *Meloidogyne* spp.). As soon as the conditions become favourable the nematodes resume activity and attack the host plants, undergoing one or more life cycles during the growth period of the host plants (Figs. 16.3 and 16.4).

Factors Affecting the Incidence

Although specific studies on factors affecting the incidence are lacking in Pakistan, observations made during surveys have shown that soil moisture contents and soil temperature determine the type and intensity of nematode attack. Soil moisture is important for the movement, feeding and egg laying of nematodes but flooding and excess of moisture are detrimental to their growth and population density as shown by incidence of both stylet and non stylet bearing nematodes after heavy rainfall; Fifteen to twenty percent soil moisture content is optimal for the genus *Hoplolaimus*. However, nematodes vary in their reaction to soil moisture; *Radopholus* spp. thrive better in wet soils as compared to *Tylenchorhynchus* spp. and the cyst nematodes. On the other hand dry conditions inhibit the activity of *Heterodera and Ditylenchus* spp. which can be reactivated by restoring soil moisture. Soil temperature is another important factor influencing the phytoparasitic activity of nematodes. The optimum range is 15º-30ºC, & activity is decreased on either side of this range while temperatures beyond 40°C and below 5°C are usually lethal. However, different nematode groups vary in their temperature requirements. Systematic investigations are needed on these aspects, especially on nematodes causing serious diseases to determine suitable cultural control measures.

Laboratory and Field Methodologies

There are well established methodologies for soil sample collection, nematode extraction, culture maintenance, nematode culturing and pathogenicity testing. A minimum of five soil samples are collected around the roots of plants showing moderate to severe symptom. These are stored in plastic bags at 15°-25°C before attempted isolation of the organisms. The extraction of nematodes is done by using Baermann funnel method or its modification. For larger forms of nematodes (*Longidoridae*) Cobb's decanting and seiving techniques (1918) or Flegg's modification (1967) or Seinhorst's two-flask technique (1955) are used. Sometimes the flotation method using sugar solution of greater specific gravity is employed to extract eggs and inactive nematodes from soil and organic debris but this may distort the specimens. Populations are counted in 5 ml suspensions in a counting tray and the total number of nematodes in 500 g of soil is calculated based on an average of several counts. The nematodes are picked up under a binocular microscope, killed by gentle heat and fixed in Trietranol Amine Formalin (TAF) for 24 hours followed by mounting in dehydrated glycerine for detailed studies.

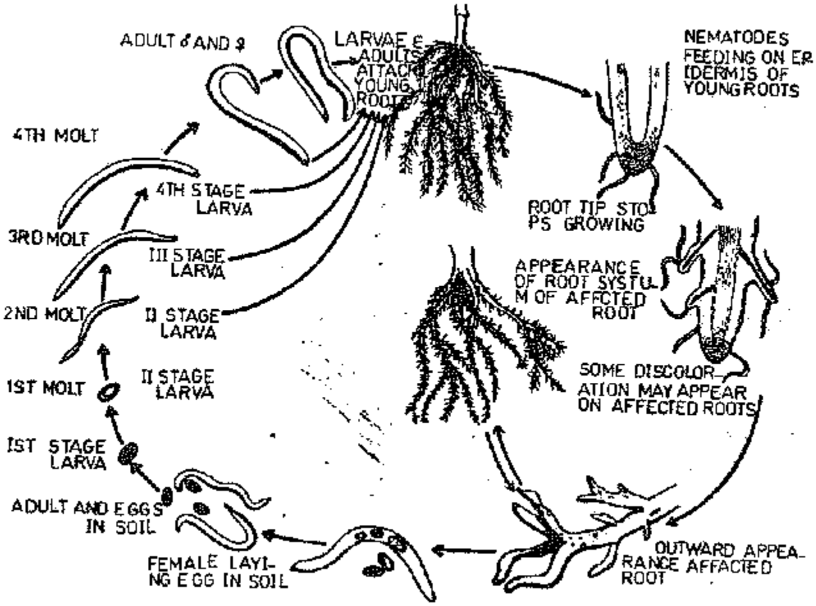


Fig. 16.3: Diagramatic representation of life and disease cycle of *stubby root nematode*

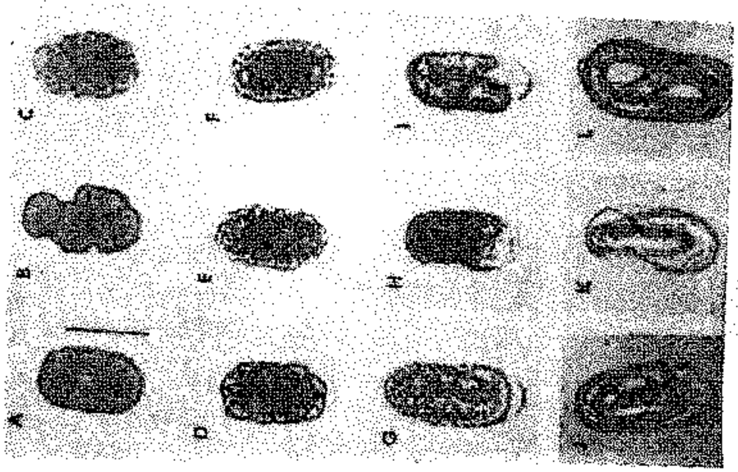


Fig. 16.4: Twelve stages of embryogery of root knot *nematodes* (M. incognita).

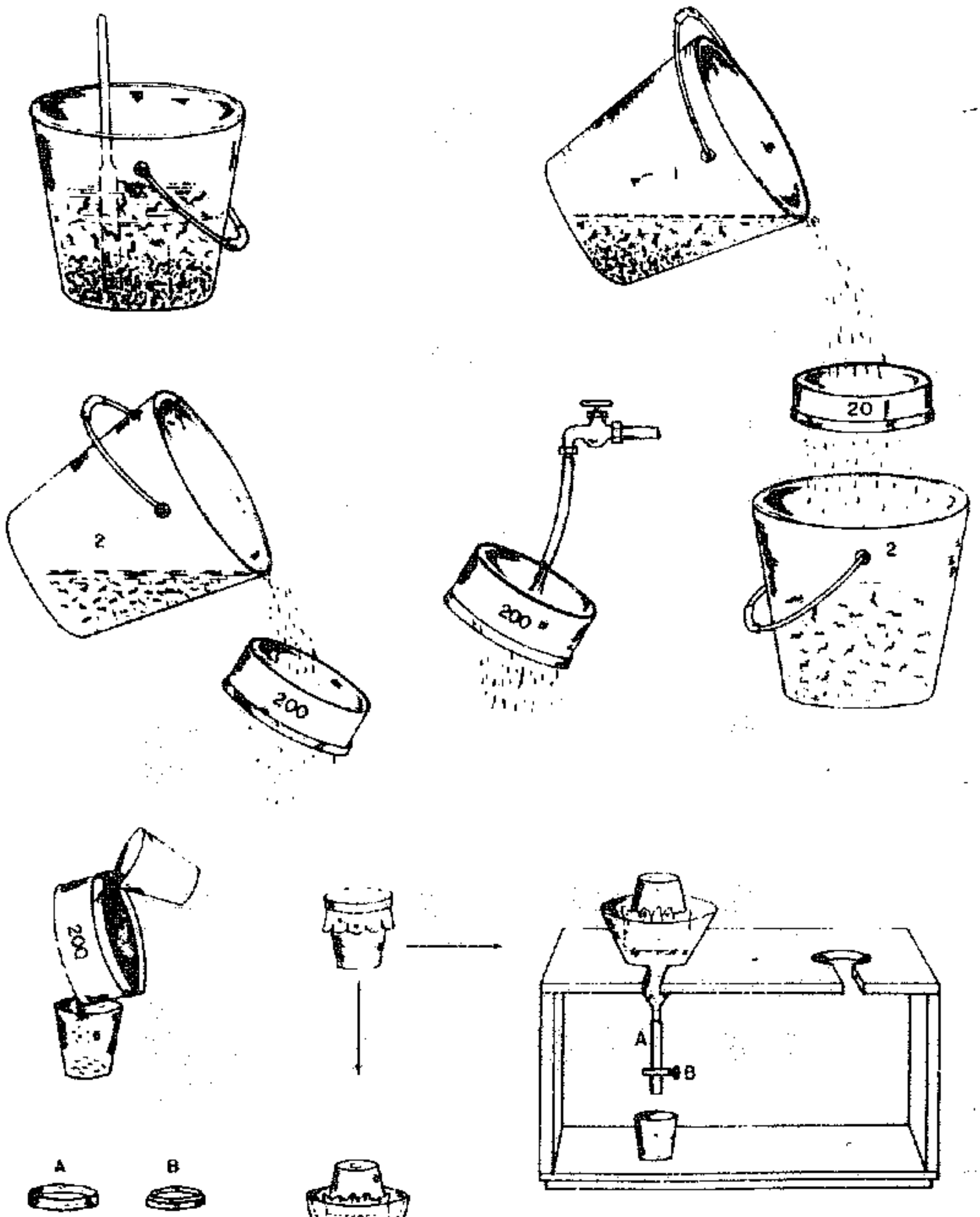


Fig. 18.5: Processing Techniques of soil samples for recovery of nematods.

A simple method of excluding undesirable forms of nematodes from cultures of single species has also been developed (Fig. 16.5).

Cultures of root-knot nematodes can be maintained in the green house in pots containing sterilized soils inoculated with egg masses or larvae and grown with susceptible plants such as tomato. Nematodes can also be cultured in the laboratory by different methods such as those proposed by Dougherty (1953 and 1959). The stylet bearing nematodes are cultured on higher plant callus tissues, usually grown on an agar medium containing nutrients, developed by various workers-White (1943) Hilderbrandt, Riker and Dagger (1946) and Krusberg (1961).

The pathogenicity tests are carried out using established methods of inoculation with pure cultures under aseptic conditions and reisolating the specific organisms from the inoculated plants. Besides conducting host differential tests for root-knot nematodes, some studies have also been carried out on host relationship and interaction between root-knot nematodes and lesion nematodes.

General Method of Control

Some studies carried out on three selected nematicides (Nemagon, Aldicarb Temik-10G, and Furadan-3G) against nematodes attacking banana, citrus, papaya, sugarcane, okra and corn have shown considerable reduction in the nematode population after 30, 60 and 90 days of treatment as compared with check plots. Two additional studies have shown the effectiveness of the aromatic fraction 400 N against *Tylenchorhynchus* spp. (at the rate of 0.75 gallon of 70 percent emulsified concentrate made in Triton - X100)& *Helicotylenchus* spp. at a concentration of 30 ppm. However, intensive and extensive researches are needed to develop and identify the most effective and economical nematicides. Simple application methods should be developed, suited to farmers conditions. Studies are also needed on the development of resistant crop varieties, nematode-free nursery plants and suitable crop rotations.

Important Nematode Diseases

There are a number of nematode diseases on which some studies have been made in Pakistan. Ear cockle of wheat, one of the most important disease, caused by *Anguina tritici* was investigated in early 1930s and is described in chapter II under wheat, while the other diseases have been put into the following three categories and described, groupwise.

A. Diseases of Roots

B. Diseases of stems and bulbs

C. Diseases producing stunting and wilting

A. Diseases of Roots

Nematodes attacking roots (ecto or endoparasitically) produce local lesions and cause physiological or mechanical injury, reducing intake of the water and minerals, depending upon the feeding habits of nematodes. Biology and life cycle, symptoms and control measures of nine genera producing root diseases are as follows:

1. Meloidogyne spp. or Root-Knot Nematode

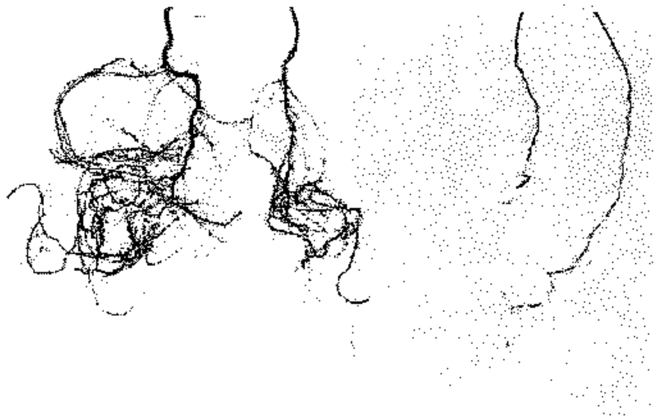
Four species of *Meloidogyne* have been recorded in Pakistan on cereals and many fruits and vegetable crops. These nematodes are secondary root and tuber endoparasites. The larvae undergo three moults and produce a large number of females under favourable conditions. They deposit eggs in gelatinous brown masses, which on hatching continue to produce new infections. The symptoms produced consist of gall or knot formations on roots, yellowing and stunting of leaves and reduction in yield according to the intensity of infection. In the absence of resistant varieties either suitable rotations or nematicidal treatment is recommended for controlling infection.

2. Heterodera spp. or Lemon-Shaped Cyst Nematode

Nine species of cyst nematodes have been recorded in Pakistan, infecting citrus, maize, sugarcane, brinjal, soybean, wheat, barley, cauliflower, potato and tobacco. These are endoparasites and the second stage larvae penetrate root tips. They moult after a week or two and the sexes are separated in the third stage. Adult females turn into cysts and deposit eggs, completing their life cycle in two months. The infected plants, develop bushy root systems, followed by stunting, wilting, yellowing and necrosis of leaves. The control consists in nematicidal treatment or rotation. Potato varieties have been developed resistant to certain pathogens.

3. Tylenchulus Semipenetrans or Citrus Nematode

This nematode infects citrus only and is an obligatory root parasite, leading a sedentary ectoparasitic life. The females lay eggs in a gelatinous martix, after hatching, the second stage larvae penetrate roots partially,



(a)

(b)

(c)

Fig. 16.6: Effect of inoculations with root nematodes (right) compared with unicoulated roots (left) (a) guava roots, (b) tobacco roots, (c) peanut pods.

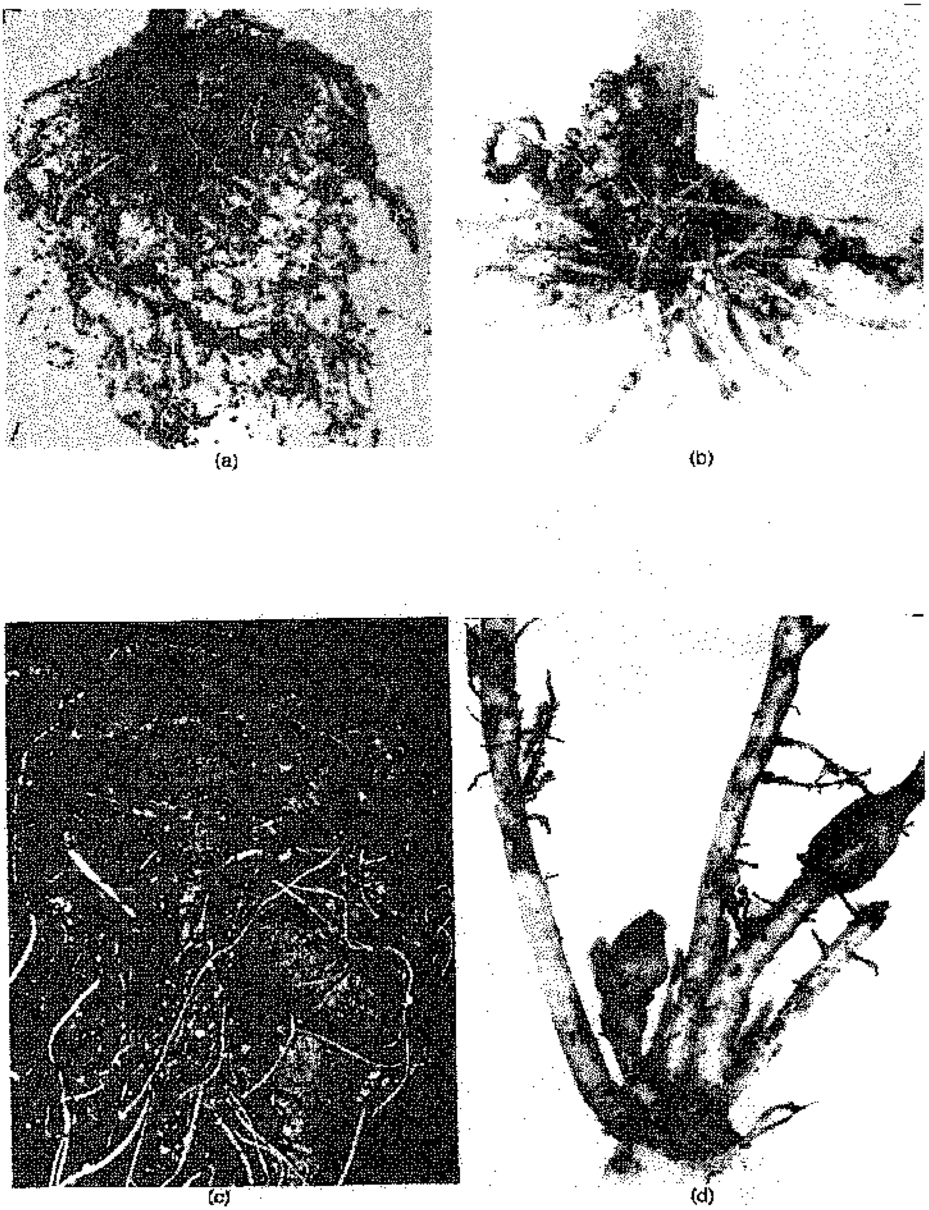
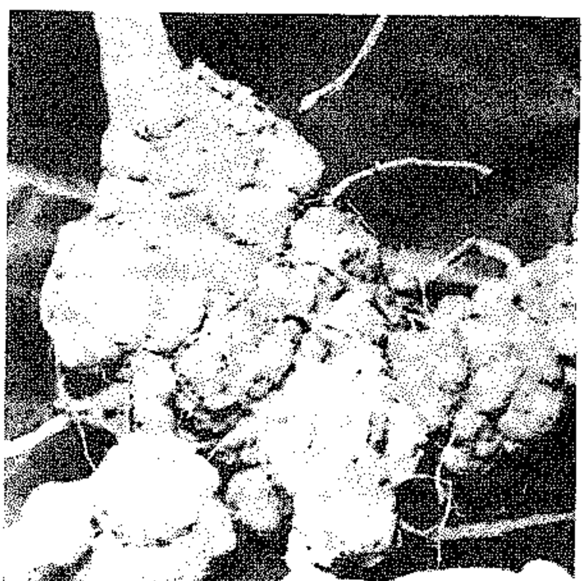


Fig. 16.7: Root knot nematodes in various crops (a) tomato, (b) Egg plant, (c) Carrot, (d) Banana, (e) Bears (f) Gourd.

(e)



(f)

Fig. 16.7: (Continued)

causing infection. The aerial parts of the infected plants show drought and malnutrition symptoms comprising yellowing and shedding of leaves as well as dieback of twigs resulting in heavy losses and slow decline of plants. Nematicidal treatment is the only possible control measure.

4. Pratylenchus spp. or Lesion Nematodes

Thirteen species of *Pratylenchus* have been reported from Pakistan, infecting many cereals, fruits and vegetable crops. They are obligatory parasites which attack young roots, the fourth stage larvae are particularly active. The females lay eggs in roots and in the surrounding soil. The larvae undergo four moults and complete their life cycle in two months. They produce on roots small lesions, which turn pale yellow to black in severe cases of infection. The leaves of the infected plants become chlorotic and stunted, producing twig blight in the later stages. Nematicidal treatment is the only cure.

5. Trichodorus spp. or Stubby Root Nematode

The stubby root nematodes have been found to infect citrus, mulberry and sugarcane in Pakistan. They are ectoparasites, which attack the roots and deposit eggs in the surronding soil. After hatching, the larvae undergo four immature stages, completing the life cycle in 45-50 days.The infected plants produce short, stunted, stubby and necrotic roots while the leaves become chlorotic and yellow. The disease can be controlled by using nematicides.

6. Rotylenchulus Reniformis or Reniform Nematode

This nematode, which has been found to infect banana, cotton, okra and soybean crops, is obligatory and sedentary ectoparasite. The females penetrate roots, feed, grow, develop and lay eggs. The eggs on hatching after a week, produce larvae which pass through three moulting stages completing their life cycle, in 25-30 days. The roots of the infected plants develop discolouration and necrosis, while the leaves start drying gradually and shedding in advanced stages.Suitable crop rotations and use of nematicides can help in controlling the disease.

7. Xiphinema spp. or Dagger Nematode

Six species of dagger nematodes have been found in Pakistan, infecting banana, grapes, citrus and wheat. They are migratory ectoparasites, which feed near the root caps of the small feeder roots. In later stages the females deposit eggs, which hatch and the larvae pass through four moults, completing the life cycle in 25-30 days. The roots of the infected plants develop swelling, necrosis and shrivelling. The only possible remedy is either suitable crop rotation or nematicidal treatment.

8. Radopholus Similis or Burrowing Nematode

This nematode, which is reported to infect banana and citrus plan-

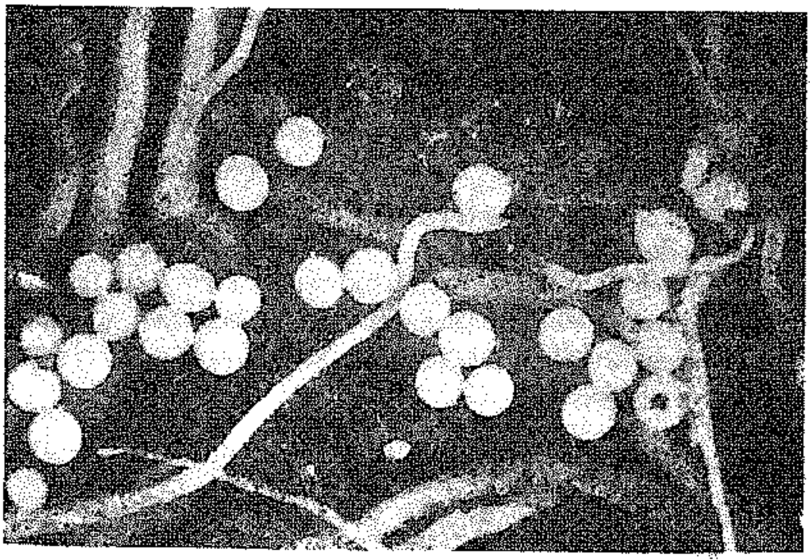


Fig. 16.8: Cyst nematodes in potato (*Globodera rostochinensis*)

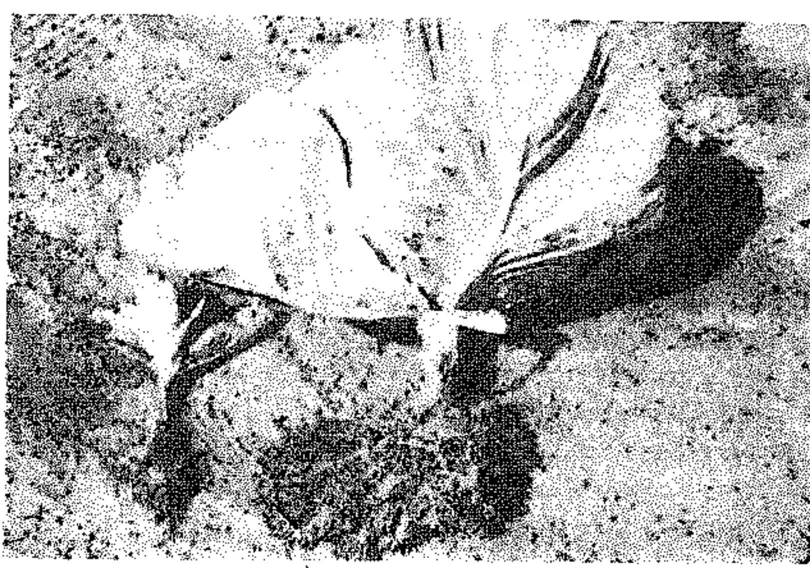


Fig. 16.9: Response of cabbage to chemical control of *Heterodera schachtii* (right) compared with infected specimen (left).

tations, has been found to be a migratory endoparasite. It lays eggs inside the infected roots and complete its life cycle in 20-27 days. The roots develop cavities and necrotic lesions and show retarded growth. The other symptoms, include yellowing of leaves and reduction in size of fruits. The diseased trees may topple over in severe cases of infection, causing heavy losses. Control measures include production and distribution of nematode-free banana suckers and/or nematicidal treatment of soil.

9. Hirschmanniella spp. or Rice Root Nematode

Five species of these nematodes have been reported to infect rice and aquatic grasses in Pakistan. These are migratory endoparasites, which can attack the roots at all stages. After a few days of infection the females lay eggs, which hatch in 4-5 days and the life cycle is completed in about 30 days. The infected roots develop surface lesions which are yellowish to rusty brown in colour. The infected plants show delayed and decreased tillering as well as reduced yield. Nematicidal treatment is the only way of controlling the disease.

B. Diseases of Stems and Bulbs

Nematodes affecting stems and bulbs of many crops like oats, potato, maize, beets, onion and garlic occur throughout the world including Pakistan, where crops such as maize, sugarcane, wheat and citrus have been reported to be attacked. The two important species - *Ditylenchus dipsaci* and *D. destructor* are commonly found in Pakistan, causing considerable damage. The work so far carried out on these nematodes is described as follows:

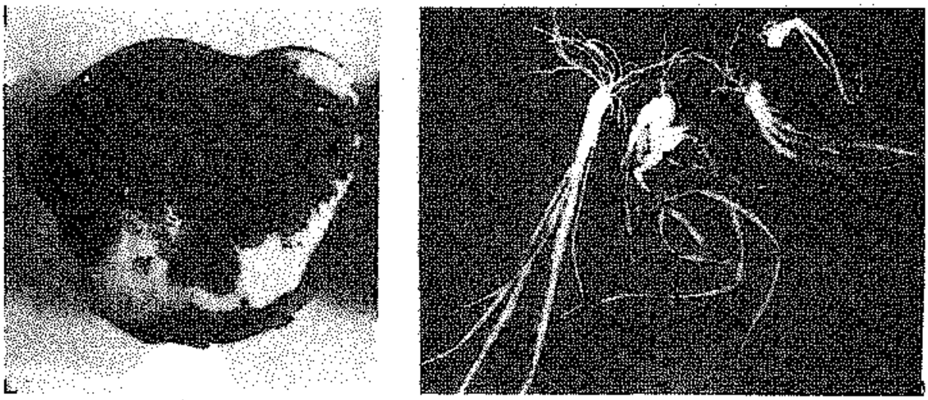
1. Ditylenchus dipsaci

This nematode has many diversified host plants like citrus, sugarcane, maize, wheat and onion. They attack roots and underground bulbs and leaves and sometimes seeds also. The nematodes complete their life cycle in about 30 days and continue causing new infections. The infected plants show production of galls, thickening of stems and twisting of leaves and bloating, in case of onions. Resistant varieties or nematicidal treat ment are the only cure.

2. Ditylenchus destructor

This nematode infects potato and some other crops and weeds. The nematode is migratory endoparasite, which feeds on under ground plant parts (stems, bulbs & tubers) entering through nature pores or potato eyes

It lays eggs inside,which hatch and the larvae pass through moults before completing the life cycle. The nematode damages the underground plant parts, producing black shrunken lesions of dry granular tissues. In the absence of resistant varieties, nematicidal treatment of the soil can help to control the disease.



(b) (a)

Fig. 16.10: *Ditylenchus* sp. in (a) Onion and (b) Potato.

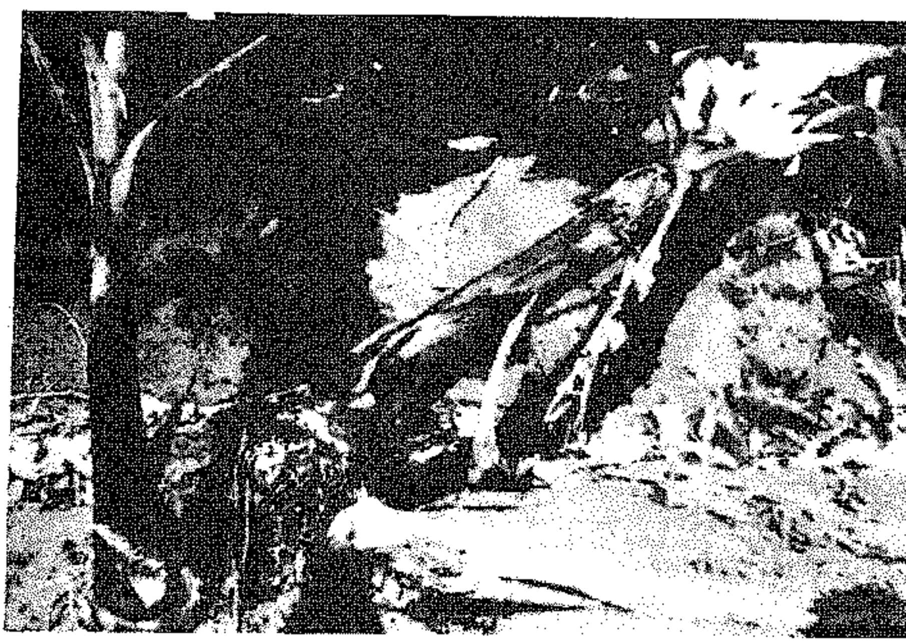


Fig. 16.11: Burrowing nematodes in banana.

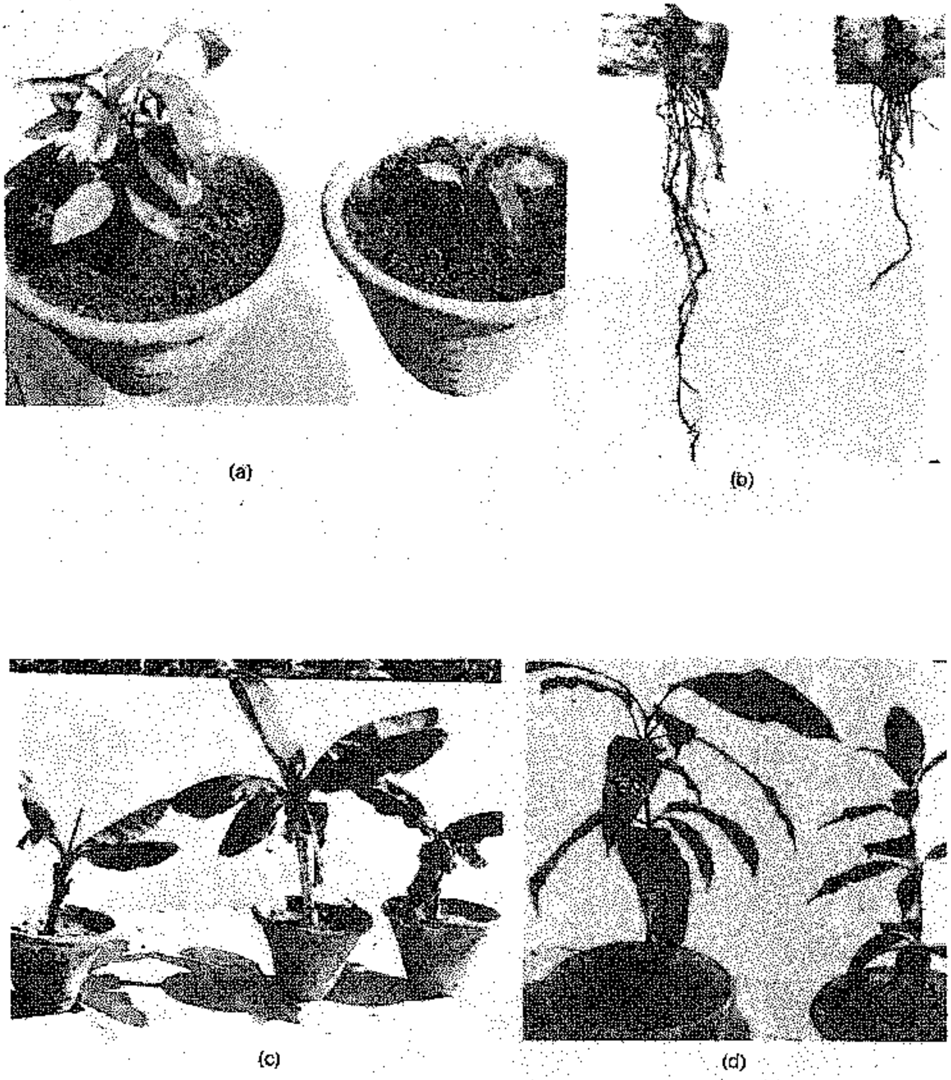


Fig. 16.12: Control of nematodes diseases: (a) Citrus in sterilized soil (left) and in infested soil (right); (b) Sugarcane in sterilized soil (left) and in infested soil (right), (c) Banana in nematode infested pots (left) and in pots with sterilized soil (right), (d) Mango in sterilized soil (left) and in infested soil (right).

Fig. 16.13: Effect of crop rotation on control of nematodes in Soybean – Corn Peanut – Soybean (upper) and continuous soybean (below).

Fig. 16.14: Response of cabbage to chemical control of nematodes.

C. Diseases Producing Stunting and Wilting (Stunt Nematodes)

Stunt nematodes have a wide distribution in the world and are important pests of cereals, fruits, vegetables, grasses, ornamentals, fibre and sugar crops. These nematodes are ectoparasites feeding on epidermal cells of plant roots and can attack in all active stages. Females lay eggs in the soil near the roots, the first moult occurs within the eggs and the sexes are differentiated in the third stage. The life cycle is completed in 35-40 days. The infected plants are stunted in growth due to invasion and feeding on the root tips, causing injury and decreasing water and mineral uptake. Infected plants produce low yields of poor quality. In the absence of resistant varieties, nematicidal treatment of the soil can help in checking the disease.

Facilities Developed for Future Work

Recognizing the growing importance of nematode diseases, matching facilities have been developed comprising training courses, a well stocked library, establishment of Pakistan Journal of Nematology and initiation of diagnostic and advisory service for the farmers besides the recent conversion of the Nematological Laboratory at Karachi into a full fledged National Research Centre on Nematology with four supporting research laboratories, one in each province.

As a result of these newly developed facilities, and strengthening of Nematology Centre at PCSIR, Karachi, work is now in progress on control of parasitic nematodes of important crops, screening of differential hosts for root-knot nematodes to identify physiological races, development of technologies for raising nematode - free nurseries and nematicides from local industrial products, breeding for resistant varieties, training and post-graduate teaching and on other essential aspects. These efforts will ultimately go a long way to protect the agricultural crops from damages caused by nematodes.

Summary

Although the diseases caused by nematodes have not received much attention in the past, investigations over the two decades have resulted in isolation of 139 species belonging to 37 genera with preponderance of *Pratylenchus, Hoplolaimus, Helicotylenchus, Tylenchorhynchus, Xiphiname, Heterodera* and *Globodera,* which have a wide spread distribution infecting many economic crops and fruit trees. Isolations also include 59 new records from Pakistan and 9 new world records. However, the serious diseases caused by nematodes are ear cockle of wheat, white tip of rice,

root-knots, root lesions, slow decline of citrus, and tuber and stem rots.

The symptoms and type of damages caused by various groups of nematodes have been described, along with modes of perpetuation, factors affecting the incidence, laboratory and field methodologies and control measures.

A brief account of some importance diseases has been given in three distinctive groups affecting (roots, stems and bulbs; and those producing stunting and wilting) describing, host plants, biology and life cycle of pathogens, symptoms and possible control measures. Mention has also been made of the development of recent facilities to strengthen and streamline the future researches on the control of nematodes diseases with a view to enhancing the agricultural productivity.

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Chapter XVII

Phanerogamic Parasitic Plants

In Pakistan, four species of flowering plants have been found to live parasitically on many agricultural crops, fruit and ornamental plants as well as on forest trees. These parasitic plants, belonging to distinct botanical families, depend for their existence on the host plants through haustoria (thread-like structures), which penetrate into the host tissues. However, they show varying degrees of parasitism. Some of the parasites like *Striga* spp., which have chlorophyll and roots, are able to manufacture their own food but still depend on host plants for obtaining certain dissolved minerals. Others like Misteletoes which have chlorophyll but no roots derive water and minerals from their hosts. Still others like Dodder and Orobanche, which have neither chlorophyll nor true roots, depend entirely on the hosts for food and water supply. Generally, such plants are never green, their leaves if any, are small and inconspicuous and their functional root system is greatly modified developing inside the host tissues. Thus, the parasitic plants cause disease-like symptoms mainly by reducing the supply of water and nutrients to the host plants leading to retarted growth. The most common and serious parasitic plants are described as follows.

1. Dodder (Love Vine Weed) *Cuscuta* spp.

Occurrence and Importance

Dodder is a widely distributed plant throughout Pakistan. It parasitizes a variety of hosts, belonging to different botanical families. It has been found to attack, alfalfa, clovers, onions, linseed, potato, sugarbeet and some legumes besides citrus, *Zizyphus*, *Artemisia* and *Acacia* spp. Hedges and ornamental plants are also infested. Dodder retards the growth and reduces the yield of infested plants. The losses range from slight to complete destruction of crops like alfalfa and linseed raised from dodder-contaminated seeds. Dodder may also serve as a bridge for the transmission of viruses from infested to healthy plants.

Fig. 17.1: Cuscuta on potato plant.

Symptoms

In the beginning, the infection is localized with the development of small thread like structures of orange to yellow colour. They rapidly grow in size and density attacking the healthy parts as well as the adjacent plants ultimately strangling the stems and the above ground parts with dense tangles of leafless strands. In later stages, each infested spot may cover 3-4 m. Thus, the dodder-infested areas appear as patches in the field. With the spread of infection, several infested patches develop and coalesce giving rise to large areas covered with yellow coloured vines (Fig. 17.1). The losses caused vary according to the crop growth stage and intensity of infestation.

Pathogen

There are many types of dodder plants belonging to different species of *Cuscuta*. They all look alike and are difficult to differentiate. However, on the basis of thickness of stems they are grouped into two types; i.e.; thick-vined species and thin-vined species. The first category, which is also known as large-seeded dodder includes *Cuscuta arvensis; C. gigantea; C. reflexa* var *anguina; C. brachystigma;* and *C. monogyna,* with stem thickness ranging between 0.98 and 2.04 mm while the average diameter is 2.1 mm. Thin-vined species include *Cuscuta planiflora; C. campestris,* (field dodder) and *C. europaea* var *indica* with stem thickness ranging between 0.25 and 0.68 mm and fruit diameter is 0.8 mm. the latter category poses comparatively more serious problem to the field crops.

Perpetuation

Dodder perpetuates from year to year either through its seed mixed with those of the crop or infested crop debris containing seeds or living bits of the vine. Under favourable conditions either the seeds germinate or the plant bits initiate growth. If the germinating seeds or the plant bits do not find any host plant, they die otherwise they develop contacts with the host establishing parasitism through haustoria and start growing. Sometimes dodder seeds are also dropped on the growing plants through excreta by birds eating dodder fruits. With time the germinating dodder plant looses its contact with the soil and start depending entirely on the host plants water and nutrient supply. It continues to grow, spreading and invading the host plant as well as developing flowers and producing seeds.

Control

The practical methods of preventing dodder infestation include use of dodder-free crop seeds, burning of crop residues and restricting the movement of animals and farm equipment from infested to healthy fields. In severe cases of infestation, it is useful to carefully collect and burn the infested patches before flowering and fruiting. Experiments carried out have given effective control by spraying the dodder seedlings with either of the chemicals such as Diesel oil; 2, 4 - D; Kerosine oil fortified with DNBP. If needed, scattered infested patches can also be sprayed. Biological control may also be possible by using the suitable type of predators. Three species of weevils (*Smicronyx ghan, S. uhoensis* and *S. inornatus*) have been found to parasitize on flowers and fruits of *Cuscuta*. It will also be useful to follow 3-4 year rotation by using non-host plants in the cropping system.

2. Striga (*Witch Weed*)

Occurrence and Importance

Striga, a chlorophyllous weed, is distributed in the Punjab, Sind and parts of NWFP and Baluchistan. It is largely confined to areas where poor tillage and monoculturing of susceptible hosts are practised. It usually parasitizes on summer-graminaceous hosts such as sorghum, Johnson grass, pearl millet, maize and sugarcane. Losses due to striga vary with the degree of infestation in the fields between 1-2 percent but may reach as high as 10-15 percent in severely infested crops.

Symptoms

The infestation of plants by striga usually appears in circular patches as a result of heavy localized deposits of seeds in the field. The striga seedlings are attached to the roots of the host plants through a large number of tentacles or haustoria for obtaining their water and nutritional requirements. In some cases, the affected roots produce masses of hairy rootlets assuming witch-like appearance and hence also named as witch weed. Due to robbing of the nutrients and water, the infested host plants turn yellow, remain stunted resulting in poor growth and reduced yield (Fig. 17.2).

Pathogen

The parasitic weed is named as *Striga asiatica*, which belongs to the family *Scrophulariaceae*. It has light green stem, 15-25 cm in height, producing multiple branches near or above the ground level. The leaves are long, slightly hairy and rough-textured and grow opposite to each other. The flowers are small, white to yellow in colour appearing above the leaf attachment and are produced throughout the growing season. The pods or capsules develop in large numbers, each containing thousands of tiny brown seeds, which are disseminated by wind, water or through contaminated soil and farm implements.

Perpetuation

The seeds of the striga over winter in contaminated fields and their dormancy is broken by certain chemical substances released by the roots of the host plants growing in their vicinity. The seeds after germination tend to grow near the roots of the host plants with which they develop contact through conical or bulbulous shaped haustoria, penetrating into the

(a) (b)

Fig. 17.2: Striga on (a) Sugarcane & (b) maize.

xylem bundles. This mechanism helps the striga plant to draw its water and nutritiional requirements from the host plants. In severe cases of infestations, many striga plants may get attached to a single host plant but a few of them survive to reach the ground surface. The striga due to its chlorophyllous nature can manufacture some supplementary food. The whole life cycle takes about 3-4 months to complete.

Control

In the absence of resistant varieties, the best treatment lies in the destruction of striga seeds in infested fields. This can be done by spraying with weed killers like 2, 4-D (0.05 percent) or any other suitable chemical before sowing the next crop. Three to four year rotation with inclusion of non host crop plants, particularly those which may stimulate germination of striga seed without being attacked is also useful in controlling the weed. However, integrated approach may be more effective.

3. Broom Rape (*Orobanche* sp)

Broom rape is an angiospermic root parasite attacking a large number of cultivated crops, fruit and forest trees, medicinal as well as many wild plants. Extensive surveys carried out in Baluchistan during 1970-80 have shown that at least 20 plant species are infested by *Orobanche* as against 70-80 globally recorded. These include *Achillea santelinal; Apium graveolens; Artemisia maritimal; Aster clataicus* Will. *Brassica campestris* L., *Capsicum frutescens; Chenopodium album; Cucumis melo* var. *fleruosus; Hyoscyamus nigra; Cucurbita moschata; Hibiscus trionum; Lufa acutangula; Ocimum sanctum; Othonnopsis intermedia; Peucedanum graveolens; Prunus amygalus; P. armeniaca; Zinnia elegans* and some *Solanaceous* spp. like tobacco, eggplant, tomato, datura, mustard, cabbage, cauliflower and turnips. It is highly infectious and prolific as a single plant may produce 500-50000 seeds within 22 days after its emergence. It can thus cause severe losses, which vary between 20-80 percent, depending upon time of appearance and nature of the host plant.

Symptoms

Orobanche is a root parasite, which after its attachment to the host plant emerges above ground. It deprives the host of water and nutrients, which reduces the growth; vigour and yield of the crop, causing near-wilt conditiions. In root crops the infection leads to formation of hard pith while in others both the quantity and quality of leaves and fruits are affected. The infestations are first observed in small patches, which gradually increase in size and ultimately cover large areas (Fig. 17.3).

Pathogen

Two parasitic species of *Orobanche* have been identified in Pakistan as against 80 species reported from other contries. These are *Orobanche aegyptica*, which has a wider host range and *O. stockii* with narrow host range. The plant is achlorophyllous, light to dark brown in colour, having succulent and rough-textured stalks growing as high as 20-50 cm. The stalks have numerous bract-like shining leaves. It starts profusely flowering within 3 weeks, producing small and minute seeds of 0.2-0.3 mm x 0.2 x 0.1 mm size. These seeds can easily contaminate the crop seeds making their separation virtually impossible. These are also dispersed through wind, irigation water or movement of animals and farm implements. The seeds can also remain viable after passing through the alimentary canals of the cattle eating the flower spikes.

Perpetuation

After receiving stimulating effect from the host plants, the *Orobanche* seeds germinate and establish parasitic contacts with their roots through the penetration of haustoria. The *Orobanche* plants then grow and develop on water and nutrients provided by the hosts plants and complete their life cycle within 20-25 days, liberating multitude of tiny seeds for future infestations.

Control

Earlier work carried out in Baluchistan has indicated the effectiveness of some chemicals like allyl alcohol; formalin; methyl bromide; sodium arsenite; 2, 4-D; 2, 4, 5-T and common salt. However, their use lacked practical field application and also involved high cost and hazardous effects on the host plants. Later work has shown that application of mineral oils (kerosine, crude oil and diesel) at 2-week interval as post emergence treatment gave 85-90 percent mortality of *Orobanche* without any detrimental affects on the cultivated crops. Wetting of the *Orobanche* stalks with solution of 5 percent ammonium sulphate, 15 percent urea or 20 percent ammonium nitrate has also yielded some good results. The main draw backs of these control measures are high cost, difficult and time consuming mode of application. Development of resistant varies (as reported to done in the case of sunflower, broadbean, lentil, musk melon, water melon, tomato, sweet potato and cucumber) will be the best and practical way of control, and work needs to be concentrated on this approach.

(a)

(b) (c)

Fig. 17.3: Broomrape on (a) Potato (b) Vegetable plant and (c) A weed plant.

4. Mistletoes

Mistletoes are the important parasitic weeds of conifer forest trees and some other types of plants, causing appreciable and extensive losses. Trees of any age (seedlings, saplings and adult plants) can be parasitized which ultimately get retarded, dwarfed or even killed. Height of the infested tree is reduced by 30-50 percent while the timber quality is deteriorated due to the formation of knots and abnormally spongy type of wood. Surveys of the temperate, dry temperate and dry regions of NWFP, Azad Jammu and Kashmir and Baluchistan have revealed the prevalence of five species (two Himalayan dwarf species and three leafy mistletoes), which have been found to infest a large number of forest trees with greater intensity in NWFP. Generally the distribution of these species is mainly influenced by the ecosystems and physiography. The salient features of the work done are as follows:

4.1 Himalayan Dwarf Mistletoe, *Arceuthobium minutissimum*

Occurrence and Importance

Dwarf misletoes have been found to parasitize blue pines (*Pinus wallichiana*) and chilghoza pine (*P. gerardiana*) in the temperate and dry temperature forests of Kalkot range of Dir and Malakand forest Division of NWFP. *A. oxycedri* has been noticed to be wide spread in Ziarat forests on Junipers in Baluchistan while infestations of blue and chilghoza pines by *A. minustissimum* are visible along the banks of Panjiukara river in the Kalkot range. Its incidence was found to be the highest (74.1 percent) on trees growing on southern aspects; closely followed by 66.4 percent on western, 60.8 percent on eastern and the lowest; i.e.; 54.3 percent in northern aspects; with an average incidence of 62.9 percent. Warmer aspects, therefore, appear to be more favourable for the attack of dwarf mistletoes than the cooler ones.

The mistletoe infection deteriorates the stand and the infected trees give a pale yellowish appearance, which is detectable from a distance. Reduction in height of trees and quick mortality of young plants are common. The incidence of attack increases with the growth in diameter of trees, being the highest (98.8 percent) in trees with 101 cm or above diameter and the lowest (14.5 percent) in 20 cm class. Using Hawkworth's 0-6 class rating; infection index of 2.7 was obtained.

Symptoms

Simple or branched shoots of mistletoe appear along the twigs and branches of the host plants and develop swellings and cankers in the affected parts. Yellow wedge-shaped haustoria of the parasite grow into the bark, cambium and xylem tissues of the branches. Some plant species, as a result of infection, produce proliferous growth of branches. Large swellings or flattened cankers may also develop on the trunks, sometimes resulting into breaking of the trees. Heavily infested trees are dwarfed, remaining stunted in growth and even die in advanced stages of attack. The most conspicuous symptom of dwarf mistletoes is the presence of witches' broom and bushy appearance of the infested trees (Fig. 17.4).

The main parasitic species has been identified as *Arceuthobium minutissimum*. It possesses stems which vary in size, colour and has simple or jointed shoots. Leaves are inconspicuous and scale-like. The parasitic plants are either male or female producing complex ramifying system of haustoria consisting of longitudinal strands, which are found parallel to the host cambium. The fruits mature within 6-16 months after pollination of the flowers and seeds are discharged. The seeds are covered by a mucilaginous sticky substance and adhere to any thing on contact and are the main source of spreading the parasite.

4.2 Leafy Mistletoes – *Viscum album, korthalsella opuntia* and *Loranthus longifloris*

Occurrence and Importance

Three leafy mistletoes have been found to be prevalent on different

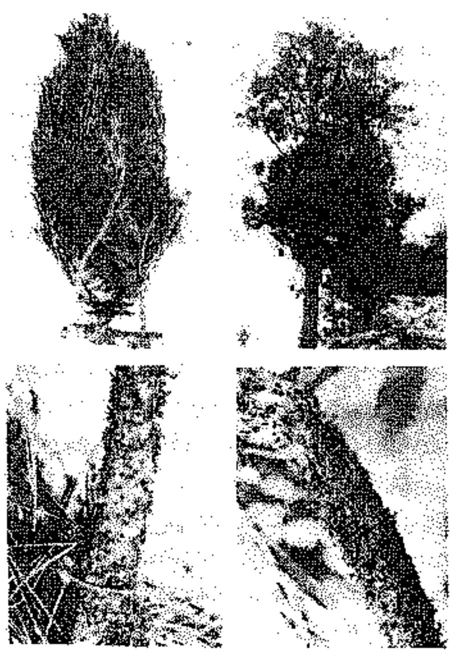

Fig. 17.4: Misteletoe attack on (a) *Pinus gerardiana;* (b) Pine tree; (c) and (d) Two branches of a pine tree.

hardwood species belonging to nine botanical families. (a) *Viscum album* has been recorded on *Prunus prostrata, Juglaris regia, Populus ciliata* and *P. alba* in the Kalkot range with an incidence ranging between 15-46 percent. (b) *Korthalsella opuntia* parasitizes on a single host (*Quercus ilex*) in the Shringal range of Dir forest Division. (c) *Loranthus longifloris* has been commonly found in Mirpur range and infests a number of angiosperms belonging to four families, which include *Acacia modesta* (with 32 percent infection), *Dalbergia sissoo, Salmalia malabarica, Zizyphus* spp. and *Lanna coromendelica.*

Symptoms

Leafy mistletoes parasitize hard wood tree species. Branched shoots of the parasite appear on the main stems and branches of trees, which develop severe swellings and cankers. Haustorial system penetrates into the bark, cambium and xylem tissues of the branches. Large swellings and canker-affected portions are liable to be weakened due to removal of water and nutrients by the parasite. In advanced stages of attack the trees break and the infected sites give poor and patchy appearance.

Pathogens

Three leafy mistletoes have been identified; i.e.; *Viscum album. Korthalsella opuntia* and *Loranthus longiflorus.* The last one is described below. It is perennial, green in colour and upto 15 cm tall. The internodes are 5-18 mm long, linear to oblanceolate; flowers 4-12 per node in cupular bracts, perianth lobes 1 mm long, oblanceolate, acute or obtuse; anthers bilocular and persistent in female flowers with 3-4 sessile stamens; Ovary 0.5 mm long, oblong; stigma sessile; berry obovoid, 1.5-2 mm long subsessile and 1-seeded. Seeds are 1 mm long and cordate surrounded.

Perpetuation

The mistletoe seeds, because of their mucilagenous nature, get attached with the bark of a twig or a young branch of the susceptible host They germinate and produce germ tubes which then reach the buds or the leaf basis where they develop haustoria, penetrating the bark directly and ultimately reaching the phloem and cambium tissues. A system of longitudinal strands, which remain permanently embedded in the wood, develops from the haustoria for absorbing water and nutrients from the host. The infected parts are either killed due to the removal of water and the nutrients or in some cases the parasite causes hypertrophy and hyperplasia in the cells resulting into swellings and deformities of branches due to the creation of hormonal imbalance. Sometimes, this imbalance also stimulates dormant lateral buds to form excessive shoots and dense growth of abnormal appearance. Heavy parasitization weakens the trees, predisposing them to breakage and the attack of wood rotting fungi, other root pathogens and beetles.

Control

The following control measures have been successfully tested and demonstrated on a large scale:

1. Physical removal of mistletoe-affected twigs and branches by pruning, cutting or sawing in order to remove the entire haustorial system;
2. Spraying with 30-40 percent diesel oil emulsion mixed in soap solution;
3. Maintaining of a protective zone free from parasite surrounding the healthy stands. This can help to contain the parasite and restrict its spread to the neighbouring trees.

Summary

After describing the nature of the phanerogamic plants parasitizing many agricultural crops, fruit and forest trees, the chapter deals with four parasitic plants (Dodder, striga, orobanche and mistletoe) found in Pakistan. The host range of these phanerogamics, symptoms produced, modes of perpetuation and distribution alongwith possible control measures have been given. Dodder (or love vine weed) is widely distributed, parasitizing many plants like alfalfa, clovers, onions, linseed, potato, sugarbeet etc., causing substantial damage. Two types of cuscuta (thick-vined and thin-vined species) have been found, latter being more problematic. The practical methods of preventing dodder infestation, which include use of dodder-free seeds, burning of crop residue, spraying dodder plants with certain chemicals and practising of long rotations have been advocated. Striga (witch weed), parasitizes on sorghum, Johnson grass, pearl millet, maize and sugarcane in all the provinces, causing losses upto 10-15 percent in severely infested crops. It perpetuates through overwintering in contaminated fields, completing its life cycle in 3-4 months. It can be controlled by destroying the seeds infesting the fields by using some chemicals although the most economical method lies in the development of striga resistant varieties. Orobanche or Broom rape has been extensively surveyed in Baluchistan infecting twenty plant species, which have been

enumerated. Two parasitic species (*Orobanche aegyptica* and *O. stockii*) have been found. The former having comparatively a wider host range. It completes its life cycle in 20-25 days and produces multitude of tiny seeds, which are responsible for spreading the disease. The control measures comprising the use of a number of chemicals as well as individual solutions of ammonium sulphate, urea and ammonium nitrate, although effective, are costly, time consuming and difficult to apply. The fourth parasitic plant (Mistletoe) has been extensively surveyed in the forests of NWFP, Azad Jammu and Kashmir and Baluchistan causing heavy damage to the infested trees. Five species (two Himalayan dwarfs and three leafy species) have been identified. Detailed studies carried out on the dwarf mistletoes (*Arceuthobium minutissimum,* parasitizing blue pine and chilghoza pine and *A. oxycedri* infecting Junipers) have been described. Host plants of three leafy mistletoes (*Viscum album, Korthalsella opuntia* and *Loranthus longiflorus*) have been enumerated. Practical control measures have been worked out and implemented on large-scale basis with promising results.

However, the phanerogaic parasitic plants have not received due attention of the scientists because of lack of suitably trained manpower. This discipline needs to be properly mobilized under a specialized research unit at national level to work on the identification of parasitic plant species, ecological distribution, host range, nature of losses, factors affecting incidence as well as cultural, chemical and varietal control measures in the larger interest of the country.

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Chapter XVIII

Weeds and Weed Control

Introduction

Weeds pose a big problem to agriculture because they are always present in varying intensities in different crops adversally affecting the quality and yields. Plants growing out of place are termed as weeds. They may be wild plants or agricultural plants growing out of place in a specific crop. Weeds often crowd out cultivated plants. They may have a short life cycle, and may reproduce vegetatively or through profuse seeding* (upto 80,000 seeds per plant are produced in poppy) and can perpetuate over long periods due to dormancy and longevity of seeds. Consequently, weeds compete with crops for water, mineral nutrients, light and space and sometimes also harbour insect pests and diseases. Weeds also increase the cost of crop production and decrease the market value of the crop due to reduction in quantity and quality of the produce. They also make the harvesting and threshing operations more difficult, costly and time consuming. Some species of weeds are also poisonous for human beings (*Lolium temulentum* and *Agrostemma githago*) and for animals (*Senecio jacobaea*). Aquatic weeds can block drainage ditches & canals, causing flooding and transport difficulties. Due to their aggressive nature, even fallow fields, if not well managed can become infested with weeds. Thus instead of the restoration of soil fertility by leaving the fields fallow, soil moisture and nutrients are depleted by weed growth. In addition the land becomes contaminated with the spread, dispersal and multiplication of seeds and vegetative parts. As "one year's seeding equals ten years

*The number of seeds produced can be extremely large; one dense weed stand was estimated to have produced more than 12,000 million seeds/ha in the United Kingdom. Weed control Handbook Vol. 1- Principles including plant growth regulators - J.D. Fryer and R.J. Makepeace, 1977 (Blackwell Scientific Publications).

weeding", it is very difficult to eradicate an established colony of weeds. It has been rightly said that:-

"If good we plant not
Vice will take its place
And the rankest weeds
The fairest soil deface"

In Pakistan it has been estimated that on an average, weed/crop plant population is 3:1. The annual losses caused by weeds are estimated to exceed 3000 million rupees, a loss greater than that caused by rodents, birds, insect pests and diseases collectively. Despite such an alarming factual position, very little systematic study has been made on weeds and their control. The joint neglect by scientists and farmers has resulted in gradual increase of weed infestation giving rise to low per acre yields and heavy losses to the crops. An attempt has, therefore, been made in the following pages to summarize the significant information available from the researches carried out in the country in order to help improve future investigations on weed control.

Survey

The cultivated crops are infested with different weed species in all the countries of the world. Surveys of agricultural crops carried out by various researchers in Pakistan have revealed the presence of 119 weeds; with more emphasis on wheat, rice, cotton, sugarcane, potato and tobacco while the other crops are not well covered (Table 18.1). In these studies weeds have been arranged alphabetically on the basis of their botanical names with information on families, common names, crops infested and morphological description.

Surveys carried out on aquatic weeds have revealed the presence of water hyacinth, *Hygrorhiza aristate, Ludwigia perennis, Nasturtium officinale, Nymphaea lotus, Polygonum glabrum, Potamogeton perfoliatus* and *Ranunculus* sp. in various degrees of infestation; water hyacinth being more serious in marshy lands, water streams and ponds in certain localities. In addition, five types of algae (*Chara, Spirogyra, Nostoc, Oedogonium* and *Rivularia*) have been recorded from rice fields (Fig. 18.1-18.4).

Weed-Crop Competition

The growth of crop plants is the result of interaction of their genetic constitution with environmental fluctuations. Thus the full exploitation of the potential for productivity of cultivated crops require the provision of

Table 18.1: Weed flora of different crops

	Botanical name	Family	Local name	Description	Crops infested
1.	*Amaranthus blitum* Linn.	Amaranthaceae	Chulai	Annual, found in kharif crops and waste lands, stem erect or prostrate, 1-2" high, flowers borne in clusters and seeds round and deep red or shiny black. Appears in April and flowers in rainy season.	Sugarcane and maize.
2.	*Amaranthus spinosus*	Amaranthaceae	Chulai	Annual and spiny, found in kharif crops and waste lands. Appears in April and flowers in September.	Tobacco and sugarcane
3.	*Ammaranthus viridis Linn.	Amaranthaceae	Jangli chulai	Annual, commonly found in cultivated and waste lands. Stem slender, 1-2" high, sparingly branched, flowers green axillary or terminal borne in paniculate spikes. Appears in March-April and flowers in rainy season.	Sugarcane, cotton, tobacco and potato
4.	*Ammannia auciculata* Wild.	Lythraceae	Chawali booti	Annual, 12-40 cm. tall, erect or decumbent. Stems usually unbranched epicalyx minute, calyx erect, capsules 2-3 mm in diameter. Flowering period August-September.	Rice.
5.	*Ammannia multiflora* Roxb.	Lythraceae	Chawali booti	Annual 15-40 cm. tall, stems erect and branched, epicalyx folding, hornlike and minute, capsules 1-1.5 mm. in diameter. Flowering period September.	Rice.
6.	*Ammannia senegalensis* Acut. non Lamk.	Lythraceae	Mehandi booti	Annual, found in moist localities and in water-scanty rice fields, reproduces by seed, stem	Rice.

			erect 6-24" high, branched and reddish, flowers minute and green, seeds reddish brown and semi circular. Appears in dried up rice patches during June/July, flowers in August/September and fruits in October.	
7.* *Anagallis arvensis* Linn.	Primulaceae	Billi booti	Annual, small sized, spreading blue flowers, seeds small and 3-angled. Appears in December/-January, flowers in February and sheds seeds by March/April.	Sugarcane wheat, barley oats, rice, tobacco and potato
8. *Argemona mexicana* Linn.	Papaveraceae	Sialkanta, Kandiali or Pilwala Dhatura	Annual, 30-125 cm. tall with yellow latex, leaves sinugate-lobulated (spinus toothed), flowers yellow and sessile, 3-8 cm. seeds many blackish brown, more or less rounded, flowering period February-May.	Sugarcane, rape and mustard.
9.* *Asphodelus tenuifolius* Cav.	Liliaceae	Piazi, Bhukat	Annual, erect and much branched. Appears in October, flowers in March and sheds seeds by mid April.	Wheat, barley, oasts, rape and mustard.
10*. *Avena fatua* Linn.	Poaceae	Jangli juvi	Annual, culms 30-150 cm. high, leaf blades 10-45 x 3-15 cm. Inflorescence open or rarely contracted panicle and large pendulous spikelets (18-25 cm. long). Flowering and fruiting period May-August and sometimes as early as March.	Wheat.
11.* *Boerhaavia repens* Linn. (Syn. *B. diffusa* L.)	Nyctaginaceas	Itsit	Prennial, found in kharif crops and waste dry places, stem and branches protrate 3-4" long, flowers minute and crowded. Sprouts from rootstocks in February/March, flowers druing May/-November and subsides in winter.	Sugarcane.

12. *Brassica campestris* Linn.	Brassicaecae	Sarson	Cultivated as oilseed crop and its leaves and shoots used as pot herb. Annual, slender tap root. lower leaves green, open flowers, petals bright yellow. Flowering period January to March.	Wheat, barley and oats.
13. *Bromus japonicus* Thunb. ex. Murr.	Gramineae	Jondri	One of the important grasses along roadsides. It is present in winter and spring.	Wheat, barley and oats.
14. *Cannabis sativa* Linn.	Cannalenaceae	Bhang	Diecious, annual, tall, erect, slender; Leaves alternate, above opposite, below plamately 3-9 foliate. Male inflorescence fasciculate, shorter than the leaves.	Tobacco.
15. *Capsella bursapastoris* (L.) Medic	Cruciferae	Bambesa	Annual or biennial, tall erect, glabrous or hairy. Fruit obtriangular, strongly compressed at right angles to the septum.	Tobacco.
16*. *Carthamus oxycantha* Bieb.	Compositae	Pohli	A serious weed of rainfed areas hindering crop harvesting. Annual, stem stout and much branched. Appears in January/February. Seeds set in yellow flower beads and are shed by May.	Wheat, barley and oats.
17. *Cenchrus ciliaris* Linn. (*Cenchrus pennisetiformis* Hochst. and ex Stend.)	Graminae	Sitti, Anjan	Common in desert places. Annual or short-lived perennial, culms 10-40 cm. high, leaf blades 2-20 x 2-5' mm. Spikelets 1-3 per burr, valuable fodder grass over a long period. Flowering and fruiting period February-April and again during August-October.	Sugarcane and maize.
18*. *Chenopodium album* Linn.	Chenopodiaceae	Bathu	A serious weed of canal colonies and moist localities, spreads through contaminated seeds, stems erect 1-3", minute flowers, seeds smooth	Wheat, barley, oats and tobacco.

			and black. Appear in November/December and sheds seeds by March/April.	
19.* *Chenopodium murale* Linn.	Chenopodiaceae	Karund	Annual, found mostly in moist soils, stems erect 1/2-1-1/2" high and much branched. Appears in November/December, flowers in March/April and sheds seeds earlier than C. *album*.	Wheat, barley, oats, potato and tobacco.
20*. *Cirelum arvensis* Linn. Hoffm.	Compositae	Leh	Annual, a serious weed, like moist water logged and saline soils, erect with creeping rootstock, stem 1-4" tall and unbranched. Flowers in March/April and seeds mature by April-May.	Wheat, barley and oats.
21. *Coix lacrymajobi* Linn.	Poaceae	Sunklu	A common grass, annual, culms 1-3 m. high, leaf blades 10-45 x 2-5' cm., spikelets 7-8 mm. long. Flowering and fruiting period from August to October.	Rice.
22*. *Convolvulus arvensis* Linn.	Convolvulaceae	Lehli	Perennial, found in grain fields, sugarcane and waste places, reproduces by seeds and creeping stock, deep rooted(5-6 m), stem slender and twining, flowers and fruits throughout the year reproducing most actively during March/June.	Wheat, barley, oats, sugarcane cotton, maize and tobacco.
23. *Convolvulus pluricaulis* Chois.	Convolvulaceae	Bey phali	Perennial, mostly found in dry areas, rarely present in waste lands of canal colonies. Rootstock woody, branched 1-3" long, prostrate, slender and hairy, flowers during March/June.	Wheat, barley, oats and sugarcane.
24 *Conyza stricta* Wilид.	Compositae	Daryai booti	Leaves undivided and lobed. Small yellow heads, flowering in autumn.	Sugarcane.

25. *Corchorus olitorius* Linn.	Tiliaceae	Wild jute	Common in cultivated and fallow lands in moist shady places. Annual or biennial, upto 3 m. tall Stems woody and branched, leaves 2-9 x 1.3-4.2 cm. Seeds greenish black and triangular.	Cotton.
26. *Corchorus tridens* Linn.	Tiliaceae	Wild jute	Found in cultivated fields and waste lands. Stems and branches glabrous, erect 30-60 cm. tall. Seeds black, angular and obliquely truncated at both ends.	Cotton.
27. *Cornopus didymus* (Linn.) Smith (Syn. *Senebiera* Linn.) Pers.	Cruciferae	Jungli Haloon Naksari	Annual, common winter weed, leaves deeply pinnate with pungent smell.	Wheat, barley and oats.
28. *Cousinia minuta* Boiss	Compositae	Kohara, Kandiari	Common in open dry spaces. Flowers are bright yellow, leaves are spiny.	Wheat, barley and oats.
29*. *Cynodon dactylon* (Linn.) Pers.	Gramineae	Khabbal, Talia, Dub	Stem runner, flowers small, perennial, deep rooted, spreads through seeds and vegetative parts and difficult to eradicate.	Sugarcane, wheat, barley, oats, cotton, rice and tobacco.
30*. *Cyperus difformis* Linn.	Cyperaceae	Bari ghulen (Ghooln)	Annual, reproduces by seed, stems erect 1-3' high, flowers during July/September and nuts mature in October/November.	
31*. *Cyperus iria* Linn.	Cyperaceae	Khanna (Bhoin)	Annual, reproduces by seed, roots fibrous, stem tufted 1-2' high, leaves as long as stem, spikelets yellow brown and 1-2" long. Appears during June/August and flowers in July/September.	Sugarcane and rice.

32. *Cyperus laevigatus* Linn.	Cyperaceae	Kanna ghas	Common in damp-boggy and marshy habitats. Annual or perennial, grass like.	Rice.
33* Cyperus rotundus Linn.	Cyperaceae	Deela, Motha	Perennial, serious weed of sugarcane and also found in rice and rabi crops, reproduces by seeds and small bulbs, stem erect 1-2' high, spikelets chestnut - brown, flowers during rainy season even earlier in moist localities and growth checked in winter.	Wheat, barley, oats, cotton, rice, sugarcane and potato.
34. *Datura alba, D. metel* Linn. (Syn. *D. fastuosa* L. Nees)	Solanaceae	Dhatura	Poisonous plant, 5-10 lobed corolla and capsule is turned downwards.	Potato and maize.
35. *Dactyloctenium aegyptium* (L.) Willd.	Gramineae	Madhani grass	Stoloniferous, annual, inflorescence open, spikes ascending or radiating from culm tips, grain coarsely transversely rugose.	Sugarcane and maize.
36. *Dasmostachya bipinnata* Linn.	Gramineae	Dhabb	Perennial grass, spreads through seeds and vegetative parts, deep rooted and difficult to eradicate.	Cotton and tobacco.
37. *Dicanthium annulatum* (Forssk.) Stapf (Syn. *Andropogon annulatus* Forssk.	Gramineae	Janewar, Bara jergi, Donda, Jarga	Perennial, geniculately ascending. Infloresscene pedunculate, racemes subdigitate lower glume sessile. Spikelet without a subapical ciliate fringe.	Rice.
38*. *Digera arvensis* Forssk. (Syn. *D. alternifolius* Linn.) Aschens	Amaranthaceae	Tandla	Annual, found in kharif crops, fallow lands and on sides of water channels, stem erect 1-3' tall, spikes 1-4" long and flowers minute and pinkish. Appears in March/April and flowers during May/October.	Maize and sugarcane.

39. *Digiteria sanguinalis* (Linn.) (Syn. *Panicum sanguinale* Linn.) (*Paspelum senguinale* Linn.)	Gramineae	Moti Khabbal	Annual, inflorescence digitate or subdigitate, spikelets binate. Margin of raciuis scabrid, nerres of sterile lemma with sparse to numerous minute siliceous spines or scabridities, over their whole length or at least upwards.	Maize and sugarcane.
40*. *Echinochloa colonam* (L)Link. (Syn. *Panicum colonum* Linn.)	Gramineae	Swank	Common in moist places.Annual, 10-100 cm. high, erect leaf blades 5-30 x 2-8 mm., and marked with purple lines, provides good fodder. Flowering and fruiting from May to September.	Sugarcane, rice, maize and tobacco
41*. *Echinochloa crusgalli*	Gramineae	Dhidan or Bara swank	Annual, polymorphic, culms 25-100 cm. high, erect, provides good fodder and grains are eatable.	Cotton and rice.
42. *Eclipta alba* (L) Hassk. (Syn. *E. prostata*(L) Hassk)	Compositae	Daryahi booti	Prostrate plant grows besides water with small white flowers.	Rice.
43. *Eleocharis atropurpurea* Kunth	Cyperaceae	Chawki booti	Annual, appears late in rainy season, common in drying rice fields. About six inch tall plants.	Rice.
44. *Eleusine indica* (Linn.) Qaertn	Gramineae	Boin grass Madhani grass	Tufted annual, flower culms erect or geniculately ascending. Inflorescence digitate composed of 1-10 slender spikes, 3-7 mm wide. Spikelets elliptic, disarticulating between the florets.	Maize and sugarcane.
45. *Eragrostis pilosa* (Linn.) P. Beauv.	Gramineae	Phullan ghas	Annual, common, spikelets linear to lanceolate Appears and flowers in rainy season.	Rice.
46. *Eragrostis japonica* (Thunb) Trin.	Gramineae	Dana ghas	Annual or short loved perennial grass, propagates through seeds, provides good fod-	Rice.

			der. Flowering and fruiting from August to October.	
47. *Eruca sativa* **Garsault**	Cruciferae	Taramira	It has pungent and unpleasant taste and smell. Mainly grown for oil.	Wheat, barley and oats.
48*. *Euphorbia dracunculoides* **Lamk.**	Euphorbiaceae	Kangi	Annual, found throughout the Punjab reproduces by seed, stem erect, 6-8" high and seeds oblong. Appears during September/November and flowers and fruits during December/May.	Wheat, barley, oats, and tobacco.
49*. *Euphorbia helioscopia* Linn.	Euphorbiaceae	Chatri dodhak	Annual, common weed of rabi crops. Cut stems give out milky sap, reproduces by seed, stem erect and much branched. Appears in grain fields in October/November, flowers from January/March and shed sheeds by mid April.	Wheat, barley and oats.
50. *Euphorbia hirta* L.	Euphorbiaceae	Dodhak	Annual, stem erect or ascending 1-1/2' high with long crisped hairs. Branches four angled. Leaves opposite 3/4-1/2", shortly petioled or subsessile, acute, toothed or serrulate. Stipules minute and linear. Floral leaves also minute.	Rice.
51*. *Euphorbia pilulifera* Linn.	Euphorbiaceae	Hazardana dodhak	Annual, also found in waste lands and on sides of water channels, leaves contain milky sap, reproduces by seed, stem erect and prostrate 1-2' long and hairy, flowers minute and fruits throughout they year with slowed growth in winter.	Wheat, barley and oats.
52*. *Euphorbia prostrata* Ait.	Euphorbiaceae	Lal dudhi (Dodhak)	It is a prostrate and a common weed. Seeds obscurely transversely wrinkled. Flowers from January/March and shed seeds by mid April.	Wheat and barley.

53. *Fagonia indica* Burm. Var. *Schweinfurthii* Hadidi (Syn. *Fagonia cretica* Auct.)	Zagophyllaceae	Dhamman Jawansa	Plant glaborous or glandular, lower leaves trifoliolate, upper unifoliolate narrow to broadly lanceolate, sepals persistent. Commonly found in river beds and water logged areas.	Wheat, barley and oats.
54. *Fimbristylis dichotoma* Linn.	Cyperaceae	Kaluro	Annual and secondary noxious. It is found in watery and and near watery habitats.	Rice.
55. *Fimbristylis Femuginea* Vahl. (Syn. *F. arvensis*)	Cyperaceae	Sada kaluro	Perennial, inhabitant of moist places or in crops receiving copious irrigation.	Rice.
56. *Fimbristylis littoralis*	Cyperaceae	Chooti Bhoin	Perennial, leaf blades more than 3 mm wide, style base not swollen, Achenes not subtended by bristles and scales.	Rice.
57*. *Fimbristylis tenera* Roem Et. Schult.	Cyperaceae	Chooti ghuien	Annual, serious weed, reproduces by seed, roots fibrous, stem tufted, life history similar to *Cyperus iria*.	Rice.
58*. *Fumaria indica* (Hausak.) Pugsley	Fumariaceae	Pit papra	Annual, leafy, much branched, 40 cm. tall, flowers white or pale pinkish appearing in March-June. Used as fodder and has medicinal value as blood purifior.	Wheat.
59*. *Fumaria parviflora* Lamk.	Fumariaceae	Shahtara, Pit papra	Annual, common in canal colonies and well irrigated areas. Stem slender, 2-24" long and much branched, bearing white or pink flowers. Appears in October/November, flowers during January/-March and shed seeds by mid April.	Wheat, barley, oats and tobacco.
60. *Heliotropium europium* Linn. (Syn. *H. eichwaldi* steud.)	Boraginaceae	Oont chara	Common, late-spring and summer weed. conspicuous white flowers arranged in two rows in helicoid cymes.	Cotton and tobacco.

61*. *Heliotropium supinum* Linn.	Boraginaceae	Oont chara	Annual or biennial, generally found in waste places and fallow lands, can infest rabi and kharif crops, stem prostrate or erect and much branched, flowers minute white and borne on short wooly spikes. Appears in January/February and flowers during March/November.	Wheat, barley and oats.
62. *Hydrilla verticillata* (L.F.) Pers.	Hydrocharitaccae	Hydrilla	Aquatic, usually submerged, plants with elongated stem and whorled leaves upto 0.3" long. Flowers actinomorphic, mostly unisexual, enclosed in a spathaceous bract.	Rice.
63. *Hypecoum trilobum* (*H. procumbens*) Linn.	Papaveraceae	Daksooa, Mitha papra	Annual, small-sized, found in sandy soils in winter, flowers small, capsule narrow and long.	Wheat, barley and oats.
64. *Ifloga fontanesii* Cass.	Compositae	Puchhal booti	Annual with a number of tufted stems about 6" tall. A common weed of waste places around fields.	Wheat, barley and oats.
65. *Lactuca dissecta* Don.	Compositae	Dud bhattal	Annual with usually most of the leaves basal. Flowers are blue. Common in spring.	Wheat, barley and oats.
66. *Lathyrus aphaca* Linn.	Leguminosae	Jungli mater Dokani	Annual, generally not very serious, reproduces by seed, stem trailing, slender, prostrate and much branched, flowers yellow and bell shaped. Appears in November/December, flowers in March and seeds mature by April.	Wheat, barley, oats and tobacco.
67*. *Lepidium sativum* Linn.	Brassiceae	Halon	Annual, 30-60 cm. tall, erect branched, glabrous, flowers small white or pinkish. Two varieties recognized as var. *Sativum* with fruiting axes non-spine tipped and var. *Spinescens* with fruiting	Wheat.

			axes spine-tipped. Commonly found in cultivated areas of NWFP and Baluchistan. Flowering period from April-June.	
68. *Linum usitatissimum* Linn.	Linaceae	Alsi	Annual, 20 cm. to 1 m. tall, stem erect, glabrous and branched. Flowers blue appearing in February-May.	Cotton and tobacco.
69. *Malcolmia africana* (L.) R. Br.	Cruciferae	Pathar	Annual, found in rabi crops, waste fallow lands, reproduces by seeds, stem erect, stout, woody and branched. Appears in October/November, flowers in February/March and matures by April.	Wheat, barley, oats and tobacco.
70. *Malva parviflora* Linn.	Malvaceae	Sonchal, Chiri chogha	Biennial, found in waste land and sides of water channels, reproduces by seeds, stem prostrate and hairy, flowers minute, pink or white and borne in clusters. Appears in October/November, flowers in January/April and matures by May.	Wheat, barley and oats.
71. *Marsilia minuta* Linn.	Marsiliaceae	Chaupatti	Common aquatic fern. Leaves with four leaflets.	Rice.
72*. *Medicago denticulata* Willd. (Syn. *M. polymorpha* Linn.)	Leguminosae	Maina	Annual, found in canal and well irrigated areas as well as in sub-mountainous tracts, reproduces by seed, provides good fodder for cattle, stem prostrate 1/2-2' long, flowers minute and borne in clusters. Appears from October/November, flowers in February/March and matures by mid April.	Wheat, barley, oats, rice and tobacco.
73.* *Medicago serrata* Linn.	Leguminosae	Maina	Leaves are serrated. Very much similar in growth habits to No. 72.	Wheat, barley, oats, rice and tobacco.

74. *Melilotus alba* Desr.	Leguminosae	Methi	Annual, erect, 30-150 cm. tall, leaflets narrowly oblong-ovate, serrate. Flowering period March September.	Potato.
75. *Melilotus indica* Linn.	Leguminosae	Senji	Annual, erect 15-60 cm. tall, stem pubseseent, flowering period March-August.	Rice and tobacco.
76. *Nonnea pulla* Lamk.	Boraginaceae	Luien booti	Annual, not very serious, reproduces by seed, medium-sized stems much branched and densly covered with stiff hairs, flowers are white.	Wheat, barley and oats.
77*. *Nymphaea lotus* Linn. (Syn. *N. nouchali* Burm. F.)	Nymphaeaceae	Kammi Nilofar	Perennial rootstock, tuberous and submerged, leaves attached with long hallow petioles and float on water, flowers pink or white and large-sized opening from night to noon, seeds small, rough and sink in water where they germinate. Start flowering in mid June and continues till November.	Rice.
78. *Nymphaea stellata* Willd.	Nymphaeaceae	Kuta Kammi Nilofar	Perennial rootstocks, similar to lotus in various marphological characters, reproduction and life cycle.	Rice.
79. *Panicum colonum* Linn. (Syn. *Echinochola colonum*) (L.) Link.	Poaceae	Paniam grass	Annual, culms erect or ascending, ligule absent, spikelet acute to cuspidate, pubescent. Racemes neatly 4-rowed, openly spaced and appressed to axis.	Cotton
80. *Panicum repens* Linn.	Poaceae	Mosmi ghas	Annual, culms tufted 14-20 cm. high, erect, firm or spongy, leaf blades broadly linear, spikelets oblong-elliptic. Flowering and fruiting period August-September.	Maize and other summer crops.

81. *Panicum repens* Linn.'	Poaceae	Torpendo grass	Perennial, culm firm, leaf blades narrow introduced as fodder grass.	Maize.
82*. *Paspalum distichum* Linn.	Graminae	Naru	Annual, torublesome weed of rice, creeping stem which gives out roots on nodes and also a good seeder, spikes close together in pairs and seeds pale yellow. Appears in mid July, flowers during August/September and fruits by mid October.	Rice.
83*. *Phalaris minor* Retz.	Poaceae	Dumbi, Sitti Booti	Annual, culms 20-100 cm. high panicle 1-6 x 1-2 cm, ovate and oblong. Found on roadsideswaste places and cultivated lands. Flowering period March-May.	Wheat and rice.
84. *Phyla nodiflora* (Linn.) Greene	Verbenaceae	Wakan Jal nim	Perennial, prostrate with woody rootstock rooting at nodes, flowers small, white and sometime pinkish and appear throughout the year.	Rice.
85. *Polygonum plebegum* (Linn.) R. Br.	Polygonaceae	Hazardani	Prostrate herb, with axilliary flowers. Flowering and seeding profusely.	Wheat, barley and oats.
86. *Portulaca quadrifida* Linn.	Portulacaceae	Kulfa	A common prostrate herb. Thick swollen sal tish leaves used combined with rape plants for eating.	Cotton and wheat.
87. *Portulaca oleracea* Linn.	Portulacaceae	Lunak or Salunak	Annual or perennial, prostrate or erect, succulent, glabrous, green or purplish. Flowers throughout the year.	Cotton, sugarcane and potato.
88. *Rumex dentatus* Linn.	Polygonaceae	Jangli palak	Common winter weed. Appearing during winter and dying off during summer. Plants may reach to height of 5 feet.	Wheat, barley. oats and tobacco.

89	*Saccharum spontaneum* Linn.	Gramineae	Kahi	Used for thatching huts and making dip pens Found in river beds.	Waste lands.
90.	*Sagittaria guayensis* H.B & K.	Alismaceae	Kutti kammi	Annual, not very serious, reproduced by seed, stemless, leaves 1-3" long and broad, mostly floating, flowers open during night till noon. Appears 2 weeks after transplantation in July, flowering starts in September and fruits during October/March.	Rice.
91.	*Saponaria vaccaria* Linn.	Caryophyllaceae	Kala takla	Annual, reproduces by seed, stem erect, stout and much branched, flowers pink or rosy. Appears in October/November, flowers in February/March and seeds mature by mid April.	Wheat, barley and oats.
92.	*Scirpus roylei* (Nees) Duthial (Syn. *S. quinquefarius* Ham ex. Bocchl)	Cyperaceae	Dumbi ghas	Stem slender, leafy only near base, ternate; spikelets in single dense head, spikelets somewhat flattened, glums 2-3 times as long as broad. Achenes subtended by bristles.	Rice.
93.	*Scirpus mucrotiatus* Linn.	Cyperaceae	Dumbi ghas	Stem coarse, leafy near the base, triquetrous, glumes ovate. Lowest bract trigonous. Achenes not subtended by bristles and scales. Principal leaf blades 5 mm or more wide; style base not swollen.	Rice.
94.	*Senebiera didyma* (L) Pers. (Syn. *Coronopus didymus*) (Linn.) Smith	Cruciferae	Jangli halion, Naksari	Annual, winter weed. Leaves radical leaving a pungent taste and odour.	Rice.
95.	*Sasbania aegyptiaca* Pers (Syn. *S. sesban* Linn. Merrill)	Leguminosae	Jantar, Dhancha	Sometimes attains tree like proportions, soft wooded shrub. Also grown for green manuring and provides fodder for sheep and goats.	Sugarcane.

96. *Silene conoidea* Linn.	Caryophyllaceae	Bora takla	Annual, found throughout the Punjab but not very serious, reproduces by seed, stem erect 6–8" high, flowers few, pink in colour. Appears in November/December, flowering in February/-March and fruits mature in April.	Wheat, barley, oats and tobacco.
97. *Sisymbrium irio* Linn.	Cruciferae	Khub kalan	Common weed appearing in early autumn and remains pretty conspicuous till early summer.	Wheat, barley, oats and tobacco.
98. *Solanum nigrum* Linn.	Solanaceae	Makoh	Perennial, grows in shade and on sides of water channels, stem erect angular and much branched, flowers develop in small clusters, seeds flattened and minutely wrinkled. Flowers and fruits during March/October and becomes dormant in winter.	Wheat, barley, oats, sugarcane and potato.
99. *Solanum xanthocarpum* Schred and Wend	Solanaceae	Kandiari Momeli	Perennial, spiny shrub with green striped berries Prostrate and common in waste arid places.	Wheat, barley, oats and cotton.
100. *Sonchus asper* (L.) Hill	Compositae	Dodak	Leaf auricles rounded and more spiny than *S. oleraceus*. Achenes obscurely muricate. Grows during November – March.	Wheat.
101. *Sonchus oleraceus* Linn.	Compositae	Sonchus	The leaf auricles acute, achenes 3-ribbed and muricate between the ribs. Grows during November – March.	Wheat.
102*. *Sorghum halepense* (Linn.)Pers (Syn. *Holcus halepense*) L. *Andropogon halepense* (L.) Brot	Gramineae	Baru	Perennial, most troublesome, also found in waste places fallow lands and on sides of waterchannels, poisonous if eaten by cattle in early stages of growth, a prolific seeder and also spreads aggressively through underground rootstock	Wheat, cotton, maize and sugarcane.

			which are of primary, secondary and tertiary nature, leave 1-2' long, spikelets appear in groups of 3. Flowers from May and seeds shed in September/November, becomes dormant in winter and sprouts again in February/March.	
103. *Spergula pentendra* Linn. (Syn. *Spergula flaccida*) (Roxb.) Aschers.	Caryophyllaceae	Jhunjhun	Leaves half cylindrical with grooves below, in opposite clusters. Flowers white, seed smooth, wing as broad as the seed.	Wheat, barley and oats.
104. *Sergula rubra* Linn. (Syn. *Spergularis rulina* L.)	Caryophyllaceae	Jhunjhun	Produce opposite leaves, commonly found in Muzaffargarh district.	Wheat, barley and oats.
105*. *Sphenoclea zeylanica*	Campanulaceae	Mirch booti	Annual, very serious weed of rice and also found in swamps, stem erect 1-2 1/2' high remains unbranched in rice fields but branches profusely in swamps, minute greenish yellow flowers, seeds rough, black and very small. Appears in July/August, flowers during August/October and sheds seeds in November.	Rice.
106. *Stachya parviflora* Linn.	Labiatae	Bui	White, hairy, bad smelling, perennial, Calyx 5 toothed, mouth closed, upper filaments not appendiculate at base. Anothers not transverse, calyx teeth without spines.	Wheat, barley and oats.
107. *Striga densiflora* Benth	Scrophulariaceae	Dhaulphuli	Small root parasite. Leaves are sessile, flowers yellow. Grows during kharif.	Sugarcane, sorghum and maize.
108. *Trianthema protulaceastrum* (L)	Aizoaceae	Wisakh	Annual, stem glabrous, commonly found in waste lands during moonsoon, flowering period May-October and can be used as fodder.	Cotton, potato and sugarcane.

109*. *Triblus terrestrs* Linn.	Zygophylaceae	Bhakra	Annual or biennial, very hardy weed of kharif crops and also found in waste lands, stem prostrate with trailing branches, flowers pale yellow and fruits thorny and hard. Appears in February/-March and flowers during May/September.	Maize and sugarcane.
110. *Trifolium alexandrium* Linn.	Papilionaceae	Bersem	Annual, erect and cultivated as winter fodder crop.	Wheat, barley and oats.
111. *Trigonella incisa* Benth.	Papilionaceae	Maini	Annual, leaf pinnately trifoliate, leaflets denlate. Inflorescence solitory, fruits cylindrical. Flowering period January-April.	Wheat, barley and oats.
112. *Trigonella polycerata* Auct. Non Linn.	Papilionaceae	Maini	Annual, reproduces by seed, stem slender, slightly hairy, 6–12" long, flowers minute and borne in groups of 2-4. Appears in October/November, flowers in February/March and matures by early April.	Wheat, barley and oats.
113. *Typha angustata* Chaub and Bory.	Typhaceae	Aira, Kundar, Patha, Dib	Common in water-logged and aquatic habitats. Long slender stems and leaves multiplies through stalks quickly invading marshy places.	Wheat, barley and oats.
114. *Vicia hirsuta* (Linn.) S.F. Gray	Papilionaceae	Rowari	Annual, trailing or climbing. Stems pubescent to glabrous. Inflorescence 2–7 floweres appearing during February-August. Pods 2-seeded.	Wheat, barley and oats.
115*. *Vicia sativa* Linn.	Papilionaceae	Rawari	Annual, tendrillar climber with narrow leaflets. Pods with more than 4 seeds. Annual, tendrillar climber with narrow leaflets. Pods 3-4 seeded.	Wheat.
116. *Vicia tetrasperma* Moench.	Papilionaceae	Rawari	Annual, climber, leaves narrow and produce seeded pods	Wheat.

117. *Withania somnifera* Dunal	Solanaceae	Aksan	Common weed, thin leaves, flowers bisexual, perfect and calyx is loose around the berries.	maize, sugarcane, cotton
118. *Xanthium strumorium* L.	Compositae	Chaghra	Annual, erect, leaves ovate with candate bases and long and lobed petioles.	Maize, cotton and tobacco.
119. *Zaleya pentandra* (L.) Jeffery (Syn. *Trianthema pentandra* Linn. Clk. non *Trianthema gorindia* Ham.)	Aizoaceae	Itsit	A diffuse prostrate perennial. Calyx persistent capsule, 1-2 locular, dehiscing by a bivalved lid longitudinally, styles 2, free.	Sugarcane.

*Most serious and noxious weeds.

Newly recorded: *Festuca cristata, Erigeron* sp. *Spergula arvensis, Terllis leptophylla* and *Neslia panicutta* in wheat and *Sphenoclea zeylani* (mirch booti) in rice.

(a) (b)

(b) (c)

Fig. 18.1: Some important weeds (a) *Datura stramonium;* (b) Ipomoea hispioa (c) A Wheat field heavily infested with Johnson grass and (d) *Amaranthus viridus.*

Fig. 18.2: Some important weeds (a) *Ipomoea hispida* infesting a crop field. (b) *Ipomoea hispida* plants, (c) Solanum nigrum; and (d) *Silybum maxianum*.

Fig. 18.3: Some important weeds: (a) *Solanum xanthocarpum*; (b) *Datura metel*; (c) *Convolvulus arvensis*.and (d) *Solanum nigrum*

favourable climatic and biological factors. Crops have also to compete with weeds for water, mineral nutrients, light and other requirements for growth. Weeds respond better than the cultivated crops even to high intensities of light and high temperatures. The CO_2 consumption/dm2 leaf area/hour is higher in many weeds than the cultivated crops. The weeds are also generally bestowed with the capability of undertaking the C4 cycle of photosynthesis. By virtue of these physiological advantages, weeds can compete with cultivated crops aggressively. Consequently, weed infestations exert a detrimental influence both on the quantity and quality of the produce. The magnitude of such losses, however, depends upon the degree and periods of infestation.

Four-year investigations carried out at Faisalabad on weed-cotton crop competition and effects of weeds on production have reported an average reduction of 14.45 per cent in yield with *Cyperus rotundus* infestation (62 plant per square foot), a 4.25 per cent reduction with *Cynodon dactylon* and a 3.37 per cent reduction with *Sorghum halepense*, while *Convolvulus arvensis* had a minimal effect (probably because being a twiner, it has very little development of underground parts). Similar results on yield reduction have been reported when cotton is infested with weeds like *Portulaca* sp. *Trianthema monogyna*, *Amaranthus viridis* and *Euphorbia prostrata*. In another study *Chenopodium* spp. depressed the yield of wheat by 16 percent and *Carthamus oxycantha* by 8-9 percent, at densities of 23 and 7 plants per square foot, respectively. Some researchers have reported yield depression ranging between 20-41 percent at Lyallpur (Faisalabad) and Kala Shah Kaku, respectively, in weed-infested rice fields during 1971 and 1972. Wheat experiments conducted at Tando Jam in 1968-70 have shown that (a) the number of weed species fell from ten in the first year to two in the second year (with a higher intensity of infestation with aggressive species), (b) the number of wheat ears in weed-infested plots was quarter of that in weed-free plots, and (c) the average reduction in yield was 1000 kg/ha. Studies carried out on biology of wheat crop weeds (*Asphodelus tenuifolius, Carthamus oxycantha, Chenopodium album, Chenopodium murale, Euphorbia helioscopia, Portulaca* spp. and *Trianthema monogyna*) have shown that most of them flowered after about 8 weeks which concided with the critical period of weed-crop competition, necessitating weed control within 2-3 weeks of their emergence. The seeds of *Portulaca* spp. did not germinate while those of *Chenopodium* spp. gave low germination, probably due to innate dormancy. Moreover, seeds of some weeds of wheat and cotton showed light sensitivity and other specific requirements for germination, suggesting the necessity of systematic studies on physiological behaviour of weeds and their response to physical and chemical treatments in order to develop cultural-cum-herbicidal weed control system.

Experimental studies carried out by various scientists in Pakistan have established that a full-season competition of weeds with different crops brings about a significant decrease in yield. For example, the full-season competition with *Chenopodium album, C. murale* (at the rate of 23 plants per square foot) has caused 16.03 per cent and 28 percent depression in yield of wheat grain and straw, respectively. Likewise, the grain and straw yields of wheat were depressed by 9.53 percent and 8.48 percent, respectively, by *Carthamus oxycantha*.

Studies to determine critical period for controlling weeds to prevent depression in wheat yield have shown that (a) the decrease in grain and straw yield is 13.87 and 10.22 percent when weeds are allowed to compete for full crop season, (b) the corresponding decrease are 11.31 and 9.3 percent when crop is kept weed free for first two weeks, and (c) there is no significant further decrease when weeds are allowed to compete beyond 10 weeks. It is, therefore, inferred that the critical period of weed-crop competition encompasses the first 8-10 weeks. The control of weeds after this period does not help to increase the yield of grain and straw in wheat.

Similarly, in cotton, the full-season competition of weeds with the crop causes substantial decrease in yield. However, the degree of depression in yield depends upon the density of weeds. The critical period of competition in cotton lies in the first 8 to 10 weeks of growth. If weeds are controlled during this period the detrimental influence on the yield will be accordingly reduced. Early control of weeds is, therefore, essential and more remunerative.

In potatoes, weed competition has been found to be greatest during the first 6 to 8 weeks and their removal over this period increased the number and weight of leaves by 36 percent and 66 percent, respectively; and potato yield by 69 percent, while branching, plant height and number of tubers per plant were not influenced.

It is interesting to note similar results achieved in Kenya for the maize crop. The yield increase was 148 percent when a local variety was grown under good husbandry conditions (early sowing with optimum plant population and early weeding) as compared with bad husbandary (late sowing, low plant population and no weeding). Good husbandry gave extra income of 300 Kenyan shillings per acre; the comparative yields being 8.8 and 21.8 bags/acre. Similarly, in Turkey early weeding increased the yield of rainfed wheat by 300 kg/ha.

Some interesting experiments have been reported from the Punjab, India on the effect or weeding time on the yields of cotton and rice (Tables 18.2 and 18.3) showing that delayed weeding, until the weeds have already inflicted adverse effects on the growth and development of the crops, is a wasteful operation and the damage done is irreversible. All these examples highlight the beneficial effects of early weeding, which increases the yield proportionate to the time of weeding.

Table 18.2: Effect of time of weed removal on the seed yield of cotton

Period of weediness followed by weed free later	Yield percentage	Weed-free period followed by weedy period later	Yield percentage
Weed free throughout	100.00	Weed free throughout	100.00
Weeks 0-2 (weediness)	93.00	Weeks 0-2 (weed free)	57. 8
" 0-4 "	81.9	" 0-4 "	61. 5
" 0-6 "	66.6	" 0-6 "	72. 8
" 0-8 "	61.8	" 0-8 "	90. 2
" 0-10 "	48.2	" 0-10 "	100. 4

No weeding 42.5

2 hoeings 75.6

Table 18.3: Effect of time of weed removal on the grain yield of rice

Treatment	Grain yield (kg/ha)	% increase over control	% of yield of weed-free crop
Control (No weeding)	3198	-	51.6
Weed free throughout	6195	94	100.0
Weed free from 2 weeks after transplanting	5471	73	88.3
Weed free from 4 weeks after transplanting	5635	76	90.9
Weed free from 6 weeks after transplanting	5468	69	88.3
Weed free from 8 weeks after transplanting	4450	39	71.8
Weed free from 10 weeks after transplanting	3235	1	52.2
LSD	1170		

Weeds as Alternate Host Plants

Weed species may be hosts for many organisms that attack crops, including insects, nematodes, fungi, bacteria and viruses and act as sources of infection or reserviors, which tend to defeat the purpose of crop rotation. In Pakistan and elsewhere many such instances have been reported (Table 18.4). The weeds, therefore, provide foci of infection for the development and spread of various diseases and pests. This suggests that in such cases the farmers should eliminate the sources of infection for controlling the diseases. Thus weed control is not only essential for increasing crop yield levels and income per unit area but also to contain certain insect pests and diseases, which parasitize the weeds.

Table 18.4: List of some weeds serving as alternate host plants

Weed	Insect pests and diseases
Amaranthus viridis *Convolvulus arvensis* *Portulaca oleracea*	*Myrothecium roridum* Causing leaf spot of cotton
Hibiscus cannabinus *Athea rosa* *Malva parviflora*	Pink and spotted boll worms of cotton
Saccharum sp. *Cynodon dactylon*	Borers of rice, maize and sugarcane
Cruciferous weeds	Organism causing club root of brassica
Agropyron repens	Organism causing take-all diseases of wheat
Alopecurus mysuroides	*Claviceps purpurea* causing ergot of wheat
Stellaria media *Spergula orensis*	Nematode-borne diseases
Many weeds attacked by aphids	Transmit virus diseases

Weed Control

The object of weed control is to shift the balance of nature in favour of cultivated crops, by suppressing the weed populations through mechanical, chemical and biological means. Though much work has been done on the weed control systems for different crops in the USA, UK, Canada and some other advanced countries, weed problems being very much of localized nature, calls for a critical evaluation of exotic technology under the local conditions. Moreover, weeds ecotypes occurring in different regions of the world may differ in response to control methods. There is no single herbicide which is good for controlling a weed under all possible crop, climate and soil conditions. Each weed-crop environmental complex requires a specific technology. Hence local evaluation of herbicides for the control of various weeds, susceptibility and tolerance of the various cultivars to different herbicides and working out of effective, judicious and safe weed control systems, are the immediate need of this country.

1. *Herbicidal*

Although weed control technology is still in its infancy, the research work on herbicides is in progress in various universities and research institutes of the country. On the basis of the results achieved, some information about herbicidal weed control in wheat, rice and cotton crops is summarized in Table 18.5.

Table 18.5: Herbicidal weed control methos for wheat, rice and cotton

Name of Crop	Herbicide	Time of application	Weed species controlled	% yield increase
Wheat	Dicuran-MA/ 2.5 kg/ha	4 weeks after sowing	*Cynodon dactylon, Cyperus rotundus, Chenopodium album,*	55-81*
	Banvel/5 l/ha Tribunal	2-3 leaf-stage pre-emergence	*Convolvulus arvensis, Melilotus alba, Carthamus oxyacantna,*	
	2,4,D/1-1/2 lbs/acre Agroxone/1-1/2 pint/ acre	6-8 leaf pre-emergence	*Asphodelus tenuifolius, Vicia hirsuta* and *Phalaris minor*	
	Phordene	Presowing	Broad-leaved weeds	
	Phordester	"	" "	
	Phonxylene	"	" "	
	2,4-Diamine	3-6 weeks	" "	

	Feroxine	after sowing		
	Bacterial-M/600 ml/acre	3-leaf stage to tillering	" "	25
	Tolkan 50% W.P 750 g/acre	3-4 weeks after sowing	Grassy weeds *Phalaris minor and Avena* sp.	30-40
	U 46 Combi 1.5 l/acre	" " "	Most of the weeds	18 69-109
	U 46 KV 4 l/acre	" " "	Most of the weeds	19
	Tribunil 3 lbs/acre	Pre-emergence	Most of the weeds	21
	Afion 0.5 to 1 l./acre	" " "	Most of the weeds	16
Rice**	2,4-D/1 lb/acre	9-10 tiller stage	No action on submerged weeds	yield equal to hand weeding
	Surcopur 8 l/acre	8-10 tiller stage	90% control	21-71
Cotton	Goal 0.25 l/acre	Pre-emer-	Most of the weeds	28-80
	Treflan 0.5 l/acre	Pre-emergence	Most of the weeds	26-52
	Stomp 2.00 l/acre	Pre-emergence	Most of the weeds	11-55
	Pregard 0.8 l/acre	Pre-emergence	Most of the weeds	6-29
	Bueno 0.5 l/acre	Post-emergence	Most of the weeds	4-72
	Dowpon 2.5 kg/acre	Post-emergence	Most of the weeds	51

Cotofor 1.5 l/ acre		Post-emergence	Most of the weeds	48
S.L. Herbicides l/acre	1.0	Post-emergence	Most of the weeds	33

*The higher figures are in case of greater degrees of weed infestation. All these figures have been extracted from various papers under reference

**The other herbicides being tested are Saturn (10 G), Macyete and Ronstar, the latter giving better results. However, hand weeding gives maximum yield.

The experimental results show marginal yield increases in most of the treatments with low cost; benefit effectivity except where there is a higher degree of infestation, when the usefulness of herbicidal control is more pronounced.

Since the chemicals change frequently as a result of new researches, the latest chemicals should be used in experimental testing and field application. Upto date list of such chemicals is given in Table 18.6 with technical information in Table 18.7.

Table 18.6 List of new weedicides

APPROVED WEEDICIDES	EXPERIMENTAL WEEDICIDES
Banvel	Afalon
Butril-M	Arelon
Disuran-MA 60 WP	Avirosan
Gesapax Combi	Cobex
Gramoxone	DMA - 6
Primetra 500 FW	Dosanex
Propanil/Surcopur/ Rough/Stam F-34	Dowpon
Saturan 10 G and 66	Esteron-76
Stomp	Gesaprim/Vectral/Atrazine
TOK	MO 9 G
Treflan-R	Primagram

*About 40-50 weedicides are in trade.

Table 18.7: Technical information on some important weedicides*

Weedicides	Crops Treated	Weeds Controlled
1 BANVEL		
Benzoci acid derivative (4 ECm 5% or 10% granules).Selective for pre or post emergence use.	Wheat, barley, oats, maize and sorghum.	Annual weeds

2. BUCTRIL (2 EC; may be mixed with MCPA to increase weed control spectrum). Selective for post-emergence use.	Wheat, barley, oats and rye.	Annual weeds
3 TREFLAN (Dinitroanaline . compound) 1/2 lb/acre mixed in 5-40 gallons of water. Selective for pre-emergence use.	Sugarcane, wheat, alfa alfa, almonds, apricots, cabbage, carrots, cauli-flowers, mungbeans potatoes, tomatoes, cantaloupes and water melon	Annual weeds, chick-weed, John-son grass and others
4. STOMP (4EC 79% WP) (Dinitroanaline compound). 1-2 lb/acre for maize and 1 1 1/2 - 1.5/acre for other crops. Selective for pre-emergence use.	Cotton, maize, sorghum, rice, wheat, peas, potatoes, tomatoes, cantaloupes and water melon	Grassy weeds
5. PROPONIL (Analide compound) 1-6 lbs/acre mixed in 10-40 gallons of water. Selective for post emergence use.	Rice and wheat	Watergrass, pigeongrass, wild rice, nut-sedge, crab-grass and goosegrass.
6. PRIMEXTRA (Formulation of Dual and Atrazine in a ratio of 2:1 and 1.5:1). 6EC, 500EC, 720EC. 1-4 lbs actual/acre. Selective for pre-emergence use.	Corn.	Red rice, nut-grass and pigweed.
7. STAURN (Carbamate compound) 4EC, 8EC, 50EC, 5% and 10% granules. 3-6 lbs actual/acre.	Rice.	Wild rice, sedge and other annual weeds.
8. GRAMOXONE (Aqueous solution 2 lbs active/ gal-	Maize.	Annual

lon) 1/2 lb actual/acre. Non selective for post-emergence use.		weeds and grasses.
9. GESAPAX (Trianine compound) 50 and 80% WP, 6-8 lbs. actual/acre. Selective for pre and post-emergence use.	Sugarcane and potatoes	Nutgrass, goosegrass, carbgrass, sow thistle & many others.
1o. DICURAN (Urea compound) 80% WP, 500 g. flowable 1.5-3 kg. a. l,/kg. Selective for pre and post-emergence use.	Cereal grains	Wild oat, rye-grass, blue-grass and many others.
11. TOK (Diphenyl ether compound) 50% WP, 2EC, 2-6 lbs/acre mixed in 40-60 gallons of water. Selective for pre and post-emergence use.	Sugarbeet, cauli-flower, cabbage, carrots, cereals and rice.	Bluegrass, carbgrass, nettle and others.

Although herbicidal researches were initiated as early as in mid 1940s, field-scale application of chemicals for control of weeds in Pakistan is almost negligible*. There are many reasons for this; the high cost of the weedicides and complicated application of chemicals which are poisonous, and can be dangerous for the sprayed and even the succeeding crops due to residual effects. These can affect the health of the farmer as well as poultry and livestock.

2. *Cultural*

A lot of work has been done on cultural methods of control which include hand hoeing, hand pulling and inter row cultivation with some promising results. Although these methods give good results, they have certain drawbacks:

- Hand-hoeing is 20-30 percent inferior to weed free condition or effective herbicides;

*A similar situation existed in advanced countries upto 1950s after which the use of chemicals became popular due to development of selective and more effective weedicides, changes in cultural operatlions through the introduction of tined implements for quicker and more shallow work, the practice of direct drilling without prior to cultivation, changes in methods of production of vegetables and fruits and greater use of machinery to replace manual labour and draft animals.

- Hand tools used are inefficient and need improvement;
- Hand hoeing is time consuming and labour intensive (needing 200-400 man hours per hectare);
- Inter row cultivation is possible only in the case of widely spaced crops like maize, sugarcane, cotton etc. and cannot be carried out until the crops are 6-8 weeks old (which is too late to avoid the bad effects of weeds). Sometimes weeds are temporarily dislodged and are liable to re-establish themselves. It cannot control the weeds growing within the crop row and there are also crop damaging effects at either end of the rows where the animals or tractors turn.

Mulching has been practised in many countries to control the weeds. It may include in situ mulching, transported mulching or mulching with cover crops. In mulch tillage system, weeds or a cover crop grown for this purpose are killed by cutting or using herbicides and crop seeds are sown through the mulch. In the second method organic mulching materials are brought from other areas and spread in the field where crop is to be sown or transparent polyethylene sheet is used for covering the fallow field to kill weed seeds through heating (e.g. seeds of *Orobanche*). Cover crops or 'living mulches' are used to suppress weeds, prevent erosion and provide additional nitrogen in case of legume covers (found useful in vegetable crops).

The other methods tested in advanced contries including flooding and submerging weeds with water for 3-5 weeks; burning weeds and grazing of weeds. These have given variable results, depending upon timing and nature of weeds and soil. For example, burning has been found to be harmful in peat lands due to destruction of peat. Flaming weeds before

*"Agent Orange", a 50-50 mixture of two herbicides; 2, 4-D and 2,4, 5-T is said to contain a by-product called dioxin, a deadly poison causing serious and possibly heritable disabilities ranging from blindness to severe skin eruptions. The use of 2, 4, 5-T has been restricted or banned in several countries (USA, West Germany, Italy, Japan, Neatherland and Newzealand). The following ballad of Truong Son, (in Central Veitnam) is still sung in the sad memory of victims of "Agent Orange".

"Come, little friends, let us play
  our stunted games.
One, two, three, four
Little dummies at the door
2-4-5T wash the plants
and make them dance
Five, six, seven, eight
Eating peanuts of a place
2-4-D add some drops into your tea
Then you'll get more children like me

Paraquat (1,1'-dimethy1-4,4'-bipyridinium-ion) is another example of a deadliest herbicide, which is near-miraculous boon for the farmers but to the doctors who treat its human victims it can be a horror when misused.

they are about 5 cm. tall have given promising results and has been successfully used in alfalfa and cotton sown in rows. Use of competitive crops has proved valuable in weed control or weed eradication. These crops are millet, sudan grass, sweet clover, sunflower, rape, barley, sorghum, soybeans, alfalfa and cowpeas. The important feature of weed control in seeded crops is a preventive one, which principally includes the use of cleanest seed free from noxious weeds.

3. *Varietal*

Little attention has been paid to breeding crops resistant to or tolerant of the damage done by weeds although considerable work has been done to breed crops resistant to parasitic weeds. This includes the development of Striga resistant sorghum and Orobanche resistant sunflower, broad bean, lentil, musk melon, sweet potato, tomato, water melon and cucumber. Work carried out at the Rice Research Institute, Kala Shah Kaku has shown that rice cultivars with long and lax leaves are more weed competitive than those with short and erect leaves. It has been reported that there are five avenues which may affect changes in crop/weed interaction. The cultivars may be (a) competitive with weeds, (b) resistant to or tolerant of parasitic weeds, (c) allelopathic to weeds, (d) resistant to allelopathic weeds, and (e) resistant to widely used herbicides. Generally, larger, quick growing and more spreading plants are good competitor of weeds and competition can also be altered by agronomic practices such as closer spacing or earlier sowings. Breeders should concentrate more effort on the development of aggressive crops varieties as a means to control weeds.

4. *Biological*

In advanced countries emphasis has been placed on phytophagous insects and plant pathogens, giving a notable success in control of *Opuntia* spp. and *Hypericum perforatum* with insects and *Chondrilla juncea* with a rust fungus. The other successful examples are the control of *Ageratina riparia* (*Eupatorium riparium*) with the fungus *Cercosporella agerantinae* in Hawaii, and that of *Rubus constrictus* with the fungus *Phragmidium violaceum* in Chile. Work is also in progress on control of 13 other species with reasonable prospects of success. Very little work has been done in Pakistan except the one quoted in Chapter XXIII on the control of locust with *Aspergillus* spp.

According to the survey carried out by the Food and Agricultural Organization of the United Nations, weed management in developing contries in terms of research and training is weaker and at lower academic level than the allied fields of plant pathology and entomology. About 80 countries have little or no improved weed management while 60 countries have only a broad beginning. Pakistan belongs to the latter group. Under these circumstances it is essential to develop trained manpower in weed management by including this subject both at graduate and postgraduate levels in the universities of agriculture. A central weed research unit should be established on a sound scientific basis for the development of weed management technology for integrated control of weeds. It should include mechanical (seed cleaning, hand weeding, hoeing, stubble burning, interrow cultivation), cultural (tillage of fallow lands, pre-sowing watering followed by tillage, clean seed bed preparation, conservation tillage, higher seed rates and closer spacing, suitable rotations), biological (use of phytophagous insects and pathogens), varietal (development of quick growing and more tillering varieties for suppressing weed populations in early stages) and chemical (judicious use of cheap, efficient and safe weedicides - non selective or selective as pre or post-emergence applications, especially in the case of cash crops). Work should also be carried out on the development of more efficient weeding tools and equipment for the application of herbicides. A number of packages of integrated control will have to be developed for different ecological zones suited to farm-application by involving both public and private sectors besides developing industry for the manufacture of weedicides to ensure availability of cheap and safe chemical products, weeding tools and spraying equipment. Aggressive research programmes will be needed at the national level to develop integrated control measures without which the present unsatisfactory and damaging situation may continue unabated.

Summary

The chapter deals with the deleterious effects of weeds on crop plants in reducing both the quantity and quality of the produce in Pakistan, causing annual losses exceeding 3000 million rupees. These are greater than those caused by rodents, birds, insect pests and diseases collectively. A description is given of work carried out on weeds, including survey, weed-crop competition, and on weeds as alternate host plants. An account is also given of progress in chemical weed control in Pakistan. Although the total number of weeds recorded in the country is 119, about

35 are important and noxious. Yield depressions in wheat, rice and cotton have been found to be positively correlated with the degree of infestation as well as with the period of weed competition with the crops; full-season competitiin being the most harmful. The need for early control is, therefore, emphasized. Many weeds have been found to harbour some insects, nematodes, fungi, bacteria and viruses, serving as sources or reservoirs of infection. Weed control is, therefore, essential to also contain such insect pests and diseases. The highlights of herbicidal weed control in wheat, rice and cotton crops are tabulated and it is concluded that integrated control of weeds is the best approach under the prevailing circumstances. Other methods of weea control, such as cultivation practices, special varieties of crops and biological methods are also discussed.

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Chapter XIX

Diseases Caused by Deficiency or Imbalance of Nutrients

Each plant needs balanced quantities of essential nutrients from the soil for its normal growth. Whenever, there is an imbalance of the available nutrients either in the form of high or low concentrations, the plant metabolism is upset, resulting in appearance of disease-like symptoms, which reduce the yield and the quality of the produce. The high concentrations of nutrients produce toxicities while low concentrations cause deficiencies. Previously, the occurrence of this imbalanced situation was known by the name of "Deficiency Diseases", but now it is termed as "Nutrient Abnormalities in Plants".

There are two groups of nutrients i.e., major or macro nutrients and minor or micro-nutrients. The first group, needed in comparatively greater quantities, includes nitrogen, phosphorus, potassium, calcium, magnesium and sulphur while the second group comprises boron, copper, iron, manganese, molybdenum and zinc. Since the latter category of nutrients are needed in small quantities, they are also known as "Trace Elements". As the actual nutritional status of different soils and plant requirements vary, the nutritional abnormalities are site-specific, requiring their exact determinations from crop to crop and area to area.

Diagnosis of Nutrient Abnormalities

Nutrient abnormalities are usually difficult to diagnose in the field, particularly in early stages of plant growth. However, the overall plant appearance and localized specific symptoms are an important aid in the identification of nutrient abnormalities. On the other hand, the visible symptoms constitute one of the several types of evidence of deficiency or toxicity of a given element. In many cases similar or identical symptoms may result from deficiencies or toxicities of different elements. For example, both nitrogen and sulphur deficiencies cause a general chlorosis. Furthermore, symptoms of a deficiency or toxicity of a certain element may greatly differ in various crops. In such instances the knowledge of symptoms in one plant species may be of very little use in identifying the abnormalities in another. It has also been noticed that sometimes the deficiencies or toxicities occurring in the field may be so severe as to reduce yields and impair the quality of the crop while the visible symptoms are still too slight to be readily spotted. Moreover, multiple nutrient abnormalities may lead to further confusion. Finally, conditions which are not due to nutrient abnormalities (such as viruses) might be mistakenly considered to be so. Thus the symptoms alone are not enough for diagnosing the specific nutrient abnormalities, although they do help to some extent.

Because of such complexities, it becomes imperative to draw on the knowledge of soil and plant tissue analysis for an early diagnosis and prevention of nutrient abnormalities. Caution, is however, required while using a soil test because essential elements may be present, but these may be in unavailable form for root absorption as it usually happens in case of phosphorus.

For determining nutrient abnormalities, many techniques are used including nutrient toxicity or deficiency symptoms, tissue analysis, chemical soil tests and biological tests. Nutrient deficiency symptoms, may include complete failure of crop, plant stunting, specific leaf symptoms, clogging of conducting tissues, abnormal maturity, poor quality and many more. Plant analysis gives an indication of the availability of a particular nutrient and may bear a relationship to nutrient concentration in the soil. Similarly, tissue tests have found an important place in rapid determination of nutrients in the plant sap. These chemical tests are usually based on variation in colours compared to the standards and can be carried out without elaborate apparatus. Chemical tests are also used for evaluation of soil fertility. Agronomic comparisons, although expensive and time consuming, are valuable tools in determining the nutrient status of soils. There are also laboratory and green house tests, especially for micro-nutrients; e.g. sunflower pot citure for boron deficiency. In such studies scientists also make use of deficiency symptoms in indicator plants, that are more sensitive to lack of nutrients. For example, milk weed (*Asclepias syrica*) is useful for diagnosing boron deficiency, Lamb's quarters (*Chenopodium album*) for diagnosing phosphorus and potassium deficiency, pigweed (*Amaranthus hybridus*) for nitrogen deficiency, ground cherry (*Physalis* sp.) and white oak (*Quercus alba*) for magnesium deficiency, and cauliflower for molybdenum deficiency.

Functions and Maleffects of Nutrients

As discussed earlier, there are six major and six minor nutrients, essential for the healthy growth of the plants and are needed in varying quantities and proportions. Each nutrient is responsible for a particular aspect of plant metabolism. Some specific characteristics of the macro and micro-nutrients are given in Table 19.1.

General Nutrient Status of Pakistan Soils

The Soil Survey Department of Pakistan with the help of FAO initiated studies in 1961 on the soil resources of Pakistan and their development possibilities. These studies have revealed clear and coherent sedimentation and land form patterns in all the areas surveyed. Large areas of naturally developed (zonal) soils have been identified, surveyed and reported. There are also extensive areas of natural saline-alkali soils of differing origin, each requiring different measures for reclamation. There are eight types of landforms. Much of the country is arid or semi arid within the subtropical continental zone and about two-third of the annual average precipitation is received during the summer months. Eleven crop ecological zones have been recognized and delineated. The difficult soils encountered have also been appraised for their relative suitability for sustained production of agricultural crops or for grazing or forestry. The soils have been grouped into eight land capability classes and seven sub-classes.

The results of studies on the nutrient status of Pakistan soils have been reported in the FAO soil bulletin No. 48, 1982 entitled "Micro-nutrients and the Nutrient Status of Soils - a Global Study". This work was carried out in Pakistan in collaboration with Soil Fertility Department, Ayub Agricultural Research Institute Faisalabad.

The summary of the results (Fig. 19.1 and 19.2) based on 242 sampling sites of the agricultural areas, highlights the following important points:

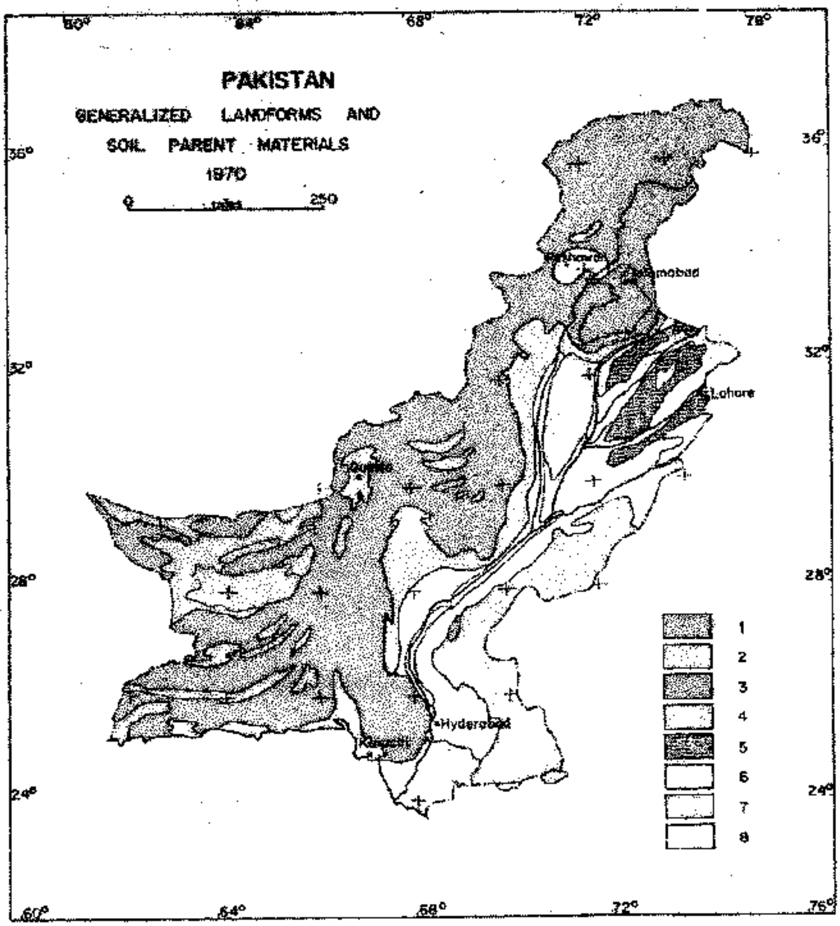
1. The distribution of various soils in Pakistan includes Yermosols

Table 19.1: Classification of nutrient effects on plants.

Nutrient	Functions	Pathological Effects: If in excess	Pathological Effects: If deficient
A) MACRO Nitrogen	Forms integral part of proteins and chlorophyll molecule. Its function is both structural and metabolic.	The plants become succulent and are prone to pest attack and lodging. Crop maturity is delayed. Causes zinc deficiency.	Produces chlorosis and etiolation; older parts being affected first; growth is slow and retarded giving unthrifty and spindly appearance. Symptoms noticeable in almost all crops. Soils with low organic matter show N deficiency.
Phosphorus	Forms an integral part of nucleic acid, pectin and phospholipids. (both structural and metabolic functions). It is required in energy transfer reactions. Helps in seed production.	Quickens the crop maturity and reduces yield. Causes iron and zinc deficiency.	Foliage becomes dark green or blue-green in many species. Growth slows down and reduced, making the plants stunted. Leaves usually become red especially along veins. Flowering and fruiting are delayed with reduced seed size. Deficiency of P occurs due to its fixation in soils.
Potassium	It is catalytic in nature and essential for following physiological functions: a) carbohydrate metabolism; b) nitrogen metabolism; c) control and regulations; of activities of various essential mineral elements; d) activation of enzymes; e) neuterilization of physiologically important organic acids; and f) stomatal movement and water relations. These activities lead to turgidity of cells, rigidity of plants and wilt resis-	Bark of trees becomes too thick. There is a relationship between potassium excess and reduced uptake of magnesium.	Necrotic spots develop on leaf blades, marginal necrosis or leaf scorch may also be found. In many species leaves turn dark green or blue green. Terminal and lateral buds show dieback symptoms. Banana and sugarcane are good indicator plants.

	tance besides increased production of carbohydrates, sugar and oil.		
Calcium	Required for middle lamella formation, protein synthesis, activity of certain enzyme systems and ion uptake as well as for root development.	Related to deficiency of potassium, iron, boron, manganese, zinc and copper.	Growing points are damaged showing progressive die-back which in case of flowers and fruits is known as "Blossom End Rot". Root system is severely reduced and becomes prone to attack of diseases. Present in acidic soils. Prominently noticed in tomato, potato and legume crops.
Magnesium	Forms an integral part of chlorophyll. Helps in manufacture of carbohyderates, proteins and oil as well as in proper use of phosphorus.	May encourage potassium and or calcium deficiency	Plants show marginal and interveinal chlorosis accompanied by a variety of pigment development; effects being more prominent in mature leaves. Present in acidic and sandy soils or in P rich soils.
Sulphur	Required for synthesis of sulphur-containing amino acids. Forms an integral part of vitamins, coenzyme A and glutathione. Activates certain proteolytic enzymes and increases oil contents and cold resistance.	Builds up soil acidity	Effects are similar to those caused by nitrogen deficiency. Plants show reduced growth; giving chlorotic and spindly appearance. Present in soils with low organic contents.
B) MICRO			
Manganese	Required for phosphorylation citric acid cycle, photo-chemical reactions and in the activation of numerous enzymes essential for carbohydrate metabolism.	May lead to deficiency of iron due to competitive absorption and translocation effects	Effects vary from crop to crop, leading to development of necrotic spots, streaks or interveinal chlorosis in leaves; in some species leaves may become malformed as in "Mouse Ear" of pecans. Stone fruits are good indicator plants. Present in acidic and sandy soils or in P rich soils. Commonly found in corn, cotton and tobacco.
Iron	Required in the activation of several enzymes. Helps in manufacture of chlorophyll.	Becomes Immobile or inactivated due to carbonates or bicar-	Leaves on new branches show interveinal and later on veinal chlorosis with reduction in size, showing more pronounced symptoms in fruit

		bonates in calcarious soils	trees. Iron and manganese deficiencies usually occur together and become difficult to distinguish. Symptoms more prominent in apple and citrus. Found in calcareous and alkaline soils.
Zinc	Activator of several enzyme systems	May upset auxin level resulting in abnormal plant growth	Produces stunted growth of leaves, internodes and whole plants. White or yellowish white spots develop on the leaves. Reduces growth as well as flowering and fruiting in fruit trees. Rice and citrus are good indicator plants. Present in alkaline soils.
Copper	Activator of several enzyme systems involved in photosynthesis.	May result in iron deficiency or abnorma increase in levels of organic acids and reducing sugars	Produces variable effects in different crops. Plants may die in seedling stage. Leaves may become chlorotic or deep blue green and develop upward curling. Young shoots of trees often dieback with emergence of new shoots giving bushy appearance. Bark becomes rough and blistered exuding gum. Citrus, apples, plums and pears are good indicator plants. Found in calcareous and alkaline soils.
Boron	Essential for carbohydrate metabolism, movement of sugar through cell membrance, cell development and pectin synthesis. Present in growing points and in xylem and phloem tissues.	As it is required as a frac tion of one part per million, the higher dose causes toxicity	Produces gummosis on trees, drying of leaves, splitting of bark, abnormal setting of flowers and fruits. Growing tips are often damaged and killed and plants become susceptible to bacterial attack. Symptoms more prominent in mango, apples and cauliflower. Present in light-textured soils and low in organic matter.
Molybdenum	Required in fixation, assimilation and reduction of nitrogen.	May cause abnormal increase in levels of sugar and ascorbic acid	Produces chlorosis, mottling, curling and rolling of leaves. In severe cases gives rise to necrosis, stunting and disintegrations of leaves excepting midrib and a part of lamina.



Landforms

1. Mountains.
2. Piedmont plains and terrace remnants
3. Dissected old loess and alluvial terraces (Potwar uplands).
4. Rolling sand plains.
5. Old river terraces (Bar uplands).
6. Subrecent river plains.
7. Indus delta.
8. Active and recent river plains.

Fig. 19.1 : Types of land Forms in Pakistan.

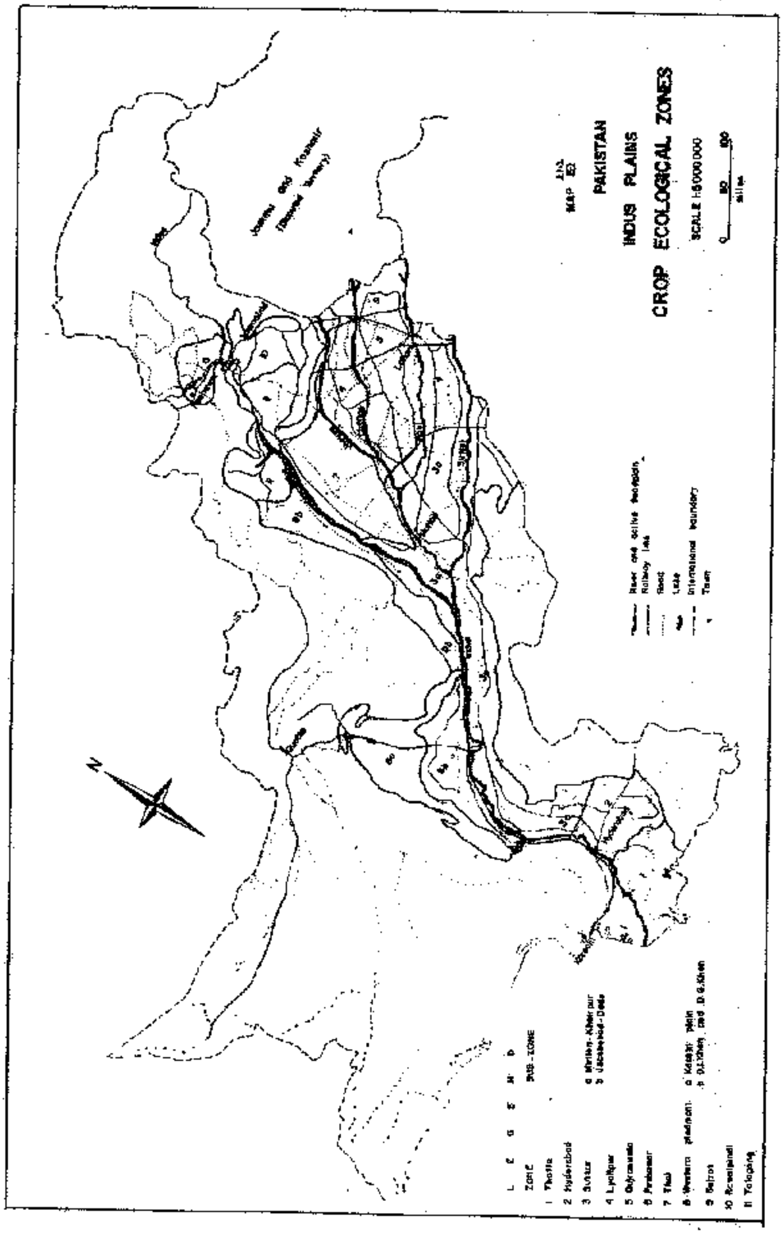
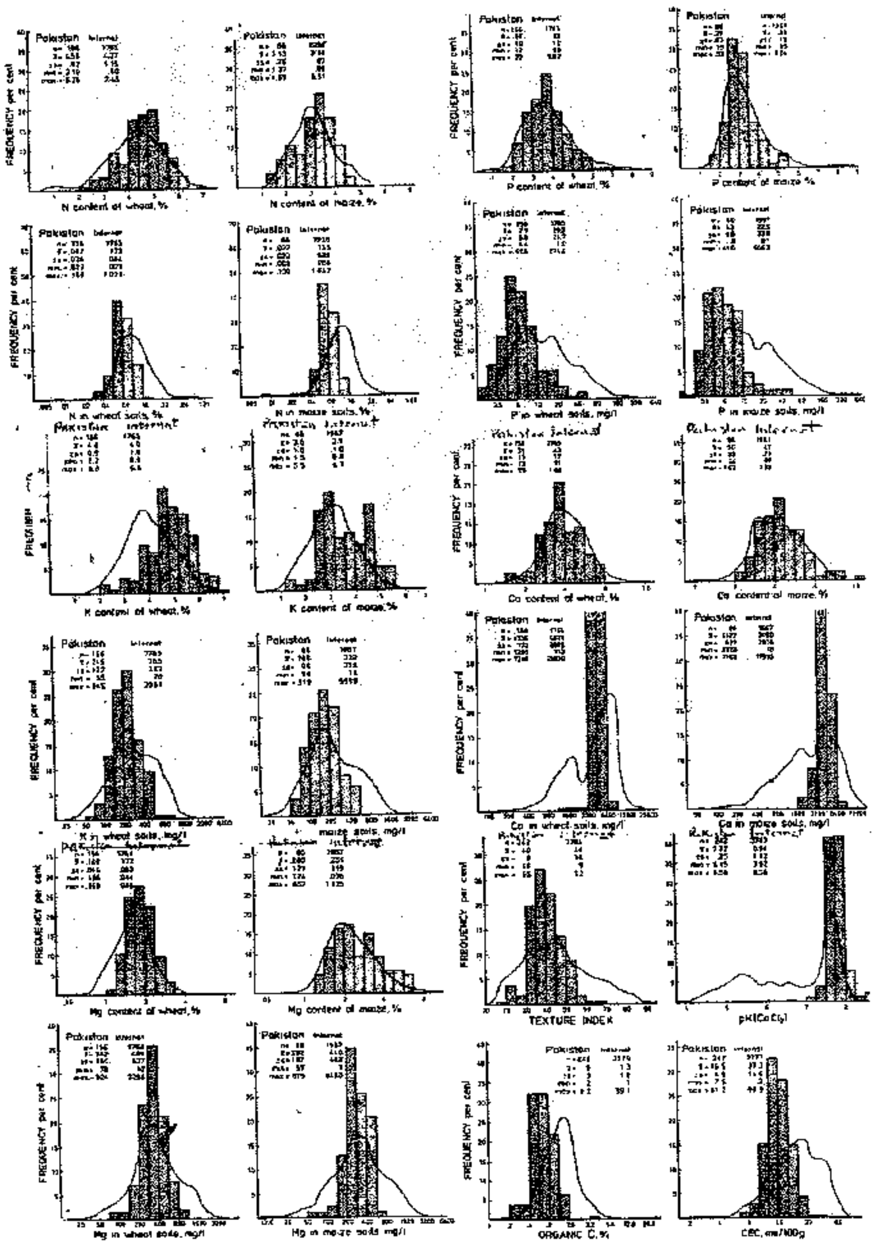


Fig. 19.2: Crop Ecological Zones of Pakistan.

Fig. 19.3: Frequency distribution of some nutrients (N, K, P, Ca, Mg) in original wheat and maize samples and their espective soils (columns) of Pakistan. Curves show the international frequency of the same characters. The other values represented are Texture index, pH, organic contents and CEC.



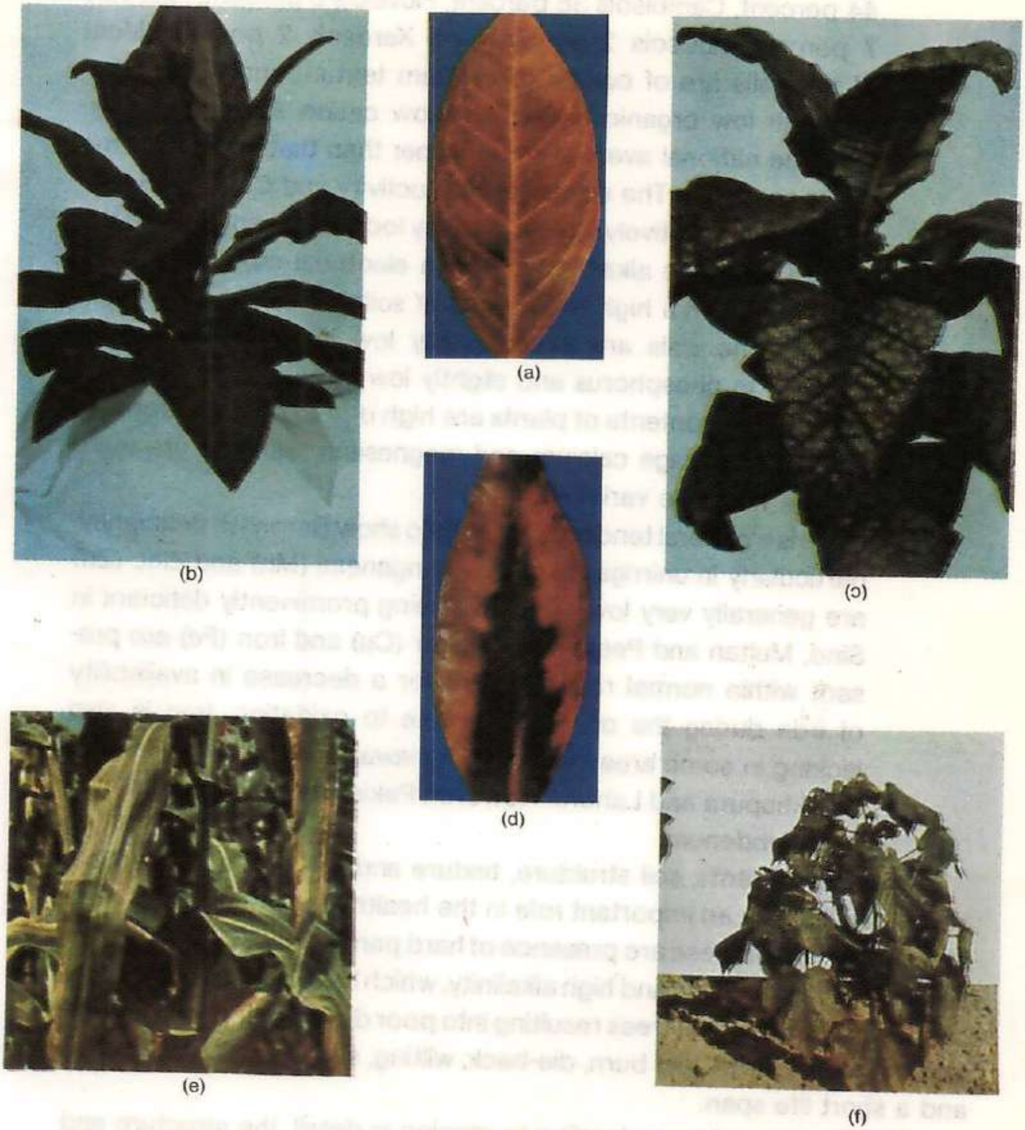


Fig. 19.4: Diseases caused by deficiency of macronutrient. (a) Nitrogen deficiency, (b) Phosphorus deficiency (c) Potassium deficiency (d) Calcium deficiency (e) Magnesium deficiency (f) Sulphur deficiency.

44 percent, Cambisols 36 percent, Fluvisols 9 percent, Halosols 7 percent, Luvisols 2 percent and Xerosols 2 percent. Most of the soils are of coarse to medium texture and highly alkaline with low organic matter and low cation exchange capacity. The national average pH is higher than that of most of the other countries. The electrical conductivity and $CaCO_3$ equivalent are also relatively higher. In many locations, especially in the Multan area, the alkalinity and high electrical conductivity are combined with a high N contents of soils.

2. Most of the soils are exceptionally low in total N contents, very low in phosphorus and slightly low in potassium contents (although K contents of plants are high due to nitrogen application). The average calcium and magnesium contents are quite normal with little variation.
3. There is a general tendency for soils to show Boron (B) deficiency, particularly in unirrigated areas. Manganese (Mn) and Zinc (Zn) are generally very low, the latter being prominently deficient in Sind, Multan and Peshawar. Copper (Cu) and Iron (Fe) are present within normal range except for a decrease in availability of iron during the dry weather due to oxidation. Iron is also lacking in some areas such as Peshawar, Lyallpur (Faisalabad), Sheikhupura and Lahore. However, Pakistan soils are often high in molybdenum.

Besides nutrients, soil structure, texture and physical and chemical abnormalities play an important role in the healthy growth of plants. The most important of these are presence of hard pan or *Kanker* layers in subsoil and of water logging and high alkalinity, which have deleterious effects on many crops and fruit trees resulting into poor development of root system, stunted growth, leaf burn, die-back, wilting, susceptibility to disease and a short life span.

Studies are underway leading to maping in detail, the structure and fertility status of Pakistan soils, which will help to improve research on problems connected with plant nutrient abnormalities.

Weather-Oriented Diseases

Before discussing the researches carried out on nutrient abnormalities in plants, it will be useful to highlight the effects of weather elements i.e.;temperature, moisture, oxygen, carbon dioxide and light on the growth and production of plants as these abiotic or physiogenic factors also predispose plants to pathogenic or non-pathogenic maladies. These effects are summarized in Table 19.2 which cover the functions, effects and remedial measures of each factor with some examples.

Apart from the effects of weather elements given in the table, many agricultural practices, if improperly employed, also cause considerable damage to plants resulting into financial losses. These include over-fertilization, over-irrigation or injuries caused by faulty chemical and herbicidal sprays. Spray injuries are of varied nature including chlorosis, leaf burning and growth deformaties. Over-fertilization can cause too much vegetative growth, burning of plant tissues and increased susceptibility to foliar diseases (like wheat rusts) while over-irrigation may result into poor soil drainage, causing root damage on account of suffocation besides dropping and withering of leaves, flowers and fruits as well as attack of root rot fungi. All these conditions lead to low productivity and need to be avoided and rectified.

Main Nutritional Diseases

This discipline has received very little attention from scientists in Pakistan. This is due, among other things, to the non-availability of specially trained manpower and laboratory facilities and the lack of team work involving soil scientists, plant physiologists, plant pathologists, virologists and plant breeders. Often the nutritional diseases are confused with those caused by pathogens or with those produced by unfavourable physical properties of soil or weather elements.However, the salient features of the work so far carried out on nutritional diseases are as follows:

1. Zinc Deficiency

Zinc deficiency with high pH soils, produces stunted growth of leaves and internodes with reduction in flowering and fruiting. It has been studied in rice, guava and citrus, producing the following typical symptoms.

The rice plants show reduced tillering, slight stunting, chlorosis and yellowing of lower leaves between the veins. The tips of the leaf blades may also develop brown spots. The deficiency becomes more severe with application of high rates of N and P, lowering the yield considerably. Experiments carried out on control measures have shown promising results. These include either (a) dipping the seedlings in zinc oxide solution at the time of transplantation, or (b) spraying the nursery beds or rice fields with zinc sulphate or zinc chloride solutions. Treatment of the nursery plants is comparatively cheaper and less time consuming.

In case of guava, zinc deficiency is characterized by chlorosis, reduced size of leaves, defoliation and reduced flower and fruit production accompanied by drying and cracking of the fruit. The plants remain stunted, manifest dieback symptoms and yield poorly. The disease is more

Table 19.2: Effects of weather elements on growth of plants

Factor	Function	Effects on plants	Remedial measures
1. High temperature	Coagulation and denaturation of proteins; disruption of cell membranes; suffocation and lack of O^2, drought and water disorders; sunscald; sunspots and water-soaked appearance of succulent leaves.	Uneven growth conditions; increased vegetative growth of some plants without reproductive phase; rolling of leaves; black heart problems in potato; stimulation of root rot, stalk rot and stem rot diseases in cotton. okra. sunhemp and sunflower. Black heart, hollow heart, growth cracks in potato tubers are caused by temperature fluctuations.	Improvement of soil texture; addition of organic manure and green manuring; use of cover crops, mixed or intercropping. light and frequent irrigations.
2. Low temperature	Hydrolysis of starch; conversion of starch to soluble sugars, late emergence, killing of buds and vines; splitting of bark; development of weak shoots and frost injury.	Cessation of growth, necrosis; decay and reddening of leaves.	Keeping the soil moist and covering of nurseries.
3. Excessive moisture	Quicker damage under hot conditions; suffocation of roots; deprivation of oxygen; decay of roots;	Decay of roots; rotting and decay causing fungi to become more active and attack cotton, guar, sunhemp,	Improvement in soil drainage; better soil management; frequent and

	water logged and anaerobic conditions.	peanut, okra and sesamum.	light irrigations.
4. Lack of moisture	Dehydration, wilting, rolling and drooping of leaves and defoliation.	Stunting of plants; development of pale green to light green colour; wilting, defoliation and death of plants tissues; increasing wilt of gram.	Application of optimum doses of irrigation before plants show signs of wilting.
5. Excess light	Generally no effect seldom any effect (except in case of radiation), sunscald, and sunburn in succulent tissues or fruits.	Development of fruit spots.	Cutting of excess light in valuable fruit trees and vegetables.
6. Sun scorch	Generally in relatively fertile soils and especially in leafy cultivars when bright sunlight follows mild weather.	Development of purplish brown and sharply defined necrotic patches on surface of leaves, which become curled. Skin burning of fruits.	Protecting young plants, seedlings or succulent material from direct sunlight.
7. Low illumination	A condition prevalent in glass houses, green houses, seed beds and nurseries.	Development of thin, elongated plants causing general etiolation, susceptibility to lodging.	Provision of alternate light and aeration in glass houses.
8. Inadequate oxygen	Desiccation of roots; collapse of	Causes black heart disease of potato	Improving ventilation

	root system; sudden death of plants, generally associated with high moisture and poor ventilation of store houses.	and apple.	and aeration in store houses.
9. Air pollution	Release of pollutants in the atmosphere such as dusts, smokes, vapours, gases i.e. ethylene, ammonia, chlorine, sulphur dioxide from factories, disposal of wastes; pollution of irrigation water.	Adverse effect on plant metabolism, interference with oxygen and carbon dioxide absorption; burning of plants, development of spots and injuries on leaves. Deformation of mango fruits.	Minimizing pollution hazards by enforcing anti-pollution laws.
10.Particulate matter	Plants near roads, cement factories, kilns, sugar mills are affected; large amount of dust and smoke particulates are deposited forming a crust on leaves.	Interference with oxygen and carbon dioxide absorption; symptoms are often confused with sooty mold attack, citrus and mango fruits deformation.	Minimizing pollution hazards and regularizing the factory sites.

serious in sandy soils. It can be rectified with the foliar application of a combination of zinc sulphate and hydrated lime (600 g of $ZnSO_4$ and 450 g of lime mixed in 100 litres of water). The number of applications will depend upon the age of the plants and degree of zinc deficiency; the younger plants respond much faster. Amendment of zinc deficiency produces marked effects on the general health of the plants, improving their growth, photosynthesis and production of flowers and fruits.

Zinc deficiency is quite common in citrus plantations throughout the country causing leaf mottling and development of chlorotic areas in between the main lateral veins on each side of the mid rib. The plants show stunted growth with increased flower shedding and production of elongated fruits of poor quality. The symptoms are more pronounced by lack of nitrogen and the productive life of the plants is shortened. As in other cases, the disease can be controlled quite effectively by spraying plants, using 1 kg of zinc sulphate combined with 600 g of hydrated lime mixed in 100 litres of water. The diseased plants respond to the treatment within 10-15 days after spraying. The leaves turn green and the general growth is improved. Application of zinc sulphate may be repeated in severe cases along with application of a substantial quantity of well rotted farm yard manure mixed with nitrogenous fertilizers.

2. Iron Deficiency

Iron deficiency usually occurs in soils with a high pH and a high content of magnesium, manganese or copper. It produces characteristic veinal chlorosis on leaves of new branches and reduction in fruit size and quality. Iron and manganese deficiencies are sometimes found to be associated, making their distinction difficult. Iron deficiency has been studied in mango, citrus and apples. The earliest visible symptoms are yellowing of newly emerged leaves, spreading to older leaves, which turn yellow and finally whitish in colour. The roots of severely infected plants usually become greyish black, rendering them poor yielders. The experiments carried out on control have shown that recovery can be induced by rectifying the iron deficiency through the application of ferrous sulphate (F_2SO_4) at the rate of 100 kg/ha. If this treatment does not produce the desired results, application of manganese in the form of manganese sulphate should be made.

3. Manganese Deficiencv

Although Pakistan soils are generally low in manganese, the deficiency has been studied only in the case of sugarcane where it is associated with yellowing and chlorosis of leaves, shortening of internodes and stunting of plants. Two symptom patterns have been observed. In one case mosaic like patterns appear on the leaves while in the other the leaves turn yellow, the internodes are shortened and the plants are stunted (see chapter V).

4. Boron Deficiency

Boron deficiency has been studied in case of mango only although Pakistan soils are generally deficient in this element (except in Multan and Sind). It has been found to cause black tip in mango, leading to the appearance of small. circular pale areas on the fruit tips with the outer skin becoming flat and hard, rendering the fleshy part firm and tasteless. These lesions can also encourage the development of saprophytic fungi and bacteria, lowering the quality and value of the fruits. Application of Borax at the rate of (500-600 g mixed in 100 litres of water) at the fruiting stage can rectify the boron deficiency while the number of sprayings may reach three to four, depending upon the degree of symptoms and extent of boron deficiency. No work has been reported on deficiencies of copper and molybdenum (Fig 19.4 & 19.5).

Although much work remains to be done on deficiency of micro nutrients in Pakistan to improve crop and fruit productivity, it is already evident that these deficiencies can be rectified at a low cost, giving a high return, provided full information on nutritional status of Pakistan soils is made available.

It is interesting to note that the importance of the micro-nutrients is now being realized and some products are available in the country to rectify their deficiencies. For example, a commercial product called OCTA (which contains a balanced combination of seven nutrients - copper, iron, zinc, manganese, boron, sulphur and molybdenum) is being sold in a package of 25 kg with instructions on methods of application.

The time is now fully ripe to strengthen and streamline research on the solution of deficiency or nutritional imbalances of crops. With increased use of nitrogen and low levels of phosphorus and potassium the lacking effects of micro nutrients have become more obvious and more damaging. This needs site and crop specific experiments which can pay rich dividents as evident from the results of the addition of micro-nutrients reported in other countries. Soil fertility will need systematic studies on soil nutrients including rotations and use of legumes and Rhizobium cultures, soil organic matter (through green manuring and addition of farm yard manure), soil moisture (through improved cultural practices including use of tine ploughs, sweep ploughs and compress seed drills, water harvesting and efficient use of water), soil conditions (water logging, salinity, alkalinity), weather elements (agrometeorology) and on atmospheric pollution (chemicals, dust. smoke

(a)

(b)

Fig. 19.5: Diseases caused by deficiency of Micronutrients: (a) Boron deficiency (b) copper deficiency.(c)Manganese deficiency (d) Iron deficiency (e)Zinc deficiency and (f) Molybdenum deficiency.

(c)

(d)

(e)

(f)

and smog). Such investigations will be of immense value in saving the crops from both pathogenic and non-pathogenic diseases. A well-equipped and well-staffed specialized research unit should be established at national level which should develop cooperative research programmes with the concerned disciplines in the provinces and the universities.

Summary

The chapter deals with the deficiencies and imbalances of major and minor nutrients essential for plant growth and deficiency identification techniques including appearance of localized specific symptoms, plant analysis, chemical soil tests and biological tests. The functions and effects of excess and deficiency of nutrients have also been tabulated covering six macro and six micro-nutrients. The general nutritional status of Pakistan soils has also been discussed. Besides nutrients, the effects of soil structure, soil texture and abiotic or physiogenic factors embracing temperature, moisture, sunlight, oxygen and pollution on plant growth have been described in a tabular form besides the bad effects of faulty cultural operations such as over-fertilization, over-irrigation and chemical sprays

It also embodies a brief account of plant diseases caused by deficiency of micro nutrients like zinc (on rice, guava and citrus), iron (on mango, citrus and apples), manganese on sugarcane and boron on mango. For each abnormality, the symptoms and remedial measures have been described. The necessity for research work on deficiency and abiotic diseases has been emphasized and the need, for the establishment of a specialized research unit at national level to carry out coordinated work, has been emphasized, involving various disciplines.

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Screening of Crop Varieties Against Major Diseases

The development of disease resistant crop varieties is an economical, effective and lasting control measure, which can greatly help in increasing and stabilizing agricultural productivity. The salient features of the work done to develop resistant varieties of wheat, rice, sugarcane, cotton, sorghum and chickpea, are given in this chapter. The investigations carried out on other crops are scanty and scattered.

Wheat

Screening of wheat varieties against rusts and other diseases, constituting one of the major items of wheat improvement, has been in progress in Pakistan since early 1960s. Work has been done both at provincial and national levels under the coordinated programme of the Cereal Diseases Research Institute (CDRI) of the PARC. The CDRI has been carrying out screening of breeding materials in the seedling stage under controlled glass house conditions and in adult plant stage in the field. It has also been responsible for the identification of physiological races of these diseases and for the maintenance and supply of live pathogen cultures for inoculation. The main results so far achieved are as follows:-

Distribution and Intensity of Rusts and Other Diseases

The distribution and intensity of rusts and other diseases are closely linked with varietal & environmental factors.Stem & leaf rusts occur throughout the country while *stripe rust* is usually confined to high elevation areas with low temperatures. Stripe rust has also been found to develop in the plains, when the night temperatures drop to 9-11°C with 90-100% relative humidity inspite of fairly high (upto 30°C) day temperatures. However, with the large-scale introduction of high yielding varieties from 1965 onwards,stem rust incidence has almost disappeared (due to the built in resistance of the cultivars)but leaf rust incidence has increased. Resistant varieties against leaf rust & stripe rust are being developed.For the occurrence of different rusts,three zones have been identified-High(northern areas of NWFP,Punjab & Baluchistan),medium(central plains of Punjab) & low (south Punjab, Sind and lower Baluchistan) according to climatic conditions. Prior to the introduction of Mexican dwarf varieties, two epidemics of stem and leaf rusts combined, occurred in 1947-48 (20-30 percent) and 1953-54 (14-20 percent) and one of stripe rust in 1958-59 (14 percent). During post introduction period there has been no epidemic of stem rust while 4 epidemics of stripe and leaf rusts occurred. The epidemics of stripe rust in 1972-73 (2-3 percent), leaf rust in 1975-76 (5-6 percent),s-stripe and leaf rusts combined in 1977-78 (10 percent) and again of stripe rust in 1979-80 (30 percent in uplands of Baluchistan only) have been reported. Whereas most of these epidemics did not cause much damage due to a late and localized appearance of the fungus, the 1977-78 epidemic of stripe and leaf rusts combined (due to an early and large-scale development) reduced the total production of wheat by 2.2 million tons. Thus the present wheat improvement strategy involves the introduction of resistance against stripe and leaf rusts to meet the requirements of the specified wheat - growing areas. Regarding other diseases, loose smut is widely spread throughout the country (2-3 percent) with a higher incidence in northern Punjab and NWFP, where the temperature and humidity conditions during flowering period are more conducive to infection. Complete bunt is restricted to uplands of Baluchistan and foot-hill areas while flag smut has assumed greater importance in the fool-hill areas of the Punjab and NWFP (upto 6 percent) with the introduction of wheat varieties of Mexican origin. The partial bunt (Karnal bunt), which was previously restricted to the foot-hill areas, has now also spread and increased in intensity in the plains. However, it should be noted that none of these diseases has been reported to cause an epidemic. They have a localized and restricted distribution.

Races and Differentials Used

The pathogens have a number of physiological races which are identified using international sets of differential varieties (Table 20.1). These are used to allow world wide comparison of races. An attempt is being made to construct a set of spring wheat differentials from Pakistan to make the work more relevant to local conditions.

Table 20.1: International differentials

Disease	Differentials
Stripe rust	Chinese 166, Lee, Heineskolben, Vilmorin 23, Moro, Strubes Dickkopf, Sown 92 X Omar, Clement, Hybrid 46, Compair, Heines VII and supplementary differentials - Giza 155, Doerfler 511-51-173C, Soltane and susceptible check Taichung 29.
Leaf rust	Malakoff, Carina, Brevit, Webster, Loros, Mediterrianean, Hussar, Democrat and Near Isogenic lines - Lr1, Lr2a, Lr2c, Lr2d, Lr3, Lr3a, Lr3ka, Lr4, Lr9, Lr10, Lr16, Lr17, Lr19, Lr20, Lr21, and Lr24.
Stem rust	Little club, Marquis, Reliance, Kota, Arnautka, Mindum, Spelmar, Kubanka, Acme, Einkorn, Vernal, Khapli and supplemental differential - Lee.
Flag smut	Baart, Federation, Oro-Federation, Ngochin, *Triticum turgidum and Tsingham.*
Loose smut	Webster, American banner, Purdue, Hussar, Early premium, Fortuna, Trumble, Kenya gypsy, Leap and Nabob.
Complete bunt	Hybrid 128, Ridit, Oro, Hohenheimer, Hussar, Albit, Martin, White Odessa, Ulka, Marquis and Cannus.

Identification of Physiological Races

Out of 4744 rust samples analysed in Pakistan upto 1983, 14 races of stripe rust, 8 of leaf rust and 11 of stem rust have been identified. Amongst the other diseases, 2 physiologic races of flag smut, 4 of loose smut and 3 of complete bunt have been discovered (Table 20.2). Relative prevalence of stem and leaf rust races are given in Tables 20.3 and 20.4.

Table 20.2: List of races identified

Pathogen	Races	*Total*
Stripe rust (1969-79 period)	*2EO, 2E16, 6E16, 38E16, 64EO, 64E16,* 66EO, 66E16, 67EO, 67E16, 70EO, 70E16, 6(38)E16	14
Leaf rust (1962-77 period)	12,20,27,77,144,149,158 and 184 (virulences identified from PL1-PL19 during 1978/81)	8
Stem rust (1962-80 period)	9, 11, 15, 15B, 17, 21, 24, 34, 40, 41 and 117.	11
Flag smut (1972-77 period)	1 and 4	2
Loose smut	1 and 2	
Complete bunt (1966-79 period)	L8, L9 and L13	3

Note: 1. Underlined races were predominant.

2. For stripe rust both European and World sets of differentials, have been used; while for leaf and stem rusts standard differentials upto 1977 and later on near isogenic lines have been used to identify virulence factors.

Table 20.3 Relative prevalence of stem rust races during 1962-74 in Pakistan

Year	Total No. of samples analyzed	Percentage of samples showing different races										
		9*	11*	15	15B*	17	21*	24*	34	40	42*	117*
1962	52	0	0	8	0	19	54	0	4	15	0	0

1963	81	0	1	12	0	52	11	0	0	21	0	0
1964	216	0	7	10	0	52	6	0	2	22	0	0
1965	252	0	3	23	0	66	0	0	1	3	0	0
1966	265	0	8	5	0	36	33	0	5	13	0.3	0
1967	201	0	7	1	0	14	31	6	13	7	20	0
1968	146	0	12	0	0	29	32	0	8	6	11	0
1969	223	0	2	2	0	36	37	2	0	3	18	0.3
1970	252	0	8	12	0	43	16	9	5	5	7	2
1,971	329	0	11	15	0	33	20	0	7	3	5	6
1972	261	0.4	8	7	1	1	8	0	25	47	0	4
1973	222	0.3	9	5	2	7	21	0	28	21	0	7
1974	242	2.0	7	9	11	4	7	0	13	25	0	22

*First recrods of new races 11(1963), 42(1966), 24(1967), 117(1969), 9(1972) and 15B(1972).

Table 20.4: Relative prevalence of leaf rust races in Pakistan during 1962–72

Year	Percentage of samples showing different races						
	12	20*	57	77	84	144	158*	184*
1962	11.8	0.0	26.5	35.5	11.8	14.7	-	0.0
1963	22.1	4.0	20.7	39.0	-	1.4	-	9.0
1964	9.5	35.9	15.3	33.9	-	0.0	-	3.0
1965	10.6	20.4	15.9	39.1	-	0.0	-	14.0
1966	25.3	9.4	35.4	16.2	-	0.0	-	14.0
1967	25.6	4.2	34.7	28.6	-	0.0	-	7.0
1968	16.0	11.0	35.0	29.0	-	0.0	-	7.0
1969	–	–	–	–	–	–	-	–
1970	0.0	0.0	64.0	35.0	-	0.0	-	0.0
1971	–	–	–	–	-	–	-	–
1972	24.6	3.3	26.2	14.8	-	0.0	23.0	8.0

*First records of new races 20 and 184 (1963) and 158(1972)

Identification of Genotypes

Host-parasitic interaction investigations, carried out during 1981-83, using more than 200 isolates of *Puccinia recondita* obtained from the commercial wheat cultivars grown under natural conditions, have shown the continued effectiveness of Lr genes *19, 24, 25, 28* and 29 contained in the near isogenic lines. *Lr26* has been found to be the main gene controlling adult plant resistance in 'Pak. 81'; *Lr22* in Pavon; and *Lr26/Lr22* in K-342 (recently released as 'Barani 83)'. On the other hand *Lr12* and *Lr13* (contained in Chenab 79, 'Punjab 81', 'Bahawalpur 79' and 'Sonalika)' have become ineffective. This suggests that wheat breeders should make use of the combined genes controlling seedling resistance and adult plant resistance in the development of broad-based resistant varieties.

Development of Improved Varieties

In Pakistan by now about 12,000 wheat varieties/lines have been screened in the seedling stage against rusts. In addition 17,000 varieties have also been screened under field conditions against rusts, flag smut, loose smut and complete bunt. Many found to be resistant have been utilized by the wheat breeders to develop high-yielding varieties with known disease reaction. After an elaborate testing procedure some of them have been approved and released for general use (Table 20.5).

Table 20.5: List of commercial wheat cultivars with potential disease reaction

Variety	Year of release	Stripe	Leaf	Stem	Smuts Flag	Loose	Mildew	Bunts Complete	Partial
C-591	1934	60S	50S	80S	S	S	MR	S	S
C-271	1957	50MR-MS	80S	30S	S	S	S	S	S
C-273	1957	30MS	S	S	S	S	S	S	S
Mexi Pak	1966	80S	80S	TrMR-MS	S	S	MS	R	S
Chenab-70	1970	60S	90S	TrMR	S	S	VS	S	S
Pak-70	1970	50S	90S	TrMR	S	S	MS	S	S
Blue Silver	1971	30MS-S	50MS-S	TrMR	S	S	MS	S	S
SA-42	1971	10R	60S	5MR-MS	S	S	MS-S	S	S
Lyallpur-73	1973	30-MS-S	30MS-S	OR	S	S	S	S	S
Pari-73	1973	30MS-S	50MS-S	TrMR	S	S	S	S	S
Sandal	1973	20-MS-S	30MS-S	TrMR	S	S	VS	S	S
SA-75	1975	20MS	50MS-S	TrMR	S	S	MS-S	S	S
Nuri-70	1975	20MS-S	20MR-MS	TrMS	S	S	MS	S	S
Yecora	1975	80S	50MS-S	30S	S	S	MS	S	I
Punjab-76	1976	90S	90S	TrMR	S	S	MS	S	-
LU-26	1977	60S	50MR-MS-S	OR	S	S	MS	S	-
Arz	1977	20MS	10MR-MS	OR	S	S	VS	S	-
Pavon	1978	50S	TrMR	OR	S	S	MS	S	-
Sonalika	1978	30MS-S	60MR-MS	OR	S	S	VS	S	S
WL-711	1978	20MS-S	90S	20S	S	S	VS	R	S
HD-2009	1978	20S	30MR-MS	30S	S	S	VS	S	S
Jauhar	1980	50MS-S	30MS-S	OR	S	S	MR	S	-
Zamindar	1980	20MR-MS	60S	OR	S	S	R	R	-
Zarghoon	1980	20MR	50MS-S	OR	S	S	MR	I	-
ZA-77	1980	50MS-S	30MR-MS	OR	S	S	MR	S	-
Khyber-79	1980	10MS-S	30MR-MS-S	OR	S	S	MS	I	-
Punjab-81	1981	50S	5MR	OR	S	S	MS	-	-
Pak-81	1981	TrMR	OR	OR	-	S	MR	-	-
Kohinoor-83	1983	TrMR-MS	20R	OR	R	S	R	-	-
Sarhad-82	1983	40MS	10R	OR	R	S	R	-	-
Sind-81	1983	30S	20S	OR	R	R	I	-	-
Faisal-abad-83	1983	40MR	20R-MR	OR	R	R	R	-	-
Barani-83	1983	10MR-5MS	10MS	OR	S	R	R	-	-

R = Resistant; MR = Moderately resistant; Tr = Traces; I = Intermediate; MS = Moderately susceptible; VS = Very susceptible and - = Data not available.

In the early period (1934-65) none of the varieties was resistant to any of the rusts, but with the introduction of the high-yielding and fertilizer-responsive genetic stocks emphasis was laid on the development of varieties resistant to stem rust (1966-70) and later also on leaf and stripe rusts (1971-83). This strategy has paid rich dividends in the development of new cultivars, which show resistance or moderate resistance to all the three rusts. This approach needs to be continued to safeguard against the occurrence of new physiological races. However, release of 30 varieties in 18 years suggests the need for the development of more lasting varieties containing broad-based resistance.

Regarding other diseases most of the varieties are susceptible to loose smut, flag smut, partial bunt and complete bunt excepting three varieties (Mexi Pak, WL-711 and Zamindar), which are resistant to complete bunt. On the other hand some varieties have shown a range of resistance to mildew (C-591, Jauhar, Zamindar, Zarghoon, ZA-77 & Pak-81). Although these diseases have not been reported to occur in epidemic form, they cause total loss of grains. It is, therefore, imperative to intensify researches on the development of resistant varieties including spring wheat differentials for race identification. Till then the use of seed disinfectants should be made compulsory for controlling these diseases.

Artificial Inoculation Techniques

To ensure successful inoculations attention must be paid to virulence spectrum of the pathogen, the collection and viability of the pathogen, the effective amount of inoculum, the time and method of inoculation. As most of the pathogens constitute populations of many physiological races, there is a danger of exposing the plant materials to a narrow range of pathogen population instead of the broadest possible spectrum of races. For example, during leaf rust surveys it has been noticed that 85 percent of collections from a single wheat variety contained only one race, 10 percent contained two races and 5 percent contained three races. The inoculum should, therefore, be collected from the largest possible number of varieties including commercial cultivars grown in different areas, to form a bulk population for inoculation purposes. If necessary the population should be broadened by multiplying the low-frequency races in the glass house. The viability of the pathogens should be tested before carrying out inoculations using standard methods. The other important factors are amount of inoculum and time of inoculation. In general, according to rule of thumb "excess of inoculum helps to guarantee success" but it may not be applicable due to shortage of inoculum. However, if properly used, even small quantities of inoculum can go a long way, for example, 5 g* of rust spores (diluted in talc, oil or water) are enough to inoculate one hectare of wheat crop. Similarly, inoculations made early in the season under favourable environmental conditions are more effective in multiplying the inoculum and spreading the diseases through secondary infections. In unfavourable conditions repeated inoculations may be needed.

Different standard methods, for carrying out successful artificial inoculations with various pathogens are described below.

Collection of Inoculum

The most effective methods include (a) use of dried leaves (6-8 leaves placed and dried at room temperature in a glassine paper envelope), (b) tapping of heavily rusted leaves for collection of urediospores (to be stored or maintained and multiplied in glass-house-raised plants) or (c) collection of urediospores through special cyclone collectors.

Storage

Freshly collected urediospores have high percentage of germination, which decreases with storage period due to the effect of temperature, moisture, light and atmospheric oxygen. Experiments carried out have shown that the viability of spores can be well maintained between 3-12 months by lowering the moisture content to 10 percent and keeping them in a sealed vial or bottle at 2-4°C. The moisture contents may be lowered by either air-drying the spores under shade for 24-36 hours or by placing them in a desiccator containing calcium chloride. The longevity period of spores can be doubled through partial or high vacuum storage. The spores will need rehydration before inoculation by leaving them in moist chamber for 12-24 hours (Table 20.6).

Table 20.6: Viability of rust spores under different conditions.

Type of storage	Storage duration (weeks)	Percentage Germination		
		Before storage	Dehydrated	After 24 hours rehydration
Air-dried	42	72	4	21
Vacuum	62	72	4	60

Stripe rust spores can remain viable for 433 days at 0°C compared with 179 and 50 days at 5° and 15°C, respectively. Similarly, stem rust spores can survive better at 5, 10 or 15°C with relative humidity ranging between 31-61 percent. Both the lower and higher humidities considerably reduce the longevity of the spores.

Multiplication of Inoculum

To improve both the volume and composition of inoculum, the spores can be multiplied by inoculating pot-grown wheat seedlings in a glass house at the first leaf stage or seedlings grown in rectangular pans (for facilitating comparatively larger multiplications). The multiplication can be increased by 3-5 times, if plants are treated with maleic hydrazide (which suppresses the development of secondary and tertiary leaves and darkens the leaf pigmentation). The spores can also be multiplied by using detached leaf culture method, which involves removing the inoculated leaves in flecking stage and placing them in a solution containing 100 percent sucrose, kinetin 40 ppm and benzimidazole 50 ppm, giving several spore flushes. A rapid and efficient method comprises boot leaf stage inoculation of adult plants of susceptible varieties grown in a glass or plastic house.

Inoculation

Laboratory inoculations are made on 5-10 cm potted wheat plants. The leaves are surface-wetted by gently rubbing with moistened fingers or by spraying them with a wetting agent like Tween 20. The spores are placed on the surface of the leaves with the help of a spatula, needle or a tooth pick (by picking the spores on dry cotton and adding a small drop of water or light mineral oil). It can also be done by clean and gentle finger rubbing, by using fine-hair brush or by holding a rusted plant and shaking it on a group of plants. The other possible methods are using of an atomiser, cyclone duster or M.B.Moore's multiple inoculator, depending upon the facilities and the quantity of spores available. In all the cases the plants, after inoculation, are kept in moist chambers for 24-48 hours to initiate infection.

For field inoculations, the simplest and most effective method is dusting of spores mixed in talc in the late evening prior to dew formation. The other methods used are (a) injection of spore suspension with hypodermic syringe into the leaf sheaths (which is very effective even under adverse environmental conditions but time consuming and is therefore confined to border-row inoculations), (b) spraying of spore suspensions in non-phytotoxic oils (6 g gallon of Mobilsol 100/acre) using knapsack sprayer with a low volume nozzle (Teejet No.730039), (c) planting border rows with a mixture of susceptible varieties, and (d) by transplanting the infected plants in between the rows and irrigating the field.

Powdery Mildews

In case of powdery mildews of wheat and barley the infected leaves showing black fruiting bodies are collected, shade-dried, stored at 2-4°C and used for inoculation of nurseries in the following season. If it fails to produce infection, the inoculum can be multiplied on detached leaves in the laboratory for increasing and bulking of the inoculum as well as for race identification. Inoculations are carried out with spore suspension or by carefully spreading the diseased debris on the plants in the field.

Bunts, Covered Smuts and Flag Smut

The disease material is collected from different localities, stored in the laboratory and used next year by dusting the seeds with the mixed populations of spores (0.5 to 1 percent of the seed weight) of a specific pathogen before sowing. In case of flag smut the "sick plot" technique is also used to obtain reliable results. For partial bunt, Moore's vacuum method and/or boot leaf hypodermic syringe inoculation with spore suspension are used.

Loose Smut

In case of loose smuts of wheat and barley the infected heads are gathered, tapped for spore collection and preferably stored at low temperatures and humidity or by using vacuum storage method to keep their viability. Inoculations are done by Moore's partial vacuum method, or by injecting spore suspension (one smutted ear in 100 ml of water mixed with 1 g of dextrose) into the two main florets with hypodermic syringe, taking care not to injure the ovary, or by puffing dry spores on to the stigmas of the developing ovaries using a rubber bulb attached to a hypodermic syringe. For the detection of embriyo infection, the Scottish method has been found to be more effective, easier and quicker than the Swedish method.

Foliar Diseases

Foliar diseases such as leaf blotches, stripes and blights, caused by *Helminthosporium*, *Rhynchosporium*, *Alternaria* and by bacteria, are treated in the same way as powdery mildews for collection and preservation of pathogens as well as for inoculations. In some cases the inoculum can be multiplied in culture and *Helminthosporium* can be grown on surface-sterilized wheat seeds.

Foot and Root Rots

The infected material is collected, preserved and propagated on artificial media and used for inoculating both the seeds and the plots. The latter are preferably developed into heavily contaminated plots over 2-3 years and used for varietal screening purposes.

Although the above mentioned methods are being used successfully in varietal screening, there is a need not only to further refine these methods but also to develop suitable methodologies for quicker and more efficient screening of large breeding stocks against major crop diseases to facilitate and accelerate the development of resistant varieties.

Rice

In spite of the minor presence of diseases like blast, *Helminthosporium* leaf spot, stem rot and kernel smut, no epiphytotic outbreak of any disease has been reported prior to 1963. However, in 1964 an outbreak of blast disease (*pyricularia oryzae* Cav.) was noticed. following the large-scale cultivation of a newly released susceptible variety (C-622). Later studies have resulted in the development of a resistant variety (Pak-178) as well as identification of sources of resistance in the following material-Giza, Narian 20, Tainaus, Taichung, 747220, IR424-3-43-PKI-2, 5603, 6071 6005, 2750, 6153 and 6119 (which are now being used by the breeders). With regard to *Helminthosporium oryzae* leaf spot, this occurs in traces with increase in plant susceptibility near flowering. Five pathogenic races have been identified in Pakistan, race 5 being most virulent. Of the present cultivars Basmati-370, Palmen-246 and Sathra-278 are resistant to races 1, 2 and 3; 2 and 4; and 4, respectively. Kernel smut is commonly found in Punjab and Sind. All the coarse varieties have been found to be susceptible (Jhona-349 , Sathra-278 , Kangni , Sada Gulab including Basmati-370). While under artificial inoculation conditions varieties like 622-B, 66107-B, Imperial Blue Rose , 197-B , Jaijai , 198-B and Bengalo have shown resistance to the disease. Regarding stem rot of rice, caused by *Tilletia barclayana* (Bref), Sacc; and Syd, which ranges in incidence from 1-25 percent, none of the 400 varieties/lines, tested so far, has been found to be resistant.

Sugarcane

The important reported diseases are smut, red rot and mosaic, needing resistant varieties for practical control. None of the commercial varieties is resistant to smut (*Ustilago scitaminea* Syd.), which is prevalent throughout Pakistan; some varieties are moderately susceptible (COL29, L-116, COL-54 and L-118), while the following varieties/lines have shown some resistance: 1-29-57, Co.356, 1-242-56, 1-39-55, Co.549, Co.961, CP-50-9, Zmex-54-86, Co.565, Co.626, Co.370, 1-181-54, COL-81, CB-36-147, 1-12-61, 1-66-61, POJ-2878 and '1395-56.' Red rot, caused by *Physalospora tucumanensis* Speg. conidial stage *Colletotrichum falcatum* Went. commonly occurs in Pakistan. Although varying degrees of disease reaction are seen, none of the commercial varieties is resistant, whereas three varieties (Co-547, Co-564 and L-118) have shown moderate resistance. Among 950 varieties/lines so far tested, 12 have been found to be resistant (1-29-53, 1-242-56, Co-549, CP-50, Co-565, Co-626, Co-370, 1-181-54, COL-81, 1-12-61, Co-338 and 1-395-56) providing useful material for the breeders. In addition, some induced mutant materials from BL-4 and L-116 have been developed.

Very little work has been done on mosaic resistant varieties except development of virus-free clones of BL-4, which are being multiplied and large-scale tested.

Cotton

Since 1967, bacterial blight (*Xanthomonas malvacearum*) has been reported to be present throughout Pakistan. None of the *Hirsutum* types grown in the country is resistant, whereas all the commercial *Arboreum* types (D-9, D-108, D-105 and 231-R) are highly resistant. As a result of large-scale varietal screening against 18 races, some exotic upland lines of cotton have shown immunity controlled by different genes; a few having polygenic resistance (Table 20.7). These sources are being used in the development of resistant varieties, which are listed in Table 20.8. As regards, root rot, the fungal pathogenicity of which has not been confirmed, none of the tested varieties has shown any resistance.

Table 20.7: Reaction of ten lines of upland cotton to 18 races of *Xanthomonas malvacearum*

Line	Reaction
1. Acala 44	Susceptible to all the races

2. Stoneville 2B-S9 (Polygenes)	Resistant to race Nos. 9 and 13 but susceptible to others
3. Stoneville 20 (B7 + Polygenes)	Resistant to race Nos. 1,3,4,5,6,7,11 and 13 but susceptible to others
4. Mebane B-1(B2 + Polygenes)	Resistant to race Nos. 1,2,3,4,5,9,11,12,13,14, 15, and 17 but susceptible to others
5. 1-10B(Bin + Poly genes)	Resistant to race Nos. 1,2,4,9,11,12,13,16 and 17 but susceptible to others
6. 20-3(Bn + Poly-genes)	Resistant to race Nos. 1,2,3,6,8,11,12,13 and 15 but susceptible to others
7. 101-102(B2B3 + unknown)	Resistant to all the races
8. Greg(unknown)	Resistant to race Nos. 1 and 2, susceptible to 11,12, and 18 but reaction unknown for others races
9. Empire B4	Resistant to all races except race No.18
10. DPXP4	Resistant to all races except race No.18

Table 20.8: List of blight resistant lines developed at Cotton Research Institute, Multan and other Research Stations under Cooperative Programmes

Origin	Family	Special Characters
Tx.ORBO-76C X B557	196-4/82	Immune to bacterial blight, okra leaf frego bract with other desirable characters
B557 X NL-11-62-1 X Tx. ORBO-76C	198-4/82	Immune to bacterial blight, okra leaf, frego bract with other desirable characters
Tx.GN-76C X NL-11-62-1 X H1/20-CB-12		Immune to bacterial blight, nectariless and high-yielding

Tx.GN-76C X FC-4245 X 407-26	199-4/82	Immune to bacterial blight nectariless with other good characters
BSI X Tx.ORH-A=76C X NL-11-62-1 X H1/30(B-12)	210-4/82	Immune to bacterial blight, and high potential for yield
Tx. Bonham X BSI	Bh-1 to Bh-5	Homozygous resistant to bacterial blight, short stature and early
Tx. Bonham X BSI	1714 to 1716-5/82	Homozygous resistant to bacterial blight hairy with other good characters

Chickpea

The two common diseases are blight *(Ascochyta rabei)* and wilt (*Fusarium* spp.). Work on screening and development of resistant varieties has been in progress for the last four decades. The earliest discovered blight resistant exotic varieties were F8, F9 and F10, followed by locally bred tolerant varieties (C12/34 and C 62-18), which ultimately fell prey to the disease. After screening of thousand of exotic varieties none has shown complete resistance although there are some varieties/lines which are tolerant (ILC's 72, 182, 191, 200, 202; ICCs 7513, 7514 and local varieties such as Aug. 426, Aug.480, 918, 1115, C44, C228, CM68, and CM72-mutants). It appears that the genetic variability, which can confer reasonable degree of resistance in chickpea cultivars, is very much limited. Similar situation probably exists for wilt resistance for which some of the reported tolerant varieties are G543, G549, C727, CM68 and CM72. Unless sources of resistance are found or developed through mutation, the achievement of real progress appears to be remote. This type of work is in progress at NIAB, Faisalabad resulting in development of 'CM-72,' which has given promising results.

Sorghum

Breeding for resistance to major diseases has not received an adequate attention in Pakistan except screening of certain genetic stocks or cultivars, indicating reasonable degree of resistance in some of them. However, these studies are in progress in the Indian sorghum improvement programme and at ICRISAT, which has a global mandate to help other countries. The main results so far achieved are given below.

1. Development of cultivars with duration matching with the rainy season has helped to overcome the problem of grain molds. These varieties are CSV-4 (CS-3541), CSV-5 (248/168), SPV-35, SPV-81, SPV-102, SPV-126, SPV-141 and SPV-249. Three characters - tan plant type, low water absorption and higher breaking strength of grain have been used as selection criteria.
2. High levels of resistance have been built up in some hybrids (CSH-5, CSH-6, SPH-24 and SPH-107) through the use of selected parents.
3. After identification of resistant parents to leaf diseases some hybrids (CSH-5, CSH-6 and SPH-61) and varieties (SPVs-105, 106, 192, 220, 224, 232 and 257) have been developed.
4. Genetic stocks and breeding materials exhibiting resistance to more than one disease are now available (Table 20.9) for use in breeding programmes.

Table 20.9: Multiple disease - resistant sorghums*

Cultivar	DM	CR	Rust	ZLS	Cer	An	SS	Helm	Asco	SD
SPVA-104 (6)	x	x	x	x	x		x			
SPV-126 (6)	x	x	x	x	x					
SPV-18 (6)	x	x	x	x	x	x				x
CSH-5 (6)	x		x	x	x		x			x
CSV-4 (5)	x	x	x	x	x					
CSV-5 (5)	x	x		x	x					
SPV-193 (5)	x	x	x	x	x					
CSH-6 (5)	x		x	x	x					x
SPH-61 (5)		x	x	x	x					x
SPH-80 (5)	x	x		x	x			x		
SPV-70 (4)	x		x	x					x	

*Number in parentheses indicates number of diseases to which this cultivar shows resistance; DM - Downy mildew; CR - Charcoal rot; ZLS - Zonate leaf spot; CER - Cercospora; AN - Anthracnose; SS - Sooty stripe; HELM - Helminthosporium; ASCO - Ascochyta (Rough leaf spot); SD - Sugary disease and x indicates resistance.

This thus shows that high levels of resistance are available for most of the sorghum diseases with information on nature of resistance. However, continued efforts will be needed to keep the resistant and high-yielding cultivars ready in the pipe line as soon as needed.

Methods of Scoring Various Diseases

In most cases standardized disease assessment methods have been used for obtaining more uniform and meaningful results. Some of the important methods are described below:

Rusts

Two types of observation are recorded on "severity" and "response" i.e., the percentage of rust infection on the plants and type of infection, respectively. In case of "severity" the percentage of infection are recorded according to the modified Cobb scale* based on visual observations. Since observations cannot be absolutely precise, short or intervals are used. (Fig. 20.1). The "response" of a variety, which refers to type of infection (or type of pustules), is recorded according to following observations:

Type	Description
0; 0 = *Immune*	No visible infection of plant.
1 R = *Resistant*	Necrotic areas with or without minute uredia present.
2 MR = *Moderately resistant*	Small uredia present surrounded by necrotic areas.
3 MS = *Moderately susceptible*	Medium-sized uredia with no necrosis but possibly with some distinct chlorosis.
4 S = *Susceptible*	Large-sized uredia with no necrosis and little or no chlorosis present.

However, for ease of reading, the data, particularly on seedling reaction are converted for classification and grouping as follows:

R = *Resistant*	Type 0, 0; and 1
M = *Moderate*	Moderate Resistant or Moderate Susceptible = Types 2 and 3
S = *Susceptible*	Type 4

To compare a large number of test entries grown at a single or multi-locations the Coefficient of Infection (C.I) is calculated for each entry according to the following formula:

C.I. = Severity X Reaction factor (based on the following reaction values)

Reaction	*Factor*
No disease	0.0
R	0.2
MR	0.4
MR - MS	0.6
MS	0.8
S	1.0

Example:
Severity = 40%
Reaction = MR = Factor 0.4
C.1 = Severity x Reaction = 40xo.4 = 16.

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*Modified Cobb Scale:

1% = 0.37%	of actual leaf area covered
5% = 1.85%	-do-
10% = 3.70	-do-
25% = 9.25%	-do-
40% = 14.80	-do-
60% = 22.20%	-do-
80% = 29.60%	-do-
100% = 37.00%	-do-

Smuts and Bunts

Percentage infection determinations in smuts and bunts studies are usually based on the number of diseased heads in relation to the total number of heads in the test population. While for studies on inheritance of resistance factors, the percentages are based on number of diseased plants. According to Rodenhiser and Holton (1945) the following systems are used.

*Reaction**		*Percentage Infection range*
System 1.	R(Resistant)	0-10
	S(Susceptible)	11-100
System 2.	R(Resistant)	0-10
	I(Intermediate)	11-40
	S(Susceptible)	41-100

*These systems are also applicable to grain smut of sorghum.

In case of partial bunt of wheat, kernel smut of rice and long smut of sorghum, the following scale of Moseman is used:

Reaction	*Percentage Infection range*
R(Resistant)	0.0-0.2
I(Intermediate)	0.3-1.5
S(Susceptible)	1.6 or more

As in case of flag smut of wheat the percentage of infected tillers is directly correlated with the degree of susceptibility, the incidence of the disease is recorded on the basis of infected tillers, using the following

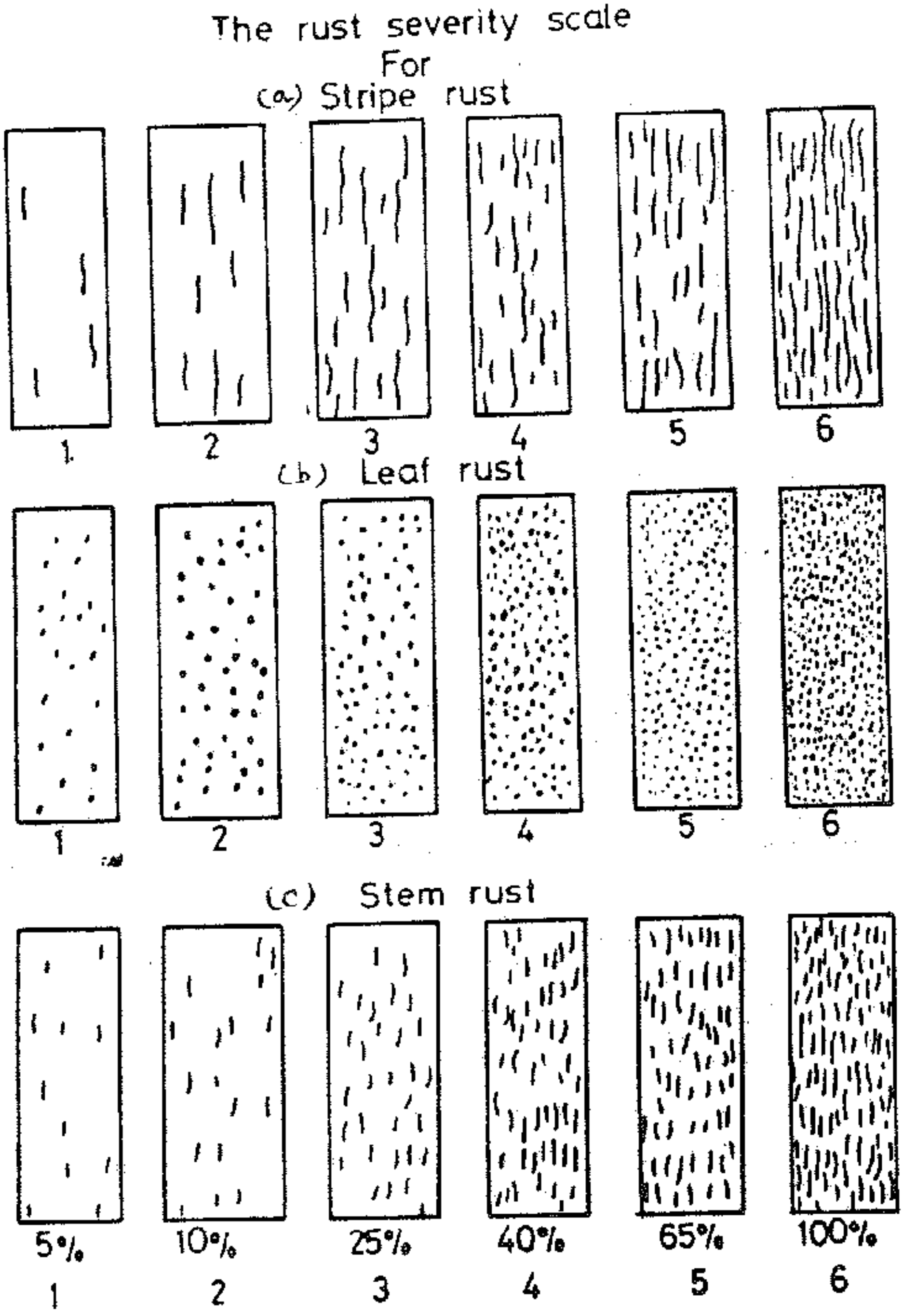


Fig. 20.1: The rust severity scale for (a) Stripe rust, (b) Leaf rust and (c) Stem rust.

scale (Yu et al. 1945). The same scale can also be used for scoring foot rot diseases.

Reaction	*Percentage Infection range*
R(Resistant)	0-5
I(Intermediate)	6-20
S(Susceptible)	21-100

Septoria.

The following scales are used for disease scoring in case of *Septoria nodorum* in field conditions:

On Heads:		*Percentage infection*
0	Immune	0
1	Resistant	20
2	Moderately Resistant	20
3	Moderately Susceptible	60
4	Susceptible	80
5	Very Susceptible	100

On Stems:

0 Immune
1 Resistant. Necrotic points. (R)
2 Moderately resistant. Spots on nodal surfaces. (MR)
3 Moderately susceptible. Spots on the nodes, early shrivelling. (MS)
4 Susceptible. Spots on the nodes abundant, girdling of the nodes, lodging begins. (S)
5 Very susceptible. Spots surrounding the nodes, complete girdling, frequent lodging. (VS)

Shipton et al. (1971) has suggested the following scale for scoring of septoria disease.

0 Immune - no pycnidial formation, no symptoms or occasional hypersensitive flecking.
1 Highly resistant - no or only occasional isolated pycnidium formed particularly in older leaf tissue, hypersensitive flecking in younger leaf tissue.
2 Resistant - very light pycnidial formation some coalescent of lesio

mainly towards the leaf tip and in older leaf tissue.

3 Intermediate - light pycnidial formation coalescent of lesions normally evident towards the leaf tip and elsewhere on the leaf blade.

4 Susceptible - moderate pycnidial formation lesions much coalesced.

5 Very susceptible - large abundant pycnidia, lesions extensively coalesced.

The scales used for septoria leaf blotch of cereals and septoria glume blotch of wheat are shown in Figs. 20.2 and 20.3.

Fig. 20.2: ***SEPTORIA LEAF BLOTCH OF CEREALS*** **(Leaf symptoms)**

Use for:

Glume blotch of wheat (*Septoria nodorum* Berk.)
Speckled leaf blotch of wheat (*Septoria tritici* Rob. ex Desm.)
Leaf blotch of wheat (*Septoria avenae* Frank f. sp. *triticea* T. Johnson)
Leaf blotch and black stem of oats (*Septoria avenae* Frank f. sp. *avenae*)
Speckled leaf blotch of barley (*Septoria passerinii* Sacc.)

Procedure:

Select a random sample of fertile tillers.

Growth stages:

Assess at growth stages 10.5 and either 11.1 or 11.2 or both. The key can also be used for recording disease at earlier growth stages, but the growth stage and leaf position (top leaf = leaf 1) should be carefully noted, so that valid comparisons can be made between crops.

Assessing severity.

Assess percentage leaf (lamina) area affected by disease on individual top leaves.

Fig. 20.3: ***SEPTORIA GLUME BLOTCH OF WHEAT***

Use for.

Glume blotch of wheat (*Septoria nodorum* Berk.)

Procedure:

Select a random sample of spikes.

Growth stages:

Assess at growth stages 10.5 and either 11.1 or 11.2 or both.

Assessing severity:

Assess percentage spike area affected by disease.

Foliar Diseases

Scorings foliar diseases of many crops such as wheat, barley, oats, rice, maize, sorghum etc. are carried out by using many systems and scales, with a view to screening to resistant genotypes. Table 20.10 and Fig. 20.4, which are used for foliar diseases of wheat will give an idea about the scoring of such diseases of other crops.

Table 20.10: Foliar disease scoring scale (0-9) for wheat:

0 = Free from infection.

0E = Free from infection, but probably represents an escape.

1 = Resistant: Few isolated lesions on lowest most leaves only.

2 = Resistant: Scattered lesions on the second set of leaves with first leaves infected at ligt intensity.

3 = Resistant: Light infection of lower third of plant, lowest most leaves infect at moderate to severe levels.

4 = Moderately Resistant: Moderate infection of lower leaves with scattered to light infection extending to the leaf immediately below the mid-point of the plant.

5 = Moderately Susceptible: Severe infection of lower leaves. Moderate to light infections extending to the mid-point of the plant with upper leaves free. *Infections do not extend beyond mid-point of plant,*

6 = Moderately Susceptible: Severe infection of lower third of plant, moderate degree on middle leaves and scattered lesions beyond the mid-point of the plant.

7 = Susceptible: Lesions severe on lower and middle leaves with infections extending to the leaf below the flag leaf, or with trace infections on the flag leaf.

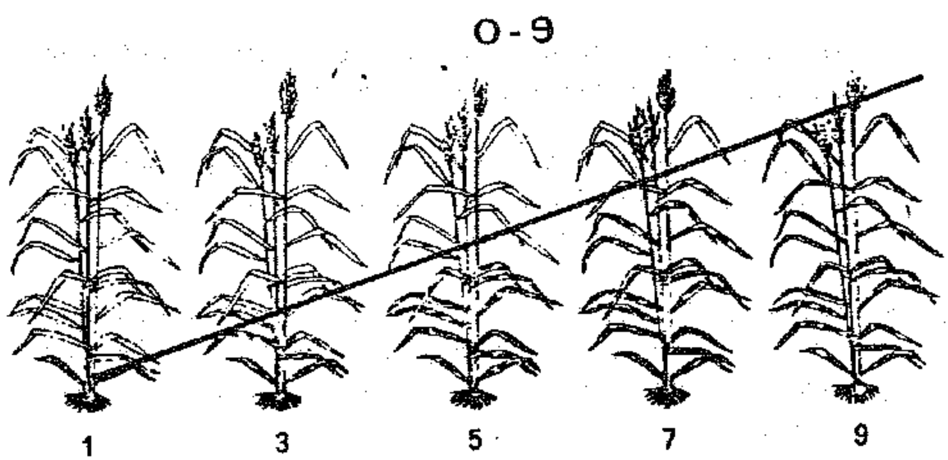
8 = Susceptible: lesions severe on lower and middle leaves. Moderate to severe infection of upper third of plant. *Flag leaf infected in*

amounts more than a trace.

9 = Highly Susceptible: Severe infection on all leaves and the spike infected to some degree. Spike infections are scored as a modified scale of the percentage of the total area covered. The percentage figure follows the numerical leaf infection score and it is separated by a / .

N = Used to indicate no scoring possible due to necrosis as a result of other diseases or factors.

Fig. 20.4: Scale for appraising foliar intensity of wheat diseases.



To have more effective and uniform scoring to be understood internationally, a good deal of research work is in progress in various countries of the world, proposing new or modified scales from time to time. Recently W. Clive James has prepared a manual on disease assessment keys covering cereal crops, forage crops and some field crops (potatoes and beans) for obtaining more uniform and meaningful results. All the keys in the manual are based on a percentage scale, which represents the actual area covered by the pustules or lesions. For example, in key for leaf rust of cereals, one percent represents the actual area of the lamina covered by pustules expressed as a percentage of the illustrated leaf. It has also been proposed that if chlorotic or dead tissue is associated with the pustule or lesion, an additional assessment should be made and added to the pustule or lesions assessment to provide an estimate of the visible area affected; thus if pustule area is 1 percent and chlorosis 4 percent, the disease percentage recorded should be 5 percent. Many other suggestions have been made on recording and interpretation of data. However, the experimental use of these keys by the pathologists in various areas will help in determining their merits and faults for further improvements.

Infact, there is a grea need for developing simple, quick and practical methodologies on varietal screening and ratings of important crop diseases for adoption on uniform and global basis to facilitate breeding programmes. By now it is well known that the evolution of resistant varieties should better be broad - based containing polygenic vertical resistance, horizontal resistance (which is usually effective against many races of pathogen and is less subject to break down) and tolerance (a compromise between the host and the parasite), realising that the resistance is not rigid, definite and quantitative parameter, but is flexible in the sense that no plant species is immune or 100 percent resistant to a disease.

Summary

The chapter embodies the salient features of the investigations carried out on the screening of crop varieties against major diseases leading to the development of the resistant varieties for controlling epidemics and stabilizing the high levels of production. The studies have been concentrated on rusts and some other diseases of wheat embracing survey, identification of physiologic races and genotypes for use in breeding pro-

grammes resulting in the development of resistant varieties. Methods are described for the artificial inoculation of rusts and other pathogens such as powdery mildews, bunts and covered smuts, loose smuts, foliar and foot rot diseases. Methods have also been presented for evaluating varieties. The outstanding achievement has been the development of wheat varieties resistant to rusts, which has helped to increase the total production more than three fold with the increased use of inorganic fertilizers.

The studies carried out on rice diseases (blast, leaf spot, stem rot and kernel smut) have helped in the identification of physiologic races and resistant genotypes with beneficial effects on the breeding programmes. In the case of sugarcane, work has been done on smut, red rot and mosaic diseases with some useful findings. As regards cotton, investigations have been made on bacterial blight resulting in the identification of some resistant genetic stocks which have been used in hybridization, but no success has been achieved in finding out varieties resistant to root rot. The studies on chickpea have been confined to blight and wilt diseases with partial success, showing that the genetic variability, which confer some degree of resistance to chickpea cultivars, is very much limited, warranting the use of mutation techniques. In sorghum resistant genotypes have been identified for majority of diseases while resistant hybrids/varieties have been developed against some of them.

In addition, the methods of scoring for various diseases have been described in detail with their merits and demerits pointing out the necessity of developing more efficient and practical techniques.

However, much more concerted efforts are needed to screen and develop resistant crop varieties for combating diseases more effectively and economically than by the use of agrochemicals.

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Chapter XXI

Soil-Borne Fungi and Biological Control

The fungi, which exist in the soil as living micro-organisms and cause serious diseases of many crop plants, have been subjected to numerous investigations during the last 60 years. The researches carried out in Pakistan on various aspects of these fungi are briefly discussed below:

Isolation of Soil Fungi

A comparative study of five culture media and five soil dilutions has shown that the highest number of fungi were isolated on Peptone dextrose agar and Jensens medium, the former favouring species of *Chaetomium, Rhizoctonia* and *Trichothecium*. The spectrum of fungal species was almost the same in soil dilutions of 1:100; 1:1,000 and 1:10,000; the number of fungal species isolated gradually decreased with further dilutions of the soil samples.

Several methods have been used by research workers for the isolation of soil fungi. The Dilution Plate Method has been used widely. It is favourable for the isolation of heavily sporing fungi, but has the disadvantage that the coarser soil particles do not stay suspended uniformly resulting in sedimentation of fungi with the residue. There is another procedure called Soil Plate Method in which a small quantity of soil is disperssed throughout the medium in the isolation plates. This method leads to the isolation of a greater number of fungal species.

The third technique, known as Screened Immersion Plate Method, permits the isolation of micro-organisms growing from the soil on the agar media placed beneath a perforated screen. This gives better results for fungi like *Rhizoctonia solani.* Later studies have resulted in the development of many other techniques viz; Immersion Tube Method, Buried Slide Method, Modified Screen Immersion Plate, Needle Method (for isolating fungi directly from the soil), New Screened Plate Method (by directly transferring a small amount of soil, without disturbing, to the isolation medium). The comparative study of seven isolation methods (using Waksman's medium, Water Agar and Malt Extract Medium) has shown the superiority of Soil Plate Method, New Screened Plate Method and Needle Method for general isolation of soil fungi as these methods could isolate. respectively, 71, 70 and 54 percent of fungal species from the soil. The various methods used are suited to different groups of soil fungi and have their limitations and uncertainties and therefore, their use will depend upon the specific nature of the studies. However, New Screened Method coupled with Needle and Soil Plate Methods can give almost a full picture of soil fungi.

Soil Fungi Isolated

During the comparative studies of isolation methods, a number of soil fungi have been isolated from the soils of Pakistan (Table 21.1).

Table 21.1: Soil fungi isolated from different soils.

Actinomycete
Aspergillus fumigatus Fresenius
Cephalosporium sp. (isolate 1)
Cladosporium cladosporioides (Fres.) de Vires
Coniothyrium fuckeli Sacc.
Cylindrocarpon radicicola Wr.
Ceratocyctis sp.
Circinella sp.
Fusarium sp.
Fusarium culmorum (W.G. Sm.) Sacc.
Fusarium oxysporum Fr.
Fusarium poae (Feck) Wr.
Fusarium roseum
Fusarium semitectum Berfi. Pers.
Fusarium solani(Mart.) Sacc.
Gliocladium deliquescens
Gliocladium roseum group.
Helminthosporium spp.
Humicola grisea Traaen.
Macrophomina phaseoli (Tani) Goid.
Monilia sp. (isolate1)

Monilia sp. (isolate 2)
Mortierella elongata Linnemann var. subtilis.
Mortierella subtilissima Oudem.
Mortierella vinacea Dixon-Stewart.
Oospora sp.
Oidiodendron flavum Szilv.
Paecilomyces carneus (Duche and Heim) Brown and Smith.
Penicillium cyclopium group.
Penicillium funiculosum Thom.
Penicillium janthinellum Biourge.
Penicillium terrestris Jensen.
Penicillium sp. (isolate 1)
Penicillium sp. (isolate 2)
Penicillium decumbens Thom.
Penicillium luteum Zukal.
Penicillium nigricans (Bainier) Thom.
Pseudoeurotium zonatum van. Beyma.
Pythium sp.
Rhizoctonia solani
Sclerotium oryzae Cat.
Scopularizais asperula (Sacc.) Hughes
Scopulariopsis parvula Moitoi and Smith.
Septomyxa affine (Faut. and Lamp.) Wr.
Sporormia megalosfora Auersw
Trichoderma viride Pers. ex Fr.
Trichosporium sp.
Verticillium nigrescens Pethybr.

The list although not exhaustive, contains 48 different soilborne fungi isolated from restricted areas and shows the richness of Pakistan soils in fungal flora. Some of these fungi are pathogenic, others are either saprophytic or decomposers of plant residues.

Distribution and Damage

Soil-borne plant pathogens, particularly those causing root diseases, are destructive and wide spread in Pakistan soils. At least 50 percent of losses caused by plant diseases in Pakistan are due to the root rots and wilts of different field crops, vegetables, fruit plants and forest trees. *Rhizoctonia solani, Fusarium oxysporum, Fusarium solani* and *Macrophomina phaseolina* are the most common and widely distributed soil-borne plant pathogens in the country.

They infect over two dozen host plants at different stages of growth; the major economic host plants are given in Table 21.2.

Table 21.2: Common soil-borne pathogens and the host plants of economic importance

Pathogens	Host plants
1. *Rhizoctonia solani*	Cotton, maize, brassica, peanut, okra, brinjal, radish, turnip, fennugreek, cow-pea, Egyptian clover, citrus, mango, apple, Indian rosewood and tobacco.
2. *Fusarium oxysporum*	Chickpea, lentil, linseed, peanut, pea, tomato, potato, Egyptian clover, citrus, mango, apple and guava.
3. *Fusarium solani*	Cotton, gourd and guar.
4. *Macrophomina phaseolina*	Sesame, soybean, okra, potato, tobacco cotton, jute and groundnut.
5. *Sclerotium oryzae*	Rice
6. *Helminthosporium sativum*	Wheat and barley.

The vulnerability of the major crops in Pakistan is due to genetic uniformity as 60-100 percent of the cropped areas are covered by one or two varieties only, which have high range of susceptibility. Unfortunately, sources of genetic resistance are still completely lacking against these pathogens. In the absence of resistant varieties the development of alternative control measures is of the utmost necessity. Chemical control has also many constraints such as non availability of selective fungicides, high cost of fungicides, the complicity of effective application, deleterious effects on useful soil microbes and pollution. In view of this situation extensive investigations have been made to control these diseases through the use of antagonistic micro-organisms.

Biological Control

Many fungi, actinomycetes and bacteria have been found to be antagonistic to the growth of certain parasitic soil fungi when they are cultured together. Although such studies have been in progress for the last many years, very little farm-application of biological control of diseases, has come into practice. However, recent investigations are showing some signs of a breakthrough in the possibility of adopting modified and practical control measures. In Pakistan these studies have been mostly concentrated at the Ayub Agricultural Research Institute, Lyallpur (Faisalabad) and the University of Karachi. The highlights of the results achieved are discussed below.

Rhizoctonia solani, isolated from root-rot affected cotton fields when cultured together with 12 isolates of *Trichoderma*, *Aspergillus* and *Penicillium* species separately, has shown the inhibition of growth of the pathogen *in vitro*. The most effective isolate has been identified as *Trichoderma viride*. For the control of *Fusarium oxysporum*, *F. lini* (causal organisms of linseed wilt) three antagonistic fungi (*Aspergillus flavus*, *Aspergillus wentii* and one isolate of *Penicillium*) have shown the best performance in *vitro*. A number of pot and field experiments carried out on the control of cotton root rot, wilt of linseed, root rots of citrus, mango and Egyptian clover by using the identified antagonistic organisms grown on various subtrates (wheat straw, rice straw, sugarcane bagasse with or without molasses) and different rates, times and methods of application at varying soil depths (including ploughing-furrows), have yielded encouraging results in considerably reducing the disease incidence. The best results have been obtained by using wheat straw substrate, which when applied between 190-380 kg/acre in case of cotton, linseed and berseem and at the rate of 3-4 1b/per citrus or mango plant at 1 ft. depth, preferably in split doses. prolonged the antagonistic activity. Most probably prolonged decomposition of wheat straw by the antagonists results in an effective suppression of the pathogen. Similar results have been reported by Garrett in his soil conditioning investigations on take-all disease of wheat (*Ophiobolus graminis*). It has been shown that the treatment favours carbon dioxide concentration and stimulation of microbial action which adversely affects the pathogenic activities. Chaffed wheat straw has proved superior because, being poorer in nitrogen it enhances the activity of the antagonists. Although the antibiotic activity has been reported to be stable in acid soils, it needs to be investigated in neutral and alkaline soils.

Later experiments in Faisalabad using 8 quintals/ha of chaffed wheat straw inoculated with *Trichoderma harzianum* for controlling root rots caused by *Rhizoctonia solani* in cotton, tobacco and berseem and 4 quintals/ha of wheat straw inoculated with *Arachniotus* sp. for controlling wilt of linseed and tomato caused by *Fusarium oxysporum*, wilt of guar caused by *Fusarium solani* and stalk rot of maize caused by *Fusarium moniliforme* have proved successful. Combined application of these two antagonists in the root zone of diseased mango and citrus plants has controlled slow decline caused by *F. solani* and *F. oxysproum*. Another equally effective antagonist has been identified as *Aspergillus flavus*. The cultures of the two antagonists (*Trichoderma* and *Aspergillus*) are now being privately marketed under the names of Tricho-pak and Aspergo-pak. The most efficient treatments developed for the control of various soil-borne diseases are summarized in Table 21.3.

Table 21.3. Effect of combined application of antagonists and organic substrate on the incidence of soil-borne diseases of various crop plants

Disease	Treatment	Percentage decrease over control
Cotton root rot	*T.harzianum*+ Chaffed wheat straw added twice at the rate of 4g/ha.in March and May or added once at the rate of 8g/ha. in May	94.11 97.02
Tobacco root rot	*T.harzianum*+ Arachniotus sp. + Chaffed Wheat straw at the rate of 8g/ha.	Complete recovery
Linseed Wilt	*Arachniotus* sp. + Chaffed wheat straw + 1% molasses + 1% Nitrogen.	87.23
Tomato Wilt	Aspergillus flavus + Rice husk	92.49
Guar wilt	Sterilized soil + *A.flavus* + Rice husk	93.00
Maize stalk rot	*Arachniotus* sp + Chaffed wheat straw at the rate of 4g/ha.	61.00
Citrus root rot	*T.harzianum* or *Arachniotus* sp. + 2kg. wheat straw/plant or *A.flavus* + 2kg. rice husk/plant.	Complete recovery
Mango root rot	*T.harzianum* or *Arachniotus* sp. + 2kg. wheat straw/plant or *A.flavus* + 2kg. rice husk/plant	Complete recovery

Note:- Biological control has also been successfully demonstrated for soil-borne diseases of sugarcane, berseem, mustard, date palm and foliar and inflorescence malformation of mango. Recently *Masonniella* sp. has indicated some promising results in controlling gram blight and gram wilt. Further work is in progress.

Recent studies have indicated some substantial increase in the yields of wheat, rice, maize, sugarcane and berseem if *Arachniotus* sp. and *Streptomyces* sp. are added to the soil along with chaffed wheat straw (80 kg/acre) during seed bed preparation. However, the variability shown in the experimental results suggests the need for further researches. In spite of its limitations the biological approach has opened new vistas for controlling the most difficult and complex group of soil-borne crop diseases.

Researches carried out at the Karachi University have also produced interesting results in controlling cotton root rot and stem rot of rice. The main results are discussed below.

Cotton Root Rot

Studies on antagonism have shown that whereas *Macrophomina phaseolina* can compete with a range of soil saprophytes, its growth is inhibited by *Pencillium nigricans, P. urticae, Stachybotrys atra, Trichoderma viride, Streptomyces griseus, S. albus, S. noursei* and *Bacillus subtilis*. The fungus *trichoderma lignorum* has also been earlier reported as an antagonist to *Rhizoctonia bataticola* by Vesudeva and Sikka (1941). Addition of organic substances like alfalfa meal and barley straw increases the population of antagonistic fungi, actinomycetes and bacteria in soil, resulting in biological control of *M. phaseolina* infection of cotton; alfalfa amendment giving more pronounced effects. Use of soil amendments (organic substances) may be one of the factors in disease reduction when cotton is sown mixed with moth (black gram) and not high humidity and low soil temperatures as reported by Vesudeva (1941). These soil amendments also reduce the sclerotial population of *Macrophomina* considerably; alfalfa giving the highest percentage (86-96) of reduction. The introduction of alfalfa or clover in cotton rotation may help to reduce sclerotial inoculum and control *Macrophomina* infection besides improving the soil fertility and texture. Mulching of soil (moist or dry) with transparent polyethylene sheets, irrespective of lucerne, or wheat soil amendments, completely eliminates the sclerotial propagules after a period of one week.

Stem Rot of Rice

Of the 63 different isolates of fungi, 16 of actinomycetes and 11 of bacteria isolated from soil and infected paddy stubbles, some were found to be detrimental to the growth of *Sclerotium oryzae* in vitro. The important ones are *Trichoderma hamatum, T. harzianum, Stachybotrys, Aspergillus flavipes, A. rugulosus, Penicillium purpurogenum, Pseudoarachinotus roseus, Streptomyces albus, S. nouresi, S. rimosus* and *Bacillus* spp. It has also been found that *Trichoderma hamatum* reduced the numbers of sclerotia of *S. oryzae* in the soil while the other soil antagonists like *A.*

flavipes, *S. atra*, *T. harzianum* and *Streptomyces* spp. have neither reduced the sclerotial numbers nor affected their viability. The two strains of *Bacilli*, however, greatly affected the viability of sclerotia. As in case of root rot of cotton, soil amendments (dried stems and leaves of lucerne at the rate of 5 percent w/w)and mulching with transparent polyethylene sheeting greatly reduced the viability of sclerotia (Figs. 21.1 and 21.2).

In the absence of genetic resistance these research findings hold out promise for the development of suitable cultural control measures by using soil amendments and practical crop rotations. Because of the high losses caused by the complex group of soil-borne pathogens, the research needs to be intensified, streamlined and concentrated at one well-staffed and well-equipped centre to meet the national needs, with special emphasis on the development of practical methods of control suited to farm-application. Such studies, if successful, will help to control the most damaging soil-borne diseases and promote crop yields.

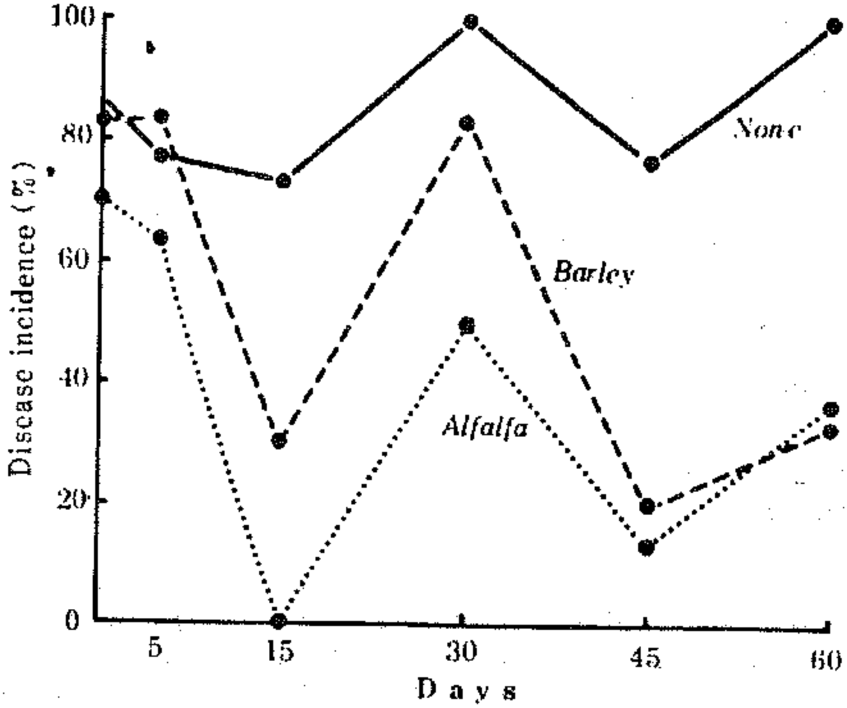

Fig.21-1: Effect of adding organic amendments to soil on infection of cotton seedlings with *Macrophomina phaseoli*.

Summary

The soil fungal flora has been discussed in some detail. Comparisons are made of the various methods of isolation with their merits and demerits. The New Screened Method coupled with Needle and Soil Plate Methods gives almost a full picture of soil-borne fungi. In all 48 soil-borne fungi have been isolated which are tabulated in alphabetical order, showing the richness of Pakistan soils in fungal flora. Some information on distribution and damage caused is also given showing that at least 50 percent of losses from plant diseases are due to soil pathogens causing root rots, wilts and blights. A table containing information on common soil-borne pathogens affecting the specific economic hosts is given, highlighting the importance of plant pathogens attacking about 42 hosts. The main reason for their vulnerability is the genetic uniformity of crop cultivars, which lack resistance. In view of high cost of chemical control, development of resistant varieties and or biological control through antagonistic micro-organisms are the only possible approaches. The work carried out on the latter discipline has produced interesting results leading to the production in private sector of two cultures (Tricho-Pak - *Trichoderma harzianum* and Aspergo-Pak - *Aspergillus flavus*) for the possible control of root rots and wilts of crop such as cotton, tobacco, linseed, tomato, guar, maize, citrus and mango (for which treatments have been tabulated). Similarly, some interesting results are reported on the effect of antagonistic organisms with or without organic amendments and mulching on population of sclerotia of the causal fungi of cotton and rice root rots. These researches need to be continued and strengthened to develop practical methods suited to farm-application.

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Cultural Methods of Disease Control

Next to the use of resistant crop varieties, cultural methods of disease control are not only simple and practical for the bulk of the farmers but these also do not need any purchased inputs. At the same time these methods stand a chance of checking the diseases caused by seed-borne and soil-borne fungi, which otherwise are very difficult to control without the use of either resistant crop varieties or costly, poisonous and hazardous chemicals. The highlights of the work, carried out on cultural methods of disease control, are given below.

Smut Diseases

Work carried out on cultural methods of control has shown that the following factors are very important in influencing the disease incidence in smuts belonging to the seedling infection group. Thus by adopting certain cultural modifications it is possible to control these diseases to a great extent. Before discussing these factors it should be pointed out that in such smut diseases infection can only take place between germination and emergence period.

Soil Temperature

Investigations on the effect of soil temperature have been carried out both in the laboratory under controlled conditions and in the field. In the field different temperatures were obtained by changing the dates of sowing. For example, work done on flag smut of wheat shows that when wheat is sown in October at Lyallpur(Faisalabad) a fortnight earlier than the normal time of sowing, at the soil temperature 28°C, there is almost no infection in the crop, while the attack is 70-80 percent if the sowings are delayed upto 3rd week of November, when the temperature varies from 15° - 18°C. Similarly, as already mentioned in the text, in other smut diseases belonging to seedling infection group such as bunt of wheat, grain smut of sorghum and smut of sugarcane, the infection percentages have been found to be governed by the dates of sowing. For example, complete bunt of wheat normally does not occur in the plains due to sowings done by middle of November. However, if wheat is sown in late December infections upto 70-80 per cent can be obtained through artificial inoculation of seed. Thus it is seen that, by merely changing the date of sowing, crops can be saved from the attack by these diseases. The reason is, that like seeds of higher plants, the spores of pathogens have an optimum temperature for germination. Hence, the infection will be influenced by the high soil temperature at the time of sowing in the case of smut diseases belonging to the seedling infection group, because of the inability of the pathogen spores to germinate at high temperatures.

Soil Moisture

Soil moisture has also been found to play a very important role in the germination of spores and ultimately in the development of such diseases. The results of experiments carried out on flag smut of wheat show that the incidence of the disease is very much reduced when seed is sown in wet soil having 18-22 percent soil moisture as compared with a high incidence in soils with medium and low moisture contents. Consequently, the infection can be reduced when wheat is sown in dry soil to which water is applied immediately after sowing. The application of water, if delayed upto 24 hours after sowing, does not lose its effectiveness but with further delay there is a steady increase in the incidence of the disease, till the infection percentage becomes normal when water is applied 7 days after sowing. It may be noted that the initial increase in soil moisture creates unfavourable conditions for the germination of spores and by the time the conditions become normal for spore germination the seedlings have passed through the critical stage and are not liable to infection any longer. Similar results have been obtained in the case of bunt of wheat, covered smuts of barley and oats, grain smut of sorghum and sugarcane smut.

Depth of Sowing

As already mentioned, disease attack in seedling-infection group of smuts can only take place between the germination and emergence period. Subsequently there is a greater risk of infection if the period of pre-emergence is increased. Hence all the factors which delay germination will be conducive to higher infection. In this respect depth of sowing is one of the controlling factors, when it is increased the seedlings take longer to emerge and are exposed to infection for a greater period. On the other hand, in case of shallow-sown seed the infection will be reduced. This hypothesis has been proved by the results obtained from the experiments carried out on flag smut and bunt of wheat, covered smuts of barley and oats and grain smut of sorghum. It has been shown that the incidence of infection is reduced by decreasing the depth of sowing. It may be mentioned that seeding at greater depth is advocated for rainfed areas for obtaining stabilized yields. The deep sown seeds do not germinate till there is a heavy shower of rain. Such seedlings can easily stand a short period of drought if subsequent rains fail for some time, unlike shallow sown seeds in which seedlings dry out after emergence due to drought. This may result in total failure of the crop. Hence shallow seeding is not recommended for rainfed areas, particularly when there are chances of drought after sowing.

Method of Sowing

Different methods of sowing have been studied with a view finding out those promoting shallow seeding and the maintenance of high soil moisture contents during the germination period, To combine the beneficial affects of both factors. It has been found that the best results are obtained when seed is broadcast on the surface of the soil followed by raking and watering immediately. By adopting this method of sowing 70-90 percent reduction in the incidence of infection is obtained in the case of flag smut of wheat, covered smuts of barley oats, sugarcane smut and grain smut of sorghum (Table 22.2).

Table 22.1: Effect of moisture content of soil and methods of sowing on the incidence of certain smut diseases

Method of sowing	Percentage of smut infection				
	Barley smut	Oat smut	cane smut	Flag smut	Grain smut
Drilling in medium wet soil	4.4	82.4	33.8	54.4	16.4
Drilling in dry soil	0.6	60.9	7.0	14.0	5.3
Broadcasting in medium wet soil	2.5	44.2	-	11.5	5.3
Broadcasting in dry soil	-	22.3	-	7.0	2.9

On comparing these results with those obtained from seeds of crops treated with different chemicals it was found that, although seed-borne infection could be checked some what more effectively by chemicals, the cultural methods are much simpler for the farmers to use and do not cost a penny.

Diseases Other Than Smuts

Broadly speaking, diseases can be divided into different groups on the basis of their modes of perpetuation. They can be seed-borne (pathogens carried on the surface of seeds or inside the seeds), soil-borne (pathogens living in the soil or in diseased plant debris) or air-borne (pathogens carried through air or rain splashings). As stated earlier, like seeds of higher plants, spores of the various pathogens have optimum temperatures and humidity conditions for germination, development and spread besides their specificity for a particular host plant. All those operations, which check the sources of primary or secondary infections of various pathogens (together with provision of less conducive conditions for their development and spread) can go a long way to contain plant diseases. These practices may include change in time of sowing, variation in soil moisture contents, seed cleaning, solar energy treatment, destruction of diseased plant parts or debris lying on the surface of the soil, methods of sowing, application of irrigation water, drainage of water, judicious use of fertilizers, use of suitable rotations including non host plants and careful harvesting, threshing and storage. For example, change in time of sowing may exercise two types of effects i.e.; sowing at a time when soil temperature is not favourable for the germination of the pathogen spores and thus reducing the chances of primary infection or sowing at a time when the flowering period does not conicide with the rains (to check floral infection) or with the period when the atmospheric temperature is unsuitable for spore germination (to check secondary aerial infection). Similarly, other factors have an important bearing on the development of diseases and their spread in various ways. An attempt has been made (Table 22.2) to show the effect of various cultural practices on the containment of the diseases.

Table 22.2: Cultural operations which can decrease the incidence of various diseases

Cultural Operations	Diseases Influenced
Change in time of sowing	Downy mildews; powdery mildews; partial bunt of wheat; long smut of sorghum; bunt

	of rice; red leaf spot of sorghum; leaf spot diseases of various crops; anthracnose of cotton; root rot; boll rot; and root rots of various crops; gram blight; blights of various crops; wilts of various crops and seed rots
Change in soil moisture contents	Many soil-borne diseases, smuts and bunts
Destruction of diseased plant parts during growing period and diseased plant debris through burning and burying in soil	Many seed, aerial and soil-borne diseases
Seed cleaning	Many seed-borne diseases carrying infection on the surface of seeds or seeds containing galls
Solar energy	Seed-borne diseases containing infection inside the seed
Irrigation water regime and drainage	Premature opening of cotton bolls, many wilts and rice diseases.
Application of fertilizers	Premature opening of cotton bolls and deficiency diseases.
Rotations	Many soil-borne diseases and phanerogamic parasites
Proper harvesting, threshing and storage	Many seed-borne and storage diseases

Although the indications given in the table are based on the results of researches carried out on different diseases, much remains to be done on systematic studies of cultural methods of control to make them more simple and practical. As the majority of the diseases perpetuate through seed or soil-borne infections, sanitary measures can effectively control the foci of primary infection as well as source of secondary infection. It is rightly said that "prevention is better than cure". Researches should, therefore, be carried out to study the longevity of the seed-borne and soil-borne pathogens and to develop suitable cultural operations to get rid of such infections either during the seed-storage period or by seed cleaning or hot water or solar energy treatment. Burial or burning of the diseased plant debris and or the development of suitable rotations to reduce the diseases should also be studied. Packages of such methods, if developed, can greatly help in getting rid of costly and repeated fungicidal sprays, which in spite of known technology are not being regularly followed by the majority of the farmers because of their expensive and complicated nature

Summary

Next to the use of resistant crop varieties, cultural methods of disease control are not only simple and easily adoptable by the farmers but also do not need any purchased inputs. Some studies have been carried out on controlling smut diseases by cultural methods. It has been found that soil temperature. soil moisture and depth of sowing play very important role in the incidence of those smut diseases where infection takes place at the seedling stage. As far as soil temperature is concerned, it has been found that the infection is highest when sowing is done at such a time when the soil temperature is optimum for germination of pathogen spores. Suitable soil temperatures for obtaining disease-free plants differ with different crops. In the case of flag smut and bunt of wheat when the soil temperature is about 28ºC there is almost no infection, while the attack is 70-80 percent if sowings are delayed upto or beyond 3rd week of November. Hence by changing time of sowing these diseases can be controlled. Similarly, if the soil moisture during the germination period is increased beyond 18-22 percent, the pathogen spores do not germinate and there is no infection. On the other hand these conditions do not affect the seed germination while by the time the soil moisture becomes favourable for spore germination, the seedlings are not liable to infection. Experiments carried out on depth of seeding have shown that the incidence of disease increases at greater depths because of the increase in the pre-emergence period of seedlings. Hence at the shallower depths of sowing the incidence of the disease is very much reduced. After testing the different methods of sowing, it has been found that the best results are obtained when seed is broadcast on the surface of the soil and raked followed by immediate application of water in the field. By adopting this method of sowing 70-90 percent reduction in the incidence of infection is obtaind in the case of flag smut of

wheat, covered smuts of barley and oats and grain smut of sorghum.

Cultural methods can also help in controlling many diseases when they tend to restrict various sources of primary or secondary infections carried through seeds and diseased plant parts in the growing crops or diseased plant debris lying in the field. Such methods may include change in time of sowing and soil moisture contents, methods of sowing, seed cleaning, hot water or solar energy treatment, destruction of diseased plant parts or debris, changing irrigation water regime, drainage of water, use of rotations including non-host plants etc. Consequently, development of suitable cultural packages can greatly help in containing various crop diseases and can prove more economical and practical than the use of chemicals as seed or as soil disinfectants and for aerial spravs.

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Chapter XXIII

Beneficial Fungi

Not that all the fungi and bacteria are harmful, many of them are also beneficial to the mankind. These include fungi like *Penicillium* used for the preparation of world-known antibiotics; antagonistic fungi and bacteria capable of controlling soil pathogens and accelerating decomposition of organic matter, industrial fungi employed in manufacture of ferments, protein food, enzymes etc. and edible fungi like mushrooms. It will be appropriate to also include this group of fungi and bacteria in the purview of the book, by summarizing the researches so far carried out on some of them in Pakistan.

Mushrooms*

The fleshy fungi have been in use both as food and medicine by different civilizations since times immemorial. These fungi had attained the status of a regular crop in France and China by 17th and 19th centuries, respectively, spreading gradually to other countries with a global annual production of about one million tons at present. The edible fungi are rich in digestible proteins containing most of the indispensable amino acids (thiamin, niacin, riboflavin), vitamins B and E, ascorbic acid, biotin, enzymes like trypsin, fatty acids (resembling vegetable fats in composition) and minerals like copper, potassium, sodium and calcium. They are low in calories and are ideal food for diabetic and heart patients, besides possessing other medicinal qualities of lowering the blood cholesterol level, warding against cancer and invigorating hair growth.

*Material contributed by Mr. Sultan M. Khan, Asstt. Professor Plant Pathology, FAU.

Survey

Surveys carried out on mushroom flora in Pakistan from 1975 to date have shown the presence of 137 different species belonging to 32 genera, distributed in different ecological zones of the country (Table 23.1).

Table 23.1: Distribution of mushroom flora in Pakistan

Genus	*Species*	*Occurrence*	*Status**	*Culinary properties*
Agaricus	12	Plains and hilly tracts	Very common	Edible and delicious
Armillaria	1	Hilly tracts as tree parasites	Rare	Edible
Bolitus	3	Hilly tracts	Common	Edible & delicious
Canthrarellus	1	Hilly tracts	Very common	Edible but taste is not good
Clavaria	4	Hilly tracts and plains	Very common	Edible
Clitocybe	2	Hilly tracts	Rare	One species is poisonous
Coprinus	10	Forests and humid areas of plains and hilly tracts	Very common	Edible but some species can produce side effects
Flammulina	1	Hilly tracts	Common	Edible and delicious
Fomes	16	Hilly tracts	Very common	Inedible
Gonoderma	6	Hilly tracts and plains and trees	Very common	Inedible
Hydnum	5	Hilly tracts and plains	Common	Edible

Lepiota	1	Plains	Common	Edible and delicious
Lycoperdon	10	Hilly tracts and plains	Common	Edible and delicious
Marasmius	7	Plains	Common	Five species edible and two inedible
Morchella	4	Hilly tracts	Common in special locations	Edible, delicious and highly prized
Panaeolus	4	Plains and hilly tracts	Common	Inedible
Omphalina	1	Plains and forests	Rare	Edible but taste is not good
Penellus	1	Plains in forests	Rare	Not known
Paxina	3	Hilly tracts in forests	Common	Edible but needs careful cooking
Paxillus	1	Hilly tracts in forests	Common	Inedible
Pleuratus	5	Hilly tracts and plains in forests	Common	Edible
Phellinus	22	Plains and hilly tracts in forests	Common in hillis in plains	Inedible
Pholiota	2	Hilly tracts and plains in forests	Common in hilly areas	Edible and delicious
Phellorina	1	Plains	Common	Edible

Podaxis	1	Plains	Very common	Edible
Pycnoporus	1	Hilly tracts in forests	Common	Edible and delicious
Russula	2	Hilly tracts in forests	Rare	One edible and the other inedible
Sarcorcypha	2	Hilly tracts in forests	Rare	Poisonous when raw and edible, if cooked after boiling and discarding the water
Sarcodon	1	Hilly tracts in forests	Rare	Edible
Schizophyllum	2	Plains and hilly tracts in forests	Very common	Inedible
Suillus	2	Hilly tracts in forests	Rare	Edible but taste is not good
Volvariella	3	Plains	Common	Edible

Although the previous surveys on fungal flora in Pakistan have mentioned the names of some fleshy fungi, these are in no way complete and specific. Contrary to the belief, the number and all-the-year round distribution of mushrooms is quite remarkable, showing wider diversity and scope of their protected cultivation as a regular crop in various parts of the country. It is interesting to note the wide-scale and well distributed natural occurrence of mushrooms in March-April in Baluchistan and after monsoon rains in Bahawalpur, Muzaffargarh, Dera Ghazi Khan and Hyderabad areas. It suggests an adequate distribution of spawn and presence of favourable soil and climatic conditions in these areas, just waiting exploitation. Similarly, the wide distribution of *Morchella* (Morels) in hilly forests (amounting upto 20 tons of exportable dried materials) further adds to its scope of large-scale cultivation through systematized efforts.

* Found mostly after the rains in the plains and almost throughout the year in forests and humid places, usually on compost, decayed stumps of wood or in rich soils.

Growth and Nutritive Value

Five selected species (*Podaxis pistillaris, Pleurotus cretaceus, Pleurotus* species - I and II, *Agaricus bitrogis* and *Agaricus* species - I), have been intensively studied for their physiological and morphological characters with the following main results:-

1. Out of the two media (malt extract agar and potato dextrose agar*) the former has given higher mycelial growth rate with greater dry weight in all the species; *Pleurotus* spp. being the top most (strain - 103 giving colony diameter of 90 mm in 144 hours at 25°C).
2. The optimum growth temperatures vary with different species; being 35-40°C in case of *Podaxis* sp. and 25-30°C for *Pleurotus*, the highest growth-producing temperatures are 40° and 25°C, respectively; with colony diameters of 70 mm and 90mm after 12 days. The growth rates are considerably reduced with deviations in these temperatures. On this base, these species can be divided into thermophilic and mesophilic groups controlling their ecological occurrence at suitable periods of the year.
3. Comparison of laboratory and climatological data on temperature relationships at Lyallpur (Faisalabad, Fig. 23.1) shows that (a) the vertical lines of the large box delimit the regular fruiting season, while the horizontal lines delimit the range over which *Podaxis pistillaris* has been found to grow on agar in experiments, (b) the corresponding lines of the smaller box represent the period of maximum fruiting and the temperature range of optimum growth and (c) the period of fruiting is clearly mediated by the availability of higher soil moisture (65-70 percent) which coincides with the monsoon rains. These results are similar to those reported from California under the corresponding conditions.
4. All the species prefer pH 6.5 to 7.0 for optimal growth, which decreases with the change in the reaction of the medium. This character determines the natural occurrence of mushrooms under various habitats.
5. The rate and quantum of sporulation is accelerated in rich media like malt extract agar as compared with potato dextrose agar, suggesting high nutritional requirements of these fungi. The other factors controlling growth and sporulation are genetic, nutritional and environmental.
6. The nutritive values of the cultivated and wild species are quite high; proteins ranging between 16-33 per cent, fat contents 0.87-1.8 percent and crude fibre 10-14 percent (Table 23.2).

Table 23.2: Chemical analysis of various muchroom species in Pakistan.

Species	Crude protein	Ether ext.	Total ash	Crude fibre
1. *Phellorina inquinans*	31.48	1.55	26.85	13.48
2. *Pleurotus ostreatus* (cultivated)	16.43	0.94	31.22	14.10
3. *Pleurotus eryngii*	22.27	0.87	14.44	11.11
4. *Podaxis pistillaris*	21.06	1.71	24.13	12.23
5. *Agaricus rodmani*	33.93	1.81	22.23	10.02

Spawn Preparation

Based on the conclusions of the laboratory experiments, investigations have been conducted on spawn preparation by comparing the mycelial growth of the six cultivated strains (*Agaricus bisporus* - button, *Pleurotus* - oyster, *Volvariella volvacea* - Chinese or straw mushroom, *Lentinus edodes* - shiitake and *Auricularia* - Wood's ear) in one - litre conical flasks on varying types of grain and waste materials at their respective optimum temperatures.

The main results are

1. Invariably, the grains provided better medium as compared with waste materials for accelerated and higher mycelial production in all the strains excepting shiitake and Wood's ear (which prefer saw dust).
2. The flasks are filled with mycelial growth of different strains on their respective best media within 6-11 days, the fast, medium and slow growing strains are chinese; oyster; button; Wood's ear; and shiitake, respectively.
3. The spawns of thermophilic or tropical strains can be safely stored at 25°C while those of mesophilic or temperate group at 2-4°C.

On the whole the results achieved have been quite encouraging for exploiting the development of suitable mushroom cultivation methods.

Identification of High-Yielding Strains

Studies carried out on the identification of high-yielding strains of

Malt extract agar: Malt extract 20 g; peptone 1g; dextrose 20g; agar 20g and distilled water 1000 ml.

Potato dextrose agar: Potatoes starch 20g; glucose 20g; agar 20g and distilled water 1000 ml.

various cultivated species on the basis of rate of mycelial growth, quantum of mycelium produced, period of life cycle completion, keeping quality food value and yield potential have indicated the following as high-yielding strains (Table 23.3).

Table 23.3: High-yielding strains of mushroom in Pakistan

Strain	No.of strains tested	Productive strains*
1. Button (*Agaricus bisporus*)	6	No.459 and No.649
2. Oyster (*Pleurotus* spp.)	8	No.467 and No.3526
3. Chinese (*Volveriella volvacea*)		HK I and T I
4. Shiitake (*Lentinus edodes*)	2	Under study
5. Wood's Ear(*Auricularia* spp.)	2	Under study

Note:
Grains Waste: Sorghum, oat, gram, pearl millet and wheat. Wheat straw, gram straw, sugarcane
Material: bagasse, oat straw, water hyacinth, cotton waste, cotton boll locules, barley straw, banana leaves, kallar grass, corn leaves, rice straw, corn cobs, horse dung, sorghum heads, sunflower heads, canna leaves, maize hulls, synthetic compost.

Mushroom Cultivation

As a result of researches on protected cultivation, some methods have been standardized for various types of mushroom. These comprise preparation of spawns and bedding materials including pasteurization; spawning or seeding; spawn running; maintaining suitable temperatures, light intensities and humidities in mushroom houses; harvesting and after care. These methods have been briefly described below, for each group *separately (Fig. 23.2 & 23.3). Some important mushroom cultivars are shown in Figs. 23.4 and 23.5.*

1. *Oyster or Shell Mushroom*

For bedding the material consisting of either chopped paddy, wheat straw, corn cobs, cotton waste, saw dust or small pieces of soft wood, is thoroughly wetted and then pasteurized in water containing 0.01 percent solution of Kelthin at the rate of 1.c.c/l at 60°C for 15 minutes. Water is then drained off and the material is allowed to cool down to 25°C. Spawn at the rate of 7-10 percent and Diazinon at the rate of 1g/kg of the dry

*These strains are now being used for commercial production in Pakistan

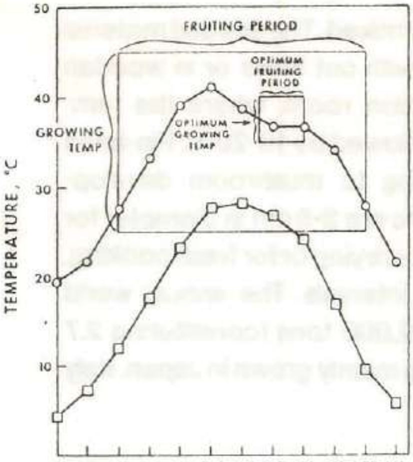
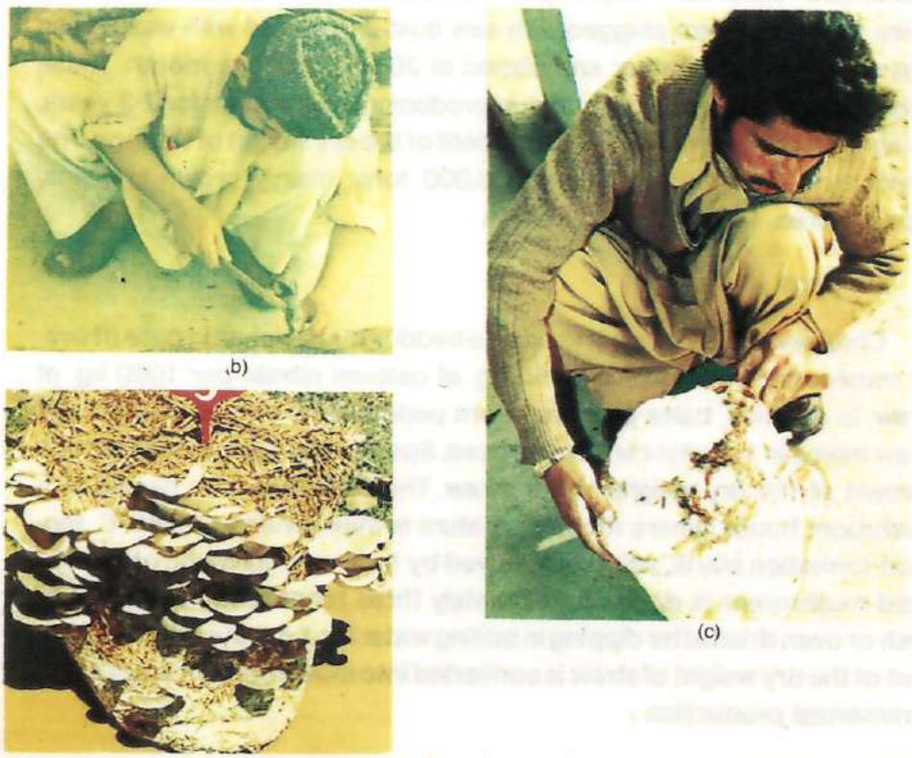


FIG. 23.1 Average maximum and minimum temperatures at Faisalabad (1). Note that fruiting occurred only in mo when the average maximum was greater than the minimum-growth temperature for mycelium. The optimum fruiting occurred during the monsoons.

(a)



(b)

(c)

(d)

Fig. 23.2: Methods of mushroom growing: (a) Spawn preparation in sterilized medium in glass bottles; (b) Spawn inoculated in a wooden log, (c) Running of spawn on a straw bed, (d) Fructification on a straw bed.

weight of the bedding material are thoroughly mixed. The seeded material is put at the rate of 2kg per polythene bag with cut holes or in wooden trays. These are then placed in an incubation room, where the temperature is maintained at 25°C for 3 weeks, followed by 10-20°C. Pin-head formation takes place in 3-4 weeks leading to mushroom development. Harvesting is done when the mushrooms are 3-5 cm in diameter for canning purposes or when they are 8-10 cm for drying or for fresh cooking. Four to six flushes are obtained at weekly intervals. The annual world production of oyster mushroom is around 32,000 tons (constituting 2.7 percent of total mushroom production); being mainly grown in Japan, Italy and Taiwan .

2. *Woods Ear or Jelly Mushroom*

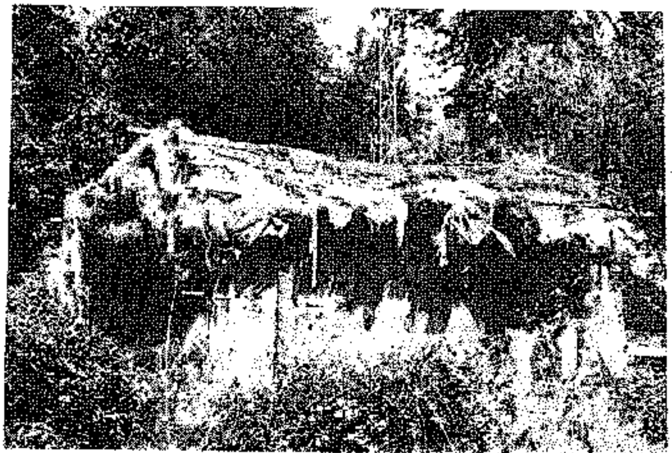
Meter long pieces of soft wood (6-15 cm in diameter with 2-5 cm drilled holes each 20 cm apart) are left in the open air for one week and then drenched in water for 7 days. Spawn, prepared in saw dust, is filled in the holes, which are then plugged with saw dust and sealed with wax. These logs are then put together and placed at 20-25°C for one month. These inoculated pieces of wood continue producing mushrooms for 2-3 years, giving yield approximating 25-30 percent of the dry weight of the logs. The world annual production is about 6,000 tons; mainly grown in China, Japan, Korea, Phillipines and Taiwan

3. *Ink-Caps Mushroom*

Chopped paddy straw is used as a bedding material, as in case of oyster mushroom with addition of 50 kg. of calcium nitrate per 1000 kg. of straw. In addition, bales prepared from paddy straw or waste paper and straw mixed in 1:1 ratio can also be used. Spawning is done at the rate of 5 percent of the dry weight of the straw. The bales are then placed in a mushroom house, where the temperature is maintained at 35-40°C. Pinhead formation starts, which is followed by fruiting. Harvesting of thumb-sized mushrooms is done approximately three times a day and used as fresh or oven dried after dipping in boiling water for 1 minute. About 60 per cent of the dry weight of straw is converted into mushrooms. It is not yet in commercial production .

4. *Button Mushroom*

The bedding material consists of semi-synthetic or fully synthetic compost, prepared according to the standardized formulae. Compost filled trays (15 cm depth) are placed in the mushroom house. For pasteurization, room temperature is raised to 48-52°C, followed by 52-55°C and



(a)

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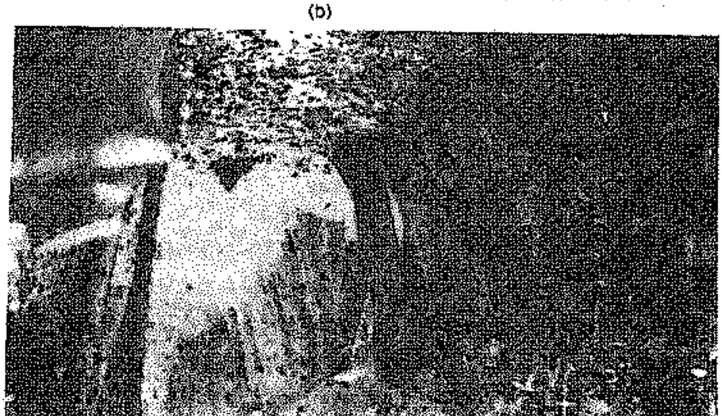


Fig. 23.3: Mushroom growing under different conditions: (a) In a thached house (outside view); (b) In a thached house(inside view) (c) Under shady trees (on wooden logs and on straw bed).

finally by 56-60°C, for 3 days in each step. Spawn, prepared on sorghum grains, is mixed at the rate of 300-400 g. per m² either in 2-3 cm deep holes each 15 cm apart or by using double layer method. About 1-1.5 inch thick layer of mixture of F.Y.M. and sand (4:1) disinfected with formalin is put on spawning trays. The room temperature is maintained at 25°C with 80 percent R.H. Trays are covered with paper or gunny bags and sprinkled with water twice a day. The temperature is then reduced to 16°C. Pinhead formation takes place in 8-10 days, followed by fruiting. The mushrooms are harvested when they are 3-5 cm and 8-10 cm in diameter for canning and fresh consumption, respectively. Drying is not possible. The yield is about 20 kg/m² obtained in 4-5 flushes. The annual world production is about 870,000 tons, constituting 71.9 percent of the total mushroom production.

5. *Shiitake or Forest Mushroom*

Host plants are oak, chestnut and some other hardwood trees. Wood logs (6-15 cm. diameter) are cut and left over in the open for 10-15 days to reduce the moisture to 40-50 percent. Spawn is grown on wedge-shaped or cylindrical pieces of wood or on saw dust. Holes of corresponding size are drilled in the logs, which are filled with spawn and waxed. The logs are placed in heaps under shade or covered with polythene or grass leaves and kept at 20-30°C. Water is sprinkled in dry weather and the logs are later on placed in a slanting position, when the fruiting starts. The logs can be placed indoor first at 25°C and later on at 16-20°C. In outdoor culture the pin-head formation takes place in 6-18 months with fruiting continuing for 5-7 years and giving yield upto 30 percent of the dry weight of the logs. Indoor culture produces fruiting bodies in 38 days. After each flush, logs are soaked in water and they produce subsequent flushes in 4-week intervals and the fruiting continues for 2-3 years. The annual world production is around 170,000 tons, which constitutes 14 percent of the total mushroom production.

6. *Chinese or Straw Mushroom*

The bedding material consists of two feet long bundles of paddy straw or fermented cotton waste. These are soaked in water and drained. Four bundles are placed on each 1 ft high and 3 ft wide soil berth during rainy season under the shade. Spawn, prepared on chopped paddy straw, is placed in 1.5 inch thick layers each 4-6 inches apart on the bundles alongwith a spoon full of gram meal. In all 6-8 layers of bundles, each seeded separately, are placed at 30-35°C. The first flush is harvested about 14 days after spawning, followed by 3-4 flushes, each after 5-10

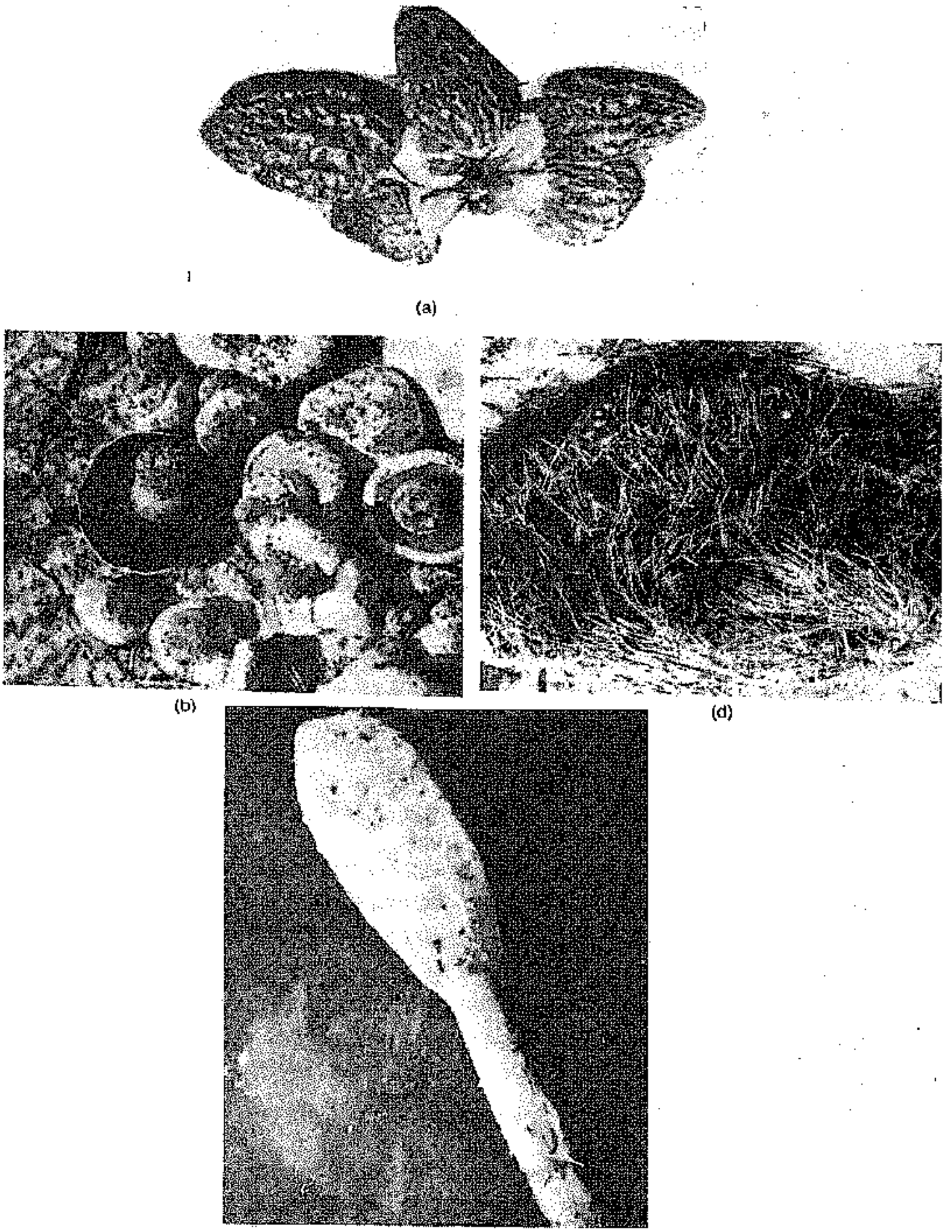


Fig. 23.4: Some common mushrooms of Pakistan: (a) Morchella or Morels, (b) Agaricus or French mushroom; (c) Podaxis or common mushroom, (d) Amanita or Death Cap mushroom.

days interval.

For indoor culture 2 ft long bundles of paddy straw are soaked in water, drained and mixed with 4 percent each of wheat bran and calcium carbonate. These are then placed under polythene sheet for 2 days which increases the temperature upto 50°C. Beds are prepared, each 3 ft long, 1-1.5 ft wide and 6 inches thick and spawning is done in the same way as mentioned above. The indoor temperature is maintained at 32-36°C. The fruiting and harvesting are almost similar to those of the outdoor culture.

Transfer of Technology

Encouraged by the overall results, a package of production technology has been developed and is being transferred to the interested persons by organizing short-term training courses including theory, practicals and cooking methods* as well as conducting semi-commercial demonstration trials at various places. In the meantime many semi-commercial farms have been established to develop mushroom eating habits and meet the local demands, especially of five-star hotels and restaurants. The present trend indicates private sector's greater interest in the indoor cultivation of oyster during winter, Chinese mushroom in summer both outdoor and indoor and Shiitake on wood in the hilly tracts. It is hoped that mushroom industry will make a steady progress and organized on scientific commercial lines for meeting local demands besides entering into export market in the near future.

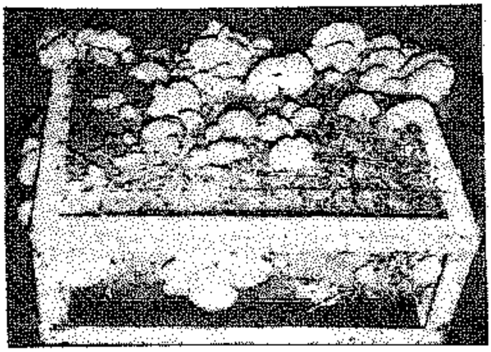
Antagonistic Fungi

This group includes those fungi, which limit the action of pathogenic micro-organisms and are used in controlling the disease caused by them. Although many fungi, actinomycetes and bacteria have been found to be antagonistic to the growth of certain parasitic soil fungi, very little farm-application of biological control of diseases has come to practice. However, the recent investigations are showing some signs of a breakthrough in the development of practical control measures. For details see chapter XXI.

Growth Stimulatory Microbes

The crop yields have been found to increase with the use of *Rhizobium* cultures as tested and reported by many scientists due to N fixation property of the bacterium, living a symbiotic life on the roots of

*A booklet containing more than 100 recipes is now available with the Coordinator, Mushroom Project at the University of Agriculture, Faisalabad. Some of the important recipes include cream mushroom soup, mushroom omelette, mushroom pickle, baked mushroom and chicken, mushroom pulao and mushroom beef stew.



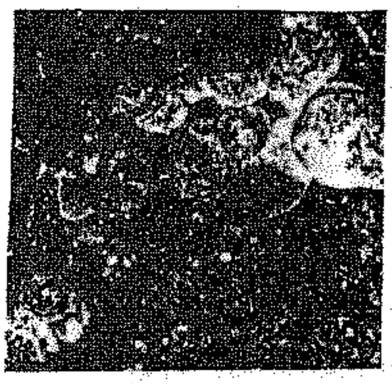
(a)

(b)

(c)

(d)

(e)



(f)

Fig. 23.5: Important mushroom cultivars: (a) Oyster growing on straw wood, (b) Wood's Ear growing on straw bed, (c) Ink-Cap growing on straw bed; (d) Button growing on compost bed, (e) Shiitake growing on wood log, (f) Chinese growing on cotton waste.

legumes. *Azotobacter chroococum* has been claimed to increase the yields of crops like corn, oats, wheat, barley, sugarbeet, potatoes, cabbage, tomatoes and carrots. Investigations carried out in Pakistan on antagonistic soil saprophytes, namely, *Arachniotus* sp. and *Streptomyces atra* have given interesting results by stimulating the crop growth and increasing the yield. The use of *Arachniotus* alongwith chaffed wheat straw (2 to 8 quintals/ha) unamended or amended with 1 to 4 percent N or NK during seed bed preparation has enhanced the yield of sugarcane by 27-38 percent, rice paddy by 20 percent, maize by 11 per cent, wheat by 24 to 42 per cent, summer vegetables by 50-94 per cent and berseem fodder by 32 to 35 percent (showing greater increases with amendments), while the percentages of increase in yields are comparatively much less in case of *Streptomyces atra*. *Archniotus* sp. has also shown some residual effects in increasing the yield of succeeding wheat crop. In many cases the use of chaffed wheat straw alone has increased or decreased the yield according to the natural presence or absence of the saprophytes in these specific areas. In the former cases these fungi, probably, accelerate the decomposition of the organic matter with beneficial effects both on the growth and the yield of the crops. However, these preliminary results need to be verified by carrying out extensive researches on identifying the real causes of yield increases. It is to be determined whether it is due to suppression of soil-borne pathogens or accelerated decomposition of organic matter or stimulation of crop growth by enzymic action or combined effect of these factors or due to some other reasons. These studies should be combined with the antagonistic activities for developing suitable farm-application methods to produce multiplying beneficial effects in both controlling the soil-borne diseases and stimulating the crop growth and the yields. This discipline is likely to produce highly productive results in the future, if systematic investigations are persued.

Entomogenous Fungi

The entomogenous fungi cause a number of diseases in insect pests of agricultural crops and medicinal plants. These fungi belong to all the four major groups i.e., *Phycomycetes* (*genus Entomophthora*), *Ascomycetes* (*Cordyceps*), *Basidiomycetes* (*Septobasidium*) and *Fungi imperfecti* (*Beauveria, Metarrhizium* and *Aspergillus*). Some fungi are restricted to a few species of insects while others have wider host range infecting as many as 200 insects species. The use of fungi for biological control of insects has been reviewed by Roberts and Yendol (1971).

A number of species have been successfully used for controlling insects pests. Baird (1956 and 1958) has listed 41 successful attempts against 28 species or groups of insects.

In addition to redistribution and introduction of fungi from one area to another in classical biological control, they can be used like pesticides. *Beauveria bassiana* and *Metarrhizium anisopliae* are good candidates for mosquito control. However, a lot of research is needed on mass production, virulance, genetics, etc. of entomogenous fungi before these can be used for pest control. In Pakistan a number of pathogenic fungi have been recorded from various insect pests (Table 23.4).

Table 23.4: Entomogenous fungi recorded from various insects in Pakistan.

Aspergillus flavus Link.	*Schistocerca gergria* Frash *Prays acmonias* Meyr. *Dioryctria abietella* (Schiff.) *Adria parvula* Dall, *Eysarcoris*) *inconspicuus* (H.S), *Dolycoris*) *indicus* Stall. *Pectinophora gossypiella* (Saunds.) *Eucosma pylonitis* Meyr.
Aspergillus fumigatus Fres.	*Adria parvula, Eysarcoris inconspicuus, Dolycoris indicus*
Aspergillus ochraceus Wilh.	*Gilpinia polytoma* (Htg.)
Aspergillus parasiticus Speare.	*Sylepta derogata* (Fab.)
Beauveria bassiana (Bals.)	*Gilpinia polytoma* *G. ghanii* Smith *G. indica* (Cameron) *Aeolesthes sarta* Sol. *Apriona cinerea* Chev. *Indarbela quadrinotata* Wlk.
Paecilomyces farinosus (Dicks ex.Fr.)	*Gilpinia indica*
Scopluriopsis sp.	*Adria parvula, Eysarcoris incospicuus, Dolvcoris indicus*

The studies carried out on *Aspergillus flavus* Link. have shown isolation of the fungus from a large number of locust individuals, causing as high as 60-70 percent death rate under cloudy humid conditions. Pathogenicity tests carried out in the laboratory have given 100 percent mortality in six days under 65 percent humidity and above, while feeding of fungus spores in bran has not produced any disease. Detailed studies are needed on entomogenous fungi to make their use more effective and practical in controlling the major insect pests of some important crops, which will also help in reducing the use of agrochemicals.

Mycorrhiza

Specific non-pathogenic soil fungi, forming a distinct morphological structure called mycorrhiza, are found invading roots of many forest trees and they live a symbiotic life to mutual benefit. There are three types of mycorrhiza: Ectrophic; Endrophic; and Ectendrophic, classified on the basis of mode of penetration and living, which depends upon nutritional factors like excess of carbohydrates in tree roots and presence of exuded metabolities (sugars, amino acids, vitamins and some unknown factors). The ectomycorrhiza - forming fungi belong to *Hymenomycetes*, *Gasteromycetes* and *Ascomycetes* which occur in soil in the form of spores, free living mycelium or hyphal strands and can be identified from the type of sporophores produced by them. The endomycorrhiza - forming fungi belong mostly to *Phycomycetes* while ectendomycorrhiza fungi are designated as E.strains and are non sporing. There is little evidence of host specificity as majority of plants have been found to possess a wide spectrum of fungi with which mycorrhiza is formed. The mycorrhiza increase absorbing capacity of roots and translocate many nutrients especially phosphorus from the soil besides protecting the tree roots from the attack of certain diseases either through physical barrier or production of antibiotics.

Mycorrhiza plays an important role in the successful establishment of nurseries of the conifers, which put up poor performance in arable sites (where agricultural crops have been grown previously) with high soil pH. Mycorrhiza can be introduced through soil inoculum as mycelial strands, short roots, fruiting bodies, spores or pure cultures or by mixing 10-25 cm top layer of soils from old conifer plantations. The inoculum is used in preparation of 10-20 parts of such soils mixed with 80 to 90 parts of local soil and raking it thoroughly before transplanting seedlings or such inoculated soils can be used in pots or in polythene tubes. Interplanting of mother seedlings from natural stand containing mycorrhiza can also help its spread to the other seedlings (this is successfully used in raising of *Pinus merkusii*, where other methods have failed). Thus introduction of mycorrhiza has beneficial effects on raising and management of conifers and should become a common practice in new afforestations. Researches carried out in Pakistan have proved the importance of using mycorrhiza in raising successful nurseries of conifers. The other studies carried out at the Botany Department, University of the Punjab, Lahore on the occurrence of VA mycorrhiza in association with damping off caused by *Rhizoctonia solani* in *Brassica napus* and influence of soil moisture contents have shown (a) higher VA mycorrhiza and *R. solani* infections in younger seedlings and (b) higher VA mycorrhiza infection at 18 per cent soil moisture level with progressively decreasing incidence at 22, 26 and 38 per cent unlike the *R. solani* infections, which were greater at higher levels of soil moisture contents. The other work relates to effect of VA mycorrhizal association on growth of rice, sunflower, cereals and weeds in wheat crop as well as on occurrence of endogone mycorrhizal spores in Pakistan soils and on soil factors influencing its population.

The main results are (1) VA mycorrhizal infection takes place quicker and earlier in seedling stage than in late inoculations. For example, sunflower seedlings can become mycorrhizal in 2-leaf stage; (2) early mycorrhizal infection produces better impact on the growth and yield of plants, particularly in P-deficient soils; (3) greater growth of mycorrhizal plant is due to higher uptake of P from the soil; (4) in case of rice, flooding of field creates unfavourable conditions for the development of VA infection due to poor soil aeration and high moisture contents. This effect is reduced during drier period resulting into improved supply of P. Hence intermittent irrigations which improve soil aeration, can produce better results than continuous flooding; (5) examination of fern roots and their rhizosphere from Murree hills, Kaghan and Siran valley shown constant mycorrhizal association throughout the year comprising mixture of several endophytes and ectomycorrhizal fungi; the former predominating and comprising VA and septate mycelium endophytes; and (6) four species of endogonaceous genus *Sclerocystis*, namely *S. sinuosa*, *S. clavispora*, *S. microcarpus* and *S. pakistanica* have been found and described.

According to surveys carried out in Pakistan, Bangladesh and India 19 ectotrophic mycorrhizal fungi have been recorded in various host plants (Table 23.5).

Table 23.5: List of recorded ectotrophic mycorrhizal fungi

Fungus	Host
Agaricus trisulphuratus	*Shorea robusta* (Sal)
Amanita hemibapha	*Pinus elliotii*
Amanita verna	*Shorea robusta*
Astraeus hygrometricus	*Pinus roxburghii* (Chir), *Pinus patula*,
Boletus species	Sal
Cantharellus cibarius	Chir
Cenococcum graniforme	Chir, Kail, Chilghoza pines; spruce(*Picea Smithiana*), Fir (*Abies pindrow*). Deodar (*Cedrus deodara*).

Geastrum fimbriatum	Kail (*Pinus wallichiana*), Deodar, *Picea abies, Pinus sylvestris.*
Lactarius scrobiculatus	Spruce and Fir
Mycelium radicis-atrovirens	Chir. Slash pine, Chilghoza pine and Monterey pine.
Pulveroboletus shoreae	Sal
Rhizopogon flavum	Slash pine
Russula delica	Sal
Scleroderma bovista	Monterey pine, Sal
S. cepa	Eucalyptus
S. geaster	Slash pine, Chir
S. verrucosum	Eucalyptus
Exerocomus bakshii	Chir
Pisolithus tinctorius	Pinus sp. Eucalyptus sp., Quercus sp., *Populus tremuloides* and Salix (Marx 1977).

Note: Five endomycorrhizal fungi have been recorded on six host plants while 15 additional hosts have been found to contain either arbuscular or vesicular infections

The researches on mycorrhiza, although scanty, are quite encouraging and need to be streamlined and strengthened with the establishment of special research unit at the University of the Punjab, where some necessary facilities exist.

However, it is worth mentioning that increasingly greater emphasis is being laid on mycorrhizal studies in advanced countries with a view to making its practical use in enhancing crop productivity through (1) improved utilization of applied fertilizers, particularly some rock phosphates, (2) improved nodulation and N fixation of grain and legumes and better establishment of forage legumes in pastures, (3) re-establishment of infection after soil sterilization, particularly in tree nurseries, (4) erosion control and rehabilitation of degraded soils and (5) control of plant pathogens, especially soil-borne. Such studies can also be taken up at the proposed research centre in Pakistan.

Summary

The chapter includes the researches carried out on beneficial fungi and bacteria with a view to highlighting their importance and possible use in the service of the farmers.

In case of mushrooms, after giving their economic and nutritional importance, the work carried out on survey (showing presence of 137 different species belonging to 32 genera and their frequent all-the-year round distribution), physiology, morphology and chemical analysis of the selected strains and on identification of high-yielding species has been described. It also covers methods of cultivation of mushrooms belonging to six different groups (Oyster, Wood's ear, Ink-caps, Button, Shiitake and Chinese) including preparation of bedding material; pasteurization; spawning or seeding, spawn running; maintaining suitable temperatures, light intensities and humidities; harvesting and utilization as well as transfer of technology for semi-commercial or commercial production.

A brief mention of antagonistic fungi has been made with reference of the detailed work embodied in Chapter XXI.

The studies carried out on growth stimulatory microbes have given very encouraging results in stimulating the growth and yields of many crops when used alone or mixed with soil amendments. The important antagonists are *Arachniotus* and *Streptomyces* which hold a good chance both in controlling the soil-borne fungi and stimulating the growth and yield by accelerating decomposition of organic matter. Such studies need strengthening to develop suitable farm-application methods.

The work carried out on entomogenous fungi has been reviewed showing a good scope of its application, if investigations are strengthened and streamlined on sound footings. Seven entomogenous fungi recorded on a number of hosts in Pakistan have been tabulated along with the highlights of the work carried out on *Aspergillus flavus* in efficient killing of locust.

A brief account of mycorrhizal fungi including their nature, distribution, inoculation methods and salient features of research findings based on the work done in Pakistan have been given, highlighting their importance, necessitating more concerted studies for enhancing crop and forest productivity.

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Research Guidelines

In the area, now constituting Pakistan, plant pathological researches have been underway over the last seven decades at the Punjab Agricultural College and Research Institute, Lyallpur (Faisalabad); first in its Botanical Section (from 1907), later on in Mycological Section (1928) and subsequently in Plant Pathology Section (1947). In the meantime research programmes were also initiated at the other provincial agricultural research institutes in Quetta, Tando Jam and Tarnab as well as at some of the universities. As a result, some outstanding research findings have greatly helped in controlling certain plant diseases and enhancing the total crop productivity.

Agricultural Research System

However,there are many constraints,which have been & are holding back the real impact of plant pathology in the fields of education, research and extension. The main constraints are (a) its full potential and status are not recognized; (b) there is a shortage of trained manpower including research leadership and research management; (c) laboratories are poorly equipped and under-staffed, and there is an absence of adequate scientific literature; (d) under-utilization of qualified scientists at the universities; (e) mono-disciplined and ill-planned research programmes not based on priorities and the development needs of the country; (f) inadequate working cooperation at institutional and inter-institutional levels; (g) poor communication and understanding between planners, administrators and research leaders and lack of competent central coordination and direction; (h) lack of proper implementation of programmes as well as presentation and evaluation of results and extension of research findings; (i) lack of a system for forecasting the diseases and the application of suitable and timely control measures; and (j) allocation of meagre research funds. Many of these constraints are common to the whole agricultural research system, which needs overall reorganization at national and provincial levels for strengthening the agricultural base as no region or country can modernize itself and develop its resources unless it begins with agriculture, more so in basically agricultural countries.

The real potential of plant pathology, in improving agricultural productivity, and quality and in saving huge pre and post-harvest losses, should be fully realized by the Government and the scientists to establish a well-knit research and extension infrastructure at federal, provincial and university levels. It should be based on the following principles:

a) A strong national centre or centres for basic or background research;
b) Regional centres (one in each ecological zone) for adaptive research, concentrating on the major crops and farming systems; and
c) Development work at extension centres to test and formulate recommendations to suit farm-application.

Although basic or fundamental research is essential, a stronger emphasis should be placed on adaptive, protective and applied research with postponement of the basic research units until highly trained personnel and technical facilities are available. However, basic research should be initiated in those disciplines, which have competent research leadership (including at the universities). Copying the type of researches being carried out in developed countries should be avoided because of the differences in the nature of the problems. It is proposed that plant pathological work be split into various units according to the similarities in modes of perpetuation and methods of control of various groups of diseases, irrespective of the crops. The Specialized Research Units or Centres of Excellence should be well-equipped, staffed, managed and financed and distributed within the country at suitable places. They should have research leaders of high calibre as well as good laboratory facilities. They should be financed by the Federal Government to serve the national interest. Subjects to be studied at these centres would include diseases caused by seed-borne, soil-borne, foliar and air-borne pathogens and those caused by bacteria, virus, nematodes, phanerogamic plants, weeds and by nutrient deficiency. They would also undertake the screening of crop varieties against major diseases, agrochemical testing, survey and forecasting and systematic mycology and other discipline. The work of these centres should be coordinated to provide better use of research funds, scientists and facilities. The time is fully ripe for joint cooperative efforts in the greater types of research work to be carried out at the federal, provincial and university level, keeping in view the three basic research components mentioned earlier. Fundamental research will be carried out at the above mentioned centres, irrespective of location and jurisdiction. Adaptive researches and development work will be done at the provincial research institutes and the extension centres.

Research Priorities

Research programmes should be based on priorities consistent with national agricultural policy. They should be realistic and oriented towards the needs of the country as well as the capabilities and resources of the farmers. The programmes should be well-formulated and must involve all the concerned disciplines and available resources and have built-in evaluation reviews. The research should be carried out on a team basis with the scientists consulting together to improve and implement research activities. The programmes should not be of omnibus types but problem-oriented and suitably supported with appropriate number of scientists, research facilities and operational budget. The following priorities are suggested in the descending order of importance.

1. Disease Resistant Crop Varieties

Emphasis should be laid on the development of practical type of control measures which have easier farm-application. Amongst them, the development of high-yielding and disease resistant varieties, which is the most economical and durable solution, should receive first priority. This approach can greatly help to increase and stabilize agricultural productivity as well as avert epidemics, if seeds of resistant varieties are made available to the farmers on a timely basis. Many success stories can be quoted of such productive programmes where both the plant pathologists and breeders have closely cooperated. As a good example the wheat improvement programmes from Pakistan can be cited. This has helped to increase per unit area production by containing the rust diseases. Such an approach, if followed for other crops and diseases, will be of significant value. Its achievement will need the combined efforts of the pathologists and the breeders necessitating the establishment of breeding centres on special crops, vegetables and fruits and the sharing of genetic pool and segregating materials for identification of varieties suited to different ecological conditions.

2. Cultural Methods of Disease Control

The second priority should be given to cultural methods of control of diseases, particularly those which are seed-borne and soil-borne. Earlier researches have clearly shown that changes in methods, time and depth of seeding, soil moisture variations and rotations can greatly help in reducing the incidence. As such methods are free from purchased inputs and can be easily adopted by the majority of the farmers, particularly small land holders, more research is needed to develop cheap technology which will also help avoiding soil and air pollution from the use of chemicals.

3. Distruction of Diseased Plant Debris

Since many diseases are carried through attached infected plant parts or debris lying on the surface of soil, it will be useful to develop such cultural methods, which can help to kill the pathogens before the new life cycles start or the succeeding crops are planted. Such methods may include pruning,collecting & burning of the diseased plant debris,or burying the debris in the soil, mulching, application of antagonistic organisms alone or with amendments or by rotations including non host plants.Research should also include studies on the effects of change in irrigation regime, application of fertilizers and lime as well as of methods of harvesting, threshing and storage. "Prevention is better than Cure" can be well practised through the use of cultural methods of control.

4. Seed Treatment

There are a number of seed-borne diseases, which can be effectively controlled through seed cleaning, chemical seed dressing, hot water treatment, solar energy treatment or treatment with systemic fungicides. For the control of such diseases compulsory seed treatment should be introduced at the seed distribution sources, while research should be intensified to develop cheaper, safer and more effective seed treatments.

5. Control of Foliar Diseases

Special efforts should be made to develop control measures for foliar and air-borne diseases, through the cheap and effective agro-chemicals used as sprays or dusts. Bordeaux mixture, Bordeaux paste, copper compounds, sulphur and lime sulphur are still the most common, safe and effective and much cheaper chemicals than the new fungicides. More research should be concentrated on the use of these chemicals and on new ones based on indigenous resources to develop safe, economical and effective means of controlling air-borne diseases. Researches are also needed on the development of cheap and more efficient spraying and dusting equipments for use by farmers.

6. Pre and Post Harvest Losses

These losses, which rob the farmers of their hard earned and valuable productivity, constitute a major blow to their economy. Such losses, may be physical, mechanical or pathogenic in nature, involving insect pests, diseases and vertebrates. They may occur during harvesting, threshing, transportation, storage, marketing and utilization. Special investigations need to be carried out on the causes of damage and the control of pathogenic and non pathogenic losses to develop a package of practical preventive measures.

7. Use of Beneficial Organisms

Beneficial fungi and bacteria (mushrooms, mycorrhyza and antagonistic pathogens) constitute an important group and also need concerted studies to make best use of them as food and for the control of diseases.

8. Integrated Control Measures

As the crops are simultaneously infected by insect pests, diseases and weeds, it will be advisable to develop integrated control measures against them. This approach will be more economical and practical, requiring all disciplines to work together. Instead of carrying out many sprays separately with different chemicals for controlling insect pests, diseases and weeds, it would be much economical to develoo simple, cheaper and effective system of controlled and combined spraying along with non chemical methods. To achieve this goal a special type of research work is needed embracing the combined efforts of different disciplines (Pathology, Entomology, Agronomy, Weed Science and Economics). Present day isolated studies are far from being satisfactory.

9. Disease Monitoring and Forecasting

The monitoring of farmers' fields is a necessary background research to develop accurate estimates of the prevalence of major and minor diseases and new diseases or races. It also allows the collection of disease specimens for herbarium and the preparation of live cultures, to improve and strengthen research and extension programmes. It is useful, too, to gain time in the development of new resistant varieties through broadening the resistance base and for developing a methodology for crop production estimates and marketing strategies. For this purpose survey and forecasting service should be established with well-planned all the year round programmes.

The research infrastructure should be supported by development of scientific trained manpower, advisory service, extension literature, demonstrations and large-scale campaigns to ensure increased crop productivity so essential for the economic development of the country.

Although the good research work cannot be strictly channelled, the above ideas will help in streamlining the plant pathological activities. Even one year's failure of an important crop can jolt the economic base, retarding the progress and prosperity of the country. Such catastrophies must be avoided by strengthening agricultural education, research and extension.

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