RESEARCHES
ON
PLANT DISEASES
OF
THE PUNJAB

SCIENTIFIC MONOGRAPH No. 1.

By

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AND

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FOREWORD

It gives me a great pleasure to introduce to the scientific world the first monograph of the Pakistan Association for the Advancement of Science. The monograph embodies research work carried out on diseases of field crops, vegetables and fruit plants during two decades at the Punjab Agricultural College and Research Institute, Lyallpur. It is hoped that the monograph will not only fulfil the long-felt desire of the research workers in Plant Pathology but will also stimulate further researches in this important field.

I am very glad to add that the authors are highly qualified persons and possess sound knowledge of the subject. The field work has been carried out with the understanding of the limitations of our farmers and they have, therefore, particularly tried to evolve simple methods of controlling common diseases of crop plants. There is no doubt that much still remains to be done in this field; but what has been achieved justifies the confidence in the future.

BASHIR AHMAD
General Secretary,
Pakistan Association for the Advancement of Science.

University Institute of Chemistry,
Lahore.
March 15, 1952.
PREFACE

The foundation of research on Plant Pathology was laid in the un­divided India in 1904 by the late Sir Edwin J. Butler and his book “Fungi and Disease in Plants” published for the first time in 1918 remains a landmark of pioneering work on diseases of crop plants and their control. The Department of Agriculture, Punjab established the Section of Plant Pathology in 1928 and the senior author has been working in this Section from its very inception. The junior author joined the Section in 1938.

A great deal of work on the diseases of field and garden crops and their control has been done at Lyallpur and it was felt that all this work should be presented in the form of a monograph so that it may be available in a handy form for research workers, teachers and students of Plant Pathology. This monograph of work done in Pakistan should serve as a companion volume to Butler’s monumental work on plant diseases in India.

The most important diseases of crop plants have been dealt with in great detail and measures of control have been suggested. Work on other aspects is still proceeding and it is hoped that, in course of time, a revised and enlarged edition of the monograph will be brought out. We have to thank Research Assistants who took part in the prosecution of the studies and whose hard labour made the compilation of the present volume possible. Thanks are also due to our colleagues in the Department of Agriculture, Punjab, who co-operated with us in carrying out certain field experiments.

We are also grateful to various Directors of Agriculture, Punjab—Mr. D. Milne, Sir H. R. Stewart and Malik Sultan Ali Noon during whose regime the work embodied in monograph was carried out, for providing facilities. Their acknowledgments are also due to Dr. Khan Abdul Rahman, the present Director of Agriculture, Punjab, for encouragement.

The authors will fail in their duty if they do not express their special gratitude to Mr. Mohammad Afzal, Director of Cotton Research, Pakistan, for going through the manuscript critically and giving some valuable suggestions.

LYALLPUR (Pakistan),
October, 1950.

ABDUS SATTAR
ABDUL HAFIZ.
ERRATA

Page 7, line 3 .. For galvanized read galvanized.
line 27 .. For earning read earing.
Page 10, line 49 .. For U. scitaminea read U. scitaminea.
Page 20, line 15 .. For 10-80 per cent read 10-40 per cent.
Page 24, fig. 14 .. For varietal resistance read varietal resistance.
Page 25, line 18 .. For Urocystis triticci read Urocystis tritici.
Page 31, line 16 .. For November read November.
Page 36, line 20 .. For one read ones.
Page 49, line 15 .. For rainfall is 2 read rainfall is 2 inches.
Page 50, fig. 41 .. For effect on read effect of.
Page 58, line 6 .. For progenies read progenies.
Page 71, fig. 48 .. For diagramatic read diagrammatic.
Page 76, line 23 .. For rouging read rouging.
Page 80, line 12 .. For fungis read fungus.
Page 81, figs. 51 & 52 .. For fig. 52 read fig. 51 and for fig. 51 read fig. 52.
Page 86, line 17 .. For Rhizoctonia solani Kuhn read Rhizoctonia solani Kuhn.
Page 88, line 6 .. For ammonical read ammoniacal.
Page 91, line 19 .. For 35° to 37° C respectively read 35°C and 37°C respectively.
Page 92, line 15 .. For heriditable read hereditable.
Page 103, line 28 .. For temperatures read temperatures.
Page 112, fig. 62 .. For diagramatic read diagrammatic.
Page 127, fig. 6 .. For fig. 6 read fig. 61.
Page 128, line 2 .. For ochraeous read ochraceous.
Page 141, lines 24 & 25 .. For on an the culture media read on all the culture media.
Page 154, line 15 .. For root brak read root bark.
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INTRODUCTION

The agricultural production of a country depends upon various factors which may have direct or indirect bearing on it. One of the outstanding factors which reduces the agricultural production considerably is the existence of diseases and insect pests of field crops, vegetables and fruit plants. The number of diseases is a fairly large one in our country. There are certain diseases in which the nature of injury is such that an infected plant does not yield any produce at all, while there are others in which case there is a partial reduction either in quantity or in quality of produce with the ultimate result that they also contribute in a large measure to the reduction of the output of the country.

The total amount of damage caused by various diseases in our country has not been calculated so far; but an estimation made of the damage caused to some of the major crops like wheat, gram, jowar, and cotton shows that our Province is sustaining an annual loss of Rs. 90 million. From this it may be deduced that the total amount of loss which our farmers are suffering annually may easily run into many crores of rupees. Hence any effort put forth in the reduction of this big loss will no doubt help in improving substantially the condition of our farmers.

The main object of the Plant Pathological Section was to find out suitable measures for controlling diseases in order to minimize the loss sustained by our Province. While carrying out this work, efforts have constantly been made, as will be seen from the text, to discover such simple methods of controlling the diseases which may be capable of easy adoption by our illiterate farmers, who unlike those of the foreign countries cannot handle various chemicals with safety. In this connection it may be pointed out that the discoveries of “Solar Energy Method” against loose-smut of wheat, “Simple Cultural Methods” for controlling smut diseases and “Evolution of Gram Types Resistant to Blight” are some of the many outstanding achievements of the Section. It will also be noted that so far attention has been mainly directed towards those diseases only which were holding a greater threat to the successful cultivation of our corps. With the establishment of Pakistan the research staff is being strengthened and it will, therefore, now be possible to continue research on these diseases in greater detail and to start investigations on other diseases as well.
CHAPTER I

DISEASES OF WHEAT (Triticum sp)

Wheat occupies a position of paramount importance amongst world's crop plants both in respect of extent of area and magnitude of food production. Normally the annual area put under wheat in the world averages 400 million acres which yield about 153 million tons of grain. Western Pakistan is one of the top ranking wheat growing countries of the world and grows annually 9.6 million acres of wheat, from which the annual production amounts to 3.4 million tons of grain. Within Western Pakistan the pride of place goes to the Punjab which is known as the granary of Pakistan on account of its extensive canal colonies. The annual production in the Punjab is about 2.8 million tons of grain from 7.1 million acres.

The prime importance of wheat in the Punjab is evident from the fact that it is a staple article of diet in the Province as it constitutes one half of the bill of fare of every Punjabi and in addition to it wheat supplies bhusa (chaffed wheat straw) which is extensively used as feed for cattle and invariably figures in the daily ration of every farm animal.

In this province wheat is attacked by many fungal diseases which bring about heavy losses in the form of reduced yields and low quality of the produce. A brief account of the work which has been carried out on most of these diseases in the Plant Pathology Laboratory, Lyallpur, is given in the text. The work on rusts of wheat, carried out by Dr. Mehta and applicable to the Punjab, has also been included.

1. LOOSE SMUT, Ustilago tritici (Pers.) Rostr. (6 and 7)

Loose smut of wheat, which is characterised by the appearance of black sooty ears containing spores of the causal fungus instead of normal wheat grains, occurs commonly in the Punjab (Fig. 1). It causes on an average 2½% damage, but in some parts the damage caused by it is as high as 10-20 per cent. Normally it brings about a loss of 13 million rupees annually.

The disease is perpetuated from year to year through sowing seed containing hibernating mycelium inside although such grains look normal from outside.

*Those numbers relate to references given in the end of the chapter,
Fig. 1 WHEAT SMUT.

1. Smutted ear-early stage.
2. Smutted ear-later stage.
4–5. Germination of spores × 500.
7. A single flower (much magnified).

For the control of this disease hot water treatment of the infected grains is recommended in foreign countries. This method is complicated and difficult for our farmers to adopt. A series of experiments have been carried out with a view to evolving some simple methods of treating the seed and the results are summarized below:–

It has been found out that if seed wheat pre-soaked in water at room temperature (65-75°F) for 4 hours is immersed in hot water at 120°F for 2 minutes and then for ten minutes at either 129°F, 130°F or 132°F, the disease is eliminated without adversely affecting the germinating capacity of the grains (Table I).
Table I. Effect of different treatments on the germination capacity of the seed and on the control of smut.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Treatment</th>
<th>1927-28</th>
<th>1928-29</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Date of treatment</td>
<td>Average percentage of germination</td>
</tr>
<tr>
<td>1.</td>
<td>145°F for 5 minutes</td>
<td>20th Nov. 1927</td>
<td>...</td>
</tr>
<tr>
<td>2.</td>
<td>136°F, 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>135°F, 5</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>4.</td>
<td>135°F, 2</td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>5.</td>
<td>132°F, 10</td>
<td></td>
<td>94</td>
</tr>
<tr>
<td>6.</td>
<td>130°F, 10</td>
<td></td>
<td>98</td>
</tr>
<tr>
<td>7.</td>
<td>129°F, 10</td>
<td></td>
<td>95</td>
</tr>
<tr>
<td>8.</td>
<td>127°F, 10</td>
<td></td>
<td>97</td>
</tr>
<tr>
<td>9.</td>
<td>Untreated</td>
<td></td>
<td>99</td>
</tr>
</tbody>
</table>

The disease is also eliminated if presoaked wheat grains are first immersed in hot water at 120°F for five minutes and then for seven minutes in second tub containing hot water, the temperature of which varies between 127-132°F (Table II).
Table II. Effect of time of hot water immersion on the germination capacity of the seed and on the control of smut.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Time of immersion in hot water (127°—132°F.)</th>
<th>Date of treatment</th>
<th>1928-29</th>
<th>1929-30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date of treatment</td>
<td>Average percentage of germination</td>
<td>Average percentage of smut</td>
<td>Date of treatment</td>
</tr>
<tr>
<td>1</td>
<td>2 minutes</td>
<td>11th Nov., 1928</td>
<td>98</td>
<td>4.7</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td></td>
<td>98</td>
<td>2.9</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td></td>
<td>97</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td></td>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td></td>
<td>96</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td></td>
<td>94</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Untreated</td>
<td></td>
<td>98</td>
<td>6.4</td>
</tr>
</tbody>
</table>

It has also been found out that presoaking of seed wheat up to seven hours' duration does not affect its germinating capacity (Table III).

Table III. Effect of period of presoaking on germination capacity of seed and control of smut.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Date of treatment</th>
<th>Time of soaking</th>
<th>Average percentage of germination</th>
<th>Average percentage of smut</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>12th Nov., 1928</td>
<td>1 hour</td>
<td>98</td>
<td>3.3</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>2 hours</td>
<td>95</td>
<td>1.7</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>3 hours</td>
<td>98</td>
<td>0.6</td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>4 hours</td>
<td>97</td>
<td>0</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>5 hours</td>
<td>95</td>
<td>0</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>6 hours</td>
<td>94</td>
<td>0</td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>7 hours</td>
<td>93</td>
<td>0</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>8 hours</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>Untreated</td>
<td>98</td>
<td>6.0</td>
</tr>
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</table>
On the basis of the results given above a simple method of hot water treatment was evolved. This method with the equipment required to carry it out is described below.

Description of the simplified method of 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 38 inches, 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 presoaking of wheat.

(iv) Two sheets of coarse cotton cloth measuring about 7′x5′.

(v) One stirrer preferably a small vessel.

(vi) One Fahrenheit thermometer.

(vii) One or more sheets of cloth of suitable size on which wheat 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 the heaters (*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.

Two and a half maunds 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 85°F. But 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 70° and 60°F. 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 is taken out and divided into nearly five equal lots.

Then about 10 gallons of ordinary water are put in each of the two tubs, and hot water from the heater (*Hamam*) is run into them until the level of water is brought up to the 25 gallons’ mark and the thermometer shows 132°F. 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 118°-122°F. Wheat is taken out, and immersed for 7 minutes in tub No. 2 where the initial temperature of water is also 132°F. The grains are stirred and the tempera-
ture falls to about 130°F and if it goes down further it should be kept at 127°F or above but not beyond 132°F during the required immersion time of 7 minutes by adding hot water but if the temperature does not fall below 127°F no hot water need be added (Fig. 2).

Fig. 2. Demonstration of hot water treatment.

Wheat is taken out, and spread out in the shade on a cloth sheet to dry. The other 4 lots of wheat are treated in the same way successively. By this method 10 maunds* of seed wheat can be conveniently treated in a day of 8 hours with one set of equipment.

The treated seed wheat after drying can be sown immediately or if desired, can be stored for 2 months but thorough drying is essential previous to storing to protect the seed from mould fungi.

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

Single-bath sun-heated water method.

Similar further experiments carried out have shown that soaking of seed wheat at 105, 110 and 115°F for 8, 6 and 4 hours respectively is sufficient to get rid of the disease (Fig. 3).

*One maund = 32 lbs.
Fig. 3. The efficiency of single bath sun-heated-water-method in controlling loose smut of wheat.

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

A galvanized iron vessel (13 inches high and 18 inches 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 wheat is added at 12 noon when the temperature of water rises to 95-108°F. At 2 p.m. the temperature further rises by 8 to 12°F and at 4 p.m. it often reaches 115-120°F when seed wheat is 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 method which has been given the name of “Solar Energy Method.” In this case seed wheat is soaked in water for four hours (8 a.m. to 12 noon) on any bright sunny day; then seed is taken out and exposed to the sun in a thin layer till it dries thoroughly.

It has been found that in localities where maximum temperature under shade goes above 100°F, 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.

Experiments on the incidence of the disease have shown that if no action is taken to control the disease, it will go on increasing every year in some localities, in others it will go on decreasing while in still others it will remain constant. This peculiar behaviour of the disease regarding such fluctuations is due to the difference in humidities present at the time of earning at different places.
2. FLAG SMUT, *Urocystis tritici* Koern. (2-5, 13-19)

**Occurrence.**

In the unpartitioned Punjab flag smut was first noticed in 1906 at Lyallpur by Butler. It is now widely prevalent in Gurdaspur, Ferozepur, Hoshiarpur, parts of Ludhiana, Ambala and Kangra districts of India. The incidence of the disease on an average comes to 5 per cent but its attack up to 60-70% has been observed in individual fields. In the Pak Punjab the disease causes about 1% damage of the wheat crop sown in the districts of Campbellpur, Sialkot, Gujrat and Jhelum.

**Symptoms, time of appearance and progress of the disease.**

The disease appears on the leaf blades in the form of black swollen lines running parallel to the veins. These lines when rupture expose a black powder consisting of multitudes of spores. The affected leaves assume a drooping form, which is followed by withering (Fig. 4).

---

Fig. 4. Wheat plants affected with flag smut.
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 per cent. Eighty-five to ninety per cent of infected plants fail to produce ears and where the ears are produced, the grains which are seldom formed, are shrivelled.

The earliest recorded lesions have been observed on plants 40 days old, 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 (Fig. 5).

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**Methods of soil infection and conduction of pot experiments.**

**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 large quantities of smutted material were needed to infect the soil on a large scale.

The following simple method has been evolved after a good deal of experimentation for obtaining the maximum amount of infection with the minimum amount of spores.
The spores are kept buried in a small sub-plot at a depth of 2 to 4 inches from the time the wheat crop is harvested to the time of sowing of wheat in the next season. The plot thus infected is kept watered throughout this period after a regular interval of 7 days. At the time of sowing the top layer of the soil up to 4 inches is worked out into a fine stage and used in infecting the required plot by putting this fine earth over the seed wheat in a thin layer so as to cover it and which in turn is covered by a layer of 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 few months before carrying out the actual sowing as it enhances their germination.

Conduction of pot experiments.

Similarly a great difficulty was also experienced in producing artificial infection in pots in the case of flag smut of wheat and other smuts belonging to seedling infection group, while on the other hand it was easy to reproduce this disease in the field under similar conditions. After carrying out experiments it has been found out that the incidence of the disease varies in direct proportion to the depth of sowing due to the fact that seeds sown at greater depths take longer period for their seedlings to come out of 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 big-sized earthen pots in order to accommodate large quantities of soil for enabling 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 three inches 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 come out of the soil level, otherwise, high soil moisture content will reduce the incidence of the disease. The technique described above has been found to be very suitable and efficient not only in the case of carrying out of artificial infection experiments on flag smut of wheat but also in other smuts like covered smuts of barley and oats (Ustilago hordei (Pers.) Lagerh and Ustilago kolleri Wille), loose smut of oats (Ustilago avenae (Pers.) Jens.), grain smut of sorghum (Sphacelotheca sorghi (Link.) Clint. and sugar-cane smut (U. scitiminea Syd.) 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 sealed by another watch glass by applying 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 much higher when small bits of infected leaves are sown as compared to that when spores alone in a powdered form are sown.

The minimum, optimum and maximum temperatures for the germination of the spores are below 15, 22-24 and between 27 and 30°C respectively. (Tables IV and V.)

Table IV. Comparison of sowing bits of infected leaves and spores of *Urocystis tritici* in powdered form.

<table>
<thead>
<tr>
<th>Type of spores</th>
<th>1st replication</th>
<th>2nd replication</th>
<th>3rd replication</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bits of infected leaves</td>
<td>45.0</td>
<td>57.0</td>
<td>49.0</td>
<td>50.3</td>
</tr>
<tr>
<td>Spores in the powdered form</td>
<td>12.0</td>
<td>18.0</td>
<td>22.0</td>
<td>17.3</td>
</tr>
</tbody>
</table>

Table V. Effect of temperature on germination of spores of *Urocystis tritici*.

<table>
<thead>
<tr>
<th>Temperature in °C.</th>
<th>1st replication</th>
<th>2nd replication</th>
<th>3rd replication</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-7</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>10-12</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>15-17</td>
<td>12.0</td>
<td>10.0</td>
<td>15.0</td>
<td>12.3</td>
</tr>
<tr>
<td>20-22</td>
<td>28.0</td>
<td>25.0</td>
<td>22.0</td>
<td>25.0</td>
</tr>
<tr>
<td>22-24</td>
<td>56.0</td>
<td>52.0</td>
<td>58.0</td>
<td>55.5</td>
</tr>
<tr>
<td>25-27</td>
<td>8.0</td>
<td>6.0</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>30-32</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>35-37</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>
Modes of perpetuation and their relative importance.

(a) 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 gets 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 hay. (Table VI.)

(b) Soil borne infection is more important than seed borne infection under natural conditions. (Table VI).
Table VI. Modes of perpetuation and relative importance of seed and soil borne infections.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall in previous summer (inches)</th>
<th>Rainfall in growing period (inches)</th>
<th>Mean soil temperature at 5 cm depth</th>
<th>Line number</th>
<th>Infected seed sown in healthy soil</th>
<th></th>
<th></th>
<th>Healthy seed sown in infected soil</th>
<th>Infected seed sown in infected soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total plants</td>
<td>Infected plants</td>
<td>Percentage infection</td>
<td>Total plants</td>
<td>Infected plants</td>
</tr>
<tr>
<td>1939-40</td>
<td>5.7</td>
<td></td>
<td>18.7°C</td>
<td>1</td>
<td>68</td>
<td>27</td>
<td>39.7</td>
<td>62</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>105</td>
<td>49</td>
<td>46.7</td>
<td>48</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>76</td>
<td>39</td>
<td>51.3</td>
<td>72</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>249</td>
<td>115</td>
<td>46.2</td>
<td>182</td>
<td>69</td>
</tr>
<tr>
<td>1940-41</td>
<td>9.8</td>
<td></td>
<td>16.7°C</td>
<td>1</td>
<td>92</td>
<td>32</td>
<td>34.7</td>
<td>96</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>87</td>
<td>29</td>
<td>33.3</td>
<td>72</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>62</td>
<td>18</td>
<td>29.0</td>
<td>52</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>241</td>
<td>79</td>
<td>32.7</td>
<td>224</td>
<td>116</td>
</tr>
<tr>
<td>1941-42</td>
<td>13.1</td>
<td></td>
<td>17.5°C</td>
<td>1</td>
<td>110</td>
<td>36</td>
<td>32.7</td>
<td>118</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>98</td>
<td>31</td>
<td>31.5</td>
<td>86</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>96</td>
<td>40</td>
<td>41.7</td>
<td>56</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>304</td>
<td>107</td>
<td>25.2</td>
<td>260</td>
<td>142</td>
</tr>
</tbody>
</table>
Viability and longevity of spores.

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

Table VII. Results of experiments on the viability of spores of *Urocystis tritici* under natural field conditions at Lyallpur.

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plot A</td>
</tr>
<tr>
<td>1938-39 (original infection)</td>
<td>27.0</td>
</tr>
<tr>
<td>1940-41</td>
<td>44.6</td>
</tr>
<tr>
<td>1941-42</td>
<td>57.1</td>
</tr>
<tr>
<td>1942-43</td>
<td>62.3</td>
</tr>
</tbody>
</table>

The spores can retain their infective capacity in compost manure prepared from diseased wheat straw.

They can also remain alive 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 below 10°C, 15.5°C to 24.8°C and 29°C respectively. (Fig. 6).
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. 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. (Fig. 7).
Fig. 7. The effect of date of sowing on infection (1943-44).

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 18.0 to 21.7 per cent. (Fig. 8).

The incidence of the disease is 2 to 3 times more if infected seed is sown in healthy or infected Vattar* soil as compared to that where sowings are done in dry soil to which water is applied immediately after sowing.

*Point ideal for sowing (Soil moisture content varying from 8.5—11.5 p.c.)
Relation to depth of sowing.

The percentage of the disease increases with the depth of sowing. From 1/2 to 3 inches the increase is much more than from three to five inches. The deeper the seed is sown the more is the time taken by the seedlings to come above ground and therefore they are liable to infection for a longer period with the result that the percentage of the disease increases. (Fig. 10).
the most important factors responsible for the distribution of the disease which is prevalent mostly in the districts where the summer rainfall is above 17 inches. (Fig. 11 A). 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 highly 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 (dusting at the rate of two ounces per 15 seers of wheat grains) 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 10-80 per cent of soil borne infection. Efficiency of these disinfectants is indirectly proportional to the infective capacity of the spores in a particular year. (Table VIII).

Seed treatment with copper sulphate or formalin reduces germination of the seed and consequently the yield. Higher seed-rate should, therefore, be used to get good yield. The use of copper carbonate is, therefore, recommended where soil-borne infection is out of question.
Table VIII. Effect of different seed treatments on the incidence of disease.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Healthy soil</th>
<th>Infected soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage Infection</td>
<td>Percentage Infection</td>
</tr>
<tr>
<td></td>
<td>(average of three</td>
<td>(average of three</td>
</tr>
<tr>
<td></td>
<td>replications)</td>
<td>replications)</td>
</tr>
<tr>
<td>Healthy seed not disinfected</td>
<td>0.03</td>
<td>16.6</td>
</tr>
<tr>
<td>Healthy seed disinfected</td>
<td>0</td>
<td>14.6</td>
</tr>
<tr>
<td>Disinfected seed coated with spores</td>
<td>18.7</td>
<td>41.4</td>
</tr>
<tr>
<td>Dusted with copper carbonate:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ounces 10 seers*</td>
<td>3.0</td>
<td>24.5</td>
</tr>
<tr>
<td>2 &quot;    15 &quot;</td>
<td>3.2</td>
<td>24.6</td>
</tr>
<tr>
<td>2 &quot;    20 &quot;</td>
<td>4.4</td>
<td>27.4</td>
</tr>
<tr>
<td>2 &quot;    30 &quot;</td>
<td>5.2</td>
<td>29.9</td>
</tr>
<tr>
<td>Dusted with copper sulphate:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ounces 10 seers</td>
<td>4.4</td>
<td>26.2</td>
</tr>
<tr>
<td>2 &quot;    15 &quot;</td>
<td>4.3</td>
<td>26.0</td>
</tr>
<tr>
<td>2 &quot;    10 &quot;</td>
<td>7.3</td>
<td>29.9</td>
</tr>
<tr>
<td>2 &quot;    30 &quot;</td>
<td>8.3</td>
<td>31.8</td>
</tr>
<tr>
<td>Dusted with sulphur:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ounces 10 seers</td>
<td>9.4</td>
<td>34.6</td>
</tr>
<tr>
<td>2 &quot;    15 &quot;</td>
<td>9.1</td>
<td>35.4</td>
</tr>
<tr>
<td>2 &quot;    20 &quot;</td>
<td>10.7</td>
<td>38.0</td>
</tr>
<tr>
<td>2 &quot;    20 &quot;</td>
<td>11.4</td>
<td>39.2</td>
</tr>
<tr>
<td>Dusted with abavit B:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ounces 10 seers</td>
<td>8.7</td>
<td>31.7</td>
</tr>
<tr>
<td>2 &quot;    15 &quot;</td>
<td>8.7</td>
<td>31.8</td>
</tr>
<tr>
<td>2 &quot;    20 &quot;</td>
<td>10.1</td>
<td>34.7</td>
</tr>
<tr>
<td>2 &quot;    30 &quot;</td>
<td>10.3</td>
<td>36.4</td>
</tr>
<tr>
<td>Treated with formalin</td>
<td>3.9</td>
<td>24.8</td>
</tr>
<tr>
<td>Treated with hot water</td>
<td>9.8</td>
<td>38.8</td>
</tr>
<tr>
<td>Treated with 2% copper sulphate</td>
<td>10.0</td>
<td>34.6</td>
</tr>
</tbody>
</table>

* 1 seer = 2 lbs.
Ceresan has been found to check 70-90% of the seed borne as well as soil borne infection. Seed treatment with ceresan at the rate of 2 ounces per 15 seers of wheat grains, is therefore, recommended in infected localities.

Rotations.
Leaving the field fallow for at least two seasons considerably reduces the incidence of the disease provided such fields are not surrounded by those containing infected crops in them.

The incidence of the disease is lowered by about 25 per cent if wheat is sown in land green-manured with gawara (Cyamopsis psoraliodies).

Roguing.
The disease can be reduced considerably by roguing out the diseased plants as soon as they appear during the growing period. This practice is, however, not practicable on a large scale.

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.

To obtain a crop almost free from the disease it is advised to sow

![Figure 12: Five years average soil temperature during October and November.](image-url)
it at such a time when the soil temperature is above 27°C. This time varies from locality to locality, being 2nd fortnight of October at Lyallpur and 1st fortnight in central and sub-mountainous districts. (Fig. 12). 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 incidence of the disease is reduced by about 50 to 75 per cent when seed wheat is broadcast in Vattar soil and by 75-94 per cent when broadcasting is carried out in dry soil to which water is applied immediately afterwards as compared with that sown by drill or kera in vattar soil (Fig. 13).

In Vattar 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 seed wheat is not reduced, it is presumed that the yield will also not be lowered down.

**Combined effect of methods of sowing and seed disinfectants.**

The efficiency of copper carbonate and ceresan for reducing the incidence of the disease is still increased when the infected seed treated
with these chemicals is sown in dry soil and water is applied immediately afterwards.

Ceresan has shown its superiority over all other seed disinfectants so much so that under Lyallpur conditions the incidence of the disease is almost negligible when infected seed treated with ceresan is sown, even at 5 inches depth in highly contaminated dry soil to which water is applied immediately after sowing.

When infected seed wheat treated with either copper carbonate or ceresan is sown in a Vattar field to which water is applied within three days of sowing, the reduction in the amount of incidence of the disease is almost to the same extent as if such infected seed, without dusting, is sown in dry soil and watered immediately afterwards.

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 *Urocystis tritici* in highly infected soil.

It has been found out that the percentage of infected tillers is directly correlated with the susceptibility of a certain variety, i.e., the more susceptible a variety is, the greater the number of infected tillers would be and consequently the yield of the grains is reduced in the same proportion. The incidence of the disease should, therefore, be recorded on the basis of 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. (Fig. 14).

As durum wheats (types 1, 2 and 3) require special conditions for their cultivation they cannot be recommended everywhere in the province. Since out of the resistant types, I.P. 80-5 has been found to compare fairly well in out-turn of grain with the improved types of the Department of Agriculture, Punjab, this can, therefore, be safely recommended for cultivation in the infected localities.

**Physiological specialization in Urocystis tritici Koern.**

Flag smut of wheat (*Urocystis tritici*) is known to occur in almost all the wheat growing countries of the world. As regards its up-to-date 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 *Urocystis tritici* from different countries. Such an attempt has been made with eleven collections from different countries like United States of America, Australia, China, Italy, Cyprus and Indo-Pakistan sub-continent. The following main conclusions are drawn from the results of the work so far carried out.

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 they 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 point remained undecided on account of the fact that the differentials got from China gave very poor germination.

3. SEPTORIA LEAF SPOT, *Septoria* sp. (8 and 9).

Septoria is a common disease of wheat as it occurs almost throughout the province. A comparative study of the species of septoria causing leaf spot in the Punjab (*Septoria* local), *Septoria tritici* Desm. and *Septoria nodorum* Berk. has been made as regards morphology and physiology. Modes of perpetuation and measures to control the disease have also been studied.
Symptoms.

*Septoria* local attacks leaf and leaf sheath producing more or less circular or oval irregular spots on which black pycnidia develop. Stems and awns are rarely attacked and no definite spots are formed on them but only pycnidia develop. *Septoria tritici* produces the same symptoms as *septoria* local with the difference that it has not been reported on stems and awns. (Fig. 15).

Artificial inoculation experiments at Lyallpur have, however, shown that it can also attack the stem, *Septoria nodorum* is characterised by producing small, irregular chocolate brown spots which are studded with black pycnidia and are found on upper half of the glumes.

The pycnidia of *Septoria local* and *Septoria tritici* Desm. have approximately the same size (150 x 100 μ) and both are bigger than those of *S. nodorum* (109 x 92μ)

The pycnosores of *Septoria local* and *Septoria tritici* are approximately equal in size (55 x 2.6 μ) and of *S. nodorum* are 21 x 3.6 μ.

The pycnosores of *Septoria local* are from 1 to 4 septate with highest frequency of 3 septate spores. Those of *S. tritici* are 2 to 5 septate with highest frequency of 3-4 septate spores and those of *S. nodorum* are 1 to 3 septate with highest frequency of 3 septate spores.

*S. nodorum* grows 3 to 4 times faster than *Septoria local* and *S. tritici*. (Fig. 16).

The maximum temperature of all the fungi is 25 to 30°C; the minimum lies below 5°C and the optimum is about 20°C.
Fig. 15. *Septoria* leaf spot of wheat.

a. Wheat leaf affected with local species of *Septoria*.
b. Wheat leaf sheath affected with local species of *Septoria*.
c. Wheat stem affected with local species of *Septoria*.
The optimum pH for growth of *Septoria* local and *S. tritici* is between 4.6 and 6.0. On the alkaline side the growth is retarded at 9.0 and on the acid side the growth stops at 3.0. *S. nodorum* grows well at a very wide range of pH, its growth being equal between pH 3.0 and 8.3.

*S. tritici* and *S. nodorum* form only one kind of spores which are in pycnidia. *Septoria* local forms conidia also in addition to pycnospores.

In artificial culture media *Septoria* local forms imperfect and very loose pycnidia.

*S. nodorum* forms pycnidia on oat meal agar and potato dextrose agar, while on the other media *tested* it does not form pycnidia. *S. tritici* forms pycnidia on wheat leaf decoction and onion leaf decoction also, in addition to the above media while *Septoria* local forms pycnidia on all the media under test.

The optimum temperature for the germination of pycnospores is about 20°C, the maximum being 25 and 30°C and the minimum is below 5°C.

Pycnospores can germinate on a wide range of pH. The optimum pH for germination of spores of *Septoria* local and *S. tritici* is 6.0-6.8 and for *S. nodorum* about 6.8.

All the three fungi are virulent parasites on wheat. The incubation period of all the three is about 14 to 16 days.

Inoculations carried out on barley and winter (rabi) weeds have not brought about any infection.

Regarding the taxonomy of the fungi under study it has been concluded that *Septoria tritici* Desm. and *S. nodorum* Berk. are different from each other and are confirmed to be good species.

The species of *Septoria* causing the disease of wheat in the Punjab (*Septoria* local) is identical with *Septoria tritici* Desm.

**Modes of perpetuation and spread.**

The pycnospores of the fungus, while held in the pycnidia borne on diseased wheat straw used as enclosures in making *bhusa* stacks remain viable throughout summer. The pycnospores of the fungus from such straw cause the disease on the next wheat crop.

The fungus also remains viable in *bhusa* made from diseased straw and also in the diseased leaves which may remain lying on the surface of the soil during summer. The pycnospores of the fungus from such diseased tissue can initiate infection in the subsequent wheat crop.

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 provides 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 & 3 are almost immune while compactum and vulgare types are susceptible to the disease.


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 rain-fed (barani) areas than in the irrigated tracts of the province.

Symptoms.

The attack of the disease has been found to start soon after the emergence of the plants 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 fungus. In some cases the disease may also 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 (ears without grains) which result in low yield. (Fig. 17).

Cause of the Disease.

(a) The disease has been found to be caused by the fungus *Helminthosporium sativum*.

(b) The fungus causing foot rot and the one producing leaf spot are identical.

(c) It has also been proved that the *Helminthosporium* species obtained from black pointed grains can also cause foot rot, if such diseased grains are sown in the field.

Modes of carry over.

(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 the causal fungus, which gives rise to the infected crop next year.
Factors affecting 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. Similarly in the field it has been discovered that sowings done after the 3rd week of November at Lyallpur are practically free from the attack of the disease. (Fig. 18).
Fig. 18. Mortality of plants due to foot rot (1944-1945).

Soil moisture above 16% reduces the infection both in pots under controlled conditions 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. (Fig. 19).

Plant mortality is reduced by 40-60% in case the first irrigation is applied 15 days after sowing against the control where irrigation is applied 35 days after sowing. (Fig. 19 A).

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

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.

**Control measures.**

The following suggestions are made for the control of the disease:

* Dusting the seed. Dust the seed with one ounce of either powdered copper sulphate or ceresan per fifteen seers of wheat 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 tried is resistant to the disease except Punjab Types 4, 7 and 9 in which case percentage of infection varies from 2.1 to 2.7 as compared to more than 10-20 per cent in other varieties.

Bunt is one of the very important diseases of wheat. It mostly occurs in the hilly tracts of Murree, North Western Frontier Province and Quetta. 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. At Kulu (Bharat) under severe conditions of soil infection the diseased ears have shown pronounced elongation which vary from 1 to 1½ feet as compared with 4 to 5 inches in the case of healthy ears. Moreover awns of the diseased ears get very much reduced in size. (Fig. 20 and Fig. 21).

![Fig. 20](image1.png)  ![Fig. 21](image2.png)

**Fig. 20.** a. Healthy ear.  
b. Bunted ear.

**Fig. 21.** a. Healthy ear.  
b. Bunted ear.

This disease which has so far been 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,
Similarly from the restricted occurrence of the disease in the hilly tracts it was considered that the disease essentially belonged to that tract. 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.

The date of sowing, on account of soil temperature has got direct influence on the intensity of the disease. The incidence of the disease varies between zero, 1-30 and 30-74% when wheat is sown from 15th of October to 1st of November, 15th November to 1st of December and 2nd fortnight of December to end of December respectively. (Fig. 22).

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% respectively.
The incidence of the disease increases with the depth of sowing. Hence the percentage of attack is more where wheat is sown by "keri" as compared to sowing by broadcasting.

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 other seed disinfectants like copper carbonate and powdered copper sulphate.

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

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

Table IX. Varietal resistance to bunt of wheat.

<table>
<thead>
<tr>
<th>Degree of infection</th>
<th>Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 -- 5 %</td>
<td>C, 245, C. 247, C. 248, C. 217, C. 296, C. 269, C. 275</td>
</tr>
<tr>
<td>21 -- 40 %</td>
<td>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</td>
</tr>
<tr>
<td>41 -- 70 %</td>
<td>T. 24, T. 217, C. 228, C. 230, C. 518, I.P. 101</td>
</tr>
<tr>
<td>More than 70 %</td>
<td>C. 215, I.P. 165</td>
</tr>
</tbody>
</table>

Thirty five collections obtained from various places in the subcontinent of Indo-Pakistan have been tried against 26 differentials—11 having been obtained from the United States of America with a view to determining the total number of physiological races. The work is still in progress to confirm the findings of the last two years.

Work is also in progress to find out the resistant wheat types and suitable methods to control soil borne infection.

*Seed dropped after the plough.
6. NEW BUNT OR PARTIAL BUNT, Neovossia indica (Mitra) Mundkur (21).

New Bunt of wheat was first recorded by Mitra in the year 1933. On examination of 10 years' old samples of wheat grains at Lyallpur a few diseased grains were found showing thereby that the infection was present in the Punjab since long. The disease attracted the attention only when its incidence increased due to the cultivation of new improved types particularly I.P. 52 which happened to be very susceptible to the disease.

Symptoms.

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 more 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 grain which also falls to the ground with the slightest disturbance. It has been seen that only individual grains are attacked and they are also partially affected. Generally the grooves or tips of the grains are affected. (Fig. 23). In the diseased portion spores like those of bunt of wheat are produced. The size of these spores is, however, almost double of that of bunt spores.

![Fig. 23. A. Bunted grain having infected tip](image)

B. Bunted grain with infected groove.

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, produce sporidia, which being lighter than air are carried by wind and fall on developing individual grains where they grow and cause infection of such grains in the same season.
Experiments carried out to test seedling infection by seed borne and soil borne spores have so far given negative results.

**Effect of environmental factors on the development of the disease.**

It has been found that weather conditions prevailing at the time of ear and grain formation exercise a profound effect on the incidence of the disease. In the absence of adequate rainfall at the time of ear emergence i.e., February and March the disease does not appear, whereas in years with high rainfall at 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. The incidence of attack depends upon the period in which the rain falls. In case this happens at the time of ear and grain formation, then infection will result; otherwise the crop will remain healthy. Further it has been seen that the incidence of the disease is always higher in the crops which have lodged than in the ones which are normal. This is due to the reason that the humidity in the former case remains higher for a longer period than in the latter one and this high humidity facilitates infection.

7. **EAR COCKLE, Tylenchus tritici (S) Bast.**

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 well irrigated areas. 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 longer period and are shorter than the normal ones. The grains are black, round, hard and short-sized. They are called galls which on breaking reveal the presence of large number of eel-worms when seen under the microscope. (Figs. 24, 25 and 26).

It has been found that ear-cockle of wheat can be controlled by sowing the seed free from galls. The seed can be cleaned by winnowing and sieving or by immersing the seed in water in which case the galls float on the surface and can be skimmed off very easily. No detailed studies could be carried out on other aspects of the disease.

Detailed studies are now being carried out by the Mycologist, N.W.F.P. under the guidance of the senior author.
Fig. 24. Ear cockle of wheat showing different types of diseased heads.
Fig. 25. Healthy wheat grains and diseased wheat grains (galls).

Fig. 26. Contents (eelwoorms and eggs) of infected wheat grains, as seen under the microscope.

Rusts of wheat and barley (Figs. 27, 28 and 29) cause a considerable loss in the Punjab. Under favourable conditions one or the other of the three rusts, specially the black and the yellow rusts, cause 10—20 per cent damage, but on an average the loss can be taken as 2%. Our present knowledge of the rusts of wheat and barley in the sub-continent of Indo-Pakistan is entirely due to the research work carried out by Mehta under a rust scheme sponsored by the Government of undivided India. Some of the salient features of the results obtained are given below.-

**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 in case these spores, after some period of rest, are frozen for about one week in ice and then kept at about 40°F.

The failure to infect barbery plants in the beginning has been found to be due to the fact that barbery plants found in the Himalayas had been wrongly named as *Barberis vulgaris* because later on it was possible to infect barbery plants raised from the seeds obtained from England.

Uredospores of black stem rust stored at 41°F and under conditions of 50% relative humidity, have remained viable for about one year.

**Alternate host plants.**

*Barberis lysium, Barberis aristata* and *Barberis coviarie* are the three alternate host plants of *Puccinia graminis*—but these host plants have been found to play very little role in the annual outbreak of black rust in the plains because the aecidia on their leaves are formed 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 an alternate host plant for brown rust does not also play any important role. No alternate host plants have been found for yellow rust.

**Annual out-break.**

In the plains, the summer heat that follows the harvest, kills all the uredospores of these 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 4000-8000 feet. (Yellow rust from 7000-8000 feet, brown rust 6000-7000 feet and black rust 4000-5000 feet).

Wheat crops in the hills get 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 have 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 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 brown rust occupies an intermediate position. As a consequence of temperature prevailing during the growing season in the Punjab the yellow and brown 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 barbery plants is of very little importance in the out-break of rusts in Pakistan and therefore the number of physiological races is also very small as compared to that found in foreign countries due to less frequent chances of hybridization. There are 9 races of black rust, 8 of brown and 10 of yellow rusts so far discovered in the sub-continent of Indo-Pakistan.

**Control measures.**

Clean up campaign of self sown wheat plants in the hills has been recommended in order to eradicate the foci of infection. This campaign, however, does not hold out any good promise on account of its physical impossibility and uneconomic nature.

Suspension of wheat and barley crops in the hills has been recommended. This is also not practicable.

The best method is to evolve rust resistant types of wheat.

**Varietal resistance.**

So far none of the wheat varieties has been found to be resistant to all the races of the three rusts.

In the case of barley none of the varieties has been found resistant to black rust while 17 varieties have been found resistant to yellow rust.
Fig. 29. Different parts of a wheat plant infected with *Puccinia triticina*.
Fig. 28. Different parts of a wheat plant infected with *Puccinia glumarum*. 
Fig. 27. Different parts of a wheat plant infected with Puccinia graminis.
SUMMARY

Investigations carried out on loose smut, flag smut, septoria leaf spot, foot-rot, bunt, new bunt, ear-cockle and rusts 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 method known by the name of solar energy method has been developed. This consists of soaking the seed wheat in ordinary water on a clear sunny day for 4 hours in the morning and spreading it in the sun in thin layers to dry.

In the case of flag smut of wheat, which is a serious disease of submontaneous districts, its modes of perpetuation, factors affecting its incidence and control measures consisting of seed disinfection, cultural methods and resistant types, have been determined. It has been found out 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 wheat in a field to which water is applied immediately after sowing or by sowing wheat early. Out of the resistant types, I.P. 80-5 has been recommended for cultivation in infected localities. Work has also been carried out on the physiologic specialization of Urocystis tritici Koern, the causal fungus of flag smut, by comparing 11 collections from U.S.A., 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 Desm. and Septoria nodorum Berk. Modes of perpetuation, factors affecting the incidence and measures to control the disease have also been worked out.

Foot rot of wheat, erroneously attributed by farmers of the province to white ant attack, has been found to be caused by the fungus Helminthosporium sativum Pamm, King and Bakke. 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 sp. obtained from black pointed grains can also cause foot rot. Factors affecting the incidence of the disease and measures to control the disease by seed disinfection, cultural methods and resistant types 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 1-1½ feet as compared to 4-5 inches, the normal size of healthy ears. Factors affecting the incidence of the disease and control measures including resistant types 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 ear 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 development of the disease.

Ear-cockle is controlled by sowing seed free from galls which can be removed by sieving and winnowing or by immersing the seed in water and skimming off the galls.

Rusts of wheat, which constitute a perpetual 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 4000-8000 feet (yellow rust from 7000-8000 feet, brown rust 6000-7000 feet and black rust from 4000-5000 feet). Wheat crops in the hills get 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 infections in the plains. The direction of air currents in the months of January to March have been found to be from hills towards the plains. Alternate host plants which have been determined for black and brown rusts, have been found to play very little role in the annual out-break of rusts in the plains. No alternate host plant has so far been found for yellow rust.

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<td>A new technique of conducting pot-experiments in smut disease belonging to seedling infection group.</td>
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<td>17.</td>
<td></td>
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<td>Occurrence and modes of perpetuation of flag smut of wheat.</td>
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19. ——

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21. ——

(Manuscript) Some studies on the new bunt of wheat in the Punjab.
CHAPTER II

DISEASES OF GRAM (Cicer arietinum L.)

In the Punjab gram (Cicer arietinum L) has an acreage of about 2 millions and occupies a very important position amongst the food grain crops. Its greatest value lies in the fact that it is almost the only rabi crop that can be successfully grown in the vast Barani (rain-fed) tracts of the Province and therefore carries a great economic importance for the bulk

FIG. 30. GRAM BLIGHT

1. A branch of gram plant affected with the fungus.
2. A branch having diseased pods.
3. A part of diseased branch.
4. A diseased pod showing pycnidia arranged concentrically.
5. A diseased leaf showing pycnidia.
of farming population of these areas. The importance of this crop has still increased after the partition of the Punjab as Pak. Punjab with a population of 60-65% of the original population of the undivided Punjab has been left with only 40% of the area under gram. Unfortunately this important crop of the province is subject to three very destructive diseases, namely, blight, wilt and smalling of leaves. Out of these diseases gram blight attracted the attention first of all as it started appearing in the form of epidemics in the districts of Attock, Jhelum, part of Mianwali and Rawalpindi. Later on with the evolution of blight resistant varieties gram wilt came into prominence. Recently smalling of leaves has been found to be doing a good deal of damage at Campbellpore. Research work carried out so far on all these three diseases is presented in this chapter.


Gram blight is a very serious disease of the gram crop. 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

![Fig. 1](image1)

*Fig. 1. Pycnidium of gram blight in culture.*

![Fig. 2](image2)

*Fig. 2. Pycnosporangia of gram blight in culture.*

![Fig. 3](image3)

*Fig. 3. Pycnidia of Phyllosticta rabiei in culture.*

![Fig. 4](image4)

*Fig. 4. Pycnosporangia of Phyllosticta rabiei in culture.*

Fig. 31. Microscopic features of the causal fungus of gram blight and *Phyllosticta rabiei.*
and leaflets. At first individual diseased plants may be observed scattered over the field but later the disease spreads and circular patches are formed. If the weather during February-April becomes wet due to rains, the whole field may be completely destroyed and the plants appear as if they are scorched by fire. In case the plants survive to produce pods, the diseased spots develop on them with great vigour and rapidity and the pycnidia of the fungus appear on the lesions in abundance in characteristic concentric zones. In severe cases the fungus can penetrate into the pods and thereby gives rise to infection spots on the grains which remain shrivelled. (Figs. 30 and 31).

The fungus causing blight in the Punjab (G) has been compared as regards the symptoms produced, morphology and physiology with two cultures of Ascochyta pisi Lib. isolated from Pisum sativum, one in India [A. pisi (Ind)] and the other in England [A. pisi (Eng.)], a fungus associated with A. pisi Ind. designated as (P), a fungus isolated from Vicia sativa at Slough, England (V), Ascochyta species isolated from Ervum-lens at Palampur, India (L) Pyllrosticta rabiei (Pass.) Trotter isolated from stem lesions of Cicer arietinum from Madrid, Spain (P. rabiei), Mycosphaerella-pinodes (Berk and Blox) Stone and Ascochyta pinodella Jones, cultures of which were got from Centraalbureau voor Schimmelcultures Baarn, Holland. (Figs. 32, 32A and 33). Cross inoculations with these fungi were also carried out on gram, lentil, pea, wild Vicia sativa and cultivated Vicia sativa and broad beans.

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

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

The fungi isolated from lentil in Indo-Pakistan sub-continent and from wild Vicia sativa in England are varieties of Ascochyta pisi Lib.

The fungus causing blight of gram in Western Pakistan is identical with phyllosticta rabiei (Pass) Trotter, but should be called Ascochyta rabiei (Pass) Lab. In the light of research carried out by Kovaceveski it should now be called Mycosphaerella rabiei.

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 blight.

A fungus isolated from peas in Western Pakistan in association with Ascochyta pisi Lib is considered to be a weak parasitic race of Ascochyta pinodella Jones.
Fig. 32. Effect of temperature upon colony diameter, after fourteen days' growth on oat meal agar.

Fig. 32 a. Colony growth on different culture media at laboratory temperature (18-23) after twenty-one days' growth.
Morphology and Physiology of Mycosphaerella rabiei (Ascochyta rabiei).

The average size of pycnidia is 182 x 150μ.

The average size of pycnospore is 10 x 4μ.

Under dry conditions 99.0% spores are non-septate and only 1% are septate, but under very moist conditions about 10 per cent become one septate.

The optimum, maximum and minimum temperatures for growth are 25°C, 32.5°C and below 10°C respectively. This fungus has got the least growth rate as compared with the other 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 is very meagre, slow and uncertain in water. They are favoured in their germination by the presence of N|50-N|25 malic acid or acidified carbon food (Tables X and XI.)
Table X. Germination of spores of *A. rabiei* in different concentration of malic acid after 48 hours.

<table>
<thead>
<tr>
<th>Strength of acid</th>
<th>Water</th>
<th>N/100</th>
<th>N/50</th>
<th>N/25</th>
<th>N/12</th>
<th>N/7</th>
<th>N/3</th>
<th>N/1.4</th>
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<tr>
<td>Percentage germination</td>
<td>15</td>
<td>80</td>
<td>95</td>
<td>95</td>
<td>25</td>
<td>10</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Average g.t. length (μ)</td>
<td>3.1</td>
<td>102.4</td>
<td>162.8</td>
<td>205.1</td>
<td>32.2</td>
<td>2.4</td>
<td>nil</td>
<td>nil</td>
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</table>

Table XI. Germination of spores of *A. rabiei* in 2% glucose solution of different pH after 48 hours.

<table>
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<tr>
<th>pH</th>
<th>Percentage germination</th>
<th>Average g. t. length (μ)</th>
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<tr>
<td>2.1</td>
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<tr>
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<td>38.4</td>
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The maximum, optimum and minimum temperatures for the germination of spores are 32.5°C, 25°C and below 10°C respectively.

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 spreading of the fungus saprophytically on the healthy gram sticks lying beside infected ones.
The diseased twigs exposed on the surface of a field for one year when used for inoculation of healthy crop can bring 100 per cent infection while those exposed for two years can only produce 9.0 per cent infection.

The fungus is killed totally if diseased twigs are allowed to remain lying on the surface of a field for a period of 3 years, showing thereby that after three years it is safe to sow 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.

The least depth of burial of the infected debris is 2 inches for getting total destruction of the fungus.

The duration of burial for obtaining cent per cent kill varies indirectly with the amount of rainfall. The more the rainfall the shorter is the period required and *vice versa.* Where the rainfall is 2 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, 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 detrimental to the mycelium and spores of the fungus.

If the infected material is buried in a manure pit for sufficiently long time (2-3 months), it is completely freed from infection and the manure resulting therefrom is safe to be used 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 is to be exercised not to replough such fields, at least for three months otherwise the buried sticks will tend to come up on the surface of the soil.

*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 2 years in the laboratory.

*In artificial culture.*

The fungus when grown in culture and kept as such in dried form retains its viability even after a period of 8 months.

*Under other conditions.*

The fungus present in the diseased material is killed when such material 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 got no adverse effect on the viability of the fungus.

**Production of concentric zones.**

Observations made in the field showed that the fungus produced pycnidia in concentric circles but some times they were absent. Hence work was carried out with a view to finding out factors responsible for the development of such concentric zones in the field as well as in the laboratory.

An analysis of the factors which have been found to be responsible for the production of zones in *Ascochyta rabiei* (Pass.) Labrousse in the laboratory and in the field 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 underdevelopment of pycnidia. Brown's starch agar was selected for carrying out detailed studies and the following main conclusions are drawn as far as the quantity and the quality of the medium are concerned.

Maximum zones are observed when the quantity of the medium is 20 c.c per petri dish of 110 m.ms. diametre.

Zones are normal in a medium on which a fair amount of pycnidia is produced; they become overlapped in higher (i.e., 2N concentration) and remain under-developed in lower concentrations (i.e. N/8 concentration).

Zonation is normal when the nitrogen source of the medium is omitted; pycnidial production increases with the increase in nitrogen and after a certain stage which varies with the nature of the nitrogen source used, the medium becomes unsuitable for zonation.

Zones do not develop when glucose and starch are totally omitted but they are normal when either of them is present. There is a steady increase in the growth of the mycelium and the reduction in the amount of pycnidia with higher concentration of carbohydrates with the result that zones are not clear above a certain concentration.

Zones are not produced when phosphates are omitted from the medium on account of absence of pycnidia.

Magnesium sulphate when varied within limits of 0-0.2 per cent does not affect zonation.

Zonation is normal within a pH range of 4.2 to 6.8; in higher acidities zones do not develop on account of increased mycelial growth and decreased pycnidial production.
The growth features of the fungus being similar in light and in darkness, zones do not develop when culture is kept under conditions of alternate light and darkness. The conditions as to quantity and quality of a medium being suitable, 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.

Other noteworthy points which have been found in this connection are:

1. Zones develop when the fungus is incubated alternately at two temperatures irrespective of the fact whether it is being kept in light or in darkness. (Figs. 34 and 35).

Fig. 34. Dishes kept at alternate temperatures of 25°C and 15°C under constant darkness.

Fig. 35. Dishes kept at alternate temperatures of 25°C and 15°C under constant light.
2. A difference of 5°C between the incubation temperatures is sufficient to bring about zonation when one of the temperatures is optimum.

3. Zones develop whenever the fungus is incubated alternately at two temperatures, irrespective of its stage of growth. (Fig. 36).

4. The number of zones correspond to the number of times the fungus is transferred to a lower temperature. Thus it is $n$, $2n$, and $4n$ when the transfers are carried out after 48, 24 and 12 hours respectively. (Fig. 37).

5. The minimum duration of exposure to a particular temperature for zonation is inversely proportional to the amount of check produced by the temperature upon vegetative growth of the fungus. Thus it is shorter at unfavourable and longer at favourable temperatures for fungal growth.
Similarly under field conditions the right type of the medium for the growth of the fungus is provided by the gram pods and in addition to this the required variation in the incubation temperature is brought about by the daily fluctuations of temperature.

**Modes of perpetuation and spread.**

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

(i) 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 shrunk, discoloured and with large lesions on their surfaces. From such discoloured seeds some percentage of infected seeds can germinate and produce diseased seedlings.

(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 on such debris initiate infection in the next gram crop when there is rain.

The fungus also remains alive in gram bhusa and during the season when bhusa is carried from field to village or from one village to another, the infection spreads.

**Effect of environmental factors.**

Rainfall. Rainfall during summer indirectly affects the incidence of the disease. Heavy rainfall washes the spore bodies off the gram stalks and thus reduces the inoculum while in scanty rainfall the inoculum is not reduced.

The critical period for rainfall is, however, from February to April which covers the flowering and fruiting period. It has been seen

![Fig. 38. Average rainfall (October to April) in various gram-growing centres of the Indo-Pakistan sub-continent.](image-url)
that the disease appears in an epidemic form in those years only when the rainfall during this period is about six inches or more.

The occurrence of blight in the Indo-Pakistan sub-continent seems to be highly correlated with the amount of rainfall during these periods. (Fig. 38).

Temperature. Very few spores germinate and cause infection during the months of December and January due to very low temperatures. The spores, however, remain viable during freezing temperature and cause infection in February and March when the temperature varies from 20-27°C.

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 above. Thus in localities where the mean temperature at the time of seed formation is 32.5°C or higher, the disease will automatically disappear in a few years even if introduced, provided plant debris is destroyed. (Fig. 39).

![Fig. 39. Normal mean shade temperatures (October to April) in different gram-growing centres of the Indo-Pakistan sub-continent.](image)

Control measures.

To begin-with the following control measures were devised and put into practice:-

(a) Use of blight free seed for sowing.
(b) Elimination of disease plant debris by
   (i) Harvesting the crop by pulling out the plants with hard.
   (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, etc.

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 these methods have proved effective but in years of abnormal rainfall the disease spreads from those fields in which the above mentioned methods are not adopted. Work was, therefore, carried out to evolve high yielding blight resistant types. For this purpose work was at first carried out to study if the fungus had any physiological races.

**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 somewhat in their colony growth (Figs. 40 and 41), they were similar in their reaction on various gram types showing thereby that they constituted one physiological race.

![Fig. 40. Colony growth of six forms of *A. rabiei* on Richards agar at 20°C.](image-url)
Fig. 41.: Effect on temperature on colony growth of the six forms of *A. rabiei* on oat meal agar at the end of three weeks.

A 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. This method of inoculation although had previously proved to be very efficient in bringing about heavy percentages of infection under controlled conditions but it was not possible to utilize this method on a large scale unless some arrangement 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 3 days. This handicap was after all overcome by evolving a very simple method in which case small bits of blighted gram plants were very carefully broadcast on the standing crop in the field after ensuring that the stalks of debris carried plenty of viable pycnidia. It may be mentioned that the fungus remains in a viable form for at least 3 years on gram plant debris lying exposed on the surface of soil. The plants inoculated by this method were not covered with any material like *Sarkanda* (*Saccharum arundinaceum* Retz.) In this case infection occurred after rain even if it was received months after inoculation. This method proved to be very easy and as successful as the original method of spraying spore suspension in water.

Resistant varieties.

At first 187 types and later on 392 types and collections of gram obtained from different places of Indo-Pakistan sub-continent and
foreign countries were tested as regards their relative resistance to *Ascocytta rubiei* by giving them heavy inoculation both with spores and spreading diseased plant debris over them. All the Indo-Pakistan types were found to be susceptible to the disease and of the foreign types Pois-chiches Nos. 4732, 199 and 281 which were renamed as F8, F9 and F10 respectively showed high degree of resistance to the disease. Later, about four hundred more collections from all over the world were also tested, but no type except the three above mentioned were found resistant. (Fig. 42.)

Of these three resistant types F8 gave the highest yield and it also possessed other desirable characters. This was, therefore, selected for distribution to farmers in the blight affected areas. As this type was found to be lower yielder 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 at least equal to Punjab type 7. For this purpose selections from natural crosses were made and also F8 was crossed with Punjab type 7. Now C12/34 and 62-18, the two hybrids are available whose yield is almost equal to Punjab type 7 and which are also tolerant to wilt. C12/34 is on the approved list of the Department. Still there is need for improvement as in dry years when blight does not appear these types yield somewhat less than

![Fig. 42. Comparison of gram type F8 (a resistant type) with Punjab types 7 and 15 (susceptible types).](image)
Punjab type 7 and do not show resistance to wilt. The work is in progress and some very promising hybrids which are expected to yield better than Punjab type 7 are in the experimental stage.

**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 experiment 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 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 germination of spores, which may be present on the resistant types, is absent up to 48 hours and is feeble even after 72 hours and the germ tube length also remains very short 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. (Fig. 43).
Inheritance of blight resistance.

The mode of inheritance of blight resistance in gram has been studied by the second author 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 cross between resistant types has given resistant progenies and that between the two susceptible parents susceptible offsprings in F1 generation. All the F1 plants of crosses between the resistant and susceptible types have been found to be resistant to blight like 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, moderate, severe and very severe 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%) F2 plants happen to be 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 per cent.
Association of morphological characters with blight reaction.

Along with studies on mode of inheritance of blight resistance work has also been carried out on association of morphological characters with blight reaction. It has been found out 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 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 strongly positive with hair density, weakly positive with the height of plant and weakly negative with number of tertiary branches per plant. (These results are in confirmation with those already stated under basis of resistance). No association exists between blight and other morphological characters.

Association results, however, indicate that they can prove very 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.

2. WILT, Fusarium orthoceros. var. ciceri. (14)

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. 44). 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.
Isolations and pathogenicity.

Isolations from roots of wilted gram plants yielded 90% Fusarium orthoceros, 0.5% Rhizoctonia bataticola, 0.5% Penicillium sp. and in 9% 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.
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.

Factors affecting the incidence of the disease.

Experiments carried in artificially infected soil have shown that at 40°C germination is about 60% and all the plants wilt within a fortnight. At 35°C seed germination is 70% and all the plants wilt within 17 days. At 30°C seed germination is 100% 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 and at 25°C the rotting of ungerminated seeds is extremely slow. All the plants under different soil moisture contents show wilting though the rate of wilting is indirectly proportional to the percentage of soil moisture.

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 the month of September and it is gradually reduced with the delay in sowing time so much so that it is almost negligible when the sowing is carried out in the month of November, but in the latter case the yield of the grain is reduced by about 50% as compared with that obtained from the crop sown in October. 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. (Fig. 45). 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 the month of October, although it may differ in different localities.
Fig. 45. Effect of date of sowing on the incidence of gram wilt.

Soil moisture near the saturation point and 9.5% moisture content are favourable for the development of the disease. When the soil moisture increases above 9.5%, the incidence of the disease decreases and the decrease is marked until 19.5% soil moisture and 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 and the available foreign types of gram have been tested for their relative resistance to *Fusarium orthoceros* but so far no type has been found resistant to the disease. The work is in progress to find out other possible causes of the disease, soil factors influencing the incidence of the disease and resistant varieties.

The Province of the Punjab can be divided into 3 belts (Fig. 46) according to the distribution of blight and wilt diseases. The first belt comprises of Campbellpur, Jhelum and Rawalpindi districts where blight is a serious disease. The second belt includes Gujranwala, Sheikhupura, Lahore and Lyallpur districts where both blight and wilt can coexist according to weather conditions prevailing in a certain year, while in the third belt 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 last zone.
3. SMALLING 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 checked growth which results in the reduced size of the various organs of the plant including leaves, leaflets, branches and stem. The plants remain stunted in growth, the leaves ultimately change colour, dry and shed down leaving the branches bare. In severe cases there is no pod formation at all and in others the pods formed are of reduced size having shrivelled grains in them.

Smalling of leaves in gram is of recent origin and is practically confined to the crop at the Agricultural Farm, Campbellpore. It started appearing in traces in 1944 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%. 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 date 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 have definitely shown that the disease can be artificially reproduced by carry-
mg 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, otherwise in late stages either the disease does not make its appearance or the symptoms remain under-developed 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 as compared to that where inoculations are carried out in 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, C6218, C12134, B.R.786, B.R.3, 3341, Pb. 7 and local types 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 percentage ranging between 80-100.) and the yield of the crop has been very much reduced and it was only 1 to 5 maunds in different varieties. However, from the yield data it has been seen that 3341 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 further 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.

The work is in progress to find out the real nature of the disease with the ultimate aim to arrive at some suitable control measures.

SUMMARY

In this chapter the work carried out on three diseases of gram crop namely, blight, wilt and smallding of leaves has been described. As far as distribution of blight and wilt is concerned, the Punjab 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 of Lyallpur, Sheikhupura, Lahore and Montgomery districts, both blight and wilt co-exist while in the third zone including Mianwali, Jhang and Multan districts wilt is the main problem.

Gram blight used to appear in epidemic form some years back when the work was taken into hand systematically. It has been found out that the disease is caused by the fungus Mycosphaerella rabiei Kovacevaski Ascochyta rabiei (Pass.) Labrousse. The disease appears from February onwards and produces 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, Phyllosticta rabiei.
isolated from Cicer arietinum (gram) from Madrid (Spain) and Ascocryta pinodella Jones and conclusions have been given. It has been determined that the disease perpetuates through infected plant 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 best of the three, has been used as one of the parents in evolving blight resistant and high yielding varieties. Ultimately blight resistant type C12-34, possessing other desirable characters, has been evolved and distributed in blight affected areas. Studies have also been carried out on the inheritance of disease resistance and on the factors responsible for resistance.

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 disease have been worked out and measures to control the disease suggested. Some preliminary work has also been carried out on smalling of leaves, a new disease of gram crop, which is making its appearance at the Agricultural Farm, Campbellpur, for the last few years.

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16. — (Manuscript) Some studies on the viability of *Mycosphaerella rabiei* (*Ascochyta rabiei*), the causal fungus of gram blight.

17. — (Manuscript) A practical method of inoculating gram crop with gramblight fungus on a large scale.
CHAPTER III

DISEASES OF SUGARCANE (*Saccharum spp.*)

The importance of sugarcane crop is very great in the Punjab even though it occupies comparatively a small area of 2.5 lacs* of acres. The value of this crop lies in the fact that it not only brings good profit to the farmers but it also provides them with a very good substitute for sugar in the form of jaggery. Since the establishment of Pakistan, the importance of sugarcane crop has been further enhanced on account of the fact that Pakistan is deficient in sugar and therefore she has to depend on other countries to meet her demands. It is, therefore, evident that all efforts, directed towards improving the present output of sugarcane, will prove ultimately beneficial to the Dominion. The protection of this crop against its 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 and chlorosis diseases of sugarcane which reduce the yield are given below:-

1. SMUT, *Ustilago scitaminea* Syd. (3, 4 and 6).

**Symptoms.**

The smut of sugarcane is essentially a disease of thin and medium varieties. The affected canes produce long, black whiplike shoots which are covered with the spores of the fungus. The smutted shoots may arise from the top of the cane or from lateral buds. (Fig. 47).

**Germination of spores.**

The optimum temperature for the germination of smut 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. The germinated spores bear sporidia at all temperatures except at 30°C.

Glucose solution (0.5 to 5%) and sugarcane leaf decoction (N/1 to N/8) are the best for the germination of spores. The germination in these solutions is so rapid and vigorous that observations on the germination and length of germ-tubes have to be recorded 5 hours after sowing, whereas in other cases these are recorded after 9 hours.

Germination does not take place in 1.0% solution of sodium carbonate and sodium chloride and N/2 to N/1 concentrations of dung extract.

Germination is very low, i.e., below 1.5% after 22 hours in 0.5 to 1.0% solutions of magnesium sulphate, potassium sulphate, sodium nitrate, N/1 soil extract, 1.0% potassium nitrate and ammonium sulphate and N/8 to N/16 concentrations of dung extract.

In the case of lower concentrations of the nutrients stated above and 0.1 to 1.0% of potassium phosphate and potassium chloride solutions and distilled water, germination is fair to good.

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*1 lac = 100,000.*
A totally smutted stool. Healthy cane showing a smutted side shoot.

A transverse section of a bud of cane infected with (Usilago scitaminea).
Fig. 47. Sugarcane smut.

Viability of spores.

The spores kept at different temperatures varying from 5°C to 35°C for 210 days gave germination up to 70%.

The spores when buried in the soil at a depth of 1, 2 or 6 inches lose their viability within 4-7 months, while those which are kept on the surface of the soil lose viability within 7-10 months.
When spores are buried after coating them on cane setts at a depth of 4 or 8 inches at different temperatures varying from 14° to 31° C and kept moist, they lose their viability after 3 weeks.

The thermal death point of the spores is 62° C.

Spores when buried in ice for even 120 hours do not lose their viability.

**Modes of perpetuation.**

It has been shown that the disease is carried over from year to year by the following methods:— (Tables XII, XIII & XIV.)

(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.

(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.

(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.

(d) By ratooning smutted canes. The mycelium remains dormant in the stumps and resumes growth as the canes grow and produces smut. (Fig. 48).

![Diagram](image_url)

**Fig. 48. Diagramatic sketch showing perpetuation of sugarcane smut.**
Table XII. Results of experiments on infection with smut spores coated on the buds of standing canes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Time of infection</th>
<th>Time of planting</th>
<th>No. of buds planted</th>
<th>No. of buds germinated</th>
<th>No. of emuted plants</th>
<th>% of smut.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>(i) Buds of standing canes infected with spores and surface sterilized.</td>
<td>August</td>
<td>Sept. 1935</td>
<td>135</td>
<td>53</td>
<td>15</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td>(ii) Control.</td>
<td></td>
<td>Sept. 1935</td>
<td>160</td>
<td>65</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(i) Buds of standing canes infected with spores and surface sterilized.</td>
<td>August</td>
<td>March, 1936</td>
<td>330</td>
<td>113</td>
<td>30</td>
<td>26.5</td>
</tr>
<tr>
<td></td>
<td>(ii) --do--</td>
<td>Sept.</td>
<td>March, 1936</td>
<td>310</td>
<td>106</td>
<td>16</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>(iii) Control.</td>
<td>Sept.</td>
<td>March, 1936</td>
<td>710</td>
<td>249</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1936</td>
<td>(i) Buds of standing canes infected with spores and surface sterilized.</td>
<td>Feb.</td>
<td>March, 1936</td>
<td>1500</td>
<td>600</td>
<td>26</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>(ii) Control.</td>
<td>Feb.</td>
<td>March, 1936</td>
<td>700</td>
<td>249</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(ii) Control.</td>
<td>Oct.</td>
<td>Oct., 1936</td>
<td>100</td>
<td>38</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table XIII. Results of experiments on the infection of buds of setts coated with smut spores at planting time.

<table>
<thead>
<tr>
<th>Year</th>
<th>Place</th>
<th>Treatment</th>
<th>Time of planting</th>
<th>No. of buds planted</th>
<th>No. of buds germinated</th>
<th>No. of smutted plants</th>
<th>Percentage smut.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>Lyallpur</td>
<td>(i) Smut spores coated on buds of setts at planting time.</td>
<td>Sept.</td>
<td>112</td>
<td>45</td>
<td>28</td>
<td>62.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control.</td>
<td></td>
<td>160</td>
<td>65</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1936</td>
<td>Lyallpur</td>
<td>I.—(i) Smut spores coated on buds of setts at planting time.</td>
<td>March</td>
<td>600</td>
<td>247</td>
<td>26</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control.</td>
<td></td>
<td>600</td>
<td>249</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lyallpur</td>
<td>II.—(i) Smut spores coated on buds of setts at planting time.</td>
<td>March</td>
<td>900</td>
<td>353</td>
<td>57</td>
<td>16.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control.</td>
<td></td>
<td>820</td>
<td>320</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lyallpur</td>
<td>III.—(i) Smut spores coated on buds of setts at planting time.</td>
<td>Sept.</td>
<td>500</td>
<td>210</td>
<td>79</td>
<td>37.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control</td>
<td></td>
<td>120</td>
<td>48</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1937</td>
<td>Lyallpur</td>
<td>I.—(i) Smut spores coated on buds of setts at planting time.</td>
<td>March</td>
<td>300</td>
<td>113</td>
<td>23</td>
<td>20.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control</td>
<td></td>
<td>200</td>
<td>78</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Lyallpur</td>
<td>II.—(i) Smut spores coated on buds of setts at planting time.</td>
<td>March</td>
<td>270</td>
<td>117</td>
<td>12</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Control</td>
<td></td>
<td>800</td>
<td>342</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table XIV. Results of experiments on ratooning of smutted canes.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>No. of canes ratooned</th>
<th>No. of plants smutted</th>
<th>Percentage smut.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935</td>
<td>(i) Ratooned from smutted canes</td>
<td>40</td>
<td>40</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>(ii) Ratooned from healthy canes</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1936</td>
<td>(i) Ratooned from smutted canes</td>
<td>30</td>
<td>30</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>(ii) Ratooned from healthy canes</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Varietal resistance.**

The different sugarcane varieties tried can be arranged in the following groups according to their performance regarding resistance to this disease. (Table XV).

Table XV. Varietal resistance to smut of sugarcane.

<table>
<thead>
<tr>
<th>Degree of infection</th>
<th>Name of variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>No infection</td>
<td>None.</td>
</tr>
<tr>
<td>10—20 percent</td>
<td>CoL. 99.</td>
</tr>
<tr>
<td>20—30 percent</td>
<td>Katha, CoL. 11.</td>
</tr>
<tr>
<td>30—50 percent</td>
<td></td>
</tr>
</tbody>
</table>

**Factors affecting incidence of the disease.**

Soil moisture during germination period plays a very important part on the incidence of the disease. With high soil moisture contents the spores of the causal fungus do not germinate well with the
result that the infection percentage is very low. The incidence of the disease is reduced by 75% when the plantings are carried in dry soil to which water is applied immediately afterwards.

Control measures.

The following measures have been found 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% mercuric chloride solution for 5 minutes or in 1.0% formalin solution for 5 minutes which is followed by 2 hours covering under moist cloth. These treatments do not adversely affect either the germination of sugarcane setts or the yield of cane and juice.

3. Smutted plants should be rogued out carefully as soon as they appear.

4. Ratooning of diseased crop should be discouraged.

2. MOSAIC AND YELLOWING DISEASES (Virus). (1, 8 and 9).

There are two important virus diseases of sugarcane on which work has been carried out. These two diseases are mosaic and yellowing. Some of the important findings on various aspects of these two diseases are reproduced below:

MOSAIC.

In the Punjab only primary symptoms of mosaic, i.e., mottling of leaves occur on sugarcane. The secondary symptoms, i.e., dwarfing of cane etc., have not been observed so far. (Fig. 49).

The incidence and amount of mosaic in different varieties of sugarcane grown in the Punjab was recorded and it was found that varieties Uba, Treru, and Co.223 were almost totally infected; S 48, Co.205, Co.309, Co.270, Co.213, Co.250, Co.287, Co.300, Co.313, Co.318, Co.346 and Katha had more than 5% and less than 20% infection and other varieties showed less than 0.5% or no infection at all.

In addition to this, observations made on many other varieties had shown that Co.203, Co.242, Co.244, Co.253, Co.260, Co.272, Co.275, Co.276, Co.294, Ponda and Dhaulu had got only traces of mosaic and Co.214, Co.227, Co.231, Co.232, Co.233, Co.243, Co.247, Co.252, Co.255, Co.257, Co.258, Co.261, Co.263, Co.265, Co.267, Co.268, Co.277, Co.281, Co.282, Co.283, Co.284, Co.286, Co.296, Co.314, Co.347, B 1217, B 6308, B 6388, A2, A42, Lalri, Kahu and Kausar did not show any mosaic at all.

It has been found that the canes show the first symptoms of mosaic about one and a half months after planting and then the amount of infection goes on increasing till October.
The results of field experiments carried out for 3 years on the sugar-cane variety Co.223 have shown that there is no significant decrease in the yield of cane, juice or gur (raw sugar) and that the quality of juice also does not deteriorate on account of mosaic. (Table XVI).

Roguing can keep the disease within limits in those varieties only which are not very susceptible to mosaic.

YELLOWING. (8 and 9).

The yellowing mosaic differs from the ordinary mosaic in causing different symptoms such as more yellowing of leaves, stunting of the cane and internodes and bringing about serious losses in the tonnage and quality of the cane, juice and gur. (Fig. 50).

Field experiments carried out by planting healthy setts against those from canes affected with yellowing mosaic have shown that the yield of stripped cane, juice and gur is reduced by 27, 25.9 and 29.1 per cent respectively. (Table XVII).

Similarly average loss in sucrose in diseased canes is 11.1 per cent at Lyallpur and 38.8 per cent at Jullundur. (Bharat)

In certain years some of the affected canes recover and the recovery is permanent while in others no recovery takes place.

This disease is also perpetuated from year to year by planting setts obtained from affected canes. A higher percentage of diseased canes appear where setts from the middle and bottom portions of canes are planted than when setts are taken from top portions.

When diseased canes are ratooned, the disease appears in 100% cases.

Out of 16 varieties tested by artificial inoculation only Co.453 has been found to be less susceptible to the disease.

Maize and sorghum have been found to be the alternate host plants.

Inoculations done on Co.313 by pricking with a needle have shown that inoculations carried out on spindle and on leaves catch cent per cent infection while those done on mid rib of leaves produce only 40% of infection.

Physiology of both the viruses.

The thermal death point of both the viruses has been found to be 60°C.

They can stand only 1-10 dilution of the standard extracts.

They can retain their infectivity after passage through Whatman No. 1 filter paper.

Their infectivity is not impaired after 24 hours storage at 27°C.
Fig. 49. Healthy and mosaic affected leaves of sugarcane.
Fig. 50. Healthy leaf and diseased leaves of sugarcane showing different stages of yellowing.
Table XVI. Effect of mosaic on the yield of cane, juice and gur (raw sugar) of Co.223 at Lyallpur, 1930-33.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area of plot in acres</th>
<th>Kind of cane planted</th>
<th>Percentage of mosaic affected cane in the grown up crop</th>
<th>Actual weight of stripped cane</th>
<th>Theoretical weight of cane</th>
<th>Difference between the two means of observed and theoretical value of cane</th>
<th>Actual weight of juice</th>
<th>Difference between the two means of observed and theoretical value of juice</th>
<th>Theoretical value of juice</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930-31</td>
<td>1/10 Healthy</td>
<td>12.1</td>
<td>38-5</td>
<td>22-31</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>18-16</td>
<td>2-37-8</td>
<td>3-36-2</td>
<td>Gur not prepared</td>
</tr>
<tr>
<td></td>
<td>1/10 Mosaic</td>
<td>100.0</td>
<td>29-31</td>
<td>18-39</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>17-27</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/10 Healthy</td>
<td>10.0</td>
<td>25-4</td>
<td>16-3</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>26-13</td>
<td>4-17-0</td>
<td>3-27-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/10 Mosaic</td>
<td>12.0</td>
<td>20-12</td>
<td>3-10-6</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>21-4</td>
<td>4-13-12</td>
<td>3-14-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/10 Healthy</td>
<td>14.2</td>
<td>45-0</td>
<td>4-13-12</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>23-37</td>
<td>4-13-12</td>
<td>3-14-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/10 Mosaic</td>
<td>100.0</td>
<td>38-11</td>
<td>3-14-8</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>22-37</td>
<td>4-13-12</td>
<td>3-14-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/10 Healthy</td>
<td>13.4</td>
<td>43-30</td>
<td>3-14-8</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>23-37</td>
<td>4-13-12</td>
<td>3-14-8</td>
<td></td>
</tr>
<tr>
<td>1931-32</td>
<td>1/20 Healthy</td>
<td>34.0</td>
<td>37-33</td>
<td>27-4</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>22-38</td>
<td>3-24-12</td>
<td>3-36-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Mosaic</td>
<td>100.0</td>
<td>42-0</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>21-24</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Healthy</td>
<td>38.8</td>
<td>37-37</td>
<td>3-24-12</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>21-24</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Mosaic</td>
<td>99.5</td>
<td>33-30</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>23-24</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Healthy</td>
<td>18.0</td>
<td>38-18</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>23-24</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Mosaic</td>
<td>100.0</td>
<td>34-33</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>20-26</td>
<td>3-10-6</td>
<td>3-24-12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Healthy</td>
<td>42.0</td>
<td>22-30</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>19-22</td>
<td>3-36-2</td>
<td>3-39-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Mosaic</td>
<td>99.5</td>
<td>34-18</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>21-11</td>
<td>3-36-2</td>
<td>3-39-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/20 Healthy</td>
<td>24.5</td>
<td>39-17</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>23-15</td>
<td>3-36-2</td>
<td>3-39-8</td>
<td></td>
</tr>
<tr>
<td>1932-33</td>
<td>1/20 Healthy</td>
<td>Not recorded</td>
<td>16-23</td>
<td>3-36-2</td>
<td>M. S.</td>
<td>M. S. Ch</td>
<td>16-23</td>
<td>3-36-2</td>
<td>Not prepared</td>
<td></td>
</tr>
</tbody>
</table>
Table XVII. Effect of yellowing mosaic on the yield of cane, juice and gur (raw sugar) at Lyallpur and Jullundur.

<table>
<thead>
<tr>
<th>Place</th>
<th>No. of plot</th>
<th>Treatment</th>
<th>Weight of stripped cane (Mds. Srs.)</th>
<th>Weight of juice (Mds. Srs.)</th>
<th>Weight of gur (raw sugar) (Mds. Srs. Ch.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyallpur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Healthy</td>
<td>8-32</td>
<td>5-30</td>
<td>0-38-1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>do.</td>
<td>8-39</td>
<td>5-38</td>
<td>0-39-7</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Diseased</td>
<td>6-24</td>
<td>4-23</td>
<td>0-29-0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>do.</td>
<td>6-14</td>
<td>4-7</td>
<td>0-27-5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Healthy</td>
<td>9-20</td>
<td>6-13</td>
<td>1- 2-14</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>do.</td>
<td>8-0</td>
<td>5-15</td>
<td>0-36-6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Diseased</td>
<td>6-26</td>
<td>4-10</td>
<td>0-27-11</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>do.</td>
<td>6-28</td>
<td>4-20</td>
<td>0-29-0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Healthy</td>
<td>7-38</td>
<td>4-29</td>
<td>0-32-0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>do.</td>
<td>8-3</td>
<td>5-15</td>
<td>0-34-9</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Diseased</td>
<td>4-18</td>
<td>2-30</td>
<td>0-18-0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>do.</td>
<td>4-35</td>
<td>3-11</td>
<td>0-20-3</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Healthy</td>
<td>7-0</td>
<td>4-33</td>
<td>0-31-15</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>do.</td>
<td>9-30</td>
<td>6-0</td>
<td>0-39-5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Diseased</td>
<td>5-18</td>
<td>3-25</td>
<td>0-22-5</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>do.</td>
<td>6-13</td>
<td>4-11</td>
<td>0-26-6</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Healthy</td>
<td>7-10</td>
<td>4-35</td>
<td>0-31-4</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>do.</td>
<td>7-20</td>
<td>5- 5</td>
<td>0-32-14</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Diseased</td>
<td>5-28</td>
<td>3-34</td>
<td>0-23-12</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>do.</td>
<td>7-17</td>
<td>5- 0</td>
<td>0-30-14</td>
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<td>0-28</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>do.</td>
<td>0-22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Healthy</td>
<td>1-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>do.</td>
<td>1-25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Diseased</td>
<td>0-19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>do.</td>
<td>0-26</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>Healthy</td>
<td>1-20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>do.</td>
<td>1- 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Diseased</td>
<td>0-26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>do.</td>
<td>0-28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Healthy</td>
<td>1-25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>do.</td>
<td>1-23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Diseased</td>
<td>0-19</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>do.</td>
<td>0-22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Healthy</td>
<td>1-20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>do.</td>
<td>1- 5</td>
<td></td>
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</table>
All the sixteen varieties tested by carrying out artificial inoculation have been found to be susceptible to both these diseases. The incidence of disease varies from 40-95 and 70-100 per cent in the case of ordinary mosaic and yellowing mosaic respectively.

The viruses extracted from diseased leaves have been found to remain viable for 9 hours at 25°C. Virus extracts kept for 4 days at 0°C in ice have given negative results on inoculation.

The mosaic diseases both ordinary and yellowing can be reproduced in healthy leaves by carrying out inoculations from the juice extracts obtained from either leaves or leaf sheaths, and leaf blades without central veins or veins only. There is not much difference between the intensities of the disease produced from these different sources. On the whole the percentage of disease got from the inoculations carried out by yellowing mosaic are comparatively much higher than those obtained from ordinary mosaic.

The inoculum obtained from diseased leaves cannot remain viable when it is exposed to 55°C for 10 minutes in the case of ordinary mosaic while in the case of yellowing mosaic the inoculum is killed after being exposed to 50°C for 10 minutes.

Control measures.

The following control measures are recommended at this stage:

(a) Use of setts from healthy canes for planting purposes.
(b) Establishment of seed plots which should be kept free from disease by constant rouging out of diseased canes.
(c) Ratooning of the diseased crop should not be practised.

3. CHLOROSIS (A deficiency disease).

Chlorosis is a disease of frequent occurrence in sugarcane crop. The early symptoms produced by this disease may be confused with those produced by mosaic diseases of sugarcane; but later on the whole leaf blade may show large chlorotic areas which are devoid of chlorophyll. The photosynthesis in such diseased leaves is greatly hindered with the result that the infected plants remain thin and dwarf and have less percentage of juice and sucrose. The disease has been found to be caused due to the deficiency of iron in soil which affects the normal photosynthetic process and thus gives rise to chlorotic areas. It has been found that when plants are sprayed with 8 per cent ferrous sulphate or ferric chloride solution in water or when 1% solution of these chemicals is applied to the soil, the plants regain their normal health in a few days.

4. STEM CANKER, Cytospora sacchari Butl. (2, 5 and 7)

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 stem gets shrivelled up and is very poor in juice. Whole stool or only
a few canes in a stool may be affected. It has been seen that the mother
setts of such stool 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 fungus has been found to be more virulent when the
cane reaches maturity. The disease also damages the canes which are
buried for seed purposes which is a usual practice in the Province in order
to protect the canes reserved for planting from frost.

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

**Mode 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 (Table XVIII).

Table XVIII. Results of inoculation experiments on standing canes
with *Cytospora sacchari* Butl.

<table>
<thead>
<tr>
<th>Date of inoculation</th>
<th>Variety of cane</th>
<th>No. of canes inoculated</th>
<th>No. of canes affected</th>
<th>Percentage of infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 21-12-1936</td>
<td>Co.323</td>
<td>20</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>(2) 15-7-1936</td>
<td>Co.312</td>
<td>16</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>(3) 4-9-1937</td>
<td>Co.371</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Co.318</td>
<td>10</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Co.313</td>
<td>11</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Co.312</td>
<td>11</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Co.373</td>
<td>20</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Co.323</td>
<td>40</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td>(4) 19-10-1937</td>
<td>(i) Co.371</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(ii) Co.371</td>
<td>10</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>(iii) Co.371</td>
<td>10</td>
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There was no infection in control canes.
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 N and 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 but the individual elimination of potassium nitrate, potassium dihydrogen phosphate or magnesium sulphate from the medium does not materially affect the growth if after elimination pH of the medium is adjusted at 5.0 (Fig. 51).

When glucose or lactose is substituted for sucrose in Richard's agar, the growth of the fungus falls, but when maltose is substituted for sucrose, the growth remains unaffected. (Fig. 52). 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 gms. per litre.

The optimum temperature for the growth of the fungus is about 30°C. the maximum lies between 35 to 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. 53). 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 agar and oatmeal agar but none on other media 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.

Light, as well as sucrose and maltose favour the formation of pycnidia (Table XIX).

![Graph showing effect of pH on colony diameter of C. sacchari after 6 days' growth at 30°C.]

**Fig. 53.** Effect of pH on colony diameter of *C. sacchari* after 6 days' growth at 30°C.

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

<table>
<thead>
<tr>
<th>Quantity of sucrose (gms)</th>
<th>Formation of pycnidia</th>
</tr>
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<tbody>
<tr>
<td>200</td>
<td>Fair</td>
</tr>
<tr>
<td>100</td>
<td>Fair</td>
</tr>
<tr>
<td>50</td>
<td>Moderate</td>
</tr>
<tr>
<td>25</td>
<td>Moderate</td>
</tr>
<tr>
<td>12.25</td>
<td>Scanty</td>
</tr>
<tr>
<td>6.25</td>
<td>Scanty</td>
</tr>
<tr>
<td>0</td>
<td>Scanty</td>
</tr>
</tbody>
</table>

*Richard's agar, Nutrient glucose agar, Brown's agar and Brown's starch agar.*
Fig. 54. Red rot of sugarcane.

a. Splitted cane showing reddened pith.
b. A cane sett showing the fruiting bodies of the fungus at the node.
Control measures.

Since the soils of canal colonies of the Punjab are alkaline and the fungus cannot grow in alkaline medium, 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.

4. RED ROT, *Colletotrichum falcatum* Went.

Red rot of sugarcane is a serious disease of *Ponda* cane (thick chewing variety) in the Punjab and is caused by the fungus *Colletotrichum falcatum*. The attack on thin varieties is generally slight. The disease first shows itself in the form of drooping and changing of colour of upper leaves when the plants approach maturity. 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 and show reddened tissue. The pith gradually dries up with the progress of the disease and ultimately rind falls in, thus giving rise to longitudinal depressions and the cane becomes very light. 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. 54).

It has been found that the disease in the Punjab is carried over from year to year by planting setts from diseased canes and also through the fungus which remains viable on diseased canes, lying in the fields after the crop is harvested.

In addition to planting of setts from healthy canes and destruction of diseased cane debris for the control of the disease, two varieties of *ponsa* cane which have been found resistant to the disease are recommended for growing. These are BFS 12(17) and B 6308. The former is late maturing while the latter matures with the local *ponsa* cane.

**SUMMARY**

Work carried out on smut, mosaic diseases, stem canker and red rot of sugarcane has been described. Smut is a common disease of thin varieties. The physiology of the causal fungus, *Ustilago scitaminea* Syd. 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 tried none has been found to be totally resistant to this disease, while there are a few varieties in which case the degree of resistance is quite tolerable. Factors affecting the incidence of the disease and control measures have been worked out.

Two types of mosaic diseases (ordinary mosaic and yellowing) have been studied. It has been found out that the ordinary mosaic is not harmful
on the varieties grown in the Punjab whereas yellowing mosaic causes much reduction in the yield of cane and its products. Number of varieties have been tested which have been found to vary in their degree of resistance. Out of 16 varieties tested by artificial inoculation, only Co.453 has been found to be less susceptible to yellowing mosaic. Maize and sorghum plants have been found to be alternate host plants for both the diseases. Physiology of both the viruses has been studied.

Studies carried out on chlorosis have shown that the disease is due to lack of photosynthesis and can be controlled by spraying the plants with 8% ferous sulphate or ferric chloride solution in water or by applying 1% solution of these salts in soil.

Stem canker, which is caused by Cytospora sacchari Butl. brings about drying of leaves from top downwards. The cane stem gets shrivelled up 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. Physiology of the causal fungus has been studied. It has been found out 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 Went. 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. In addition to planting of setts from healthy canes destruction of diseased cane debris is helpful for the control of the disease. Two varieties of Ponda (thick) cane which have been found to resist the disease are also recommended for growing.

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<td>5.</td>
<td>—</td>
<td>1940</td>
<td>Some studies on the physiology of <em>Cytospora sacchari</em> Butl., the causal fungus of stem canker disease of sugarcane. Proceed. Ind. Acad. Sci., Vol. XII, 172-188.</td>
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CHAPTER IV

DISEASES OF COTTON (*Gossypium spp.*)

Cotton is one of the most important cash crops of Western Pakistan. The importance of this is due to the fact that foreign exchange of Pakistan depends mostly on silver and golden fibers of cotton and jute crops. The normal annual production of cotton in Western Pakistan is 1.4 million of bales out of which 0.85 million bales are produced in the Punjab only from an area of about 1.9 million of acres. The balance is produced in the Province of Sind and State of Bahawalpur in the ratio of 2:1, respectively.

The cotton crop is subject to two important disease, viz., root rot and tirak (premature opening of bolls). Both these diseases are causing havoc to the cotton crop with the result that the Province is losing a great deal.

A brief account of the work carried out on these two diseases is given below. A mention has also been made about smalling of leaves in American cotton which broke out in early thirtees.

1. ROOT ROT, *Macrophomina phaseoli* (*Rhizoctonia bataticola* C strain) and *Rhizoctonia solani*. Khun. (15 to 29).

Root rot is prevalent throughout the cotton growing tracts of Western Pakistan. As the name implies the disease affects the roots exclusively, causing shredding of the root bark, producing, at first, wilting of shoots which ultimately results in the death of the entire plant. (Fig. 55). 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 rate of death of plants gradually declines and the disease almost ceases to appear by the end of September. Both American and desid (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% of the total area under cotton. A loss of eight million rupees is sustained annually by the Punjab alone.

The following important results have been obtained from the systematic investigation carried out for 9 years at Lyallpur, by a special research staff under a scheme sponsored by the Indian Central Cotton Committee.

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 dessication 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 even at 40°C and no growth occurs at 45°C even on this medium. The minimum temperature for both the fungi is below 20°C. They have very wide range of tolerance to acidity and alkalinity, i.e., between pH 2.4 and 9.2; they have fairly good growth between pH 3.2 and 8.5 and it is optimum near the neutral point.

*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* is increased in the presence of certain other fungi which are added in the inoculum.

Mercuric chloride 0.09%, copper sulphate 0.3% and phenol 0.5% 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 of 18 inches after 6 days and kills the sclerotia of both the fungi.

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.

Total and ammonical nitrogen, iron and the ratio of calcium and potassium are significantly higher in diseased than in healthy roots. The ratios of iron in leaf to iron in root and calcium in leaf to calcium in roots are lower in diseased plants and ratio of potassium in leaves to potassium in roots is higher in diseased than in healthy plants.

Cotton plants suffer higher mortality from root rot due to *Rhizoctonia solani* and *Rhizoctonia bataticola* at temperature of 35°C to 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.

There is no difference in the texture and the chemical composition of healthy and diseased soils except that the diseased soils contain higher amount of acid soluble calcium and have a higher calcium magnesium ratio.

Soil fumigation with calcium cyanide, para-dichloro-benzene, various cultural treatments such as 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 and ammonium sulphate plus superphosphate do not reduce the incidence of the disease. Similarly the addition of mineral elements such as borax, zinc sulphate and mangnesium chloride do not reduce 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.

Recent work, carried out on this disease, has shown that contrary to the results obtained under the scheme it has not been possible to produce infection by artificial inoculations with the fungi, viz., *Macrophomina phaseoli*—(*Rhizoctonia bataticola*) and *Rhizoctonia solani* both in field and in pots. Indications have also been obtained that there are some unknown factors which predispose the cotton plants to the attack of the causal fungi. This view is further strengthened by the fact that the disease appears in patches in the field and it always remains almost confined to those patches in spite of all the cultural operations carried out year after year. Even sometimes these patches have also been found to disappear which might
be due to the improvement of soil brought about by continuous cultural operations or by some other factors.

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 to the attack of the fungi. 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 explained as being due 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. Moreover, these methods of control although effective to some extent are open to the following two important objections:

1. 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.

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

Further work has been carried out in the Plant Pathological Section to establish connection of Rhizoctonia bataticola isolated from cotton plants and some other isolates of Rhizoctonia bataticola. The results obtained have been reproduced below:

During the investigations on root rot of cotton, Vasudeva could not produce pycnidia of Rhizoctonia bataticola artificially and therefore, failed to connect this fungus with any spore forming stage. Similarly forms of Rhizoctonia bataticola which occur commonly on tobacco (Nicotiana tabacum), citrus and chillies (Capsicum annum) in the Punjab, have not been connected before with any such stage. On Sesamum indicum, however, Rhizoctonia bataticola freely produces the pycnidial stage of Macrophomina Phaeola (Maulb.) Ashby. With a view to establishing the connection of Rhizoctonia bataticola occurring on these hosts with the sporing stage, inoculation experiments, 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 tubes at 30°C were carried out. 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 catjang*. 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 on citrus twigs both of these are produced less frequently.

Single pycnospore isolations from pycnidia of all the isolates have given sclerotial culture 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 academic and economic points of view. As far as academic point of view is concerned it is the first record of the establishment of the connection of *Rhizoctonia bataticola*, which, according to Vasudeva, is one of the two causal fungi of root rot of cotton in Pakistan and of *Rhizoctonia bataticola* occurring on tobacco, citrus and chillies with the pycnidial stage, *Macrophomina phaseoli*. According to another interesting finding it has been shown that pycnidia of many isolates of *Rhizoctonia bataticola* can be formed at will on twigs of living or dry sesameum plants. They can also be formed frequently on citrus twigs.

From economic point of view it is important to note that the inclusion of sesameum in the rotation in localities, where crops susceptible to *Macrophomina phaseoli* are grown, is dangerous. The sesameum plants attacked by the disease will infect the soil of large areas during a single season by means of the pycnospores, which will be formed on the plant and will be carried away by wind or rain splashings.

As already mentioned, Vasudeva has shown that *Rhizoctonia bataticola* freely attacks cotton and produces root rot, but the experiments carried out in the main Plant Pathology Laboratory, Lyallpur, tend to show that neither the isolates from cotton, nor those from tobacco, sesameum, citrus and chillies have been able to attack cotton. This view has been further strengthened by the results of experiments which are in progress at Lyallpur in collaboration with Agricultural Chemist. These results indicate that unless certain soil factors which may be in the form of hard pan or higher concentration of salts, are present, the fungus probably will not be able to attack cotton. If this view is upheld by further experiments, then the growing of sesameum in the cotton areas may not prove so harmful,
2. TIRAK OR PREMATURE OPENING OF BOLLS. (2 to 14).

Tirak of cotton is characterised by bad opening of the bolls and therefore the disease causes reduction in yield up to about 75% in years of epidemics. It affects both quality and quantity of the lint produced (Fig. 56). Work has been carried out on this disease under a special scheme sponsored by the undivided Indian Central Cotton Committee and the results of the findings are summarised below:

The break-down of the photosynthetic apparatus is found to occur prematurely in the leaves of plants that develop the external symptoms of the disease.

The accumulation of the tannins is found to occur in leaves of plants which later develop the reddening and shedding of the leaves and the bad opening of bolls. Such accumulation of tannins is not found to occur at any stage in leaves of normal plants. The leaves of plants from bad soil show the largest accumulation of tannins at early stage of growth while the leaves from plants grown on good soil do not show accumulation of tannins at any stage of growth and no bad opening of bolls occurs on these plants. The leaves from plants of medium soil show slight accumulation of tannins with low percentage of badly opened bolls.

![Diseased plants](image1)

![Healthy plants](image2)

Fig. 56. Tirak of cotton.
A positive test for tannins is given by the leaves of plants from the unmanured plots by the beginning of September while the test is negative from the leaves of the fertilized plants. A positive test for tannins in leaves of cotton plant in the Punjab at its flowering phase i.e. August and September is thus an index of nitrogen deficiency at that stage, which can be remedied by applying 2 maunds of ammonium sulphate per acre at that time. In late sown crops the tannins develop later in the leaves than those of the early or normal sown plants.

The soils where tirak occurs are found to contain abnormal amount of sodium salts i.e. 0.2% or more in the sub-soil from the 3rd or 4th foot downwards. Sodium in the soluble or exchangeable form is found to be higher than calcium. In such soils tirak occurs every time when cotton is grown there. If the quantity of total salts is 0.01 to 0.15%, tirak does not appear under favourable conditions of weather and under adequate water supply but it is developed on such plots in years of dry and hot weather or in the absence of adequate water supply.

The physical texture of soil, the sodium calcium ratio and the relative amounts of different sodium salts present are important soil factors that increase and decrease the intensity of tirak. Another type where tirak occurs is light sandy land which produces deficiency of nitrogen in plants at the flowering stage. In such soil, the tirak can be ameliorated by the application of ammonium sulphate.

Late sowing and application of extra water at the time of flowering and fruiting has proved to be successful in remediing tirak on soils which are not only sandy and deficient in nitrogen but are also saline or alkaline in the sub-soil. The application of nitrogen on such soils does not improve opening of bolls even though it raises the yield through more profused bearing. June sowing decreases the disease irrespective of the tirak promoting soil conditions. The yield results in late sowings are also favourable provided closed sowings are carried out.

The tirak years are characterized by hot and dry summer months.

3. SMALLING OF LEAVES IN AMERICAN COTTON. (1)

A survey was made on this disease during 1932-34 in the Punjab. The disease was found to be serious in the fields of Punjab Agricultural College estate. The incidence of the disease was above 40% 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 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 very 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 escaped infection. The disease was not found to be of hereditable nature. It could not definitely be established whether the disease was of physiological or virus origin.
Since then this disease has not been found to occur. It thus shows that the occurrence of the smalling of leaves in American cotton only was probably not a disease but was due to the effects brought about during the early acclimatization period of American cotton and, therefore, on account of its having been established the abnormal growth of the plants has disappeared.

**SUMMARY.**

This chapter includes the work carried out on root rot, *tirak* (premature opening of bolls) and smalling of leaves of cotton. Investigations carried out on root rot of cotton have shown that it is caused by *Macrophomina phaseoli* (*Rhizoctonia bataticola*) and *Rhizoctonia solani*, Khun. Physiology of these two fungi has been studied in detail and it has been found out that temperature ranging between 35-37°C. is optimum for their growth. Chemical analysis of the 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. Further studies carried out by the senior author have shown that there are some unknown factors which predispose the cotton plants to the attack of the fungi. This view is further strengthened by the fact that the disease appears in patches in the field and always remains almost confined to these patches in spite of all the cultural operations carried out year after year.

*Tirak* of cotton, which is characterised by bad opening of bolls, has been investigated in detail. Analysis of infected plants has shown that there is break-down of photo-synthetic apparatus in leaves and tannins develop. Largest accumulation of tannin occurs in plants grown either in alkaline soils or unmanured plots. Development of tannin has been correlated with the deficiency of nitrogen in soils or presence of abnormal amounts (0.2% or more) of sodium salts. Disease is also more 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.

Some preliminary investigations carried out on smalling of leaves in American cotton 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 thus has shown that smalling of leaves in American cotton was not probably a disease but was due to the effect brought about by the early acclimitization period of American cottons.

**REFERENCES**

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CHAPTER V

DISEASES OF RICE (*Oryza sativa* L.)

The rice crop 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 water table it is not possible to grow other crops. The districts of Gujranwala, Sialkot, Sheikhupura and parts of Lyallpur and Montgomery are very well suited for the cultivation of rice. The area put under this crop is about 700,000 acres annually. This crop is also subjected to many diseases out of which stem rot is very important and the results of the investigations carried out on this disease are given below:

1. **STEM ROT, Sclerotium oryzae** Catt. (1 and 2).

   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 brought about by this disease surpasses even 80 per cent or more. The average loss can be taken at 2\%.

**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 begin to rot. At this time the fruiting bodies (sclerotia) of the fungus appear as small black dots at the basis of dried leaves and certain leaf sheaths. At first a small darkish spot appears and then 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. 57).

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

Inoculation experiments carried out in pots as well as in field showed that the fungus *Sclerotium oryzae* was parasitic on rice plants.

**Modes of perpetuation.**

The disease is produced whether seed is sown directly or seedlings are at first grown in infected soil. Rice grown on land which carried a diseased crop in the previous year gets infected. (Table XX).
Fig. 57. Stem rot of rice plant showing:—

a. Rot of the first internode of a rice plant.
b. Rot of the second internode of a rice plant.
c. Rot of the third internode of a rice plant.
d. Sclerotia of *Sclerotium oryzae* on the base of a leaf sheath.
e. Sclerotia of *Sclerotium oryzae* inside the affected stem of a rice plant.
### Table XX. Results of infection experiments in pots.

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Total No. of plants</th>
<th>No. of diseased plants</th>
<th>Percent infection</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Showing stem</td>
<td>Showing drying of leaves at the bases</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>symptoms.</td>
<td>of plants.</td>
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<tr>
<td>1933</td>
<td>Soil infected with diseased rice stubbles</td>
<td>52</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Soil infected with pure culture of the fungus</td>
<td>56</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Soil uninfected (control)</td>
<td>112</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1935</td>
<td>Soil infected with diseased rice stubbles</td>
<td>52</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Soil infected with pure culture of the fungus</td>
<td>51</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Soil uninfected (control)</td>
<td>108</td>
<td>0</td>
<td>0</td>
</tr>
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</table>

**Variatel resistance.**

Nineteen varieties were tried and it was found out that they differed markedly as to their relative susceptibility to the disease. Varieties No. 14, 349, 346, 360, 390, 337/A, 202, 125, 278 were very 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 transplantations are carried out but they are not recommended on account of their 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 now and then the incidence of the disease is reduced to a great extent.

3. 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 where the diseased rice stubbles are not burnt.

SUMMARY

Rice crop occupies an important position amongst the food grain crops. It is subjected to many diseases out of which work has been carried out on stem rot. It has been found out that 2 to 3 months old plants start withering and drying. Stem near the soil level begins to rot 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 whether seed is sown directly in infected soil or seedlings are at first grown in infected soil and then transplanted in healthy soil. Rice grown in land, which carried a diseased crop in the previous year gets infected. Varietal resistance trials have shown that varieties differ markedly as to their relative susceptibility to the disease. Work has also been conducted with a view to finding out other suitable control measures.

REFERENCES


CHAPTER VI
DISEASES OF SORGHUM (Andropogon sorghum Brot).

The sorghum or jowar crop is one of the important crops of the Punjab as it serves a dual purpose, being used for fodder as well as grain. Jowar is a kharif crop and is sown in March-April and harvested in July-November. It occupies an important position in the districts of Multan, Dera Ghazi Khan and Muzaffargarh where it is mostly used as a grain crop. This crop is subjected to a number of fungal diseases which bring about heavy losses. Some of the diseases like grain smut, red leaf spot and long smut have been under investigation for a number of years. The results of importance are summarized below.

1. GRAIN SMUT, Sphacelotheca sorghi (Link) Clint. (2).

Grain smut of jowar is essentially a disease of grains, which instead of starch contain a black mass of spores (Fig. 58). This disease is very commonly met with in almost all the fields put under this crop. Although

Fig. 58. Jowar head infected with grain smut.
no exact data are available regarding the incidence of the disease, it is safe to assume the average percentage of infection as 3—10.

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 one chatank (2 oz) per 15 seers of jowar grains. Treatment of the seed with formalin solution (one part of formalin in 320 parts of water) is also very efficient to get rid of the disease. In addition to this the following useful cultural methods of control have been developed.

The disease can be checked by about 70—90 per cent when jowar seed is broadcast on dry soil to which water is applied immediately after sowing.

The date of sowing exercises a great influence on the incidence of the disease. The percentage of attack is the highest (23.7%) when jowar is sown in the month of May, soil temperature being 90-95°F, while the incidence of the disease varies from 1-2% in sowings carried out during the month of June when the soil temperature is 100-102°F.

Fig. 59. Jowar heads infected with long smut.
2. **LONG SMUT, ** *Tolyposporium filiferum* Busse. (1).

Long smut of jowar was first recorded in 1930 from Dera Ghazi Khan. It is also prevalent in the districts of Multan and Muzaffargarh. The incidence of the disease on an average comes to 5 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. The spore sacs are cylindrical in appearance, their size varying from 6 to 28 mm. in length. (Fig. 59).

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

**Modes of perpetuation.**

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

(i) By sowing contaminated seed in the soil.

(ii) By sowing seed in the soil, which is contaminated with the spores in the previous season.

(iii) The secondary infection in the same growing season also takes place either from the spores shed in the soil in the previous year or from the spores produced in the infected sacs in the same year.

**Germination of spores.**

The spores start budding after 3½ 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 25-35°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 to 3 per cent) are suitable media as far as germination is concerned, but glucose peptone solution is not good for sporidial formation.

**Effect of toxins.**

The spores in the separated form are killed:—

(i) By dipping them in either 1.0% or 0.5% copper sulphate solution for 1 minute and 10 minutes respectively.

(ii) By dipping them in 1.0% or 0.5% mercuric chloride solution for 1 minute and 5 minutes respectively.

*There are two types of spores—big sized (14-16 µ) and small sized (6-8 µ). Big sized spores could not be germinated during these experiments.*
(iii) By treating them in formalin solution from 1:320 to 1:640 strengths and covering them under moist cloth for 2 hours.

The spores in the broken sacs are killed:

(i) By dipping them in 3% mercuric chloride solution for 10 minutes.

(ii) By immersing them in 1% ammonia liquor without covering or in formalin solution (1:320) with covering.

**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 sowing 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 either it is unfavourable or less favourable. The unfavourable temperature consequently checks or reduces seedling 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 crop sown in April and May fall in the rainy weather.

**Control measures.**

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

(i) Seed should be obtained from healthy crop.

(ii) Seed should be treated with copper carbonate at the rate of 1 chank (2 oz.) per 15 seers of jowar grains, as this will help in reducing the seed borne infection.

(iii) Infected sacs should be destroyed by carefully picking and burning them, as far as possible.

(iv) A few years' rotation should be followed, if possible.

(v) Type 20 has been found to be fairly resistant to the disease. It should be grown wherever agricultural conditions permit.

2. **RED LEAF SPOT, Phyllosticta sorghina Sacc. (3)**

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 diseases of jowar as it causes quite a good deal of damage to this crop. Small red spots appear on the leaves and stems which later on join up and give rise to large infected areas which ultimately result in the drying up of the plants. (Fig. 60).
Fig. 60. Red leaf spot of jowar.

(a) Diseased stem of jowar.
(b) Diseased leaf of jowar.
(c) Leaves of jowar showing typical spots produced by the fungus *Phyllosticta sorghina* Sacc; after 15 days of artificial inoculation.

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.

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 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 15°C respectively (Fig. 61). The spores are killed when they are immersed in 1.1% copper sulphate solution for one minute or in 0.01% mercuric chloride solution for 2 minutes. The thermal death point of the spores is 68°C.

4. RED LEAF SPOT, *Colletotrichum graminicolum* Ces. (3).

This disease is more common than the *Phyllosticta* leaf spot of jowar and has been doing much damage to the jowar crop. The symptoms are essentially the same as described for the *Phyllosticta* leaf spot of jowar. Studies carried out on the disease during 1946—48 have yielded the following important results:

The causal fungus of the disease has been found to be *Colletotrichum graminicolum,*
Fig. 61. (a) Pycnidia of *Phyllosticta sorghina* Sacc; after 15 days of artificial inoculation.
(b) Conidia of *P. sorghina*.
(c) Germinated conidia after 24 hours of sowing.

The fungus has not been found to sporulate throughout its cultural studies on other media* except a very small amount of spores is produced in case of the 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.

**Modes of perpetuation.**

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

(a) By sowing seed artificially contaminated with conidia.

(b) 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.

(c) By diseased plant debris lying in the soil.

**Control measures.**

The following methods have been recommended for controlling the disease:

(a) By sowing healthy seed or seed treated with hot water, which consists in soaking the seed in ordinary water for 4 hours and then immersing it in hot water for 1½ hours at 130°F.

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*Oatmeal agar, Richard’s agar, Brown’s agar, Brown’s starch agar, glucose peptone agar, nutrient glucose agar.*
(b) By careful removal and destruction of the diseased plant debris. Work is in progress to find out some suitable resistant varieties.

SUMMARY

Work carried out on grain smut, long smut and red leaf spot diseases of sorghum is given in this chapter. Grain smut of sorghum 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 jowar seed is broadcast on dry soil and water is applied immediately afterwards. The date of sowing has also got a great influence on the incidence of the disease. Sowings carried out during June, when soil temperature is above 100°F tend to reduce the incidence of the disease considerably.

Long smut of jowar which causes a good deal of damage in South-Western districts of the Punjab has been investigated for the first time as regards its life history, which was so far unknown to the scientific world. 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). 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 months of April and May and the crop sown in June is either free from the disease or the incidence is considerably reduced. Control measures have been discovered which include disinfection of seed, destruction of diseased heads and a few years' rotation. Work on varietal resistance is in progress.

Work carried out on red leaf spot diseases has shown that there are two types, one caused by Phylllosticta sorghina Sacc. and the other by Colletorichum graminicolum Ces. 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 of seed in ordinary water for four hours and then immersing it in hot water for 1½ hours at 130°F. Careful removal and destruction of the diseased plant debris is also very helpful in checking the disease.

REFERENCES

CHAPTER VII

DISEASES OF PULSES (Phaseolus spp.)

*Mung* (Phaseolus radiatus), *moth* (Phaseolus aconotifolius) and *mash* (Phaseolus mungo) constitute the important pulse crops of the Punjab. The total area under these crops is about 6.5 lac acres. 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. (1-2)

The disease affects leaves, leaf stalks, twigs and pods and the symptoms are like those produced in gram blight disease.

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

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

Spores of both the fungi germinate within 6-8 hours of sowing. In fungus (B) septa appear in about 70 per cent 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 fungus (A) but with the fungus (B) only on *mung* and *mash*. Fungus (A) can attack all the four species of *phaseolus* and *sesamum indicum* to a slight extent while fungus (B) attacks both *mung* and *mash*. Fungus (A) has proved to be comparatively more virulent than fungus (B).

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.

The disease is perpetuated either by sowing infected seed (seed containing hybernating 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.

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 jowar or bajra (Pennisetum typhoideum) can check the spread of the disease to a great extent.

2. ANTHRACONOSE, Gloeosporium phaseoli Rich (1 and 2).

The disease affects leaves, leaf stalks, stems and pods. The diseased spots are scattered to begin with but later on they may join up giving rise to broad lesions and ultimately the areas lying below the infected spots become dead. The leaves sometimes become torn. The petiole may become so badly affected that it cannot support the leaf. Similarly seedlings from badly diseased seeds show blackened cankers on the cotyledons.

The causal fungus has been identified as Gloeosporium phaseoli.

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°C-35°C and 10°C-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.

Use of healthy seed and destruction of diseased plant debris are helpful in getting rid of the disease.

SUMMARY

Mung, (Phaseolus aconotifolius), moth (P. radiatus) and mash (P. mungo) constitute the important pulse crops of the Punjab. 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 Sacc. and Ascochyta phaseolorum Sacc. The physiology of both the fungi has been worked out. 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 (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 are helpful in checking the disease.
Anthracnose of pulse crops has been found to be due to *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. Use of healthy seed and destruction of diseased plant debris are helpful in checking the disease.

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2. (Manuscript) Some studies on the blight diseases of some cultivated species of *Phaseolus* in the Punjab. II. Factors affecting the incidence of the diseases and their control measures.
CHAPTER VIII

CULTURAL METHODS OF CONTROLLING CERTAIN SMUT DISEASES. (1-4)

Work carried out in this direction has shown that the following factors are very important in influencing the percentage of infection in smut diseases belonging to seedling infection group and by adopting certain cultural modifications it is possible to control them to a great extent. Before discussing these factors it may 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, where 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, a fortnight earlier than the normal time of sowing, when the soil temperature is above 28°C, there is almost no infection in the crop, while the attack is 70 to 80% if the sowings are delayed up to 3rd week of November, when the temperature varies from 15°C to 18°C and is, thus, suitable for the germination of the spores. Similarly, as already mentioned in the text, in the case of 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. Thus it is seen that, by merely changing the date of sowing, crops can be saved from the ravages of these diseases. It is, because like seeds of higher plants, the spores have also got optimum temperature for germination. Hence, the infection will be influenced by the soil temperature at the time of sowing in the case of smut diseases belonging to seedling infection group.

Soil moisture.

Soil moisture has also been found to play a very important role on the germination of the spores and ultimately on development of diseases. The results of the 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 per cent soil moisture while the attack is quite high in soils with medium and low moisture contents. The disease can also be reduced to a great extent when wheat is sown in dry soil to which water is applied immediately after sowing. The application of water, if delayed up to 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 it becomes normal when water is applied 7 days after sowing. It may be noticed
here that soil moisture contents are increased only with a view to creating 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, infection in smuts, which belong to seedling infection group, can only take place between germination and emergence period. Subsequently there will be 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 also one of the controlling factors as when it is increased the seedlings take longer to emerge and are exposed to infection for a greater period (Fig. 62). On the other hand, the shallower the seed is sown, the lesser will be the infection. This hypothesis has been proved by the results obtained from the experiments carried out on flag smut of wheat, bunt of wheat, covered smuts of barley and oats and grain smut of sorghum. It has been seen that the incidence of the disease is greatly reduced by decreasing the depth of sowing.

Fig. 62. Diagramatic sketch showing seedlings emerging out from seeds sown at different depths.

Methods of sowing.

Different methods of sowing have been studied with a view to finding out those with which it is possible to sow the seed very shallow and to maintain high soil moisture contents during the germination period so as to combine the beneficial effects of both of these factors. It has been seen that the best results are obtained when seed is broadcast on the surface of the soil, which is raked and watered immediately after sowing. By adopting this method of sowing 70 to 90 per cent reduction in the incidence of the disease is obtained in the case of flag smut of wheat, covered smuts of barley and oats and grain smut of jowar. (Table XXI).
Table XXI. Effect of moisture content of soil and methods of sowing on the incidence of certain smut diseases.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Vattar sown kera</td>
<td>4.4</td>
<td>82.4</td>
<td>33.8</td>
<td>54.2</td>
<td>16.4</td>
</tr>
<tr>
<td>Dry sown kera</td>
<td>0.6</td>
<td>60.9</td>
<td>7.0</td>
<td>14.0</td>
<td>5.3</td>
</tr>
<tr>
<td>Vattar sown broadcast</td>
<td>2.5</td>
<td>44.2</td>
<td>..</td>
<td>11.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Dry sown broadcast</td>
<td>..</td>
<td>22.3</td>
<td>..</td>
<td>7.0</td>
<td>2.9</td>
</tr>
</tbody>
</table>

On comparing these results with those obtained from seeds of the respective crops dusted with the different chemicals it was found out that the seed-borne infection could be checked somewhat more effectively in the latter case. But the points in favour of cultural methods are that they cost nothing and at the same time they are foolproof and can thus be easily adopted by the farmers, who on the other hand cannot handle the poisonous chemicals, the use of which has so far been advocated. The last but not the least important point is that the soil-borne spores cannot be killed by chemicals dusted on the seeds. The cultural methods of control, therefore, stand a very good chance of becoming popular with our farmers in such cases.

SUMMARY

Some studies have been carried out on controlling smut diseases by cultural methods. It has been found out that soil temperature, soil moisture and depth of sowing play very important role on the incidence of those smut diseases in which case infection takes place in seedling stage. As far as soil temperature is concerned, it has been found out that the infection is the highest when sowing is done at such a time when the soil temperature is optimum for germination of spores. Suitable soil temperatures for obtaining disease free plants differ with different crops. In the case of flag smut of wheat when the soil temperature is about 28°C there is almost no infection, while the attack is 70-80% if sowings are delayed upto 3rd week of November. Hence by changing time of sowing smut diseases can be controlled. Regarding soil moisture, it has been found out that if the soil moisture during the germination period is increased beyond 18 to 22% the infection does not take place because the spores fail to germinate on account of high moisture content of the soil, while the seeds of crops can germinate and by the time the spores are able to germinate, the seedlings become resistant to infection. Experiments carried out on
depth of sowing have shown that the incidence of the disease increases with the increase in the period of seedlings’ pre-emergence, which is in turn affected by depth of sowing. Hence at the shallower depths of sowing the incidence of the disease is very much reduced. Different methods of sowing have been studied with a view to finding out those with which it is possible to sow the seed very shallow and maintain high soil moisture contents during the germination period so as to get disease free crops. It has been seen that the best results are obtained when seed is broadcast on the surface of the soil, raked and watered immediately afterwards. By adopting this method of sowing 70-90% reduction in the incidence of the disease is obtained in the case of flag smut of wheat, covered smuts of barley and oats and grain smut of sorghum.

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CHAPTER IX

DISEASES OF OILSEEDS AND OILSEED CROPS

Oilseed crops include all those crops which are well known for their high oil contents and are, therefore, cultivated throughout the Punjab with a view to meeting the need for vegetable oils of the Province. The importance of these crops has been still enhanced on account of partition of the Punjab as the greater percentage of the area under these crops has gone to the lot of East Punjab. The work has been in progress on some of the important diseases like wilt of linseed, storage diseases, blight, root and stem rots and wilt of groundnuts.

1. WILT OF LINSEED, *Fusarium lini* Bolley. (2).

Linseed wilt is one of the very important fungal diseases of this crop. The extent of damage goes as high as 50-80 per cent 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. (Fig. 63). The disease has been found to be caused by the fungus *Fusarium lini*.

![Fig. 63. Wilted and healthy linseed plants.](image-url)
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 a 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 N12, N14, NIB, 2N, 4N 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 di-hydrogen 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 while it is 18.3 x 3.6 µ at 20°C and 20.2 x 3.6 µ at 35°C. Bigger-sized spores are produced at 4.4 to 6.4 pH values and comparatively small-sized spores at the remaining pH values.

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 up to 68 after 8 hours. Nutrient solutions such as sodium chloride, potassium sulphate, potassium chloride, potassium nitrate and glucose are quite good for the germination of spores.

The appearance of the disease in infected soil is the quickest at temperatures of 25°C and 30°C whereas it is bit slowed down at 20°C and 35°C.

The disease starts appearing earlier at 9 and 12 per cent moisture contents of soil while it takes a few days more for the disease to appear at 15 and 18 per cent moisture contents of soil.

The incidence of the disease is the greatest in early sowings carried out on 5th to 25th of October than in the case of late sowings done during the month of November, which is due to low soil temperatures present in the latter case. (Fig. 64).

The incidence of the disease is reduced by 21% 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 per cent toluene, 2% 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 per cent respectively.

Out of 223 crosses and varieties of linseed tried in naturally highly infected soil, 64 varieties have so far shown a great degree of resistance towards wilt disease. These 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.


2. STORAGE DISEASES OF SARSON (Brassica campestris), TORIA (Brassica napus), LINSEED (Linum usitatissimum) and GROUNDNUT (Arachis hypogaea) (1).

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

Conditions of storage.

Sarson. 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 sem areas (areas where water table is high) are damp. In villages the local oil seed crushers store only a small quantity of seed in gunny bags on kacha flooring. This type of storing does not matter to them as they generally consume the stock within a few days.

Toria. 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. 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 fashion as sarson and toria.

Groundnut. 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 caused by storage diseases.

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 of rotting. The cotyledons of rotten seeds turn brown. Oil content of rotten brassica oilseeds often decreases to nil. The percentage of rotting varies according to conditions of storage. It has been found to vary from 4 to 42 per cent in different stores with an average of 14 per cent.

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 causes 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 good deal of reduction in oil contents. Apparent damage done to groundnut in storage varies from 5 to 38 per cent.

**Study of the 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 bring about a good deal of 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 testas of the seeds become soft at higher humidity and are, therefore, easily attacked by 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 from below coming in 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.

3. **BLIGHT OF BRASSICA, Alternaria brassicae** (Berk.) Sacc.

Blight is a common disease of brassica causing spotting on leaves, branches and twigs (Fig. 65.) with the result that the plants are heavily damaged. The incidence of disease is severe in heavy and closely planted crops but light in poor and thin sown crops.

The disease has been found to be carried over from year to year by either sowing infected seed which contain hibernating mycelium of the causal fungus or by the spores which remain viable in diseased plant debris of the previous year's crop.
The mycelium in the seed is killed by soaking the seed in hot water at 122°C for 10 minutes.

Spraying with Bordeaux mixture (4:4:50) is quite effective in checking the spread of the disease. The economics of spraying, however, requires to be worked out.

4. WILT OF TORIA, *Fusarium* sp.

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

The optimum, maximum and minimum temperatures for the 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.

5. ROOT ROT AND WILT DISEASES OF GROUNDNUT, *Rhizoctonia bataticola* and *Fusarium* sp. (1).

Root rot and wilt diseases have been found to cause 5 to 100 per cent damage to the groundnut crop in the districts of Ludhiana, Hoshiarpur and
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.

The varietal trials have shown that all the three improved Punjab types A2, B1 and D3 are susceptible to both the fungi.

6. STEM ROT OF GROUNDNUT, Diplodia sp.

This disease is characterised 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 diseased specimens. This has been proved to be pathogenic on groundnut plants. Further work is required to be carried out with a view to finding out some suitable control measures.

SUMMARY

Oilseed crops are attacked by many diseases out of which work has been carried out on wilt of linseed, storage diseases of sarson, linseed, toria and groundnut, blight, root and stem rot and wilt of groundnut. Wilt of linseed has been found to be caused by Fusarium lini Bolley, the physiology of which has been worked out in detail. It has been found out that the incidence of disease is the highest in early sowings carried out on 5th to 25th of October. The disease is reduced considerably by carrying out sowings in dry soil to which water is applied immediately afterwards. The seed disinfectants tried have failed to control the disease while soil disinfectants like toluene and formaldehyde tend to reduce the attack. Out of 223 crosses and varieties of linseed tried 64 have shown a great degree of resistance.

Storage diseases of sarson (Brassica campestris), toria (B. napus), linseed (Linum usitatissimum) have been studied and it has been found out that a good deal of damage is done to these crops in storage due to abnormal temperature and high humidity of the store houses. Four different types of fungi namely, Aspergillus spp., Penicillium spp., Fusarium spp. and Rhizoctonia spp. have been isolated and inoculation experiments carried out under suitable conditions of humidity and temperature have been successful in proving the pathogenicity of these fungi. On the basis of work done regarding factors affecting the incidence of the disease control measures have been devised. Studies have also been carried out on blight of Brassica which is caused by Alternaria brassicae, root and wilt diseases of groundnut caused by Rhizoctonia bataticola and Fusarium spp. and root rot of groundnut produced by Diplodia spp.

REFERENCES

CHAPTER X

DISEASES OF TOBACCO (Nicotiana tabacum)

Tobacco crop provides a good deal of profit to the farmers of the Punjab in addition to satisfying their need of smoking. This crop is very susceptible to a number of virus and fungal diseases out of which some studies have been carried out on root and stem rot disease with the following results:

1. ROOT AND STEM ROT, Macrophomina phaseoli and Rhizoctonia solani Kuhn. (1-3).

One of the important fungal diseases of this crop is root and stem rot which has been found to be doing a lot of damage to this valuable crop. As the name implies the roots and stem show rotting symptoms with the result that ultimately the affected plants wilt. (Fig. 66).

Fig. 66. Healthy and root-rot affected tobacco plants.

Two fungi have been found to cause this disease. They have been identified as Macrophomina phaseoli (Rhizoctonia bataticola C strain Haigh) and Rhizoctonia solani Kuhn.
Physiology of the fungi.

The linear colony growth of *Macrophomina phaseoli* is increased with the quantity of medium used while *Rhizoctonia solani* produces good linear colony growth on all the depths of media tested.

*M. phaseoli* likes rich medium while *R. solani* produces the largest colony growth on comparatively poor medium.

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*.

*M. phaseoli* likes normal Richard's agar and its growth falls at higher and lower concentrations while *R. solani* does well on lower concentrations like N|2, N|4 and N|8.

The growth of both the fungi is the highest at pH 4.4-4.8. It declines very sharply in the case of *Macrophomina phaseoli* with even a slight change in reaction while in the case of *Rhizoctonia 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.

In the case of *Macrophomina phaseoli* sclerotial formation is maximum on Richard's agar and in the case of *Rhizoctonia 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. Moreover, for *Rhizoctonia solani* comparatively lower concentrations are suitable for sclerotial formation.

The size of sclerotia of *Rhizoctonia solani* is 317-110 x 236-131 μ and that of *Macrophomina phaseoli* is 80-174 μ x 76-121 μ.

Sclerotia of *Macrophomina phaseoli* are killed in 0.05% mercuric chloride solution when steeped for 10 minutes and in 0.1% if steeped for 5 minutes while the sclerotia of *Rhizoctonia solani* require 10 minutes steeping in 0.2% 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 point of *Macrophomina phaseoli* lies between 75-80°C and that of *Rhizoctonia 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.
Macrophomina phaseoli produces sclerotia both on the host and in culture media while Rhizoctonia 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 (the seed of this type is not available in Pakistan at present) 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 1-2 tons per acre makes the soil alkaline and the attack of the disease is considerably reduced in the case of Rhizoctonia solani and is almost checked in the case of Macrophomina phaseoli.

The host range of the fungi has been worked out. Macrophomina phaseoli has been found to attack the following plants which are arranged in the descending order of their susceptibility:

- *Sesamum indicum.*
- *Arachis hypogaea.*
- *Citrullus vulgaris var. fistulosus.*
- *Cucumis melo'utilissima.*
- *Phaseolus radiatus.*
- *Zea mays.*
- *Glycine hispida.*
- *Vigna catjang.*

Rhizoctonia solani attacks the following plants:

- *Vigna catiang.*
- *Arachis hypogaea.*
- *Cucumis melo.*
- *Citrullus vulgaris var fistulosus.*
- *Zea mays.*
- *Citrullus vulgaris.*

**SUMMARY**

Tobacco crop is subjected to a very serious disease 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 Haigh) and *Rhizoctonia solani* Kuhn have been found to cause this disease. Physiology of the fungi as regards growth rate, aerial mycelium, sclerotia formation has been studied. Inoculations have been carried out on many plants and host range has been worked out. Inoculation

Generally Punjab soils are alkaline but they tend to be acidic due to acid secretions from the roots of tobacco plants.
experiments have been conducted on 104 varieties of tobacco and out of these type 244 has been found to resist the attack of both the fungi. The application of lime @1-2 tons per acre makes the soil alkaline and thus the attack of the disease is considerably reduced.

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CHAPTER XI
DISEASES OF VEGETABLES

Vegetables constitute a very important aspect of farming as these crops bring about a good deal of profit to the farmers. They are mostly grown near big towns both in kharif and rabi seasons. The number of vegetables is very great and they are subjected to many fungal diseases. Investigations have been carried out only on some diseases of potatoes, bhindi and chillies. The results of these investigations have been reproduced below:—

1. TUBER ROT OF POTATOES, *Fusarium* spp. (3-5).

The potato crop, which appears to have been introduced in the hilly tracts of the Punjab in the middle of 19th century, is now one of the most important vegetable crops of the country. The total area under this crop in the Punjab is about 7,000 acres. However, considering the importance of the crop, the area is rather small. This is mainly due to the fact that the cost of seed and manures is very high and proper irrigation facilities are not available everywhere and, therefore, every farmer cannot afford to take up the cultivation of this crop. One of the outstanding reasons for the high cost of the seed potatoes is the loss brought about by tuber rot of potatoes.

**Symptoms.**

In the Punjab the symptoms differ according to the conditions under which tubers are stored. Thus in tubers stored at high temperatures of 35 to 40°C the rot is always wet, while at lower temperatures, generally dry rot results. In wet rot brown discolouration appears on the surface which spreads and involves the whole tuber. The diseased tissue becomes soft and can be crushed easily and gives out drops of brown liquid having an offensive smell. In the case of dry rot, sunken, shrivelled or wrinkled areas occur on the surface of tubers. These affected areas are brown to black in appearance but sometimes growth of the causal fungus appears on them. When such tubers are cut open, cavities are noticed lined with the mycelium of the fungus. The tubers exhibiting dry rot symptoms, are finally transformed into dry, somewhat hard, crumbling masses of greyish colour. (Fig. 67).

**Cause of the disease.**

There are two main causes of the disease.

(i) The disease has been found to be caused by the following two species of the fungus *Fusarium*:—

(a) *Fusarium angustum* Sherb.

(b) *Fusarium oxysporum* Schl.
(ii) In tubers stored at high temperature of 35°C or above, wet rot is produced even in the absence of the causal fungi.

**Fig. 6. Tuber rot of potatoes.**

**Physiology of the fungi.**

The maximum temperature for the growth of the fungi 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 fungi produce abundant linear colony growth on 2N to N/4 concentrations of Richard's agar; on 4N and N/8 the growth falls somewhat but on 8N it is almost half of that produced at N.

The amount of aerial mycelium is almost the same on all the concentrations of Richard's agar except at 8N and 4N.

The amount of aerial mycelium is abundant on all the temperatures varying from 15-30°C but at 35°C and below 15°C the amount is much less.

Aerial mycelium is maximum at pH 4.0 to 4.8 although the amount is also good on other pH values.
The colony colour of both the fungi is almost creamy white. In the case of fungus (b) it becomes pinkish in constant light and ochreous salmon on Richard's agar.

The amount of sporulation is almost the same at 25°C and 30°C, but at 35°C and below 15°C it is much less.

Abundant sporulation is produced at pH values varying from 4.0 to 8.0; it is minimum at 9.4.

In the case of fungus (a) the mean length and the mean breadth of the macrospores on different media varies from 20.2 to 26.2 x 2.1-2.9 μ and those of the fungus (b) from 29.2 to 34.0 x 3-3.63 μ.

The average size of microspores of fungus (a) varies from 7.9 to 10.0 x 2.1-2.9 μ and that of fungus (b) from 9.3-10.0 x 1.8-2.1 μ.

The spores of fungus (a) are 0-4 septate and those of fungus (b) 0-5 septate.

In both the fungi septation is less at higher temperatures than at lower ones.

The spores start budding when sown in distilled water after 30 and 40 minutes in (a) and (b) respectively, and the germination is maximum after 6 hours of sowing.

The minimum strengths of mercuric chloride, formalin and copper sulphate solutions required to kill the spores of the fungi when they are soaked in these solutions for 5 minutes are 0.025%, 1:320 and 0.25% respectively.

**Recommendations for the control of the disease.**

Recently some cold stores have been constructed both through the efforts of Government and private firms but they need further extension. On the basis of the work carried out, the following suggestions are made which should be considered before bringing the potato tubers in the stores:

**Selection of suitable variety.**

It has been established by actual inoculation experiments that varieties of potato differ considerably as regards their relative susceptibility to tuber rot. The relative susceptibility of the varieties tested is given below: —

<table>
<thead>
<tr>
<th>Variety</th>
<th>Percentage rotting</th>
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</thead>
<tbody>
<tr>
<td>Kangra local</td>
<td>25.0</td>
</tr>
<tr>
<td>Patna white</td>
<td>25.0</td>
</tr>
<tr>
<td>Factor</td>
<td>37.0</td>
</tr>
<tr>
<td>A-Pilot</td>
<td>50.0</td>
</tr>
<tr>
<td>King George</td>
<td>62.5</td>
</tr>
<tr>
<td>President</td>
<td>62.5</td>
</tr>
<tr>
<td>Kers pink</td>
<td>75.0</td>
</tr>
<tr>
<td>Darjeeling red</td>
<td>75.0</td>
</tr>
</tbody>
</table>
It is, therefore, suggested that the varieties which are relatively less susceptible to the disease, but otherwise possess suitable characters as regards yield and quality, should be selected for growing so that when stored for seed purposes they keep comparatively better.

Selection of crop free from early blight and other diseases.

In the Punjab, early blight (Alternaria solani) of potatoes often attacks the crop in the field and sometimes causes a considerable loss. It has been found that tubers from the crop attacked by early blight rot considerably more in storage than those got from healthy crop. It is, therefore, necessary that, for storing, the seed tubers should be obtained from healthy crop which can be kept free from early blight by spraying with 4 : 4 : 50 Bordeaux mixture.

Similarly, tubers required for storing should also be obtained from potato crop free from wilt disease, the organism of which is also responsible for causing tuber-rot in the stores. Unfortunately the temperature conditions for the development of wilt disease are suitable in the spring crop from which tubers are required to be stored for raising the autumn crop.

Another point which needs mention is that usually potato tubers of small size are selected for storing. In doing so, potato tubers from mosaic affected plants are also selected unintentionally because of their small size. It is, therefore, necessary that potatoes for storing should be selected only from crops free from virus diseases.

Selection of tubers of suitable maturity.

As the tubers reach maturity they become more resistant to tuber rot disease. It is, therefore, recommended that tubers required for storage should be dug up, when they are fully mature.

Selection of sound and healthy tubers.

Wounded and bruised tubers rot more quickly than sound and healthy ones. It is, therefore, evident that for storing only sound tubers should be selected and hence the potatoes required for storage should be dug up very carefully:

Surface sterilization of potato tubers.

The causal fungus of the tuber rot disease lives in the soil also. It is, therefore, possible that the tubers at the time of digging up may be contaminated with the spores of the fungus. It seems, therefore, advisable that potatoes required for storage should be disinfected either in 0.025% mercuric chloride or 0.25% copper sulphate solutions or in a solution containing one part of formalin in 320 parts of water for 5 minutes. In the latter case these should be kept covered under moist cloth for 2 hours after taking them out from the solution.
Disinfection of store-rooms.

The store-rooms should be disinfected before potato seed tubers are brought into them. Disinfection of the store-rooms can be done either by spraying the rooms with formalin solution (one part in 320 parts of water) or by burning sulphur at the rate of half a pound per 1,000 cubic feet space of the room.

Storing at suitable temperature.

It has been found out that if the temperature of the store-room is maintained at about 12-15°C, tuber rot is reduced to negligible proportions. Investigations are, however, required to be conducted to find out a practicable method of maintaining this temperature in store-rooms. In this connection the practicability and economics of the following three methods should be considered:

(i) Potatoes grown in lower hills, where the crop is harvested in June, may be stored there for 2 months and sent down to the plains at the time of planting. The temperature in such places varies between 20-25°C during July and August. It requires investigation to find out a practicable method by which the temperature may be lowered down by 5-10°C in order to avoid rotting.

(ii) Near some big potato growing centres in the plains there are localities at a distance of 40 miles or so, where the temperature during summer remains fairly low. It may be possible that after the crop is harvested in May, the tubers can be sent to such cooler places, stored during summer and brought down to the plains in September at the time of planting.

(iii) Cold stores may be constructed in the plains for storing of tubers during summer. The possibility of storing the potato tubers in the ice factories as side business should also be investigated. It may be mentioned here that some cold stores have been recently opened in the plains, for storing potato tubers.

2. WILT OF POTATOES, Fusarium sp. (2 and 5).

The first traces of the disease are visible when the plants are about a foot high. Affected plants show yellowing, wilting and drying up of the leaves. In badly affected plants root-lets and root hairs get rotted. A transverse section of the affected root-let shows delicate filaments of the fungus in xylem bundles under the microscope. Under conditions of plenty of moisture and high temperature the disease makes rapid progress.

Wilt of potatoes is known to occur in all the potato growing countries of the world and is caused by different species of Fusarium. The work on
this 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 an appreciable amount of seed potatoes was being obtained previously for sowing the autumn crop in the plains. Since the establishment of Pakistan we have been confronted with a similar problem even in a more serious form as the potato seed supply in Western Pakistan is interlinked provincially because the farmers of the Punjab have to obtain seed potatoes for their spring crop from Baluchistan (where this crop has favourable conditions for the development of wilt disease) which in turn is dependent for her seed supply on the autumn crop of the Punjab. A scheme is under the active consideration of the Central Government of Pakistan to produce and distribute disease-free seed of potatoes in Western Pakistan. This work has a direct bearing on the solution of the problem. The results of the investigations carried out on this disease show that in the Punjab, the disease is caused by *Fusarium* species which was identified by Dr. Bisby of Imperial Mycological Institute Kew, London, as *Fusarium oxysporum* Schl. It is clear from the pathogenicity tests that the plants cannot be artificially infected in the autumn crop while the disease can be 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 temperature is probably the governing factor which is favourable for the development of the disease in the spring crops as it is almost the same temperature which has been found to be optimum for the growth of the fungus under the experiments carried out in the laboratory. The following are some of the main conclusions drawn from the cultural experiments carried out on the fungus in the laboratory:—

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 3N4 concentrations of Richard's agar, at higher concentrations the growth is very much reduced.

The amount of aerial mycelium is almost the same at temperatures varying from 15°C-30°C.

The amount of aerial mycelium is maximum at pH 4.0 and 4.8 and is fairly good up to 9.4.

The amount of sporulation is good at 25°C and 30°C but it is very little 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.

The germination percentage of spores at 25° C reaches a figure of 60-70 after six hours. The germination can occur at a wide range of pH values.

The minimum strengths of mercuric chloride, formalin and copper sulphate solutions required to kill the spores of the fungus when they are soaked for 5 minutes are 0.25%; 1 part in 320 parts of water and 0.25% solutions respectively.

It may be noted that after the establishment of Pakistan, the importance of wilt disease has increased tremendously due to the fact that the seed supplies in the plains for the spring crop, in which there are chances for the development of the disease, as explained above, are being obtained from the potato crop of Baluchistan where the disease is usually present.

3. SHORTENING THE REST PERIOD IN POTATO TUBERS (1, 7 and 8)

One of the methods of solving the seed potato problem is to make freshly dug out potato tubers suitable for planting by breaking their dormancy. The experiments carried out in this direction have confirmed the findings of Appleman and those of Pall and Nath that the dormancy of potato tubers can be broken by peeling and keeping them in moist sawdust for a week. The total peeling method has given better results than half peeling, pricking or boring. According to Pall and Nath, though this method is of immense value for potato breeders, it is not practicable due to high cost of peeling and moist storing and heavy losses on account of rotting.

From the experiments carried out in the Punjab, it has been found that for the spring crop much losses due to rotting in peeled potato tubers do not occur on account of comparatively low temperatures, prevailing during that period. In the case of autumn crop 5 to 15 per cent rotting does occur under natural conditions of storage when temperature is 90°F to 94°F, but if some other arrangement is made for lowering down the temperature, the rotting can be prevented. This requires to be developed and it may be possible to make such arrangements at a low cost. The cost of peeling can also be reduced by 75 to 80 per cent if peeling of potato tubers is done by a new method developed during the investigations. This new method consists in rubbing potato tubers against a wooden cot* woven with rough fibers. It has been found to be the easiest, cheapest and the quickest of all the methods tried, in addition to being quite efficient (Fig. 68).

It has been found out that freshly dug out potato tubers in which dormancy is broken compare fairly well with the actual seed potatoes as regards their germination and yield. The experiments carried out on 24

*Charpoy.
varieties have further shown that there are certain varieties such as Kangra local and Bishop which have very short dormancy period and response better to this treatment (Fig. 69). Thus there is a good scope of selecting high yielding varieties possessing otherwise desirable characters as regards quality with better response to the peeling treatment.

Fig. 68. Difference in rates of germination of treated and untreated resting tubers.

Fig. 69. Difference in rates of germination of different varieties.
4. DIE BACK OF CHILLIES, *Vermicularia capsici* Syd. and *Gloeosporium piperatum* (9).

**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 show partial drying and dead necrotic spots on their surface. In later stages the end branches turn white and silvery in appearance having black dot like structures, which are acervuli of the fungus, studded on them. (Fig. 70).

![Fig. 70. A. Healthy seedlings of chillies. B. Young infected seedlings after ten days of artificial inoculation.](image)

**Cause of the disease.**

Isolations from diseased material from all over the Province yielded the fungus *Vermicularia capsici*. Artificial inoculations with the pure culture of the fungus have proved that it is strongly parasitic on chillies. Along with this another fungus *Gloeosporium piperatum* was also isolated from branches which showed partial drying and formed dead necrotic spots on pods. This fungus has also been found pathogenic but is not so virulent as the first one.

**Cardinal temperatures for the growth of the fungi and the germination of their spores.**

The maximum, optimum and minimum temperatures for the growth of the fungi have been found to be between 35°C-40°C, 25°C-30°C and below 20°C respectively. Germination of spores takes place readily in distilled water and the maximum, optimum and minimum temperaters for germination have been found to be between 35°C-40°C, 25°C and 10°C-15°C respectively.

**Toxic effect of certain chemicals on the fungi.**

Dipping the spores of *Vermicularia capsici* in 0.1% copper sulphate solution for one minute and 1-320 formalin solution for two minutes kills them while the toxic strength for *Gloeosporium piperatum* is 0.5% copper sulphate solution for one minute.
Modes of perpetuation of the disease.

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

(a) By sowing diseased seed (seed containing hibernating mycelium) obtained from diseased crop.

(b) The fungus remains viable in diseased plant debris till next year and the spores from there initiate infection.

(c) By sowing seed contaminated with conidia.

Factors affecting the incidence of disease.

The disease is favoured in its attack and development by moist weather. 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 the month of 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% copper sulphate solution for two minutes and if the mycelium of the causal fungus is hibernating in the seed, it is presoaked for 5 hours in water at 61°F to 86°F and then immersed in hot water at 115°F for 6 minutes or the unpresoaked seed is steeped in water at 120°F for 2 minutes.

(b) Spraying the crop with 4:4:50 Bordeaux mixture before the appearance of the disease. If necessary this should be repeated after about 3 weeks to one month.

(c) Destruction of diseased plant debris.

5. ROOT ROT OF BHINDI, Macrophomina phaseoli (6 and 10).

Bhindi (Hibiscus esculentus) is an important vegetable crop of the Punjab and is subjected to a very serious fungal disease usually known by the name of root rot.

A brief account of the work carried out on this disease during 1946-48 is given below:-

Symptoms.

The disease starts making its first appearance in the month of June and it continues till October, while the attack is very severe in the month of 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 advanced stage of attack get 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 are visible in later stages. (Fig. 71).

Cause of the disease.

The disease is caused by the fungus *Macrophomina phaseoli*.

Fig. 71. *Bhindi* plant showing root-rot symptoms.

Cultural studies.

Detailed cultural studies of the fungus were carried out in the laboratory with a view to better understanding of its physiology under varied conditions so that the information thus obtained may
prove helpful in evolving some suitable control measures to overcome this disease. The results are given under 'Comparative studies of the fungi causing root, stem rot and blight diseases of certain plants' in chapter XIII.

Host range.

It was found by inoculation experiments that besides bhindi this fungus could attack important plants like tobacco, sesamum, mung, mash, groundnut, potatoes and tomatoes.

Factors affecting the incidence of the disease.

A preliminary type of work carried out in this direction has shown that the incidence of the disease is very high when the soil temperature varies between 25°-30°C. Similarly high soil humidity has also been noted to be very favourable for the development of the disease. The reason for the suitability of high temperature for the greater development of the disease can be understood from the fact that this temperature is optimum for 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.

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 suffer badly from the disease.

3. 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 will have to be taken for excluding crops of tobacco, sesamum, mung mash, groundnut, potato and tomato as they are liable to be infected by this fungus.

SUMMARY

Investigations have been carried out on some diseases of potatoes, bhindi and chillies. Tuber rot of potato is of two types in the Punjab, dry and wet. These rots are caused by Fusarium angustum Sherb. and F. oxysporum Schl. The physiology of the fungi has been studied in detail and factors affecting the incidence of rots have been worked out. On the basis of this work recommendations for the control of the disease have been suggested.

Wilt of potatoes attacks the potato crop grown in spring and has been found to be caused by the fungus F. oxysporum. It has been found out that high temperature during the growing period of the crop is conducive to the development of the disease. Some suggestions have been outlined for the control of the disease. Studies have also been carried out
on shortening the rest period in tubers which can be helpful in solving the potato tuber rot problem indirectly. A very simple method for breaking the dormancy in freshly-dug up potato tubers has been evolved.

Dieback of chillies, which causes heavy damage to the crop has been investigated. The fungi *Vermicularia capsici* Syd. and *Gloeosporium piperatum* have been found to be responsible for this disease. The physiology of the fungi has been studied. The disease has been found to perpetuate through sowing diseased seed and diseased plant debris lying in the soil. It has been found out that moist weather is very favourable for the development of the disease. Crop sown in March-April by broadcasting suffers comparatively less. Control measures have also been worked out.

Root rot of *bhindi* is one of the very destructive diseases of this crop. Symptoms produced are similar to those of cotton root rot. The disease is caused by the fungus *Macrophomina phaseoli* which has been found to have a wide host range. Factors affecting the incidence of the disease and control measures have been investigated.

**REFERENCES**

2. — (Submitted for publication) Some studies on wilt disease of potatoes in the Punjab.
3. — —do— Some studies on tuber rot disease of potatoes in the Punjab.

CHAPTER XII

DISEASES OF FRUIT TREES

The area under gardens has increased tremendously during the past few years in the Punjab on account of the persistent and combined efforts of the Irrigation and Agricultural Departments by allowing an enhanced supply of water for fruit plantations.

At present the area under fruit plants in the Punjab is about 58,345 acres. The gardens consist of many varieties of fruit trees but the most important of them are citrus and mango trees. There are a number of diseases which attack the fruit trees with the result that heavy losses are being sustained by the fruit growers on account of reduction in both quality and quantity of the produce.

1. WITHERTIP OF CITRUS, *Colletotrichum gloeosporioides* Penz. (2 and 10).

Citrus withertip is one of the very serious diseases of citrus plantation and it has been found to be doing great damage to citrus plants throughout the Punjab. 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*. This disease spreads from the small twigs to branches and brings about their destruction with the result that this disease if allowed to continue for some years, kills the plants outright. (Fig. 72).

Work has been carried out by Chauduri of 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:

C. gloeosporioides is pathogenic on citrus plants (in pathogenicity tests cut leaves, cut twigs and a few potted plants were used). (In the opinion of the present authors, in pathogenicity tests cut twigs and cut leaves should not have been used because 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 frequent in most of the orchards.

Manuring with ammonium sulphate or nicifos @ 2 lbs per tree cannot prevent the disease.

Further studies have been carried out in the Plant Pathology Laboratory, Lyallpur, in order to clarify the relation between *Colletotri-
Fig. 72. Different parts of a citrus plant showing symptoms of withertip disease.
chum gloeosporioides, the fungus occurring on citrus in the Punjab, 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 summarised below:

1. All the three fungi produce acervuli on the branches, leaves and fruits of their respective hosts. There is no appreciable difference in the size of conidia of the three fungi on their natural host plants. Setae are absent in the case of G. limetticolum while there are only a few in the case of the fungus occurring on mango and they are always associated with C. gloeosporioides.

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. gloeosporioides and G. limetticolum is 25°C and for the mango fungus is 30°C. The growth of all the three fungi is restricted below 15°C and there is no growth at 40°C or above.

All the three fungi can grow well on a wide range of pH from 4.0 to 9.0. The growth of G. limetticolum is checked at 2.8 while others tolerate this concentration, but in all of them there is no growth at 1.8 pH.

The amount of sporulation in all the three fungi varies directly with the richness of the culture media.

Setae are always produced in the case of C. gloeosporioides on an the culture media while in the case of the mango fungus the setae are produced on majority of the culture media and no setae are formed in the case of G. limetticolum on any of the culture media used.

The size of conidia of all the three fungi on all the culture media is approximately the same.

The conidia of G. limetticolum germinate after three hours and those of the other two fungi after three and a half hours in water. Before germination, the conidia swell and become one septate. The germ tubes are given out from ends as well as sides of the spores.

The maximum temperature for germination of spores of all the fungi is between 35° to 40°C, the optimum is 25°C and the minimum below 10°C.

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 all 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*, *sangtra*, rough lemon, *Jullundari khatti*, *kaghzi* lime, grape fruit and *mokri*, either they do not cause any infection or cause very slight infection.

The three fungi cause rotting and premature falling of *malta*, *sangtra* and mango fruits still attached to the plant. The inoculated fruits fall off prematurely.

*C. gloeosporioides* and the mango fungus cause rotting of detached fruits of all citrus varieties under test except *kaghzi* lime.

From the results given above, the following conclusions are 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 on citrus it can attack fruit and fruit stalk easily, while on twigs either it does not cause infection at all or causes extremely slight infection. On citrus leaves the infection is very rare.

From the results of the experiments it has been proved that *Colletotrichum gloeosporioides* is not an active parasite of citrus twigs as stated by Chauduri. Experiments carried out in this direction have further shown that the infection cannot be brought about unless the plants have been pre-disposed to the attack on account of their becoming weak, either due to high percentage (0.2%) of total soluble salts in the root zone, or 8.5 or more pH values of soil, or other adverse soil factors. Work is in progress to determine the nature of such soil factors which are responsible for creating suitable conditions for the fungus to cause infection. So far the control of the disease consists in pruning dried branches and the application of ammonium sulphate and farm-yard manure (at 1 lb ammonium sulphate plus 10 lbs of farm-yard manure per plant) in addition to carrying out spraying of the plants with Bordeaux mixture as detailed under citrus canker.

2. CANKER OF CITRUS, *Phytomonas citri* Hasse. (1 and 7).

Citrus canker occurs commonly in the Punjab and ranks as one of the major diseases of citrus plants in the Province. The disease affects leaves, stem and fruits. On young leaves it is first visible generally on the lower surface in small yellowish spots. The lesions with age become brown corky and hard. The lesions 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 development period of the disease. The lesions which are scattered in the beginning join up later on. The canker spots are similar on twigs and fruits (Fig. 73). Detailed studies carried out on this disease for many years have yielded the following results:-

The disease has been found to be caused by a bacterium called *Phytomonas citri* (Hasse). The causal organism is carried in rain splashings from the infected plants and also by contact of diseased parts with healthy ones.
Fig 73 Different parts of a citrus plant showing symptoms of canker disease
In the Punjab the citrus varieties have been found to be affected by this disease in the following order:-

4. Sweet lime, *Citrus aurantifolia*.

*Sangtra*, *Citrus nobilis* var. *deliciosa* is not attacked.

Experiments were carried out to find out the suitable strength of Bordeaux mixture and the number of applications required for the control of the disease.

The strengths of Bordeaux mixture tried were 3 : 3 : 50; 4 : 4 : 50 and 5 : 5 : 50. The number of applications were 1, 2 and 3.

Controls, which consisted of unsprayed plants, were kept in each set. The three sprayings were applied at the following times: -

The first application was given in the middle of May, the second in the end of July and third in the end of September. The results showed that one spraying reduced the disease on the fruit from 30 to 15% and 2 & 3 sprayings reduced the infection from about 30% to about 10%.

(Table XXII).

Table XXII. Results of spraying experiments.

<table>
<thead>
<tr>
<th>Strength of Bordeaux mixture.</th>
<th>One spraying</th>
<th>Two sprayings</th>
<th>Three sprayings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of fruits observed</td>
<td>Percentage of diseased fruits</td>
<td>No. of fruits observed</td>
</tr>
<tr>
<td>3 : 3 : 50</td>
<td>879</td>
<td>17.2</td>
<td>913</td>
</tr>
<tr>
<td>4 : 4 : 50</td>
<td>836</td>
<td>17.7</td>
<td>1027</td>
</tr>
<tr>
<td>5 : 5 : 50</td>
<td>Observations not recorded</td>
<td>1365</td>
<td>7.8</td>
</tr>
<tr>
<td>Control</td>
<td>645</td>
<td>27.9</td>
<td>1075</td>
</tr>
</tbody>
</table>

Later on the pruning of the diseased portions of the plants was also included in the spraying test and the sprayings were carried out as usual. The observations recorded showed that the disease was reduced to less than 1% in the case where the plants were sprayed while it was about 25% on the unsprayed fruit trees. The experiments further showed, that an additional spraying carried out during the months of December to February helped considerably in reducing the amount of infection.
to control the disease on affected *kaghzi* lemon plants have not so far met with a complete success. The cost of operations including the cost of material and charges for labour was also calculated and it varied between 16-23 rupees per acre for four sprayings. Experience has also shown that if the infected trees are sprayed 4 times annually for two years, the number of sprayings in the subsequent years can be safely reduced to two.

Recent work carried out on the factors influencing the incidence of the disease has shown that 70-90% of the infections occur in the months of July and August when there are rains. Thus, the spraying of the plants in the rainy months is very useful in controlling the disease. In order to avoid the washing off the spraying material by rains, rosin is added to Bordeaux mixture. Two lbs. of rosin and 1 lb of washing soda are boiled in 1 gallon of water thoroughly till rosin gets dissolved. This is added to 25 gallons of Bordeaux mixture.

2. WILT OF CITRUS, *Fusarium* spp. (8).

Citrus wilt is found usually in nurseries though older plants are also affected. The disease prevails more severely in canal irrigated tracts than in sub-montane 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 fruit falls prematurely.

About 90% 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 are between 5 and 10°C and 35 and 40°C respectively.

Both the fungi grow fairly well from pH 7.0 to pH 9.2 and they 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).

The longest spores are formed on Brown's starch 'agar in both the fungi. The size of spores is 47.0 μ in (F) and 29.4 μ in the case of fungus (O).

Mercuric chloride solutions of 0.05 and 0.025 per cent strengths are effective to kill the spores of the fungi (F) and (O) respectively in 5 minutes while 3% copper sulphate solution can also kill the spores of the fungi (F) and (O) in 5 and 10 minutes respectively.

The spore germination in both the fungi is 100% at 25°C and 30°C.

The specific identity of these fungi has not been made yet,
Both the fungi can cause rotting of seeds of khatti (Citrus medica), mitha (Citrus limetta) and kaghzi lime (Citrus curantifolia) as well as wilt in their seedlings.

4. ROOT ROT DISEASE OF CITRUS, *Rhizoctonia bataticola* and *Rhizoctonia solani* Kuhn (9).

Root rot disease of citrus is mainly the disease of young nursery plants. It occurs throughout the Punjab but unlike citrus wilt it is comparatively more serious in sub-montane tracts than in canal colonies.

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.

All the isolations made 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*.

The fungi A, B, C and D grow fairly well on higher concentrations like 8 N, 4 N and 2 N of Richard’s agar while the fungus E does well on N/4 concentration.

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 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% strength is required.

The isolations A, B, C and D belong to the C strain of the species *Rhizoctonia bataticola* and hence are called *Macrophomina phaseoli*. The fungus E belongs to the species of *Rhizoctonia solani* (sclerotial stage of *Corticium solani* Prill & 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.
5. ANTHRACNOSE OF MANGO, *Glomerella cingulata* Stonem (S & V. S.) *Colletotrichum gloeosporioides* Penz (4-6).

The disease attacks leaves, petioles, twigs and fruits. On leaves it forms numerous oval and irregular brown spots of very variable size. 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 tissue.

The petioles when affected turn black or grey and the leaves droop down, 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 twigs go on drying from top to bottom. When the fruits are attacked, black spots develop on them and rot sets in (Figs. 74 and 75).

Fig. 74. Mango leaves and mango twig affected with anthracnose.
The fungus causing the disease has been identified as \textit{(Glomerella cingulata Stonem)} \textit{(Colletotrichum gloeosporioides Penz)}.

Inoculation experiments have shown that the fungus is pathogenic on leaves, petioles, stem 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, the minimum is between 10-15°C and the optimum between 25-29°C.

The amount 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; at pH 3.5 on the acidic side and at pH 8.2 on the alkaline side the growth falls considerably.

The maximum temperature for germination of spores is between 35-40°C and optimum is 25°C and the minimum between 10 and 15°C.

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. These are, therefore, responsible to initiate fresh infections.

The following measures for the control of the disease have been suggested:

(i) Removal of all the diseased mango leaves and twigs lying about in the garden.

(ii) Pruning of all the diseased twigs and burning them. The cut ends of big branches should be coal-tarred.

(iii) Spraying of the plants with 3: 3: 50 Bordeaux mixture three times a year during February, April and September.

6. MALFORMATION OF MANGO INFLORESCENCE.

The disease commonly known as malformation of mango inflorescence has recently come into great prominence. Although the disease has been in existence for many years past but its incidence remained generally low. During the last few years, however, the disease has been doing great damage and the incidence is on the increase. The percentage of attack has been found to vary very greatly from variety to variety and tree to tree in the same variety.

Symptoms.

The symptoms of the disease are very typical. In some cases the panicle is much reduced and thickened. The floral branches are bunched together in the form of cone which later on changes into black mass. Such masses may continue to hang on the trees for a long time. Evidently no fruit is set in such inflorescences. In other cases the panicle is only moderately reduced 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 other cases it has been noted that vegetative leaves appear on the panicle intermingled with the small cones. It is interesting to note that in many cases the branches bearing malformed cones in the previous years produce both malformed and healthy types of inflorescence next year (Fig. 76).

Cause.

The investigations carried out by the Entomologist, Punjab Agricultural College, Lyallpur, with regard to the cause of this disease have shown that it is not caused by any insect. Work carried out in the Plant Pathological Section has shown that no fungus or bacterial organism is responsible for causing the disease. From the nature of attack, spread of infection and increase in the incidence of the disease from year to year it appears that the disease may be of virus origin. It is also possible that the disease may be due to some physiological cause. Work is, however, in progress to determine the real cause of the disease.
7. MAIN STALK ROT OF BANANA*, Gloeosporium sp. and Botryodiplodia (3).

The disease has been found to affect the main stalk of the banana plant and is responsible for bringing about the rotting of the stem. Two fungi namely, Gloeosporium sp. and Botryodiplodia have been found to be responsible for this disease.

8. BLACK TIP OR FINGER TIP OF BANANA, Botryodiplodia sp. (3).

This disease affects the banana fruits on their tips, which turn black and start rotting. (Fig. 77). In severe cases it affects the whole of the fruit. The fungus Botryodiplodia has been found to be responsible for this disease. The incidence of rotting has been studied at different temperatures with the following results:

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Percentage rot</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C</td>
<td>10</td>
</tr>
<tr>
<td>20°C</td>
<td>15</td>
</tr>
<tr>
<td>25°C</td>
<td>45</td>
</tr>
<tr>
<td>30°C</td>
<td>75</td>
</tr>
<tr>
<td>35°C</td>
<td>90</td>
</tr>
<tr>
<td>40°C</td>
<td>10</td>
</tr>
</tbody>
</table>

*Work on diseases of banana was carried out by Dr. B. L Chona during 1931-32 in the Plant Pathology Laboratory, Lyallpur.
The increase in the intensity of the disease at higher temperatures explains for the prevalence of the disease in plantations situated in hot localities.

9. PSEUDO-STEM ROT OF BANANA, *Gloeosporium* sp. and *Botryodiplodia* sp.

Two fungi namely, *Gloeosporium* sp. and *Botryodiplodia* sp. have been found to be pathogenic.

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% copper sulphate solution for 10 minutes and dried before planting.

10. STEM END ROT OF BANANA, *Gloeosporium* sp. and *Botryodiplodia* (3).

This is the only serious disease which has been met with in curing pits. The fungi which are responsible for it are *Gloeosporium* sp. and *Botryodiplodia* which have been found to be active at 30-40°C. Cultural studies carried out on both these fungi have shown that the optimum temperature for both the fungi is 30°C but the attack is more vigorous at 35°C.
SUMMARY

Some investigations have been carried out on some diseases of citrus, mango and banana. In citrus Colletotrichum gloeosporioides Penz. is commonly associated with citrus wither tip. It has been found out that citrus twigs can only be infected by this fungus in case they are poor in health. All factors such as lack of nutrition and high percentage (0.2%) of total soluble salts in the root zone or 8.5 or more pH values of soil, which weaken the plants are conducive to the development of the diseases. The fungus C. gloeosporioides is, therefore, a weak parasite on citrus twigs. Physiology and morphology of the fungus 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 distinct from G. limetticolum. C. Gloeosporioides is actively parasitic on mango leaves, fruits and twigs but on citrus it can attack fruit and fruit stalks easily, while on twigs it does not cause infection at all or causes extremely slight infection.

Citrus canker is another important disease, which is responsible for bringing heavy losses to citrus plants. This disease which is caused by Phytoponas citri Hasse attacks leaves, twigs and fruits by producing corky, hard and raised lesions. The infection spreads through rain splashings and by contact of diseased portions with healthy ones. Work carried out on factors influencing the incidence of the disease has shown that 70-90% of the infections occur in the rainy season. Varietal resistance has also been investigated. Control measures which consist in removal and destruction of diseased plant portions and spraying the plants with Bordeaux mixture have been worked out.

Work has also been carried out on citrus wilt caused by Fusarium spp. and root-rot disease of citrus caused by Rhizoctonia sp. in which case the physiology of the causal fungi, factors affecting the incidence and measures to control these diseases have been studied.

In the case of mango, studies have been carried out on anthracnose which has been found to be caused by Glomerella cingulata Stonem S & V.S. (Colletotrichum gloeosporioides Penz). 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 portions, which remain attached to the trees. The control measures have been suggested.

Some preliminary studies have also been carried out on malformation of mango inflorescence, which is the second important disease of mango.

Some banana diseases like main stalk rot, 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.
# REFERENCES

<table>
<thead>
<tr>
<th></th>
<th>Author(s)</th>
<th>Year</th>
<th>Title and Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>— (Manuscript)</td>
<td>—</td>
<td>Preliminary studies on citrus wilt in the Punjab.</td>
</tr>
<tr>
<td>10.</td>
<td>— (Submitted for publication)</td>
<td>—</td>
<td>A comparative study of the fungi causing citrus withertip and anthracnose of mango.</td>
</tr>
</tbody>
</table>
CHAPTER XIII

COMPARATIVE STUDIES OF THE FUNGI CAUSING

(A) ROOT & STEM ROT AND (B) BLIGHT DISEASES

OF CERTAIN PLANTS.

1. ROOT AND STEM ROT, Rhizoctonia sp. (2).

The fungi A to G have been isolated from the roots of the crops noted against them:—

A. Tobacco (Nicotiana tabacum).
B. Bhindi (Hibiscus esculentus).
C. Sesamum (Sesamum indicum).
D. Cotton (Gossypium arboreum).
E. Citrus (Citrus species).
F. Chillies (Capsicum annum).
G. Pigeon peas (Cajanus indicus).

The symptoms produced by different fungi on their respective host plants are as follows:—

(i) The fungus A affects tobacco plants. Roots and stem show rotting symptoms which when developed kill the plants outright. Detailed symptoms have been described under (Root and Stem rot of Tobacco).

(ii) The fungus B brings about first yellowing and ultimately drooping and wilting of bhindi plants. Wilted plants can be pulled out very easily and they show shredded roots and rot-lets and when pressed they give out drops of liquid having offensive smell. In advanced stages of attack minute black bodies, sclerotia of the fungus, are found scattered over the stems of infected plants. The extent of damage goes as high as 80 to 90 per cent in the years when conditions are favourable for the development of the disease.

(iii) The fungus C isolated from Sesamum indicum produces lesions of the disease at the base of the main stem. In light attacks the fructifications of the fungus may be present at the base only but in severe attacks the whole plant shows the presence of sclerotia or pycnidia. Affected plants lose their grip on the soil and can be easily detached. Roots may be sound or shredded having decayed or rotten bark. Sometimes the hollows of the stems contain mycelium and sclerotia of the causal fungus. The disease is quite common in Lyallpur District. In severe cases mortality has been observed as high as 50 to 90 per cent.

(iv) The fungus D is responsible for causing root rot in cotton plants. The disease affects the roots exclusively, causing the shredding of
root break, producing at first wilting of shoots, ultimately resulting in the death of entire plants. The damage brought about by the disease is quite considerable as the disease is present throughout the cotton growing tracts of Western Pakistan.

(v) The fungus E occurs on citrus nursery plants, which show symptoms of damping-off. Roots decay and bark gets shredded. Small black sclerotia are seen at the base of plants when the stem is shredded. They are usually below the bark. No pycnidia have been observed on diseased citrus plants in nature.

(vi) The fungus F occurs on chillies. Leaves and young branches wilt and plants die. Root hairs and small lateral root-lets decay. Occasionally conducting vessels also get blocked up with mycelium of the causal fungus. Sclerotia which are small and round are rarely observed. Pycnidia do not develop on the infected plants.

(vii) The fungus G occurs on pigeon peas which wilt and ultimately die. All the roots except tap root decay and get attacked easily. The base of the stem blackens due to the formation of lesions. Sclerotia are formed at the base of the plants. Pycnidia have not been observed on wilted plants.

Cultural studies of the fungi and their pathogenicity.

No fungus forms pycnidia on the host plants except the fungi B and C.

Efforts made to produce pycnidia in artificial culture media have not yielded any definite results.

Inoculation experiments have been conducted on the hosts of these fungi and various other plants in pots as well as in the field. In Table XXIII the names of the fungi are given against each plant on which they have been proved pathogenic.

Table XXIII. The host range of the fungi under study.

<table>
<thead>
<tr>
<th>Host plant</th>
<th>Fungus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Arachis hypogaea</td>
<td>A, B, C, D, E and F.</td>
</tr>
<tr>
<td>2. Cucumis melo var utilissima</td>
<td>A</td>
</tr>
<tr>
<td>3. Citrullus vulgaris var, fistulosus</td>
<td>A, C, D and F.</td>
</tr>
<tr>
<td>4. Citrullus vulgaris</td>
<td>A, D, E and F.</td>
</tr>
<tr>
<td>5. Cucurbita moschata</td>
<td>B</td>
</tr>
<tr>
<td>6. Glycine hespida</td>
<td>A, C, D and F.</td>
</tr>
<tr>
<td>7. Lycopersicum esculenta</td>
<td>B</td>
</tr>
<tr>
<td>8. Nicotiana tabacum</td>
<td>A, B, C, D, E and F.</td>
</tr>
<tr>
<td>9. Phaseolus curesus</td>
<td>B</td>
</tr>
<tr>
<td>10. Phaseolus radiatus</td>
<td>A, B, C, D, E and F.</td>
</tr>
<tr>
<td>11. Sesamum indicum</td>
<td>B</td>
</tr>
<tr>
<td>12. Solanum tuberosum</td>
<td>A, C, E and F.</td>
</tr>
<tr>
<td>13. Vigna catiang</td>
<td>A, C, D, E and F.</td>
</tr>
<tr>
<td>14. Zea mays</td>
<td></td>
</tr>
</tbody>
</table>

*None of the strains attacked cotton plants.*
The results of inoculations have shown that:-

(a) All the fungi mainly attack root and root-lets causing their decay and ultimately bringing the death of plants.

(b) None of the fungi has got specialization of parasitism and under suitable conditions they can be made to attack a variety of plants.

Observations for the pycnidial formation of these fungi on inoculated sesame plants, sterilized twigs of sesameum and citrus twigs have shown that all the fungi except G can produce pycnidia on them. The fungus A also forms pycnidia on Cajanus indicus.

As regards the morphological, cultural and pathological characters, these fungi fall into three groups. The fungi A, B, C, E and F fall in the first group, the fungus D in the second and the fungus G in the third group. The main characters of these fungi are given in the Table XXIV.

Table XXIV. The characteristics of the three groups of the fungi, under study.

<table>
<thead>
<tr>
<th>Character</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Sclerotia formation on host plant.</td>
<td>Sclerotia are formed on the host.</td>
<td>Sclerotia are formed on the host.</td>
<td>Sclerotia are formed on the host.</td>
</tr>
<tr>
<td>(ii) Classification according to size of sclerotia on the host*</td>
<td>Falls in C strain.</td>
<td>Falls in C strain.</td>
<td>Falls in C strain.</td>
</tr>
<tr>
<td>(iv) Colony</td>
<td>Regular and uniform.</td>
<td>Irregular and form sectors.</td>
<td>Regular and uniform.</td>
</tr>
<tr>
<td>(vi) Colour of substratum</td>
<td>Blackish plumbeous.</td>
<td>Black.</td>
<td>—</td>
</tr>
<tr>
<td>(vii) Sclerotia formation</td>
<td>In the substratum on the surface.</td>
<td>In the substratum.</td>
<td>In the thin upper layer of substratum.</td>
</tr>
</tbody>
</table>

* A — 102.6 µ
B — 69.2 µ
C — 103.7 µ
D — 85.3 µ
E — 89.2 µ
F — 98.1 µ
G — 93.3 µ
On the basis of the main characters given in the table above it is proposed that the fungi under study should be named as *Macrophomina phaseoli* but they should be divided into three varieties with the fungi A, B, C, E and F forming the first variety, D the second and fungus G the third variety.

<table>
<thead>
<tr>
<th>Character.</th>
<th>Group I.</th>
<th>Group II.</th>
<th>Group III.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Temperature</td>
<td>Biggest at 35°C and smallest on 15°C.</td>
<td>Biggest at 35°C and smallest at 25°C.</td>
<td>Biggest at 20°C smallest at 35°C.</td>
</tr>
<tr>
<td>(c) pH value</td>
<td>Biggest at 4-4.8 and smallest at 8.0.</td>
<td>Biggest at 5.0 and smallest at 8.4 and no sclerotia at 9.0</td>
<td>Biggest at 5.8 and smallest at 9.0</td>
</tr>
<tr>
<td>(ix) Pycnidial formation</td>
<td>All form pycnidia on sesamum and citrus.</td>
<td>Forms pycnidia on sesamum and citrus.</td>
<td>Not inoculated.</td>
</tr>
<tr>
<td>Size of pycnidia</td>
<td>A. 134 x 128 μ</td>
<td>D. 160 x 151 μ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. 132 x 146 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C. 142 x 131 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E. 140 x 121 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F. 158 x 154 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of pycno-spores</td>
<td>A. 21.1 x 8.8 „</td>
<td>D. 21.2 x 8.4 μ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. 21.1 x 7.9 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C. 20.8 x 8.5 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E. 20.1 x 8.3 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F. 16.9 x 8.8 „</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classification according to the size of sclerotia in culture*</td>
<td>C strain (under certain conditions they can be shifted to B strain)</td>
<td>C strain (under certain conditions it can be placed in B strain).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Richard's agar</th>
<th>Brown's agar</th>
<th>Richard's agar</th>
<th>Brown's agar</th>
</tr>
</thead>
<tbody>
<tr>
<td>*A 161 μ</td>
<td>71 μ</td>
<td>E 153 μ</td>
<td>100 μ</td>
</tr>
<tr>
<td>B 109 „</td>
<td>105 „</td>
<td>F 153 „</td>
<td>110 „</td>
</tr>
<tr>
<td>C 167 „</td>
<td>80 „</td>
<td>G 142 „</td>
<td>102 „</td>
</tr>
<tr>
<td>D 114 „</td>
<td>49 „</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The economic importance of the pycnidial formation in these fungi on the living plants of sesamum has already been discussed under root-rot of cotton.

2. BLIGHT, *Phyllosticta* spp. and *Phoma* spp.

Blight is one of the very common diseases of cultivated and wild plants. Comparative studies have been started on blight diseases of eight different plants. The fungi isolated from them are listed below against each plant.

1. *Phyllosticta* sp. on Loquat (*Eriobotrya japonica*).
2. *Phyllosticta* sp. on Mango (*Mangifera indica*).
3. *Phyllosticta* sp. on Ber (*Zizyphus jujuba*).
4. *Phyllosticta* sp. on Ficus (*Ficus bengalensis*).
5. *Phyllosticta* sp. on Guava (*Psidium guajava*).
6. *Phyllosticta* sp. on Grape-fruit (*Citrus maxima*).
7. *Phyllosticta* sp. on Sorghum (*Sorghum vulgare*).
8. *Phoma* sp. on Mango (*Mangifera indica*).

**Symptoms in general.**

The blight disease as is evident from the very word is essentially a malady of the aerial parts of plants. In the case of *phyllosticta* blight the disease appears on the leaves in the form of small round spots of varying size. The spots may be grey reddish brown, fawn coloured or ashen in appearance. They are small round and scattered to begin with but later on they enlarge and in some cases unite with each other covering large areas. In advanced stages of attack small dark spots constituting pycnidia of the fungus make their appearance in the centre of the lesions. In severe cases defoliation results thus bringing heavy losses to the suscepts.

The *phoma* spp. although similar in many of the characteristics produced by *Phyllosticta* spp. attack mainly stems of the plants. The parasite in each case is mainly confined to the diseased lesions.

**Pathogenicity of the fungi.**

The individual plants on inoculation with the species of the fungus isolated from them have given positive results of infection by producing symptoms similar to those observed in nature. The disease is produced within 7 to 15 days of artificial inoculation.

**Cultural studies.**

The fungi under study have been subjected to a series of laboratory tests in order to compare their physiological features under varied environmental conditions. The main experiments have given the following results:–

All the species of *Phyllosticta* and *Phoma* have yielded very good linear colony growth on different media tested.
The growth of all the fungi except the one isolated from sorghum stops at 40°C. The optimum temperature required for growth is 30°C in the case of *Phyllosticta* species isolated from *logan*, *ficus* and sorghum while it is 25°C for the other species under test. The minimum temperature in each case is below 15°C.

The optimum pH required for the growth of the various strains of *Phyllosticta* and *Phoma* under observation is 5.2 except in the case of *Phyllosticta* isolated from *Ficus bengalensis* where the optimum pH is 6.3. The growth in each case retards with the increase and decrease in pH value. No growth in any case is observed at pH 9.5.

Cross inoculation experiments are still in progress.

**SUMMARY**

This chapter includes an account of the comparative studies carried out on fungi causing root and stem rot in different plants and blight diseases of some economic plants. Fungi isolated from root rot affected plants of tobacco, *bhindi*, *sesamum*, cotton, citrus, chillies and pigeon peas have been studied as regards symptoms produced by them on their respective host plants, morphology on host plants and cultural characters in artificial cultural media. Inoculation experiments have been conducted on the hosts of these fungi and various other plants in pots as well as in field. As regards the morphological, cultural and pathological characters these fungi fall into three groups. On the basis of the main characters it has been proposed to name all these fungi as *Macrophomina phaseoli* but they constitute three different varieties.

*Phyllosticta* spp. and *Phoma* spp. have been isolated from 8 different economic plants and their physiology and pathogenicity have been studied.

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