THE WHEAT RUST PROBLEM OF INDIA

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INDIA is one of the prominent wheat-growing countries of the world and the largest producer of that commodity in the British Empire yet, with the exception of a temporary revival at present, she has been steadily losing her position in the international market. Considering the fact that on an average there are 34 million acres under wheat each year, a yield of less than 10 million tons is exceedingly poor. This is largely due to the fact that nearly 80 per cent. of the area is covered by the inferior quality, indigenous (*dési*) varieties. Inadequate manuring, absence of irrigation and the frequent failure of winter rains over large tracts are the other obvious causes of poor yield. In addition, rusts are responsible, year after year, for a colossal damage to the wheat crop.

In view of the rapid increase in the population of this country, as revealed by the recent census, there is danger of a serious shortage in the supply of wheat even for home consumption in the near future. It is necessary, therefore, to stress the need of a fuller understanding of the problem under review so that efforts be made, at an early date, to obtain a much higher yield from the same area by mitigating, as much as possible, the huge loss that is caused by rusts at present.

Unfortunately, in the greater part of the wheat area, all the three rusts, black, brown and yellow, are fairly common. Yellow and black rusts also attack barley, which covers an acreage of 8–9 millions per year in this country.

Rusts of wheat are caused by three different species of a parasitic fungus belonging to the genus *Puccinia*. Each rust spreads from plant to plant by microscopic germs (spores) that are blown by wind. Under favourable conditions of weather, a single spore may give rise, within 7–10 days from the time it alights on a wheat plant, to several blisters (pustules) containing hundreds of fresh spores. That explains how, from an handful of diseased plants in a field, a serious epidemic might be caused within 4–6 weeks, if conditions of weather happen to be favourable for the spread of rust.

For a review of contemporary work carried out in North America, Europe, Australia and elsewhere as well as for fuller information on different aspects of the wheat rust problem of this country, reference may kindly be made to the various contributions by the writer.[1–6] In the present article, for want of space, only a brief summary of the more important results is given.

SOURCES OF ANNUAL RECURRENCE

Butler[8] stated that *Berberis*, the well-known alternate host of black rust in temperate countries, may be left out of account in India. Butler and Hayman[10] found that after five minutes' exposure at 45° C. or on exposure to the sun for a few hours when the shade temperature was 95° F., uredospores (the winter stage) of yellow rust lost all viability. These authors concluded that in the plains of India infection from the previous crop was extremely unlikely. Burns (1909, work unpublished) concluded, from inoculation experiments carried out under the shade of a mango tree during May at Poona (1850 ft. a.s.l.), that given a series of wheat plants, two or almost three generations should secure the continuance of black rust from season to season in the uredo-stage. Later, Butler[9] stated that teleutospores (the summer stage in this country) of black rust have lost their power of germination in the plains and that it is doubtful if the barberries carry the race of the parasite, which is found on wheat, even in the hills. He concluded that no satisfactory answer could be given to the question as to how rusts tide over the unfavourable season when they have no wheat to feed on.

That raised the fundamental question as to where lies the source? The present state of our knowledge regarding the fresh infection of wheat by each of the three rusts, from year to year, is summarized below:—

(1) Fortunately, *Berberis vulgaris* Linn. and *Thalictrum flavum*, the two most susceptible species of alternate hosts of black and brown rusts respectively, do not occur in India and so far no alternate host

has been discovered anywhere for yellow rust.

Germination of teleutospores of black and brown rusts was obtained, in this country for the first time, during the course of recent studies and a large number of inoculations were made on their alternate hosts.

(2) *B. lycium* and only seedlings of two other indigenous species have been found to be moderately susceptible to black rust. Similarly, two indigenous species of *Thalictrum* have shown moderate susceptibility to brown but there is no case on record, nor could any evidence be obtained during recent studies, of an outbreak of either of these rusts starting from its infected host in nature. In India, barberries and *Thalictrum* grow only in the hills.

(3) On the other hand, black and brown rusts have been found to break out, year after year, at several places in the plains as early as December-January, *i.e.*, 3–4 months prior to the period of the earliest possible infection of their alternate hosts in the hills.

(4) Recent studies have clearly shown that the alternate hosts, referred to above, play little part in the annual recurrence of black and brown rusts, at any rate, as far as the plains are concerned.

In view of the scarcity of viable teleutospores even in the greater part of the wheat area in the hills and the general dryness of weather during spring, infection of barberries and *Thalictrum* is more likely at higher altitudes (nearly 7,000–9,000 ft. a.s.l.) during the monsoon, June–August but this should be of little consequence to the crops which are ready for harvest by the end of June practically all over the hills.

(5) On account of the intense heat of summer that follows the harvest, it is almost impossible for uredospores of any of the rusts of wheat to survive in the plains and consequently there is no local source of infection at the time of the next sowing.

(6) Uredospores of all the three rusts, two of which as stated above also attack barley, have however been repeatedly found to oversummer on self-sown plants and ratoon tillers of wheat and barley in the hills because of milder weather. At Simla (nearly 7,000 ft. a.s.l.) all these rusts have been found to oversummer as well as overwinter in miniature plots during the last 10 years.

(7) Several times, fresh outbreaks of rusts have been observed in the hills after 4–6 weeks of sowing of the new crop, within a few feet of rusted stray plants of wheat and there is plenty of uredo-material, at altitudes suitable for each rust, at the time of new sowings. Black rust of wheat has also been found simultaneously on some wild grasses but no evidence could be obtained of its propagation, from season to season, on any of them.

(8) Well-advanced infection of *early* crops in some of the hills has also been found long before rust outbreaks in the neighbouring plains. In general, rusts have been observed to appear much earlier and plant for plant there is heavier infection at foot-hills than at places farther off in the plains.

(9) Wheat sown 'out of season', at some of the foot-hill stations at writer's request, got infected as early as September–October, 2–4 weeks before the normal period of sowings in the neighbouring plains.

It is clear that all the three rusts of wheat are largely propagated by uredospores in the hills, from season to season. The rôle of uredospores in the annual recurrence of rusts, therefore, is a factor of outstanding importance and far more potent than that of alternate hosts.

Dissemination in Relation to Initial Outbreaks

In the plains of India, initial outbreaks of rusts are delayed by 2–3, sometimes 3–4 months from the time of sowings, whereas wheat inoculated several times, with uredo-material of black and brown rusts brought down from the hills during October-November, in a cage at Agra, which is one of the warmer places, got infected in 7–8 days. In the case of yellow rust, which thrives in cool weather, infection took place only towards the end of November. That should leave little doubt regarding the suitability of weather from the start for black and brown rusts and in the case of yellow from the end of November onwards, yet normally none of these rusts breaks out at Agra before the middle of February. It is conclusive, therefore, that there is no local source of infection in the plains at the time of sowing and that rusts are re-introduced therein, year after year, from some other source. Consequently, rust outbreaks in the plains can only be caused as a result of dissemination of the inoculum from the hills by the most obvious agency, *i.e.*, the wind.

A comprehensive study of Rust Dissemination was, therefore, started in the year 1932. During the course of this work, arrangements were made for catching rust spores on slides in aeroscopes at 62 representative stations. Spores were also caught at Agra with the help of mechanical traps, kites, and balloons. A few slides were exposed from aeroplanes also at Delhi. Besides the examination of a huge number of slides, 11,355 wind-trajectories were prepared and scrutinized in connection with the initial outbreaks of each of the three rusts, under review, at 20 representative stations. The writer is unable to supply much information on this subject because his second monograph giving details of Rust Dissemination has not yet been published. However, results obtained from work already published are summarised below:—

(1) Uredospores of each of the three rusts were caught from the air, well before its appearance on the local crop at a large number of stations.

(2) The similarity between the physiologic-race flora (the different strains of each rust) of hills and the plains is another proof, and a strong one too, of the fact that the source of all the three rusts, under reference, lies in the hills.

(3) In all probability, black and brown rusts are disseminated from comparatively low altitudes where, on account of milder winter, their uredospores occurring at the time of sowing cause infection on the new crop rather early in the season. In the case of yellow rust, the inoculum must be blown down originally from higher altitudes because, normally, it is unable to survive during summer below 6,000–7,000 ft. a.s.l.

(4) Two important foci where, due to early crops, there is plenty of inoculum, year after year, at the time of sowings in the plains, have been located. These are central Nepal in the north and Nilgiris and Palni hills, taken together, in the south. In addition, hills with altitudes of 6,000 ft. and above are potential foci of all the three rusts. Black and brown rusts may also be disseminated, at least occasionally, from altitudes of nearly 4,000 ft. and above.

Physiologic Races

Just as there are different varieties of wheat, each of the three rusts, under reference, has different strains, better known as Physiologic Races. The occurrence of Physiologic Races within the 'Specialized Form', *Puccinia graminis tritici*, the black rust of wheat, was first recorded by Professor E. C. Stakman of Minnesota, U.S.A.

As elsewhere, this study has been carried out on the lines standardized by Stakman and Levine. The work was started in the year 1932 and the Physiologic Races met with till March 1938 are mentioned below:

(1) Black rust of wheat.—Out of 144 races reported from different parts of the world, only six were found from a study of 586 collections obtained from plains as well as the hills. These are Nos. 15, 21, 24, 40, 42 and 75 of the International list. Races, 15, 40, 42 and 75 were also found on barley from the study of 33 collections. Seven collections from three wild grasses yielded races 15, 40 and 42 of this rust.

(2) Brown rust of wheat.—In 408 collections from different parts of the country, only six races were found. These are Nos. 10, 20, 63, 106, 107 and 108, the last four are new and had not been found anywhere else till the year 1939, when the last International list of 108 races was issued by Humphrey, Johnstone and Caldwell, U.S.A.

(3) Yellow rust.—A study of 236 collections yielded Nos. 10, 19, 20 and 31 out of a list of 38. Besides, four new races that have provisionally been labelled as A, D, E and F were found. These had not been reported from any other country till 1937. Race 19 of this rust was also found in five collections of barley.

The occurrence of a small number of physiologic races in India makes the breeding of resistant varieties more hopeful than is the case in some other countries. During the course of these studies, work in connection with the breeding of rust resistant wheats, for cultivation in the hills, was also started in the year 1935, in collaboration with the Imperial Economic Botanist. Recently, a very promising wheat from Kenya was found to be highly resistant to the most virulent race 15 as well as 40 of black rust, Mehta and Pal.[7] This discovery has greatly simplified the breeding of a wheat resistant to black rust.

Control of Epidemics by Direct Means

Rusts are known to cause huge damage in every country where wheat and barley are extensively grown. No reliable figures are available in this country regarding the actual loss but considering the acreage of 43 millions under the two crops, taken together, it may amount to 60 million rupees a year. Even this figure might be an underestimate, based as it is on a loss of only·6 per cent. of the value of the entire yield.

Now that the problem under review has been largely solved and we know definitely the sources of initial infection, wherefrom rusts are disseminated year after year, it is time efforts were made to control them. It is obvious that the survival of rusts from season to season only in the hills, which occupy less than 5 per cent. of the entire area under wheat and barley in this country, offers a unique opportunity of control by relatively simple and inexpensive means. The writer's opinion on the practicability of the various methods of combating rusts, with special reference to the conditions in India, is briefly discussed below:—

(1) In order to eradicate rusts at the source, the writer, Mehta,[2] suggested that cultivation of wheat and barley should be suspended in the hills for 2–3 years. This method would be effective only with the co-operation of neighbouring States that own a considerable part of the hilly area.

(2) Dusting the wheat crop with sulphur powder from aeroplanes, which has been attempted on a small scale in some parts of North America, would be impracticable in this country because nearly 80 per cent. of the area is covered by the highly susceptible, indigenous (*dési*) varieties. This method would involve huge expense over weekly applications of sulphur and cost of aeroplanes, etc. Besides, on account of prevailing dry weather during the period of growth of wheat in the plains, most of the sulphur is likely to be blown off the surface of plants, from time to time.

(3) The other method of control, which is universally recognized, is to cultivate resistant varieties. For the reasons given above, in this country it would suffice to grow resistant varieties of wheat and barley *only* in the hills, wherefrom rusts are reintroduced into the plains, from year to year. As stated above, breeding of rust resistant wheats is in progress and it is hoped that similar work on barley will soon be started. In view of the prevalence of all the three rusts in most of the hills the task of breeding a wheat, which would resist them all, is likely to take several years and for an effective control at the source we need also a variety of barley resistant to black and yellow rusts.

(4) 'Clean-up', *i.e.*, rigorous destruction of 'out of season' wheat and barley (self-sown plants, tillers and stubble), which carry over the rusts, 1–2 months before sowing in all the hills and hilly tracts should be an effective method of control in India in view of the small holdings.

(5) Considering the small acreage under *early* crops in the Nilgiris, Palni hills and central Nepal, suspension of the first crop, sown during April–June in the first two areas and postponement of sowings in the last to the normal period, *i.e.*, October, should be the most effective methods of direct control of rust epidemics in the greater part of Peninsular India and the Indo-Gangetic plains, respectively.

In connection with No. (3), it is essential to refer to an important recent observation by Professor Stakman of U.S.A., a leading authority on cereal rusts, stating that rust resistance in varieties so far known is a variable character like any other plant character. Further, that even so resistant a variety of wheat as Hope may rust quite normally when light intensity is reduced and that under cloudy conditions, therefore, when there is considerable moisture, it may be heavily rusted if large numbers of spores are present in the air.

The above conditions of weather are of frequent occurrence in the hills of India and there is a considerable amount of inoculum always present in those parts. It would be wise, therefore, to enforce 'Clean-up' in the hills at an early date and not put it off till resistant varieties are available, when this method will have to be adopted for the success of control by their cultivation. Notwithstanding the difficulties of supervision of 'Clean-up' in the hilly areas and a certain amount of expense to Provincial Governments and the States concerned for such arrangements, the writer is fully convinced that this method is worth attempting and if carried out rigorously should mitigate considerably the huge loss that is caused by rusts, from year to year.

In conclusion, it may be stated that the direct methods of control described under (4) and (5) are practicable and ought to be tried without delay. In the earlier stages of their adoption, rusts may appear here and there but should not break out *early* enough to cause devastating epidemics over large tracts of the country, as at present. That should lead to a saving of millions of rupees annually whereas the cost over these measures would amount only to a few thousands.

These methods have been approved for trial by competent bodies of the Imperial Council of Agricultural Research as well as by some of the leading scientists abroad and it now remains for Provincial Governments and the States concerned to test their efficacy over a number of years *simultaneously* in their respective territories.

ACKOWLEDGMENTS

The writer wishes to express his warmest thanks to the Imperial Council of Agricultural Research for various grants sanctioned for the continuance of investigations on cereal rusts, with the help of temporary research staff, since the year 1930, prior to which this work was carried out by the writer for a period of seven years at considerable personal expense.

Other acknowledgments due have been fully recorded in the two monographs, referred to above, and for want of space it is unnecessary to repeat them here.

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OBITUARY

DR. W. L. DAVIES, Ph.D. (Cantab.), D.Sc. (Wales), F.I.C., N.D.A.

IN the sudden death in Delhi of Dr. W. L. Davies, at the early age of 45, the cause of scientific research in milk and milk products has suffered a grievous loss.

After a distinguished career at the Reading University where he was Advisory Agricultural Chemist to the Southern Advisory Province from 1924 to 1927 and Research Dairy Chemist to the National Institute for Research in Dairying, Shinfield, from 1927 to 1939, Dr. Davies arrived in India to take up the duties of the newly created post of Director of Dairy Research under the Government of India. He applied at once with characteristic enthusiasm to the establishment of an Imperial Dairy Research Institute in New Delhi, but the war unfortunately interfered with the immediate financing of an ambitious project. Undaunted, Dr. Davies approached the Imperial Agricultural Research Institute for such laboratory facilities as can be spared, and, on these being readily offered, he initiated research work on urgent problems of the dairy industry, particularly detection of adulterants in *ghee*. The considerable knowledge which he acquired in the course of a preliminary survey of the indigenous industry he embodied in a brochure entitled "Indian Indigenous Milk Products". The standard of this book is such as to be useful to all interested in the exploitation of milk in India, especially students of dairying, agricultural and animal husbandry, biochemists, analysts and technologists. The other contrbutions while in India include articles on (*a*) Colloid aspects of milk technology, (*b*) Deterioration of butter during storage, (*c*) Conservation of grass, and (*d*) Anti-oxygenic effect of cereal flour paste as a coating on contact wrappers for fatty foods. Dr. Davies' great reputation as a Dairy Chemist will, however, continue to be enshrined in his Monograph on "The Chemistry of Milk" (being Volume 10 of a series of monographs on Applied Chemistry under the Editorship of Dr. Howard Tripp; Chapman & Hall) which was so well received by the scientific world that a second edition was called for within three years of its original publication in 1936.

During the 22 months he was spared to live in India, Dr. Davies made many contacts, and impressed all as a good "mixer" and a devoted scientific worker.

B. V. N.