STUDIES ON FORECASTING OUTBREAKS OF BLAST DISEASE OF RICE

I. Influence of Meteorological Factors on Blast Incidence at Cuttack

BY S. Y. PADMANABHAN

(Central Rice Research Institute, Cuttack)

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INTRODUCTION

As an economic spray schedule for the control of blast disease of rice has been worked out (Padmanabhan *et al.*, 1956, 1959, 1962 and 1963) it was considered necessary to develop forecasting and forewarning services for blast outbreak so that plant protection measures could be applied effectively. Such forecasting services have been successfully developed in late blights of potato and tomato, downy mildews of vine and tobacco and in rust diseases (Anon, 1955). Progress has been made on the forecasting of rice disease such as blast and seedling blight in Japan (Miller, 1952; Kawada, 1954; Padmanabhan *et al.*, 1960).

In this contribution an attempt is made to relate the incidence of blast disease in the Institute Farm (Cuttack) during 1950–1962 to the trend of the chief meteorological factors with a view to develop some basic principles on which forecasting of blast outbreak could be developed in India.

TREND OF BLAST DISEASE AT CUTTACK

The incidence of blast follows more or less a definite pattern at Cuttack in all years. Generally, stray cases of infection are noticed late in the seedling stage but only in exceptional years seedling infection occurs as an epidemic. During the heavy monsoon season of July and August, leaf blast in the tillering phase can be seen only very rarely in the most susceptible types, but immediately with the cessation of heavy rains, during September, and later in October, the maximum incidence of blast is noticed both as foliar blast or as neck infection in the types which come into flower during this period. The varieties, which come to flower late in November or early in December,

do not suffer much damage from neck infection. Within this general pattern of incidence, the actual intensity of the disease varies from year to year.

METHOD ADOPTED IN THE STUDY

The incidence of blast disease has been observed each year on the genetic stocks, varietal susceptibility trials, spraying trials to control blast in some years on manurial and fertilizer trials, etc. Based upon these data, each year could be classified into "very favourable" or as "unfavourable", "moderately favourable" in respect of seedling infection (July–August), leaf and neck-infection (September–October) and neck-infection alone (November). The data on the incidence of the disease in each year and the classification of the year accordingly are presented in Tables I, II, III and IV.

The various meteorological factors during the period, *viz.*, maximum and minimum temperatures, rainfall and relative humidity, were obtained from records of the meteorological observatory, at the Central Rice Research Institute. The data were tabulated for periods of ten days for each of the months of July, August, September, October and November, for the years 1950–1962. From these primary data certain secondary data were derived which are considered as important in the present context, *viz.*, in each ten days period for the above months.

(i) The number of days the maximum was 28° C., 30° C., 32° C. and 34° C.

(ii) The number of days the minimum was 26° C. and below, 24° C. and below, 22° C. and below 20° C. and below.

(iii) The number of days the difference between maximum and minimum was above 10° C., 11°–15° C., 16°–20° C., 21°–25° C. and also 26° C.

(iv) The number of days the minimum was 26° C. and below, etc., associated with relative humidity of 90% and above, or 85% and below.

With the help of the above tables of meteorological data for ten-day periods for the months of July–November the trend of these factors in the "favourable", "unfavourable" and "moderately favourable" years were studied. The results are presented below.

RESULTS

(*a*) *Seedbed Infection*

There was no clear-cut differences between the maximum temperature of "favourable" and "unfavourable" years but the years 1960 and 1961

TABLE I *Seedbed infection data on blast disease of rice in various experiments during 1950–1962 and the classification of the year as favourable or otherwise with respect to blast infection*

	1950	1951	1952	1953	1954
1. No. infected in Genetic Stock	..	..	..	78 out of 450 observed were infected. 148 varieties infected out of 450 included in varietal test	Nil
2. Seedling infection in other seedbeds	Present	Present	Absent	..	Very little
3. Classification of the year in respect of blast seedbed infection	Moderately favourable	Moderately favourable	Unfavourable	Moderately favourable	Unfavourable
	1955	**1956**	**1957**	**1958**	**1959**
1. No. infected in Genetic Stock	55 types only	146 types	1,173 types	Negligible in Genetic Stock	141 types in Genetic Stock
2. Seedling infection in other seedbeds	21 out of 246 infected. Good infection in August in segregating progenies in hybridisation projects	195 out of 295 in varietal trials late in Aug., Sept., Oct. Very slight infection in segregating progenies in hybridization projects	Very high infection in segregating progenies	Slight infection in segregating progenies	73 out of 490 in artificial infection. Slight infection in segregating progenies
3. Classification of the year in respect of blast seedbed infection	Moderately favourable to favourable	Moderately favourable	Very favourable (epidemic outbreak)	Unfavourable to moderately favourable	Moderately favourable
	1960	**1961**	**1962**		
1. No. infected in Genetic Stock	Nil	Nil	(i) 64 infected out of 184 (ii) 131 infected out of 231 (iii) 139 infected out of 230		In varietal susceptible trials
2. Seedling infection in other seedbeds	Nil	Nil	Heavy infection in seedling of uniform blast nursery and other seedbed trials		
3. Classification of the year in respect of blast seedbed infection	Unfavourable	Unfavourable	Unfavourable		

TABLE II. *Leaf infection data in various experiments during* 1960–1962 *(September–October) and the classification for the year as favourable or otherwise with respect to blast infection*

	1950	1951	1952	1953
1. Data on leaf infection in various experiments	320 out of 420 tested infected and found susceptible in artificial infection Manurial trial T-1145 leaf score upto 7-8 Bulk Co. 13—Very severely infected	Date of planting experiment Co.13 (*a*) Leaf infection score—1·32–4·8 Estimate of loss in percentage of yield associated with leaf-infection 0·40%	Very slight in spraying trial No loss in yield due to leaf-infection ..	Infection moderate in Co. 13 in spraying tests Estimated loss in percentage of yield associated with leaf-infection—0·21% ..
2. Classification of the year with respect to leaf-infection due to blast	Very favourable epidemic year	Moderately favourable	Unfavourable	Moderately favourable

	1954	1955	1956	1957
1. Data on leaf infection in various experiments	Infection on Co. 13 present Estimated loss in percentage yield —0·36%	Infection on Co. 13 present Estimated loss in percentage yield —0·09%	Infection on Co.13 present Estimated loss in percentage yield associated with leaf infection—Nil	Infection very low on Co.13 Estimated loss in per centage yield associated with leaf-infection —Nil
2. Classification of the year with respect to leaf-infection due to blast	Moderately favourable	Moderately favourable	Moderately favourable to unfavourable	Unfavourable

	1958	1959	1960	1961	1962
1. Data on leaf infection in various experiments	Infection present on Co.13 Estimated loss in yield associated with leaf-infection—0·72% Experiments —0·17%	Infection present on Co.13 Estimated loss in yield —6·77% ..	Infection low on Co. 13	Infection very little on Co. 13 (Flooded)	Severe infection present on Co. 13 in uniform blast nursery .. ..
2. Classification of the year with respect to leaf-infection due to blast	Favourable	Favourable	Unfavourable	Unfavourable	Favourable

TABLE III. *Neck-infection data due to blast in various experiments in* 1950–1962 *and the classification of the year as favourable or otherwise with respect to blast*

	1950	1951	1952	1953	1954	1955
1. Neck-infection in spraying trial	No. spraying trials	1. Unmanured 3·38–30·06% 2. Manured 17·94–64·56%	13·5% in Co. 13 9·5% in manurial trial	31·5% in Co. 13 ..	29–32% ..	6·21% Present in hybridisation project
2. Neck infected in other experiments	Present in Co. 13 bulk	Date of planting experiment	..	..	..	..
3. Classification of the year in respect of neck-infection due to blast	Moderately favourable	Favourable	Unfavourable	Favourable	Favourable	Unfavourable

	1956	1957	1958	1959	1960	1961	1962
1. Neck infection in spraying trial	2·35–8·77%	1·81–7·82%	13·56–78%	5–12%	Below 5%	Below 1%	42·59%
2. Neck-infected in other experiments	Present in hybridisation project	Present in hybridisation project	Present in hybridisation project	..	..	..	..
3. Classification of the year in respect of neck-infection due to blast	Unfavourable	Moderately favourable to favourable	Very favourable	Unfavourable	Unfavourable	Unfavourable	Favourable

TABLE IV

Showing the different years classified as "favourable" and "unfavourable" for blast in Cuttack from 1950–1962 (*other years not shown are moderately favourable*)

Years favourable for			Years unfavourable for		
Seedling	Leaf-infection	Neck-infection	Seedling	Leaf-infection	Neck-infection
1957	1950	..	1952	1952	1955
..	1951	..	1954	..	1959
1962	1958	1958	1960	1960	1960
	1962	1962	1961	1961	1961

which were unfavourable for blast were characterised by the maximum number of days in the range of 28°–30° C. whereas in the other years the maximum was generally in a higher range.

The minimum temperature may be said to have some association with the development of seedbed infection. The year 1957, in which there was a blast epidemic in the seedbed was characterised by having 50 days out of 62 within 24°–26° C. whereas the year 1960 and 1961 which were clearly unfavourable for infection had only 38–39 days within the range. In addition, in 1957, there were 2 days in August in the range 22° C.–24° C. In other years in which some degree of seedbed infection occurred, *viz.*, in 1950, 1956, the number of days in the temperature range of 24°–26° C. were 55 and 51 days respectively; there were 2 days in the range 22°–24° C. in 1956 in the third week of August.

There was no clear correlation between other meteorological factors studied and seedling infection except that in the year of severe infection, the rainfall and the number of rainy days was less than in other years. (Fig. 1).

(*b*) *Leaf- and Neck-infection in September-October Period*

The maximum temperature did not show any apparent relation to blast outbreak, *i.e.*, in both types of seasons, *viz.*, "favourable", "unfavourable" for blast; the variations of temperature during September-October was similar.

The examination of the minimum temperature for the different years showed that there was some association between the minimum of September–

October and blast incidence; the years of high infection having generally more days under 24° C. than the unfavourable years.

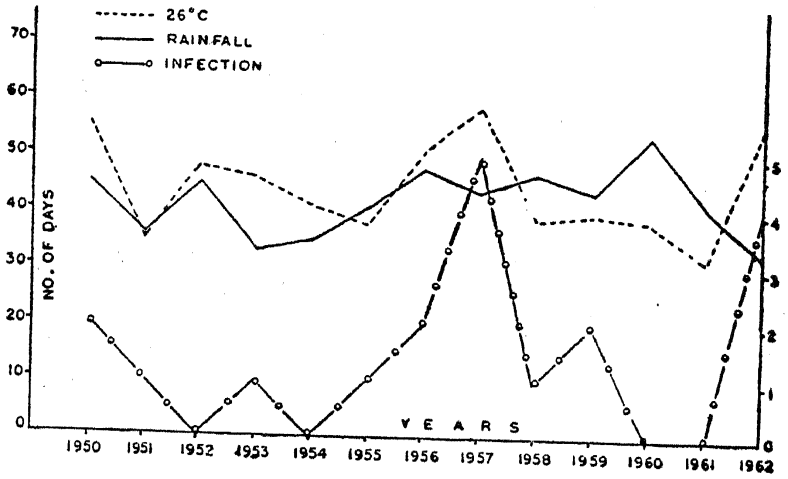

FIG. 1

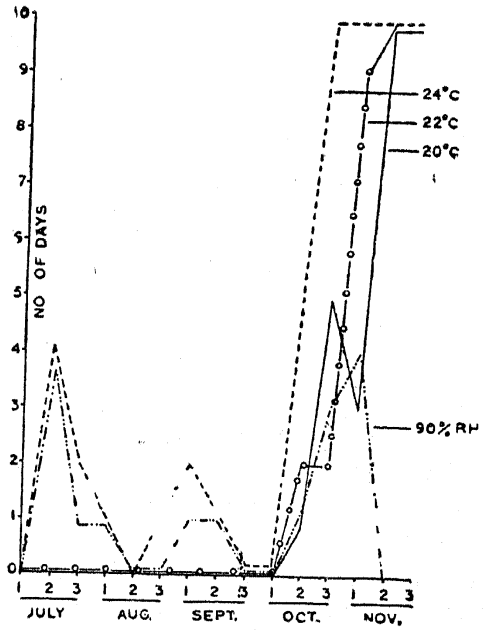

FIG. 2

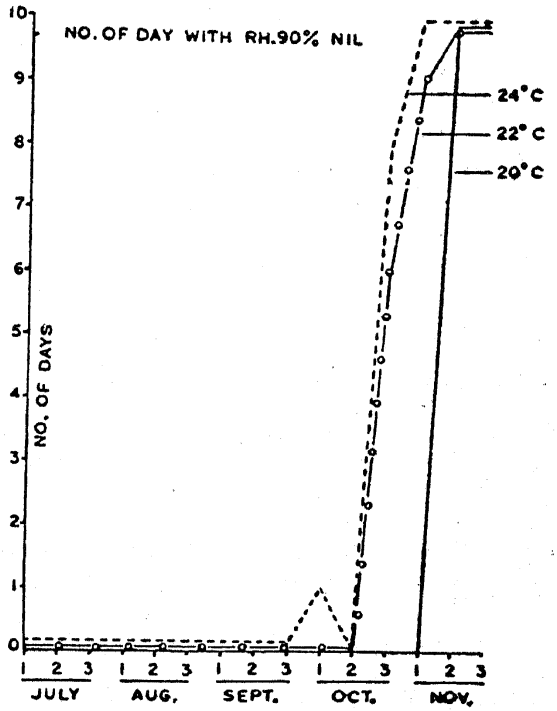

FIG. 3

FIGS. 1–3. Fig. 1. Incidence of seedling infection of blast in relation to rainfall and minimum temperature. Fig. 2. Unfavourable for leaf- and neck-infection, 1960. Fig. 3. Unfavourable for seedling, leaf and neck-infection, 1962.

Apparently, there were also other factors operating in conjunction with the minimum during this period. For instance, it was observed that the

date of onset of 24° C. and its continuance earlier in September had a pronounced effect on leaf-blast incidence as in 1950. Secondly, the number of days the low minimum occurred in conjunction with high relative humidity of 90% and above was definitely associated with blast incidence; the years with a larger number of days so associated being more favourable for blast than the years in which such days were less (Figs. 2–6).

(*c*) *Neck-infection*

The year 1958, which was characterised by highest neck-infection, had very few days with minimum below 20° C. whereas in all the other years 23–30 days of November were well below 20° C. (Fig. 5).

Relative humidity, rainfall and number of rainy days had a very clear association in the month of November with blast incidence.

DISCUSSION

From a critical study of the meteorological factors it is clearly seen that the most important critical factor favourable for blast incidence is a minimum temperature range of 20°–24° C. (or 26° C. for seedling infection). In addition to this, a high relative humidity associated with such a range of temperature appears to be equally essential.

Suryanarayana (1958, 1959) and Sadasivan *et al.* (1963) have drawn attention to the role of low nycto temperature 20° C. in causing blast infection. *Piricularia oryzae* releases spores in the night only. The high relative humidity in the presence of a fall in night temperature would result in heavy dew formation on the leaf surface providing an ideal condition for germination and penetration into the host by the pathogen, which require contact with water on leaf surface for 5–10 hours at different temperatures (Hemmi and Abe, 1931; Anderson *et al.*, 1947).

The early onset of such conditions in September during the most susceptible stage of the host would result in a build-up of the inoculum potential to an extraordinary degree and would result in an outbreak of the epidemic as in 1950 at Cuttack.

As might be expected, outbreak of neck-infection would depend upon the build-up of inoculum in the preceding leaf-infection phase. But, however, heavy might be the build-up, unless favourable conditions exist for the infection during neck-emergence phase, an epidemic at the latter phase is not

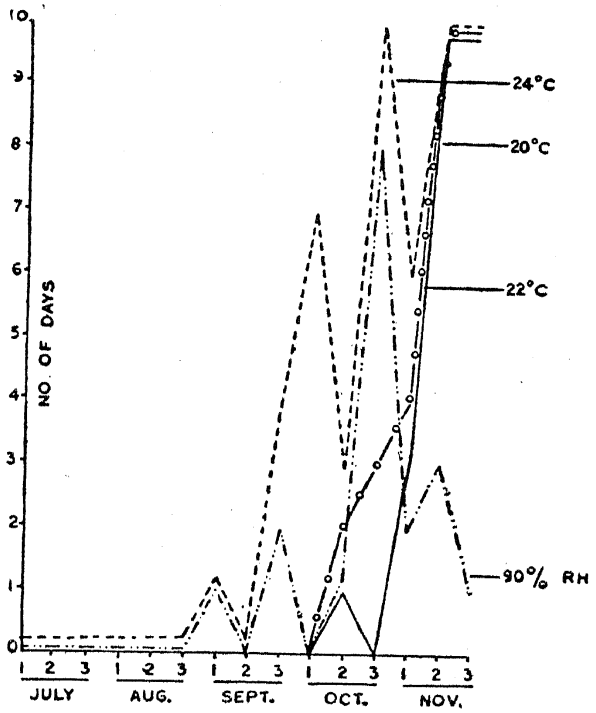

FIG. 4

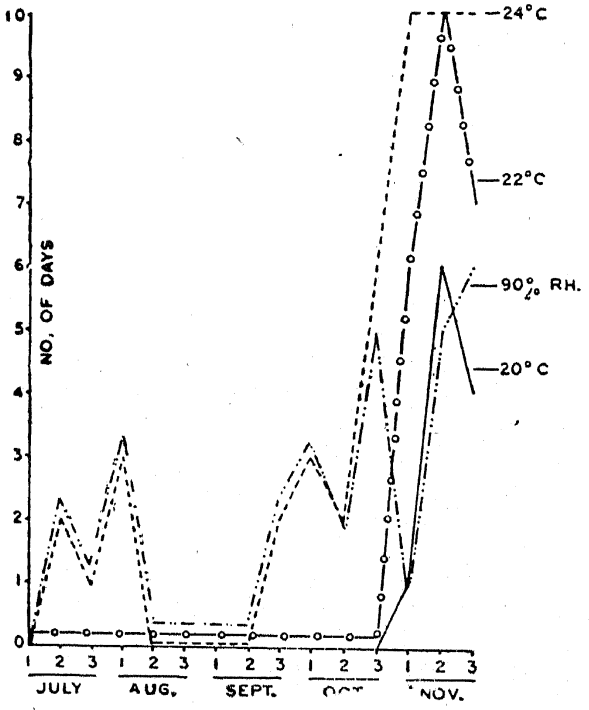

FIG. 5

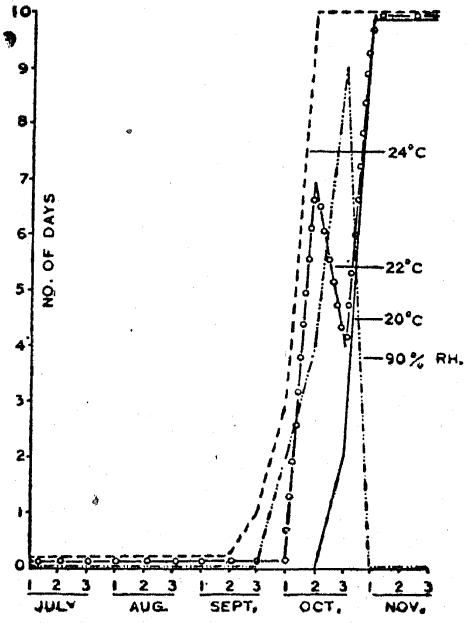

FIG. 6

FIGS. 4-6. Fig. 4. Favourable for leaf-infection, 1950. Fig. 5. Favourable for leaf- and neck-infection, 1958. Fig. 6. Favourable for leaf and neck-infection, 1962.

likely to result. Such ideal conditions for outbreak appeared to have existed in 1958. During November, under Cuttack conditions, the minimum temperature falls far below the optimum range, *i.e.*, 20°–24° C., and the relative humidity is also not generally high and, therefore, neck-infection is not seen in late flowering varieties (November and December). But in 1958, there was some light rainfall scattered over a few days and the minimum did not fall below 20° for 23 days; the relative humidity was continuously very high for 21 days, whereas in other years, high relative humidity was not present in association with favourable range of temperature for many days. This might explain the high neck-infection of 1958. During 1950, however, the huge build-up in September–October was not followed by high incidence of neck-infection as the minimum temperature was well below 20° C. for the whole month in November and the number of days of high relative humidity was also far less (*i.e.*, 4 days) than in 1958 (12 days).

Govinda Rao (1963) while discussing the blast and epidemic of 1958 and 1960 in Chinnagottigallu block of Chittoor District in the Andhra State has compared the rainfall data and difference between night and day temperatures at Madanapalli between the blast epidemic years of 1958 and 1960 on the one hand and those of 1959 on the other when there was very little blast incidence. According to his report, there was heavy rainfall and the number of rainy days were more in 1958 and 1960 when compared to the non-blast year of 1959. He also noted that there was less difference between night and day temperatures in the epidemic years.

Govindaswamy (1964) has laid stress on the number of days with a minimum 20° C. (68° F.) as favourable for blast and has drawn the general conclusion that the colder months of October, November, December and January are more favourable for blast than the preceding months. From the data presented by him it is seen, however, that in the years 1945–46, 1948–49 and 1949-50 the minimum temperature during the months of November, December and January was not less than those for the years 1943–44, 1944–45, 1950–51 and 1951–52; yet, there was no infection in the former years, while heavy outbreak was noticed in the latter years. Studies on the associated factor like rainfall, relative humidity, etc., might reveal the critical factor or factors which favour the development of blast epidemic in the colder season of October–January. In the Tanjore delta, as under Cuttack conditions, the minimum temperature in association with relative humidity and dew formation in the night are perhaps the deciding factors for the outbreak of epidemic.

It is felt that the association established above between weather condition and blast outbreaks justify attempts at forecasting blast outbreaks in India in the manner indicated below:

For seedling infection.—Severe seedbed infection has been found to develop when more than 50 days in July and August had low night temperatures of 26°–24° C., therefore, forecast of seedbed infection can be based upon the minimum temperature remaining at below 26° C. for more than 45 days; if the minimum is in the range of about 26°–24° C. or below even for 4–7 days then also seedbed infection can be forecast.

For leaf infection in the tillering phase.—The plants are susceptible to leaf infection at the tillering phase. If the night temperature falls below 24° C. accompanied by a high relative humidity of 90% and heavy dew formation, severe infection is likely to result; if the onset of 24° C. is quite early in the post-transplanting and tillering phase of the crop, *i.e.*, during the first week of September and continues to remain low thereafter with high relative humidity, heavy blast is likely to set in. Therefore, blast warning can be issued if the minimum temperature remains at 24° or below for a 4–5-day period continuously during the post-transplanting and tillering phase accompanied by high relative humidity.

For neck-infection.—Neck-infection is not likely to be severe without a preceding favourable or moderately favourable season for leaf-infection. Therefore, forecasting of neck-infection will depend upon (i) conditions favourable for leaf-infection in September–October followed by favourable temperatures of 20–24° C. for a number of days during flower emergence and maturity with high relative humidity, light rainfall, etc. Therefore, blast neck-infection forecast can be based upon the severity of disease in leaf-infection phase, followed by observations on minimum temperature during the flower emergence period. If temperature remains between 20° C. and 24° C. with high relative humidity during this period, blast infection may be forecast.

It may be mentioned that the years 1950–51 which were years of severe epidemic during November to January in Tanjore were also years of severe incidence of blast in the tillering phase in September–October in Cuttack. Similarly the year 1958 which was an epidemic year for neck-infection at Cuttack also happened to be the epidemic year for neck-infection in Chinnagottigallu in Chittoor District of Andhra Pradesh. If further sets of such comparisons were possible between the data on blast incidence in the northern,

central and southern regions of India and if ths pattern of incidence proves to be not just coincidence, then it might be possible to be forewarned against blast incidence in the southern regions on the basis of their forecast or actual incidence in the northern and central regions earlier in the year.

The need, therefore, is for a greater concerted study on the pattern of disease development with the associated meteorological factors in a number of research stations. The Indian Council of Agricultural Research has been appraised of the advance made in this direction and the Special Committee of the Indian Council of Agricultural Research have under consideration a scheme of for the setting up of a number of forecasting stations in the different parts of India.

SUMMARY

An account is given of the incidence of blast disease of rice in correlation with some meteorological factors. The results show that forecasting of blast outbreak in India can be attempted on the basis of minimum night temperature range of 20°–26° C. in association with a high relative humidity range of 90% and above lasting for a period of a week or more during any of the susceptible phases of crop growth, *viz.*, seedling stage, post-transplanting, tillering stage and at neck-emergence.

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