

EFFECT OF ENVIRONMENTAL FACTORS ON INCEPTION AND DEVELOPMENT OF SEEDLING BLAST IN UPLAND BLAST NURSERY IN SRI LANKA

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ABSTRACT

Blast disease caused by *Pyricularia oryzae* Cav. is the most destructive fungal disease of rice in Sri Lanka. Use of resistant varieties is the most effective and economical approach to control the disease in farmers fields. Development of blast resistant varieties involves an important step of screening breeding lines against blast in upland blast nurseries. To obtain reliable and consistent screening results, uniform occurrence and development of blast disease in upland blast nursery are essential. Environmental factors are known to play a key role on inception and development of blast disease. In order to study the effect of various environmental factors such as maximum and minimum air temperatures, grass minimum temperature, wind velocity, relative humidity, dew formation and raining periods on inception and development of blast disease in upland nurseries, blast screening results of eleven rice varieties, over 14 seasons were analyzed. It was found that cool nights having air minimum temperature of 20-22°C, grass minimum temperature of 17-20°C, low wind velocity of less than 5km/h, rain-free days and long dew hours extending up to late morning were conducive for the occurrence and development of blast disease.

KEY WORDS : Blast disease, Disease forecasting

INTRODUCTION

Blast disease caused by *Pyricularia oryzae* Cav. is the most destructive fungal disease of rice in Sri Lanka. Blast is predominantly experienced in the field at two crop growth stages. Leaf blast at early crop growth stage is a field problem specially in upland rice cultivation in eastern region and in upcountry Badulla area. On the other hand, panicle blast at flowering stage may occur specially in late maha season (December - January) in upland as well as in lowland rice cultivation.

Use of resistant varieties is the most effective and economical countermeasure to protect rice plant from the disease (MacKenzie, 1981). Development of resistant varieties necessitate the use of resistant donor

parents in the hybridization programme and subsequent screening of breeding lines at each generation to select resistant lines for their advancement. In Sri Lanka, the rice breeding programme is handled as a modified bulk method where from F_1 up to F_4 generation, the breeding materials are advanced as bulk populations and from F_4 generation onward as pedigree lines. Therefore screening of individual pedigree lines for any disease or insect pest is possible only from F_4 generation and onward. Uniform highland blast nursery technique is usually adopted to screen breeding lines and varieties against blast disease. However, to obtain reliable and consistent screening results, the uniform occurrence and development of disease in the screening nursery is very imperative.

A susceptible plant, virulent pathogen and conducive environmental conditions are the three essential elements that should come together in order to incite a plant disease (Tarr, 1972). In case of a blast screening nursery, having a known standard susceptible variety uniformly spread over the nursery space could fulfil the first requirement. Presence of a virulent pathogen can be assured by establishing blast disease on a susceptible variety, adjacent to screening beds well ahead of screening schedule, in order to provide a good source of initial inoculum where the natural air-borne inoculum density is not sufficient. Therefore it is clear that the prevalence of conducive environmental conditions becomes critical for the inception and development of blast disease in the nursery. Many studies have been reported in Japan (Hashioka 1963) and India (Sadasivan *et al.*, 1963) on the influence of various environmental factors on occurrence and development of blast disease in the field at adult plant stage and under experimental conditions. However, such information is scarce in Sri Lanka. The objective of this paper is to report the observations made on the effect of various environmental factors on inception and development of blast disease in upland blast nurseries. The findings will facilitate (i) to use meteorological data in selecting blast screening sites with favourable microclimate, (ii) to determine the period of time during the year in which screening should be done within the site identified, based on weather pattern and (iii) to determine whether

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infection in the nursery at seedling stage is incited by similar or different meteorological condition to those which have been reported earlier to cause disease at adult plant stage in the field.

MATERIALS AND METHODS

Blast screening results of 11 selected varieties, over 14 seasons (Table 1) from yala 78 to maha 84/85 at Central Rice Breeding station (CRBS), Batalagoda were used for this study.

Table 1. Time period considered for computing mean weather data values during blast screening periods

<i>Seasons grouped according to severity of blast incidence</i>	<i>Date of sowing</i>	<i>Time period taken for computing mean weather values</i>	
		<i>From</i>	<i>To</i>
Severe incidence			
maha 78 / 79	12-12-78	22-12-78	11-01-79
maha 79 / 80	13-12-79	23-12-79	12-01-80
maha 80 / 81	10-12-80	20-12-80	09-01-81
maha 81 / 82	14-12-81	24-12-81	13-01-82
maha 82 / 83	15-12-82	25-12-82	14-01-83
maha 83 / 84	27-12-83	06-01-84	26-01-84
maha 84 / 85	18-12-84	28-12-84	18-01-85
Moderate incidence			
yala 79	24-05-79	03-06-79	23-06-79
yala 81	20-05-81	30-05-81	19-06-81
yala 82	29-05-82	08-06-82	28-06-82
Low incidence			
yala 78	03-06-78	13-06-78	03-07-78
yala 81	20-05-81	30-05-81	19-06-81
yala 83	08-06-83	18-06-83	08-07-83
yala 84	17-06-84	25-06-84	06-07-84

Varieties were selected so as to include different degrees of blast resistance namely, resistant (R), moderately resistant (MR), moderately susceptible (MS), and susceptible (S), evaluated according to the standard evaluation system (SES) scale of International Rice Research Institute (IRRI). Accordingly varieties Tetep, Bg 11—11 and Bg 367—4 as R (0—1 score on SES), varieties Bg 380, H4 and Bg 90—2 as MR (2—4 score on SES), Bg 34—6, Bg 94—1 and Bg 276—5 as MS (5—6 score on SES) and Bg 34—8 and Pachchaiperumal as S (7—9 score on SES) were selected.

The 14 blast screening seasons were separated into 3 groups based on the level of blast severity on standard susceptible variety, Pachchaiperumal (PP). Seasons in which PP showed a disease severity scale of 6—9 on SES were grouped as severe incidence seasons. Similarly the seasons in which PP had disease severity scale of 3—5 on SES were grouped into moderate incidence seasons and finally the seasons in which PP had disease severity scale of 1—2 on SES were grouped into low incidence seasons. Under each group of seasons, mean blast severity values were computed for each variety (Fig. 1).

The mean values of following environmental factors were computed for the last 3 weeks of the screening period in each season with the data recorded at the meteorological unit of CRBS, Batalagoda which is situated 200 m to the east of the blast nursery:

- * Mean maximum air temperature
- * Mean minimum air temperature
- * Mean grass minimum temperature
- * Mean soil temperature at 5 cm depth
- * Mean relative humidity (RH) at 8.30 am and 3.30 pm
- * Mean wind velocity

The above mean values are presented under 3 groups of seasons with severe, moderate and low level of blast incidence (Fig. 2).

Number of dew formed days within last three weeks of each screening period was computed based on air minimum temperature (Fig. 3) and grass minimum temperature (Fig. 4). First the dew

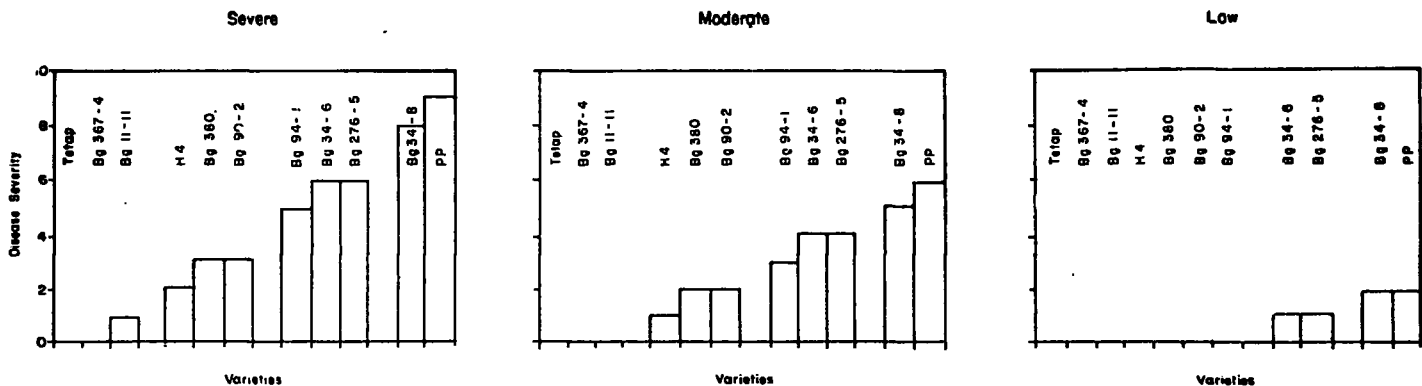


Fig. 1. Mean blast disease severity of test varieties categorized into three of levels blast incidence (severe, moderate and low)-Batalagoda. Severe category was the mean of maha seasons 78/79, 79/80, 80/81, 81/82, 82/83, 83/84 and 84/85; Moderate category was the mean of yala seasons 79, 81 and 82; Low category was the mean of yala seasons 78, 80, 83 and 84.

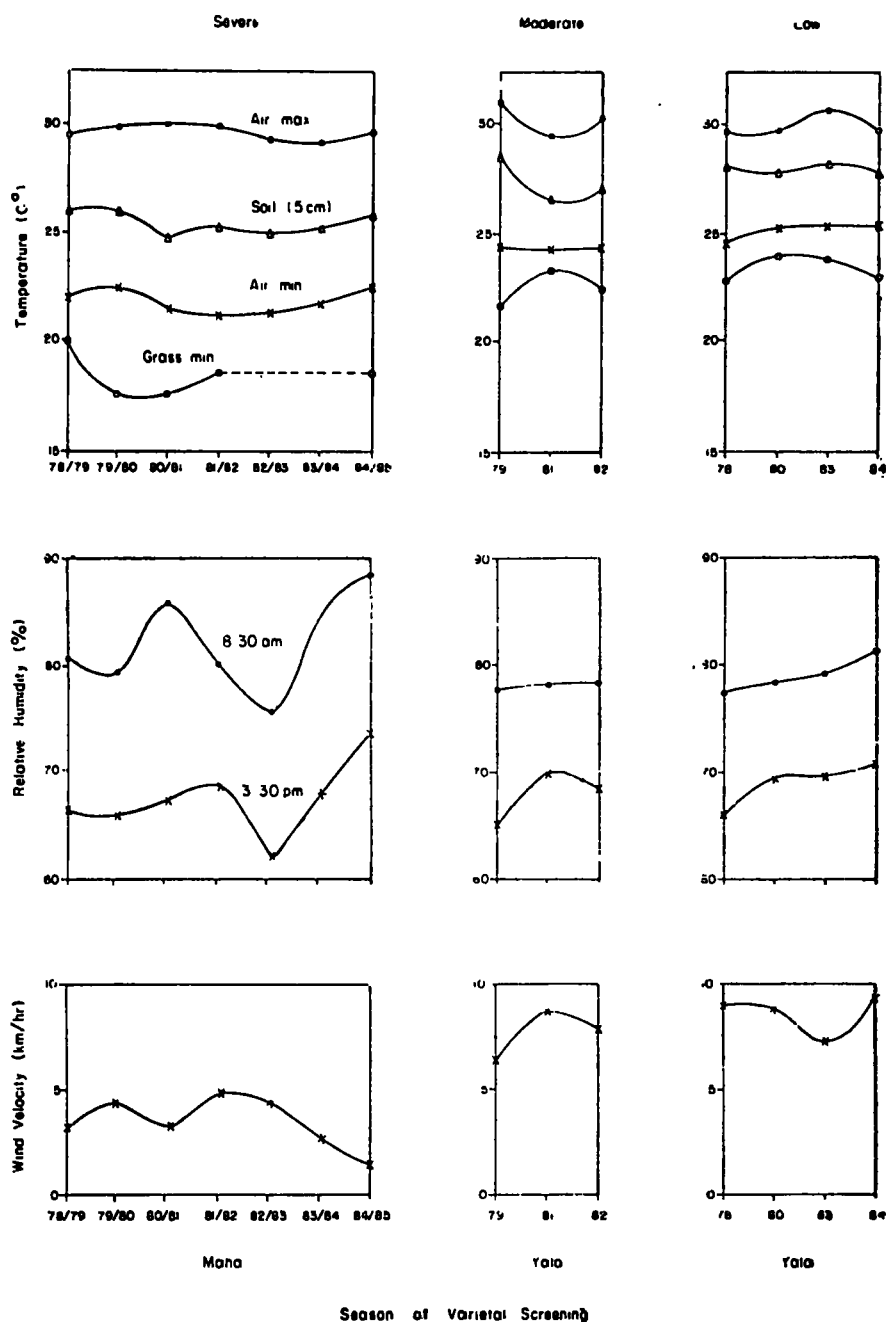


Fig. 2. Mean weather parameter values for last 3 weeks of each screening season under 3 groups of blast incidence levels—Batalagoda

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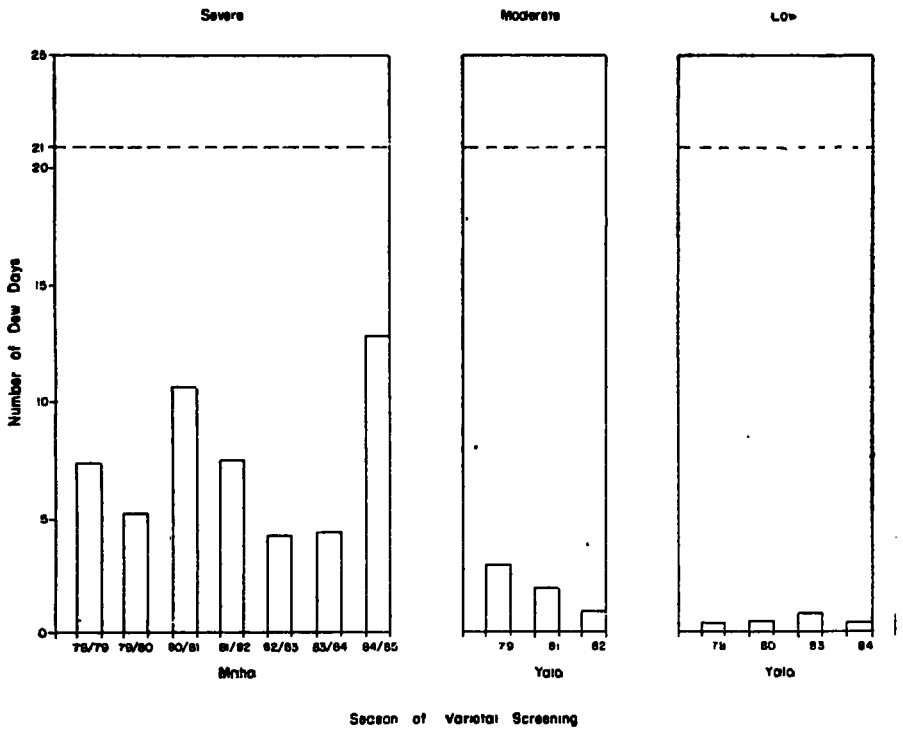


Fig. 3. Number of dew days in each season based on air minimum temperature, grouped under the 3 levels of blast incidence—Batalagoda.

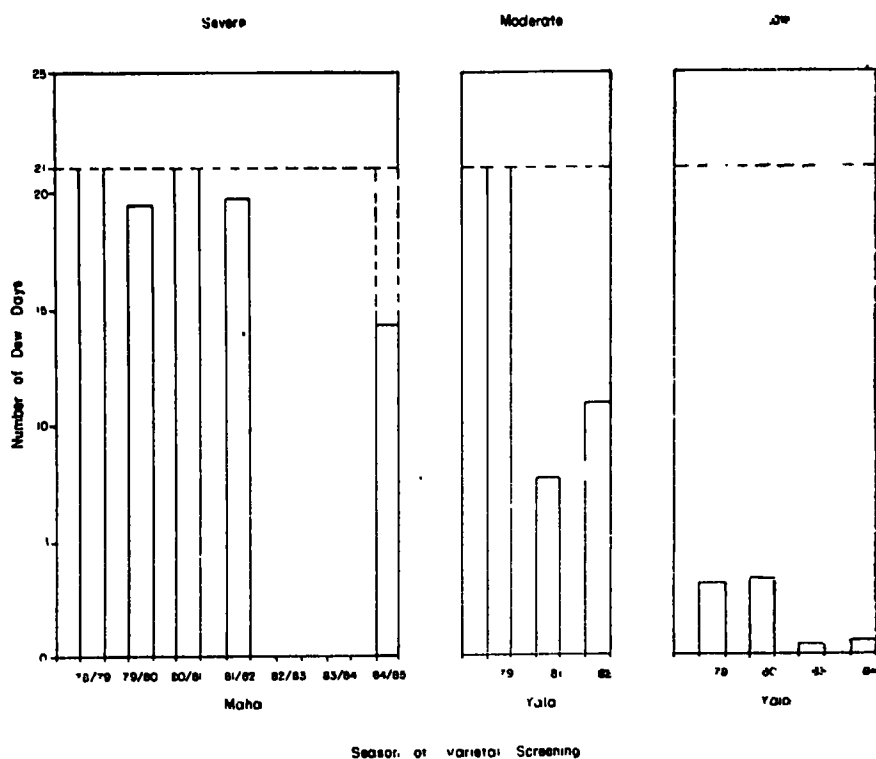


Fig. 4. Number of dew days in each season based on grass minimum temperature, grouped under the 3 levels of blast incidence — Batalagoda

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point temperature was calculated using psychometric charts for each screening day. The days in which dew point temperature was higher than air minimum or grass minimum temperature were considered as dew formed days.

Rainfall during the screening period for the different seasons is shown in the form of wet and dry pentades (Fig. 5). Here screening period of one month in each season from sowing to final scoring

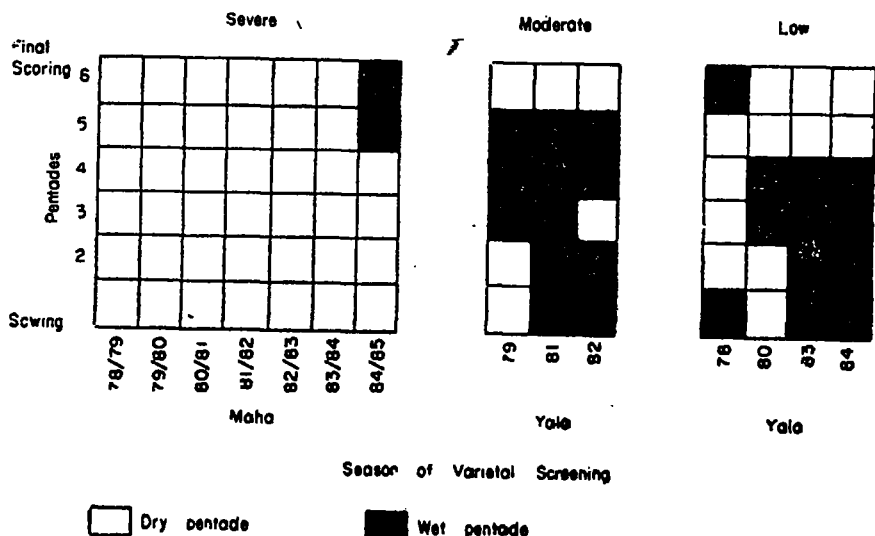


Fig. 5. Rainfall presented as pentades (5-day periods) during screening periods in each season under the 3 levels of blast incidence—Batalagoda. The middle pentade in any sequence of three is considered wet if 38 mm or more rainfall occurs over the 3 adjacent pentades and over 8mm rainfall occurs in at least 2 of the 3 pentades.

was divided into six, 5—day periods (pentades). Each pentade was designated either wet or dry depending on a particular rainfall criterion. The criterion chosen in this case depends on the rainfall received in three adjacent 5—day periods; the middle pentade was considered wet, if a rainfall of 38 mm or more occurs over the three adjacent pentades and a rainfall of over 8 mm occurs in at least two of the three pentades (Bird and Zainudeen, 1989).

Finally blast severity values of varieties under each category of seasons in Fig. 1 were compared with the mean weather parameter values of the corresponding group of seasons in Fig. 2, No. of dew

days in Figs. 3 and 4, and rainfall data in Fig. 5, in order to find out the importance of environmental factors in inciting and development of blast disease.

Weekly mean values of the following weather parameters were computed for standard meteorological weeks of the year maintained by Meteorological Department (Figs. 6 and 7). Data recorded at CRBS, for a twenty-five year period from 1960 to 1985 were considered for computing the mean values.

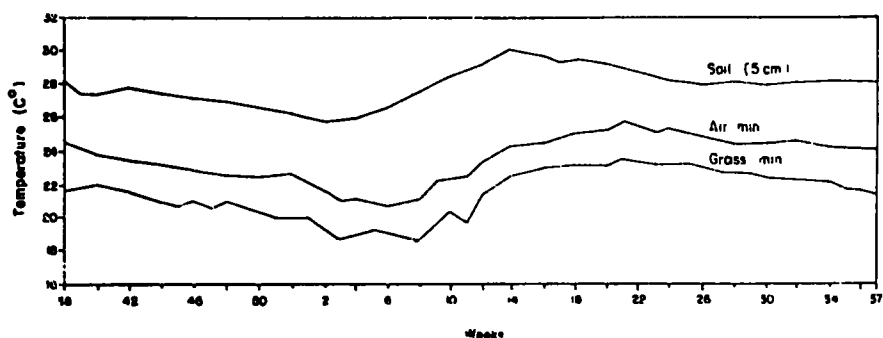


Fig. 6. Mean weekly temperatures (Soil, air and grass)—Batalagoda (1960—1985)

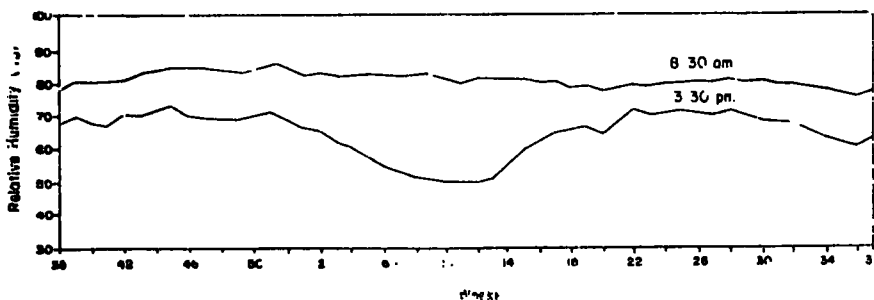


Fig. 7. Weekly relative humidity — Batalagoda (1960—1985)

- * Soil temperature at 5 cm depth
- * Air minimum temperature
- * Grass minimum temperature
- * Relative humidity at 8.30 am and 3.30 pm

Weekly variation of above weather parameters within the year was scrutinized to find out the period of the year which is conducive for occurrence and development of blast disease.

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RESULTS AND DISCUSSION

Varietal reaction to blast incidence

Clear differences were observed of the blast severity of test varieties among the three groups of seasons (Fig. 1). In seasons when blast incidences were severe in highly susceptible variety Pachchaiperumal, the test varieties showed their true genetic resistance level to blast as expected. As the occurrence of blast severity dropped to moderate and low levels, the varieties Bg 34-8 and Pachchaiperumal known to possess susceptible (S) reaction and Bg 94-1, Bg 34-6 and Bg 276-5, known to possess moderate susceptible (MS) reaction, did not show their true susceptibility. However resistant (R) varieties, Tetep, Bg 367-4 and Bg 11-11 did not show any difference irrespective of seasons.

This indicates that resistant varieties will show their genetic resistance irrespective of the suitability of environmental conditions for blast development. On the other hand susceptible varieties show their true level of susceptibility under certain environmental conditions while they are not affected under certain other environmental conditions, showing thereby the critical influence of environmental factors on varietal reaction for blast. Rice blast disease is a polycyclic disease.

Reproduction is mainly through asexually formed conidia (Ou, 1985). The entire process of lesion development which is one pathogen cycle, consists of several events, spore depositions, spore germination, germ tube growth, appressorium formation, penetration, infection (establishment), mycelial growth and sporulation. One pathogen cycle may take 4-18 days depending on environmental conditions, pathogen virulence and host resistance as discussed below under the different weather factors:

Effect of mean maximum air temperature (MMAT)

There was no marked difference of MMAT values among the three different groups of seasons (Fig. 2). Values ranged from 28-32°C. Earlier observations by Hashioka (1963) confirm that the

disease could occur in this temperature range. He has also reported that above 36°C fungal growth was inhibited. Thus the MMAT range found in the screening locations was not a decisive factor for blast occurrence.

Effect of mean air minimum, grass minimum and soil temperature

Mean air minimum temperature was less than 22.5°C in severe blast incidence seasons; for moderate and low incidence seasons it was around 24°C and 25°C respectively (Fig. 2). Mean grass minimum temperatures were well below 20°C in severe blast incidence seasons, around 22.5°C in moderate and around 23.5°C in low incidence seasons (Fig. 2). Mean soil temperature at 5 cm depth was around 25°C in severe blast incidence seasons while for seasons of moderate and low incidences it was around 27.5°C and 28°C, respectively (Fig. 2).

These observations indicate that in seasons having relatively low air, low grass minimum and low soil temperature, the occurrence and development of blast disease was promoted.

Predisposition of rice seedlings to blast disease has been reported when they were subjected to low air and soil temperature. Accordingly rice seedlings became susceptible when they were kept at low temperature, 18—20°C, for several days prior to inoculation; the seedlings became resistant at moderate temperature, 25—28°C, which favour growth and stability of seedlings (Sadasivan *et al.*, 1963).

Several workers have reported earlier that certain stages of infection cycle are favoured by low temperatures. Optimum temperature for sporulation was 25—28°C. However, when the temperature dropped from 28°C to 16—24°C, sporulation period appeared to increase even after 15 days (Henry and Andersen, 1948). Optimum temperature for appressorium formation was between 15—18°C. The minimum period required for fungal penetration into host tissue has been 6, 8, 10 hours at 24°C, 25°C, 28°C, respectively and at 32°C no invasion occurred (Hashioka, 1963). He also found that reproduction and propagation of the rice blast fungus to be greatest at high humidity and at comparatively low temperature (21—24°C).

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Effect of mean relative humidity (RH) and dew formation

Mean relative humidity at 8.30 am varied between 80—90% in severe incidence seasons, except in maha 82/83 season which had exceptionally low humidity level, whereas that under moderate incidence season was around 80—81% and in low incidence seasons between 77.5—81% (Fig. 2).

Observations on the effect of RH on blast development in this study showed that RH values were rarely above 95% even in seasons with very high blast incidences (Fig. 2). However, it was clear that dew had been formed on most of the days in seasons with high disease incidences (Figs. 3 and 4). This suggests that RH had increased up to 100% during the night before dew formation. Therefore low RH values recorded during day time at 8.30 am and at 3.30 pm had no significance on disease development.

Relative humidity influences the sporulation of fungal pathogens and their invasion of host plant tissues (Tarr, 1972). Optimum relative humidity values reported for various stages in the pathogen cycle have been different (Hashioka, 1963). Optimum conditions for dispersal of conidia were a temperature between 20.5—21.8°C and RH over 90% for 10 h or more. The critical RH for spore germination was 92—96% and germination was improved when RH level was increased. However even at 100% RH, water drops were essential for germination. Water drops on leaf surface consist of rain, dew and gutation drops. The critical RH for invasion of the fungus into the host tissues was between 90—92%. The rate of sporulation on rice plants increased at RH above 90%. Sporulation did not occur at RH of 88% and less, although the size of lesions on the leaves extended. However if enough water was supplied to the lesions from surrounding parts, lesions could sporulate well, despite low humidity (Hashioka, 1963).

Lesion development as a whole, however had been better at a lower humidity of 88% than at saturation, while sporulation on lesion occurs only at RH of more than 90% (Hashioka, 1963). Furthermore, the rice seedlings grown under moderate humid conditions (RH=84—95%) for more prolonged periods such as 10 days

increased their susceptibility considerably, but they were impaired or less infected when the environment was either extremely damp or dry (Hashioka 1963).

Conidia in nature disseminate at night. Dissemination begins at midnight, increases till day break and ceases at sunrise. This phenomenon seems to be related to the micro humidity, especially dew condition of the air surrounding the rice plant (Hashioka, 1963). Clear differences of number of dew days among the three categories of seasons were observed. In severe blast incidence seasons there were average of 20 dew days out of 21 days of screening period (computation based on grass minimum temperature). Average number of dew days under moderate and low incidence groups were 10 and 3 days respectively out of 21 days (Fig. 4).

A similar trend was seen for the number of dew days among different groups of seasons when the computation was based on air minimum temperature (Fig. 3).

Effect of mean wind velocity

Mean wind velocity values were less than 5 km/h in severe blast incidence seasons, whereas that under moderate and low incidence seasons were around 7.5 km/h and 8.5 km/h respectively (Fig. 2).

Wind has a direct influence on spore disposal. Conidia separate from conidiophore in proportion to wind velocity under experimental condition (Hashioka, 1963). However on the other hand, the dew drops on rice leaves are taken away by strong wind and RH may be reduced. The observation on the effect of wind velocity in this study support this assumption. In seasons of high disease incidence the mean wind velocity was considerably lower than in seasons of moderate or low disease incidence. High wind velocity may be important in causing disease epidemics over a large area, where inoculum dissemination over long distance is facilitated by high wind velocity.

Effect of rainfall

A close look at rainfall occurrence indicates that occurrence and development of blast were best in seasons without any rainfall (Fig. 5).

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Influence of rainfall on occurrence of plant diseases had been very well established (Krause *et al.*, 1975). Therefore, rainfall is used as one factor in disease forecasting models. Intensity and distribution of rainfall have different effects on disease occurrence and development. Heavy rains, accompanied specially by wind may cause physical damages to the host tissue facilitating entrance of passive pathogens into host tissues.

Since blast fungus is an active parasite which can penetrate the host tissue on its own, it does not need damaged tissues for infection. On the other hand, low rainfall intensity may create drought condition, and it has been shown that drought condition induces the occurrence of blast disease (Hashioka, 1963). In this study it is clear from the Fig. 5 that occurrence and development of blast disease were best when the screening period was dry.

CONCLUSIONS

Inception and development of rice blast disease appear to be influenced by the interaction of several weather factors having effects on reproductive ability of the pathogen and resistance of the host plant. Thus, an occurrence and development of rice blast in a given location cannot be explained solely by the relation between the pathogen and meteorological conditions.

Low night temperatures 18—23°C, early dew formations in the night and presence of dew up to 9—10 am on the following day, low wind velocity (5—6 km/h), medium temperature during day time (24—28°C) and rain-free days appear to be very conducive for the inception and occurrence of blast disease in screening nurseries. Such meteorological conditions are found at CRBS, Batalagoda during maha season (December—January period). However, in yala season (May—June) screening could be carried out provided the screening site is separated by a wind barrier to remove the effect of wind and by sprinkling the nursery frequently with water to create conditions favourable for dew formation.

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