

Weather based operational plant protection on rice hispa and blast of paddy

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सार – मौसम पर आधारित पूर्वानुमान यथासमय जारी करके धान हिस्पा और धान के प्रध्वंस (ब्लास्ट) रोग द्वारा हुई क्षति को नियंत्रित कम करने की संभावना का पता लगाने के लिए अध्ययन किए गए। पादप संरक्षण, संगरोध एवं भंडारण विभाग (पी.पी.क्यू. एवं एस.) फरीदाबाद द्वारा 1988–93 तक किए गए सर्वेक्षण से यह पता चला कि धान हिस्पा और प्रध्वंस (ब्लास्ट) घटनाएँ दोनों की रबी/ग्रीष्म ऋतु की तुलना में खरीफ की फसल में अधिक हुई। विशेष रूप से उड़ीसा, असम, केरल और आंध्र प्रदेश में धान हिस्पा सामान्य से लेकर अधिकतम तक देखा गया। कर्नाटक, आंध्र प्रदेश, उड़ीसा, महाराष्ट्र, मध्य प्रदेश, उत्तर प्रदेश में प्रध्वंस (ब्लास्ट) रोग अधिक देखा गया। नमी की स्थिति (सुबह की सा.आ. > 90% ; और दोपहर की सा.आ. > 80%) और मेघमयता की स्थिति में अधिकतम (< 32° सें.) और न्यूनतम (< 24.5° सें.) तापमान में गिरावट धान हिस्पा की घटना के लिए मौसम की स्थिति के अनुकूल पाई गई। मेघमयता की स्थिति में न्यूनतम तापमान (< 23.5° सें.) में कमी और सुबह की सापेक्ष आर्द्रता (> 90%) में वृद्धि के कारण फसल में प्रध्वंस (ब्लास्ट) रोग की घटनाएँ हुई। इस अध्ययन के परिणाम 1993 के बाद लिए गए फसलनाशी कीट एवं रोग प्रेक्षण के सुसंगत रहे। इसका यह निष्कर्ष निकला है कि विद्यमान मौसम प्राचलों के आधार पर कृषि मौसम परामर्श सेवा के माध्यम से धान हिस्पा और प्रध्वंस (ब्लास्ट) रोग की पूर्व चेतावनी पहले ही देना संभव है।

ABSTRACT. Studies were made to explore the possibility of control/minimise the damages caused by the rice hispa and blast disease of rice by issuing timely weather based forecast. From the survey conducted by the Department of Plant Protection, Quarantine and Storage (PPQ&S) Faridabad from 1988-93, it was observed that both rice hispa and blast incidences were comparatively more in *kharif* than *rabi/summer* season. Rice hispa appeared more frequently in moderate to severe intensity particularly in Orissa, Assam, Kerala and Andhra Pradesh. Blast disease appeared more in Karnataka, Andhra Pradesh, Orissa, Maharashtra, Madhya Pradesh, Uttar Pradesh. Drop in maximum (< 32° C) and minimum temperature (< 24.5° C) under humid condition (morning RH > 90%; and afternoon RH > 80%) and cloudy condition was found to be the congenial weather condition for the incidence of rice hispa. Blast incidences on the crop were found to be favoured by the decrease in minimum temperature (< 23.5° C) in association with increase in morning relative humidity (> 90%) under cloudy condition. The findings of this study validated fairly well with the pest and disease observation made after 1993. It is concluded that forewarning of the incidence of the rice hispa and blast on rice could be possible, well in advance, through Agromet Advisory Service based on the prevailing weather parameters.

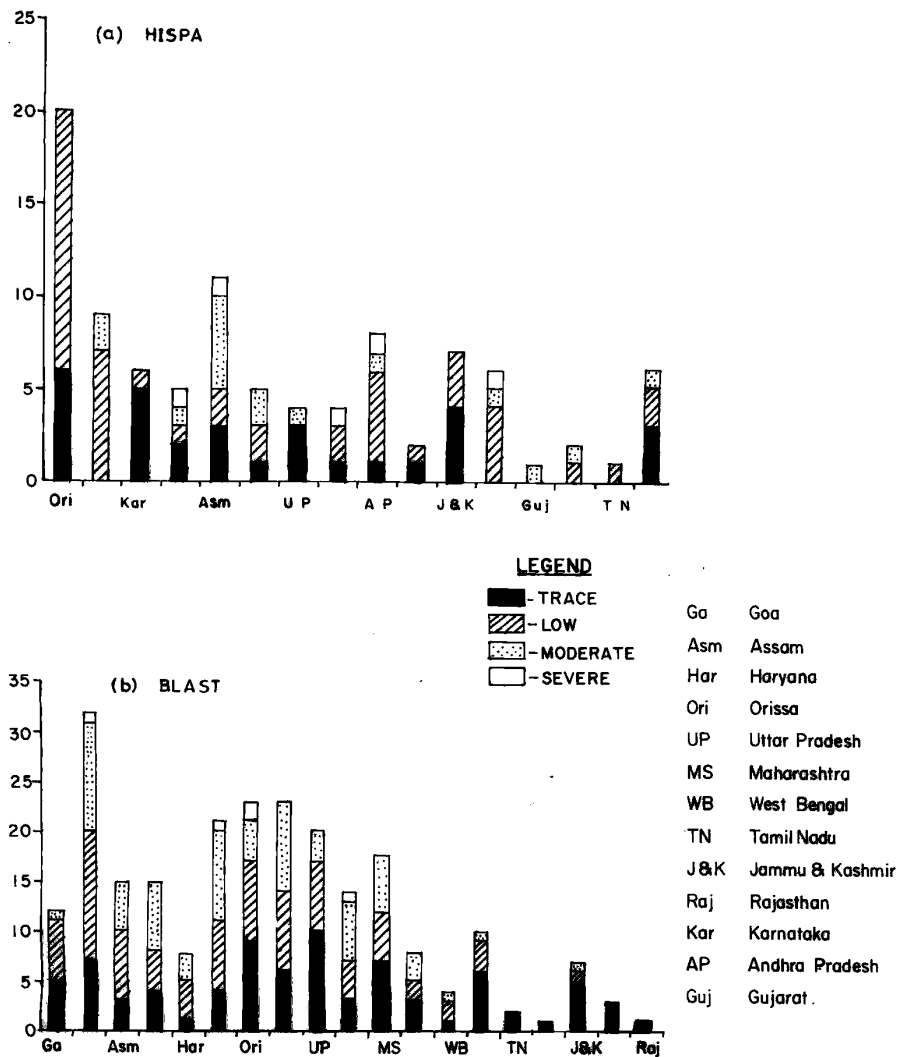
Key words – Agromet advisory service, Blast disease, Operational plant protection, Rice hispa, Weather based forewarning.

1. Introduction

Rice hispa, *Dicladisa armigera* (Oliver) is a serious pest of rice in some parts of east Asia (Hazarika 1990). Considerable economic losses are often caused by the pest in Bangladesh. In India, it occurs sporadically in almost all the rice growing areas and considered as a major pest of rice in the eastern region particularly in the north eastern part of the country. It is an endemic to certain low lying areas of Assam causing 35-65% loss in yield in wet season (Hazarika and Dutta 1991, Puzari and Hazarika

1992). The pest is reported to be active in hot and humid climate during monsoon season (Nair 1986).

Blast, *Piricularia oryzae* Cav, is a widespread disease in most of the humid rice producing areas of the world. In the country the disease is reported from almost every part where rice is grown commercially. In severe cases, loss amounting to 70 to 80 % grain yield are reported (Rangaswami 1975). In 1969 in Japan blast accounted for 24.8 % of total yield loss. It has been reported that in epidemic areas of Philippines 50% yield

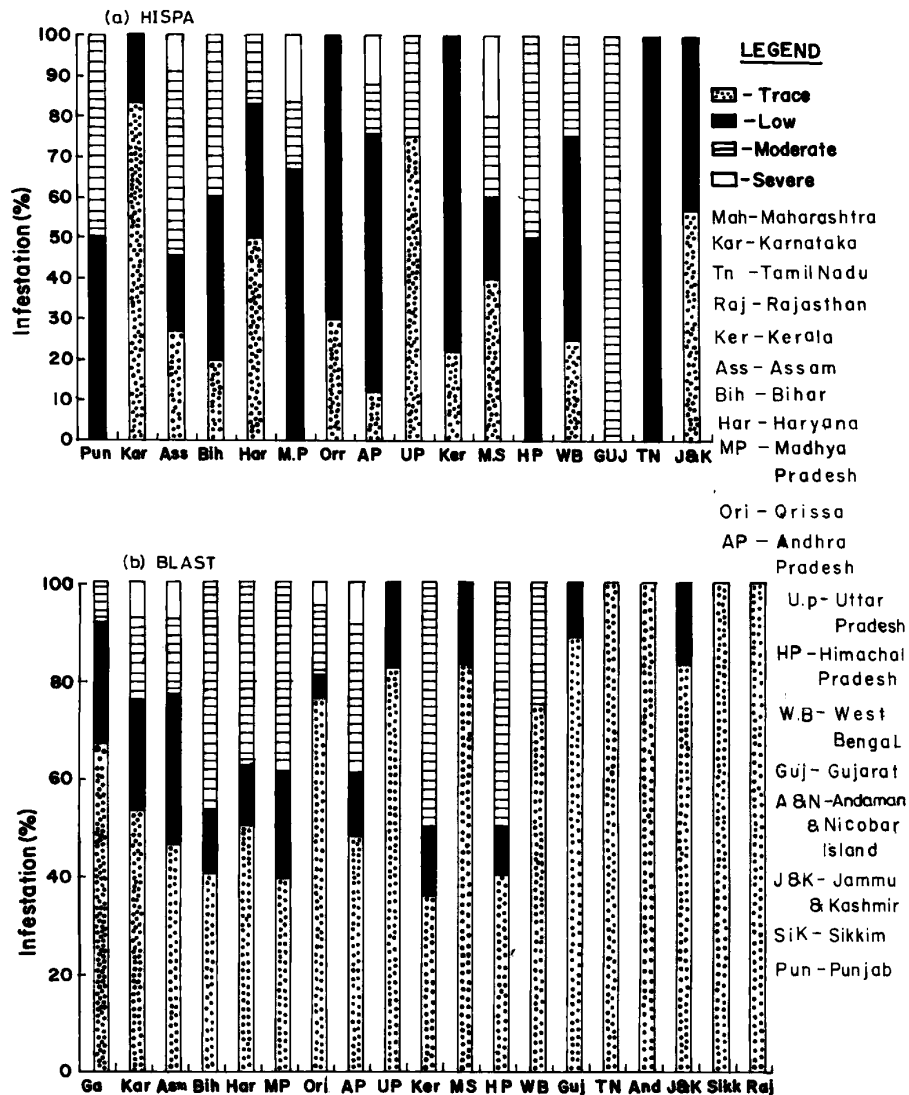


Figs. 1(a&b). Frequency of occurrence of rice (a) hispa and (b) blast in different intensities in the country

loss has been caused on thousands of hectares (Pan Manual 1976). In India, occurrence of this disease was first reported from Tanjore district of Tamil Nadu in 1918, Maharashtra in 1923 and subsequently in several parts of the country. During winter season 1966, CO 29, a high yielding rice variety, was found to be severely affected by blast disease resulting in almost complete loss of crop in many parts of Coimbatore. Meteorological parameters are the most important pre-disposing elements in the outbreak of the disease. Attempts were made in India and abroad to utilise the weather conditions in developing forecasting schedule for the appearance of the disease. In Japan, an effective blast disease forecast system has been evolved based on the weather data collected over a period

of years. According to Padmanabhan (1965a) forecasting of the disease can be attempted on the basis of minimum temperature and relative humidity.

From the literature it is seen that the rice grown at different parts of the country is susceptible to the rice hispa and blast incidence in different rice growing seasons and as a result there is a chance of substantial damage of the rice crop by this pest and disease under favourable climatic conditions. Sensitivity of rice hispa and blast incidence on the prevailing weather conditions was reported by a number of workers (Subramaniam 1967, Hazarika *et al.* 1998, Prasad and Rana 2002).



Figs. 2(a&b). Percentage of occurrence of rice (a) hispa and (b) blast at different intensities in different states

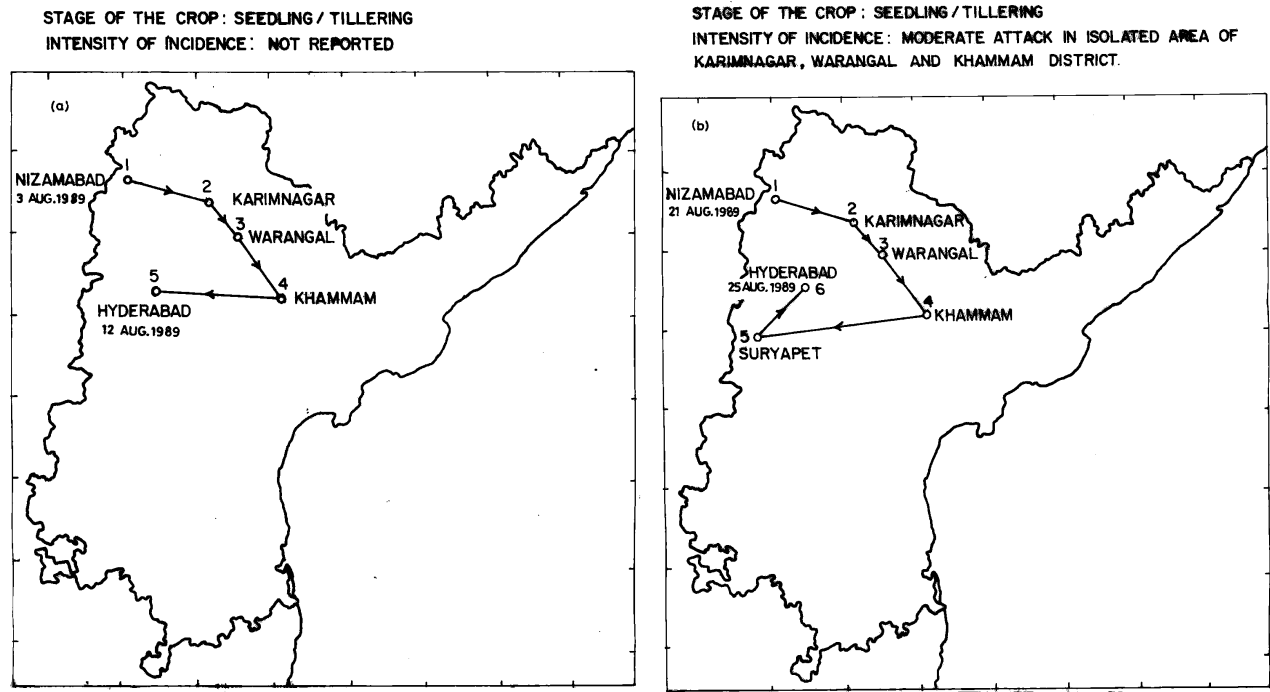
Keeping in view of the above, the present study was undertaken with the following objectives:

- (i) Identification of places of attack, duration and intensity of occurrence of rice hispa and blast disease at different states of the country.
- (ii) To establish the relationship, if any, between the incidence of the pest and disease and meteorological parameters.
- (iii) Development of weather based forecasting guidelines for the pest and disease incidences on rice.

- (iv) Dissemination of the forecasting guidelines to the user's community through Agromet Advisory Service for efficient plant protection measures at right time.

2. Data and methodology

Central Integrated Pest Management Centre, Directorate of Plant Protection, Quarantine and Storage (PPQ&S), Government of India, Faridabad in collaboration with the State Departments of Agriculture and Indian Council of Agricultural Research monitors pests and disease situation on major crops every month by deputing their staff in the predetermined routes in the



Figs. 4(a&b). Previous and current survey route and period in Andhra Pradesh

period of present study are presented in Fig. 1(a). Occurrences of this pest was highest in Orissa (20) followed by Assam (11), Kerala (9), Andhra Pradesh (8), Jammu and Kashmir (7), Karnataka (6), Haryana (6) and Madhya Pradesh (6). Moderate to severe attack of rice hispa was found in Assam, Bihar, West Bengal, Gujarat, Punjab, Maharashtra and Madhya Pradesh. This observation is in consonance with the finding of Dhaliwal and Arora (1998) who reported that rice hispa appear in moderate to severe form in Assam, Gujarat, Himachal Pradesh and Punjab. According to Ramkrishnan Ayyar (1940) the third paddy crop in South Karnataka suffer from this pest very seriously in certain years. Percentage of occurrence of rice hispa under this category was highest in Assam followed by Bihar, Maharashtra, Madhya Pradesh and West Bengal [Fig. 2(a)]. The pest was found to be present almost throughout the country in some parts or the other in different months of the year. It occurred more in the monsoon months and the month of June and August are most vulnerable period when the pest appeared more frequently and at moderate to severe level [Fig. 3(a)]. Kadam *et al.* (1976) reported that rice hispa is usually active from July to September and severe generations might be completed in a season. It was observed that the pest damaged the rice mostly in early stage of the crop.

3.2. Duration and intensity of blast in the country

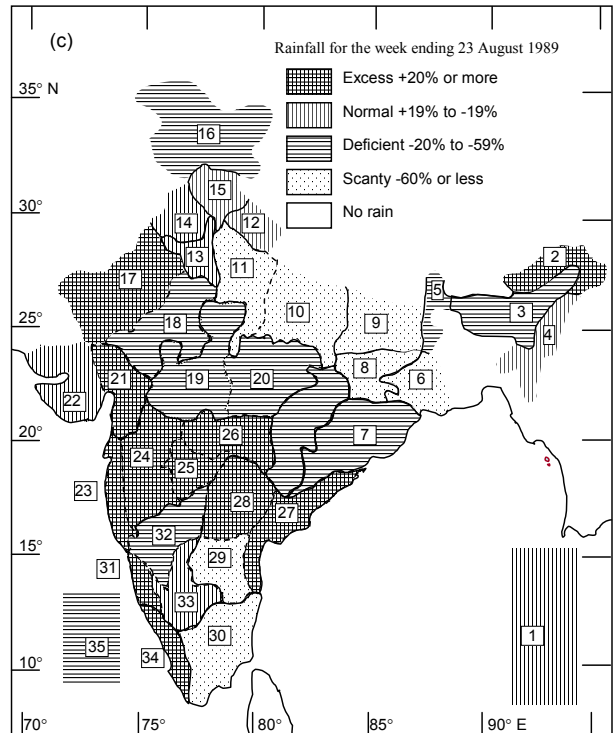
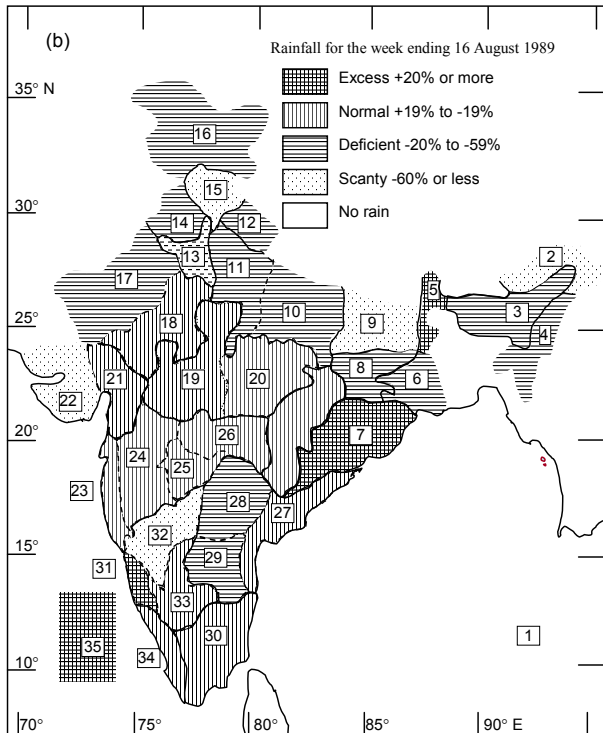
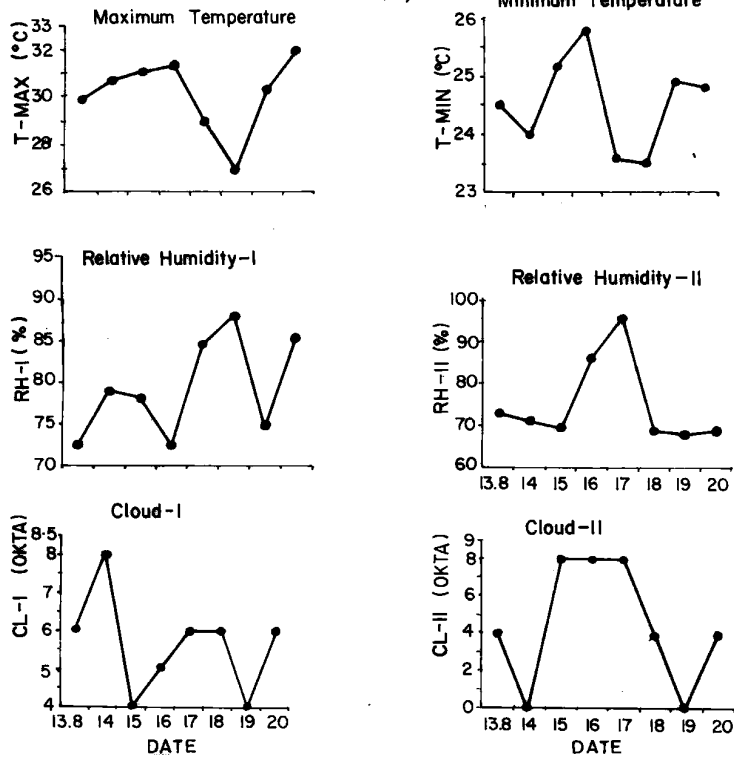
Occurrence of the disease incidence was maximum in Karnataka (33) followed by Andhra Pradesh (25), Orissa (21), M.P. (18), Bihar (15), Goa (12) and Himachal Pradesh (10). Moderate to severe attack of the disease was reported from a number of states namely Assam, Bihar, Orissa, West Bengal, Karnataka, Andhra Pradesh, Kerala, Haryana, U.P., H.P., M.P., Maharashtra and Goa [Fig. 1(b)]. Fig. 2(b) shows that percentage occurrence of blast under this category was highest in Kerala, H.P., Bihar, M.P., Haryana and A.P. It has been observed that blast disease damaged the crop from tillering to maturity stage. Blast disease was observed from August to October and January [Fig. 3(b)].

3.3. Sensitivity of weather parameters to rice hispa incidence

A critical analysis of daily meteorological parameters in relation to rice hispa incidences at ten stations reported moderate or severe attacks was made. It revealed that maximum and minimum temperature, both morning and afternoon relative humidity and clouding jointly played important role for the outbreak of the pest. In general, it was observed that drop in maximum

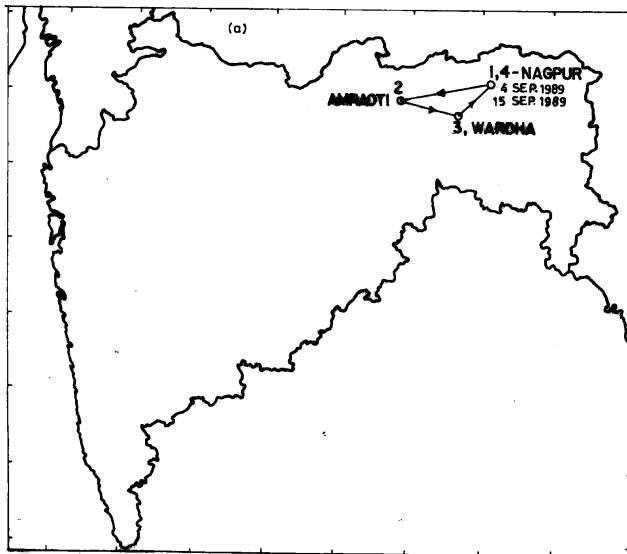
KHAMMAM

(a)

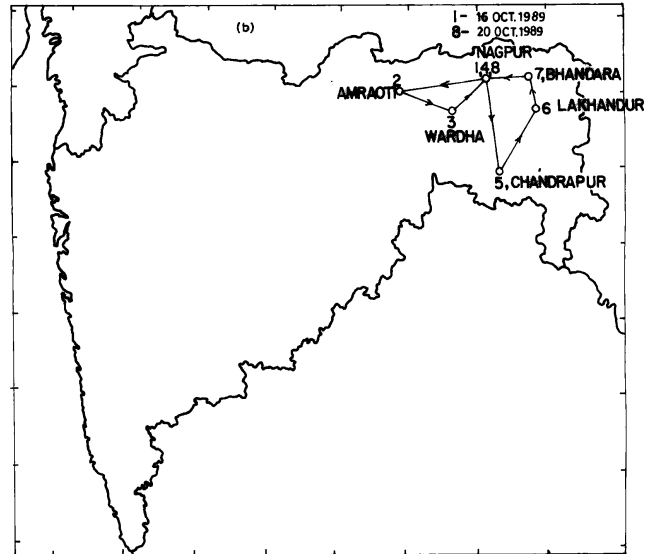


Figs. 5(a-c). Variations of weather parameters prior to the incidence of rice hispa

STAGE OF THE CROP : TILLERING / BOOTING
INTENSITY OF INCIDENCE : LOW INCIDENCE IN ISOLATED AREA.



STAGE OF THE CROP : EARHEAD
INTENSITY OF INCIDENCE : MODERATE TO SEVERE INCIDENCE IN ISOLATED AREA.



Figs. 6(a&b). Previous and current survey route and period in Maharashtra

temperature ($< 32^{\circ}\text{C}$) and minimum temperature ($< 24.5^{\circ}\text{C}$) under high relative humidity (morning RH $> 90\%$; afternoon humidity $> 80\%$) rain under overcast sky condition (> 7 oktas) in more number of days created an ideal environment for the out break of rice hispa at all the ten stations located in different parts of the country. Moderate attack of rice hispa on paddy in isolated areas of Karimnagar, Warangal and Khammam districts of Andhra Pradesh in survey conducted from 21 to 25 August 1989 [Fig. 4(b)]. The rice was at seedling to tillering stage of the crop. Incidences of the pest was not reported in the previous survey (3 to 12 August 1989) carried out in the same survey route [Fig. 4(a)]. Critical analysis of different meteorological parameters of the stations affected by rice hispa incidence mainly Khammam (Dist. Khammam), Kothgundam (Dist. Khammam), Hanamkonda (Dist. Warangal), Ramagundam (Dist. Karimnagar) showed similar variations of meteorological parameters which might created congenial environment for the pest incidence in moderate level. At Khammam, the maximum temperature (31.3°C) and minimum temperature (25.8°C) started decreasing from 15 August and attained the value 26.9°C and 23°C respectively on 18 August. Besides the relative humidity and clouding were more than 90% and 6 oktas respectively from the afternoon of 17 August to the morning of 18 August [Fig. 5(a)].

Similar changes, in the above mentioned variables were also observed during the same period at

Hanamkonda, Ramgundam and Kothagundam. It has been reported that there was a low pressure area near Andhra coast on 16 August. The low pressure area intensified into deep depression and crossed Andhra coast near Kalingapatnam on 17 August. Monsoon was vigorous on 1 to 3 days in Telangana and heavy rainfall on 1 to 3 days was also reported. All the above stations reported a good amount of rainfall during this period. Khammam, Hanamkonda and Kothigundam received 7.6cm , 7.2cm and 6.2cm total rainfall on 17 August and 18 August. During this period Telangana received excess rainfall [Fig. 5(c)] and in the previous week this subdivision *i.e.*, Telangana received deficient rain [Fig. 5(b)]. It is anticipated that these synoptic features caused the above fluctuations of meteorological variables which ultimately favoured the incidences on paddy.

In 1988 moderate attack of rice hispa was reported in Burdwan district of West Bengal in the survey conducted from 11 to 14 August when the paddy was seedling to tillering stage. It was noticed that prior to the incidence of pest, maximum and minimum temperature decreased from 6 August to 8 August respectively from 32.7°C to 30.9°C and 25.1°C to 23.8°C . Afternoon and morning RH on 6 and 7 August were 92% and 98% respectively and the sky was reported to be almost overcast (7 to 8 okta) on these days. From synoptic charts it revealed circulation between 4.5 and 7.5 a.s.l. was observed over north Bay and neighbourhood. Under its influence, a low pressure

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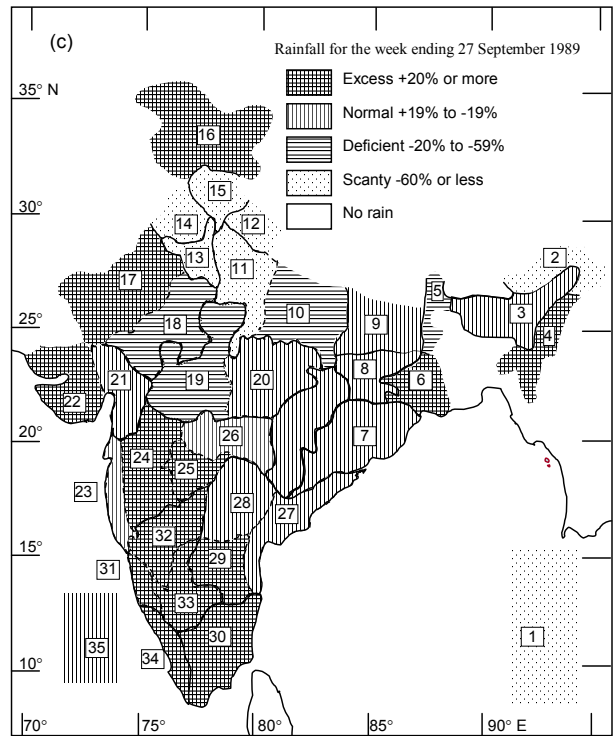
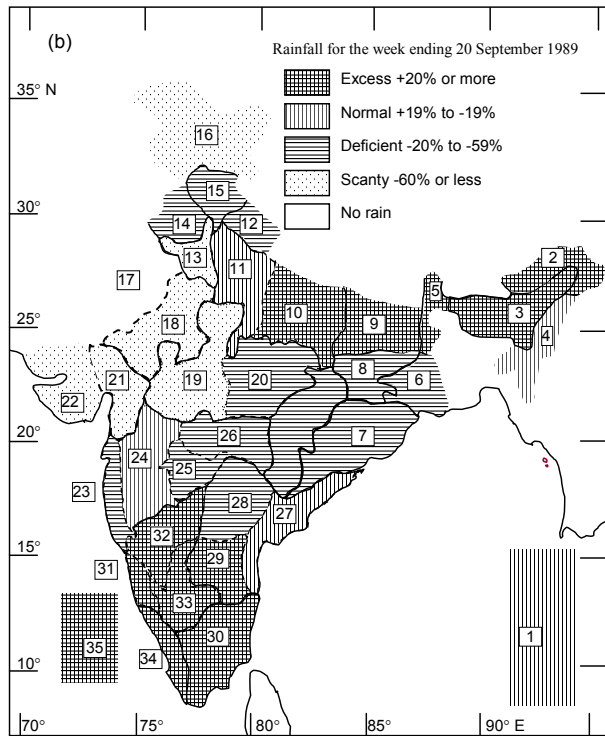
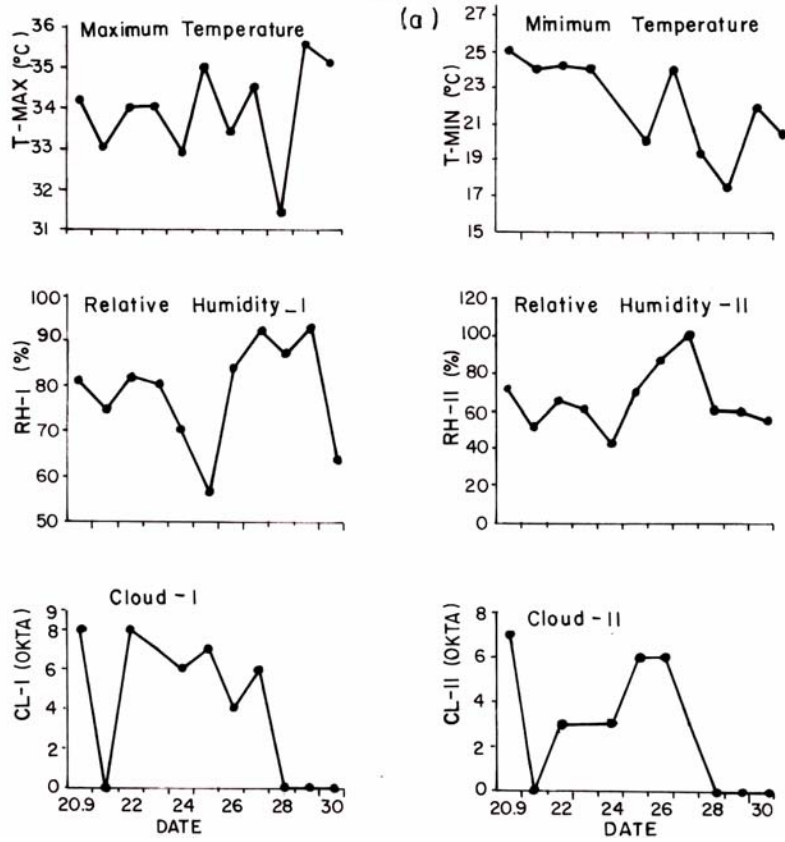


Fig. 7(a-c). Variations of weather parameters prior to the incidence of blast disease

area formed over north Bay and adjoining West Bengal and Bangladesh on 7 August. During this week Gangetic West Bengal received normal rainfall. Burdwan station received rainfall everyday of this week about 1 cm on 7th and 8th. This drop in temperature in association with high relative humidity, rain and cloudy condition caused by the prevailing synoptic situations encouraged rice hispa incidence on paddy grown in Burdwan district of West Bengal. Hazarika and Puzari (1995) found that eggs of rice hispa were most vulnerable in the field when the relative humidity was excessively high *i.e.*, 97%.

Similar weather conditions favoured the incidence of pest in 24 - Parganas of West Bengal in July 1988, Guwahati October 1986 and July 1988, Tezpur October 1986 and Puri September 1988.

Thus, the conditions favourable for rice hispa are

- (i) Decrease in maximum ($< 32^{\circ}$ C) and minimum temperature ($< 24.5^{\circ}$ C).
- (ii) Increase in relative humidity (morning R.H. $> 90\%$, afternoon RH $> 80\%$).
- (iii) Overcast condition.
- (iv) Occurrence of rain.

3.4. Sensitivity of blast incidence to the weather conditions

Analysis of disease and weather data revealed that drop in minimum temperature under humid, rain and cloudy conditions favoured disease incidence. In 1989, moderate to severe incidence of blast disease was reported from the isolated areas in the survey route of Nagpur – Amravati- Wardha – Nagpur – Chandrapur – Lakhandur – Bhandara – Nagpur during the survey conducted from 16 to 20th October. During this period crop was at earhead stage [Fig. 6(b)]. In the previous survey (4 to 15 September, 1989) blast was reported low to moderate level [Fig. 6(a)]. It is anticipated that congenial weather condition might favoured the disease to appear as severe level. At Wardha, minimum temperature decreased from 25° C to 19.4° C from 20 to 27 September and morning and afternoon relative humidity increased to 92 % and 100% respectively. On 27 September when sky was partly cloudy, morning clouding 6 okta and afternoon clouding 3 okta (Fig. 7). During this period a trough of low pressure lay over east Central Arabian Sea off Karnataka and Goa coast on 25 September. It persisted off south Maharashtra – Karnataka coast on 27 September. Normal rainfall occurred in Vidarbha region of Maharashtra [Fig. 7(c)]. The sub-division received deficient rain in the previous week [Fig. 7(b)]. This

synoptic situation might have favoured the decrease in minimum temperature and increase in relative humidity under clouding encouraged blast disease on rice. The station received the good amount of rain during this week.

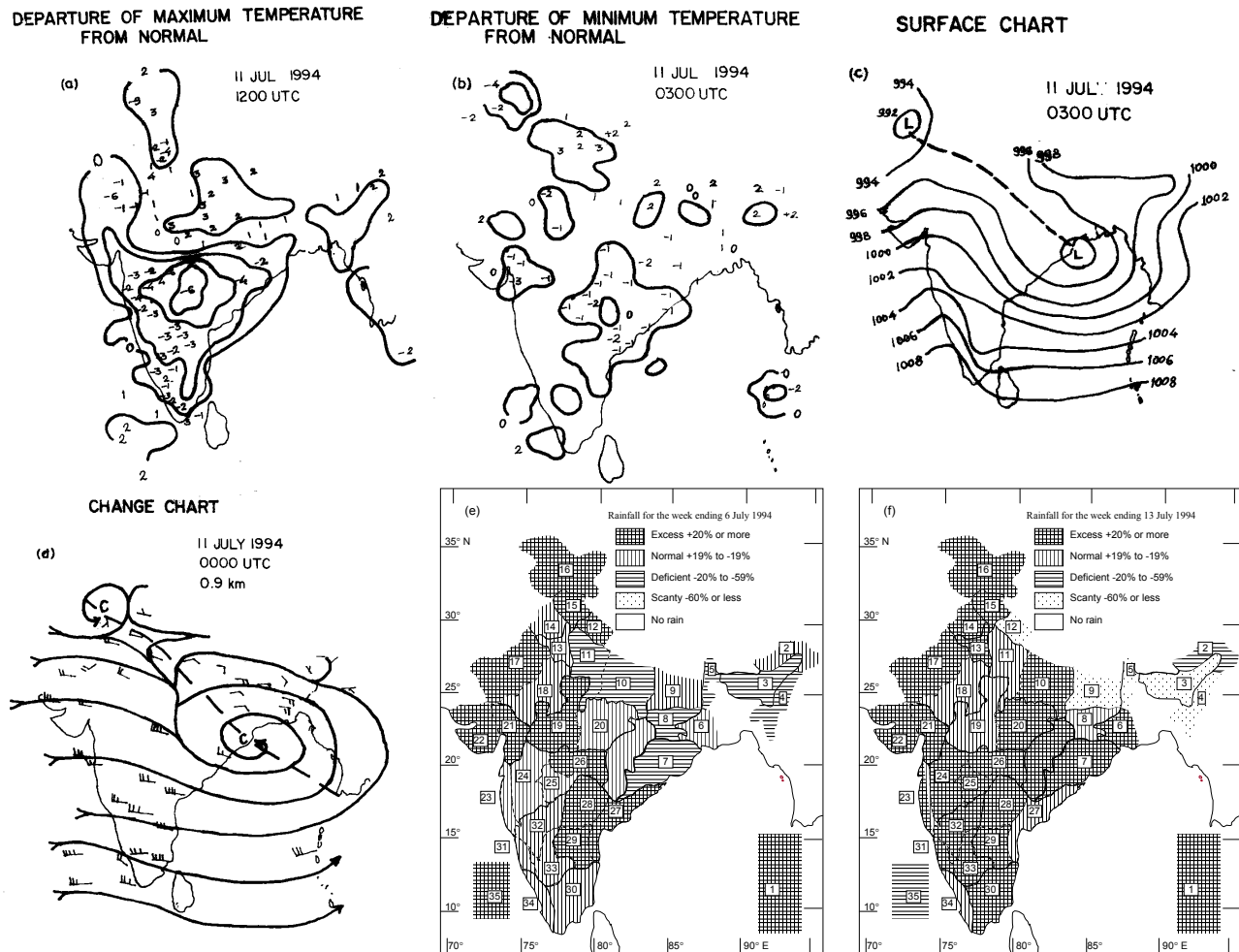
Moderate attack of blast on paddy was also reported in isolated areas of the survey route - Mysore - Karwar - Belgaum - Dharwar - Chitradurg - Bangalore - Mysore during 21-28 August 1989. The crop was at tillering to booting stage. Subramanian (1967) found that at high temperature of 20° C with high humidity the susceptible varieties showed three fold increases infect of the disease and in severe form even also to the resistant varieties. According to Rangaswami (1975) the blast disease invades the rice leaves most rapidly at mean temperature of about $24 - 28^{\circ}$ C with a high relative humidity (92%) and cloudy weather. Similar findings were reported by Dickson, 1947, Hashiyoka, 1943 & 1950, Suryanarayan 1958, Sadasivan *et al.* 1965, Mundker and Chattopadhyay 1967, Prasad and Rana 2002 and Singh 1983. In the previous survey on 7 August 1989, around Mysore disease was not reported. It has been reported that minimum temperature was below 23° C and sky was completely overcast for number days prior to the incidence both in Mysore and Chitradurg and on 17 August afternoon humidity was above 80% and on 18 August morning relative humidity was above 90%. A cyclonic circulation extending upto mid tropospheric level was observed over N.W. Bay on 10 August. Under its influence a low pressure area formed over N.W. Bay on 11 August with associated cyclonic circulation extending upto mid tropospheric level. Monsoon was active on 1-2 days in south – interior Karnataka in the week ending 16 August. Rainfall was normal in south interior Karnataka.

Thus the conditions favourable for rice hispa are

- (i) Decrease in minimum temperature ($< 23.5^{\circ}$ C).
- (ii) High humidity condition (morning RH $> 90\%$; afternoon RH $> 80\%$).
- (iii) Partly to full clouding.
- (iv) Occurrence of rain.

4. Validation

The above findings were validated with the observations made in July 1994. Severe attack of pest was reported in the Nalgonda district of Andhra Pradesh during the survey conducted from 4 – 29 July. The crop was at tillering stage. The previous survey *i.e.*, 1 –30 June trace to low incidence was reported from the similar survey period. As the gap between the two consecutive



FIGS. 8(a-f). Synoptic features prior to the incidence of rice Hispa in July 1994

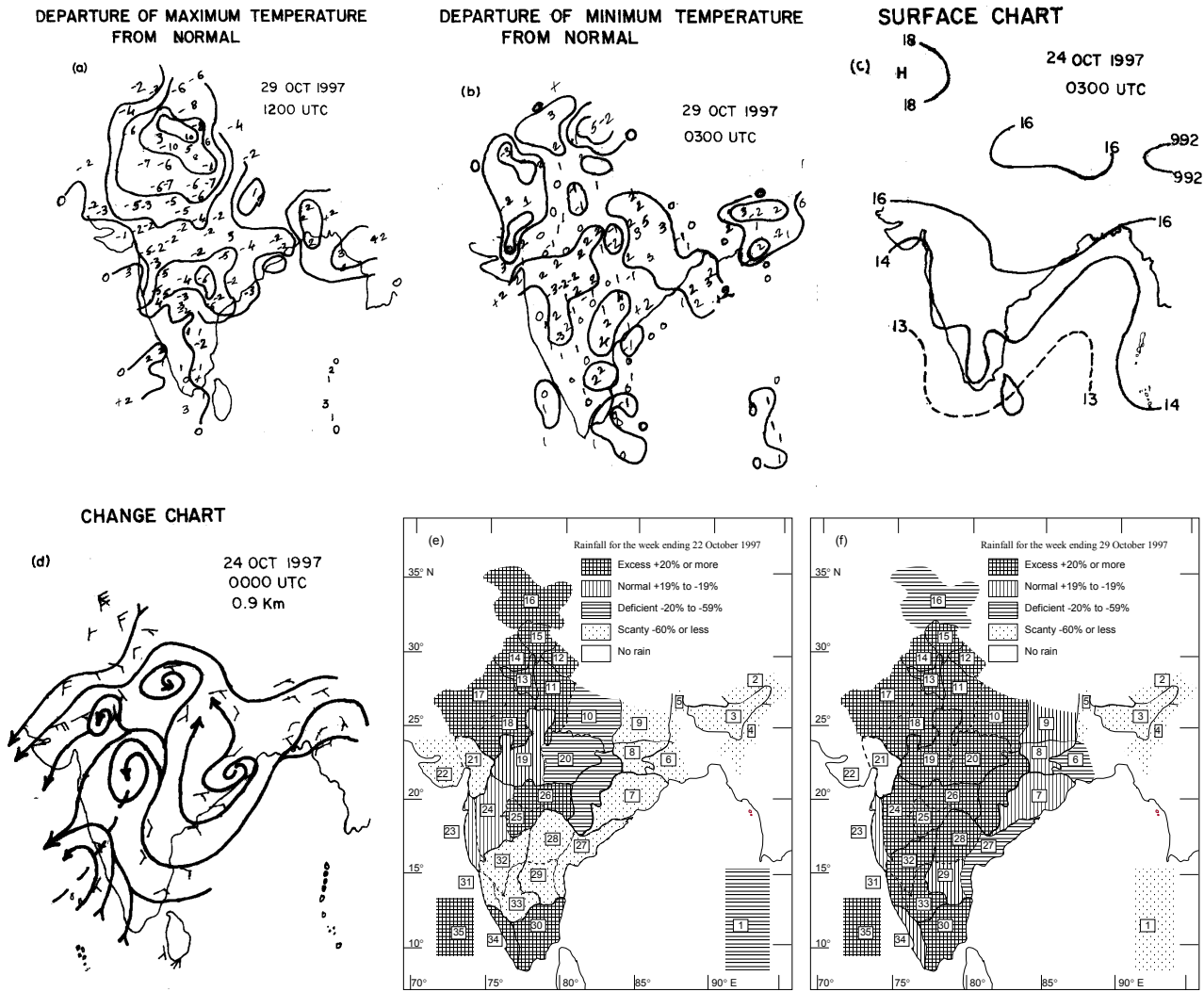
survey periods was too short it is presumed that the pest might have occurred during the current survey *i.e.*, 4 - 29 July. Decrease in maximum and minimum temperature from 37°C to 27°C and 28.6°C and 24.4°C respectively from 7 to 11 July and morning and afternoon relative humidity were more than 90% on 10 July when the sky was completely overcast. Both the week ending 6 July and 13 July Telangana sub-division experienced excess rainfall.

A low pressure area formed over northwest Bay and neighbourhood with associated cyclonic circulation extending upto mid tropospheric levels on 8 July. Moving north westwards it became well marked on 9 July over coastal parts of Orissa, West Bengal and northwest Bay and remained quasi stationary until 13 July [Figs. 8(c&d)]. A number of stations showed below normal temperature a couple of days in this period [Figs. 8(a&b)]. Very heavy

rain occurred in 1 to 3 days in Telangana [Fig. 8(f)]. Monsoon was vigorous on 1 to 3 days in Telangana during the survey period conducted from 4 to 29 October. Telangana sub-division also received excess rainfall in the previous week *i.e.*, week ending 6 July [Fig 8(e)]. Thus the conditions favourable for rice hispa incidences on paddy in parts of Telangana area.

The findings already emerged out of the blast study were validated with the observation made in November 1997. Rice blast has been observed at moderate to severe form on paddy when it was flowering to maturity stage in isolated fields of Maddur area of Mandya district. Disease was not reported in the previous survey.

A cyclonic circulation extending upto 3.1 km a.s.l. lay over Karnataka - Goa coast on 25th and it became less marked on 26th 1997. It was seen in the lower levels from



Figs. 9(a-f). Synoptic features prior to the incidence of Blast in October 1997

north Tamil Nadu to south Rajasthan areas. Interior Karnataka on 27th and it was again seen from south Maharashtra coast to Kerala coast on 28th and became less marked [Figs. 9(c&d)]. During this week excess rainfall was reported for Karnataka [Fig. 9(f)]. Very heavy rain has occurred in south interior Karnataka. Heavy rain has also occurred on 3 to 5 days in south interior Karnataka. Scanty rainfall was reported in the state in the week ending 22 October [Fig. 9(e)]. Decrease in maximum and minimum temperature below normal was shown by a number of stations Figs. 9(a&b). Prior to the incidence of pest the minimum temperature was below 22° C for number of days and the relative humidity increased above 90% on 27th afternoon and 28th morning which ultimately favoured blast incidence on crop in severe level.

5. Conclusion

(i) Rice hispa incidence on rice was reported to damage more on eastern parts of India particularly Assam, Bihar, West Bengal followed by Maharashtra and Madhya Pradesh during the early stage of the crop.

(ii) Paddy grown in eastern (Assam, Bihar, Orissa, West Bengal), southern (Kerala, Andhra Pradesh, Karnataka), northern (Uttar Pradesh, Himachal Pradesh, Haryana) and central parts of the country (Madhya Pradesh, Maharashtra and Goa) was found to be damaged occasionally by the blast disease during tillering to maturity stage of the crop.

(iii) Drop in both maximum ($< 32^{\circ}$ C) and minimum temperature ($< 24.5^{\circ}$ C) under high humidity (morning RH $> 90\%$; afternoon RH $> 80\%$), rain and overcast condition for a period of 3 - 4 day are the favourable condition for the incidence of rice hispa on paddy.

(iv) Decrease in minimum temperature ($< 23.5^{\circ}$ C) under high humidity (morning RH $> 90\%$; afternoon RH $> 80\%$), rain and partly to full clouding at least for one dayfavoured the incidence of blast disease on paddy.

(v) Forewarning the incidence of rice hispa and blast on paddy can be issued well in advance by the appearance of synoptic situation which cause the variation of above meteorological parameters.

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References

- Dhaliwal, G. S. and Ramesh Arora, 1998, "Principles of Insect Pest Management", Second Edition Kalyani Publisher, New Delhi, 1-297.
- Dickson, James, G., 1947, "Diseases of Field Crops", First Edition. McGraw-Hill Book Co., New York, 1-405.
- Hashiyoka, Y., 1943, "Studies on the rice blast disease in the tropics", IV. Influence of temperature of air and soil upon the resistance of rice plants to the blast disease, *J. Soc. Trop. Agri.*, Taiwan, **15**, 53-65.
- Hashiyoka, Y., 1950, "The micro climate of paddy field in connection with the prevalence of rice blast disease", *J. Agril. Metereol.*, Tokyo, **6**, 25-29.
- Hazarika, L. K., 1990, "Rice hispa management in north east India", Paper presented in the Workshop on Integrated Pest Management for north-eastern States, held during 18-21 September 1990 at Assam Agricultural University, Jorhat.
- Hazarika, L. K. and Puzari, K. C., 1995, "White Museardine fungus (*Beauveria Bassiana*) pathogenic to different stages of rice hispa", (*Di cladispa armigera*), *Indian Agric. Sci.*, **65**, 368-372.
- Hazarika, L. K., Puzari, K. C. and Saika, D. K., 1998, "Seasonal and host-correlated variation in the susceptibility of rice hispa to *Beauveria bassiana* in the field", *Indian Agric. Sci.*, **68**, 361-363.
- Hazarika, L. K. and Dutta, B. C., 1991, "Reaction of rice cultivars to rice hispa", *Int. Rice Res., News Letter*, **16**, 14-15.
- Kadam, M. V., Bhat, M. V. and Patel, G. A., 1976, "Pests of cereals crop pests and how to fight them", (Edited by S. R. Chopade). Second Edition, Directorate of Publicity, Government of Maharashtra, Bombay, 39-46.
- Mundker, B. B. and Chattopadhyay, S. B., 1967, "Fungi and plant disease", Second Edition, Macmillan and Co. Limited, Calcutta, 1-339.
- Nair, M. R. G. K., 1986, "Insects and mites of crops in India", Second Edition, Publication and Information Division, Indian Council of Agricultural Research, New Delhi, 1-375.
- Padmanabhan, S. Y., 1965a, "Studies on forecasting outbreaks of blast disease of rice and influence of meteorological factors on blast incidence at Cuttack", *Proc. Indian Acad. Sci.*, **52**, 117-129.
- Pans Manual no.3, Pest Control in rice, 1976, Second Edition, Center for Overseas Pest Research, London, 1-281.
- Prasad, R. and Rana, R. S., 2002, "Weather relations of rice blast in mid hills of Himachal Pradesh", *J. Agromet*, **4**, 149-152.
- Puzari, K. C. and Hazarika, L. K., 1992, "Entomologogenous fungi from north east India", *Ind. Phyto.*, **45**, 35-38.
- Ramakrishna Ayyar, T. V., 1940, "Hand Book of Economic Entomology for south India", First Edition Superintendent of Government Press, Madras, 1-508.
- Rangaswami, G., 1975, "Diseases of crop plants in India", Third Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 1-471.
- Sadasivan, T. S., Surayanarayanan, S. and Ramakrishnan, L., 1965, "Influence of temperature on rice blast disease", In the rice blast Disease 163-171, Baltimore, Maryland, Johns Hopkins Press.
- Singh, J. P., 1983, "Crop protection in the tropics", First Edition, Vikas Publishing House Pvt. Ltd. New Delhi, 1-363.
- Subramaniam, S., 1967, "Effect of temperature on blast disease (*Piricularia oryzae*) and metabolic changes in rice", Abstr. Intern. Symp. Pl. Path., New Delhi, 11-12.
- Suryanarayan, S., 1958, "Role of nitrogen in host susceptibility of *Piricularia oryzae*", *Curr. Sci.*, **27**, 447-448.