

Weather based forewarning of leaf folder attack on kharif rice and operational crop protection at Pattambi, Kerala

R. P. SAMUI, N. CHATTOPADHYAY and J. P. SABALE

Agricultural Meteorological Division, Pune, India

and

P. B. GOPINATHAN, ABRAHAM and P. JAYPRAKESH

Regional Agricultural Research Station, Kerala Agricultural University, Kerala, India

(Received 25 August 2004, Modified 19 March 2007)

e mail : agrimet_pune@yahoo.com

सार – केरल के पट्टम्बी क्षेत्र में खरीफ और रबी के मौसम के दौरान बोई जाने वाली धान की फसल में खरीफ के मौसम में मुख्यतः पिटिका मषकाम, लीफ फोल्डर और ग्रीन जैसिड कीट जैसे रोग पनपने लगते हैं। मौसम की अनुकूल स्थितियों में फसल में लीफ फोल्डर बीमारी के लगने से फसल को काफी नुकसान पहुँचता है। इस अध्ययन से यह पता चला है कि धान की खरीफ की फसल पर अधिकतम और न्यूनतम तापमान, सुबह और दोपहर की सापेक्ष आर्द्रता तथा अच्छी साप्ताहिक वर्षा लीफ फोल्डर कीट की उत्पत्ति और उसकी अवस्थावार वृद्धि के लिए बहुत अनुकूल है। 1987 से 1999 तक की अवधि के आँकड़ों का उपयोग करके कीट की प्रत्येक अवस्था में इसके तीव्र प्रकोप की अवधि के लिए मौसम पर आधारित बहुसमाश्रयण निदर्शों का विकास किया गया और 2000 से 2001 तक के प्रेक्षित मौसम वैज्ञानिक और कीट संबंधी आँकड़ों का उपयोग करके इस निदर्श की सार्थकता की पुष्टि की गई है। इस अध्ययन के परिणामों के आधार पर धान की खरीफ की फसल में ग्रीन जैसिड कीट के लिए कीट मौसम कैलेंडर बनाया गया है। यह कैलेंडर लीफ फोल्डर के आक्रमण की पूर्व चेतावनी और उसके आक्रमण से धान की फसल के व्यावहारिक संरक्षण के लिए उपयोगी सिद्ध होगा।

ABSTRACT. Kharif and Rabi rice grown extensively over Kerala is mainly infested by gall midge, leaf folder and green jassid in kharif season. Under favourable weather conditions leaf folder become the dreaded pest and cause considerable damage to the crop. The study revealed that maximum and minimum temperature, morning and afternoon relative humidity and weekly total of rainfall have profound effect on the development of leaf folder at their successive generations on kharif rice crop. Weather based multiple regression models for the peak infestation period for each of the generations of the pest were developed using data for the period 1987-99 and validated using observed meteorological as well as pest data for 2000-2001. Based on the findings of this study pest weather calendar for leaf folder of kharif rice was prepared. This calendar would be useful for early warning and operational rice crop protection from leaf folder attack.

Key words – Leaf folder, Weather based forewarning, Operational rice protection.

1. Introduction

At Pattambi (10° 48' N, 76° 12' E), rice is grown both in kharif and rabi seasons but the yield in both the seasons is much below the potential yield due to several reasons. One of the most important reasons is the pest and diseases attack which causes considerable damage to the crop. Under favourable weather conditions kharif rice crop is infested heavily by leaf folder (*naphalocrocis medinalis*) year after year (Samui *et al.*, 2002). On an average 15 to 20% damage has been reported due to the leaf folder at Pattambi (Karthikeyan, 2002). It is reported that proper plant protection measures at appropriate time can save the loss in yield of rice even upto 50%

(Rangaswamy, 1988). With this in view, an attempt has been made to explore the feasibility to develop forewarning models based on the weather experienced by the rice leaf folder at successive generations by finding the possible relationship between the leaf folder population and various weather parameters. These relationships would be useful in evolving a pest management scheme at and around Pattambi, Kerala.

2. Materials and method

Systematic and detailed daily observations relating to leaf folder and weather during kharif season for different generations were recorded using light trap for 15 years

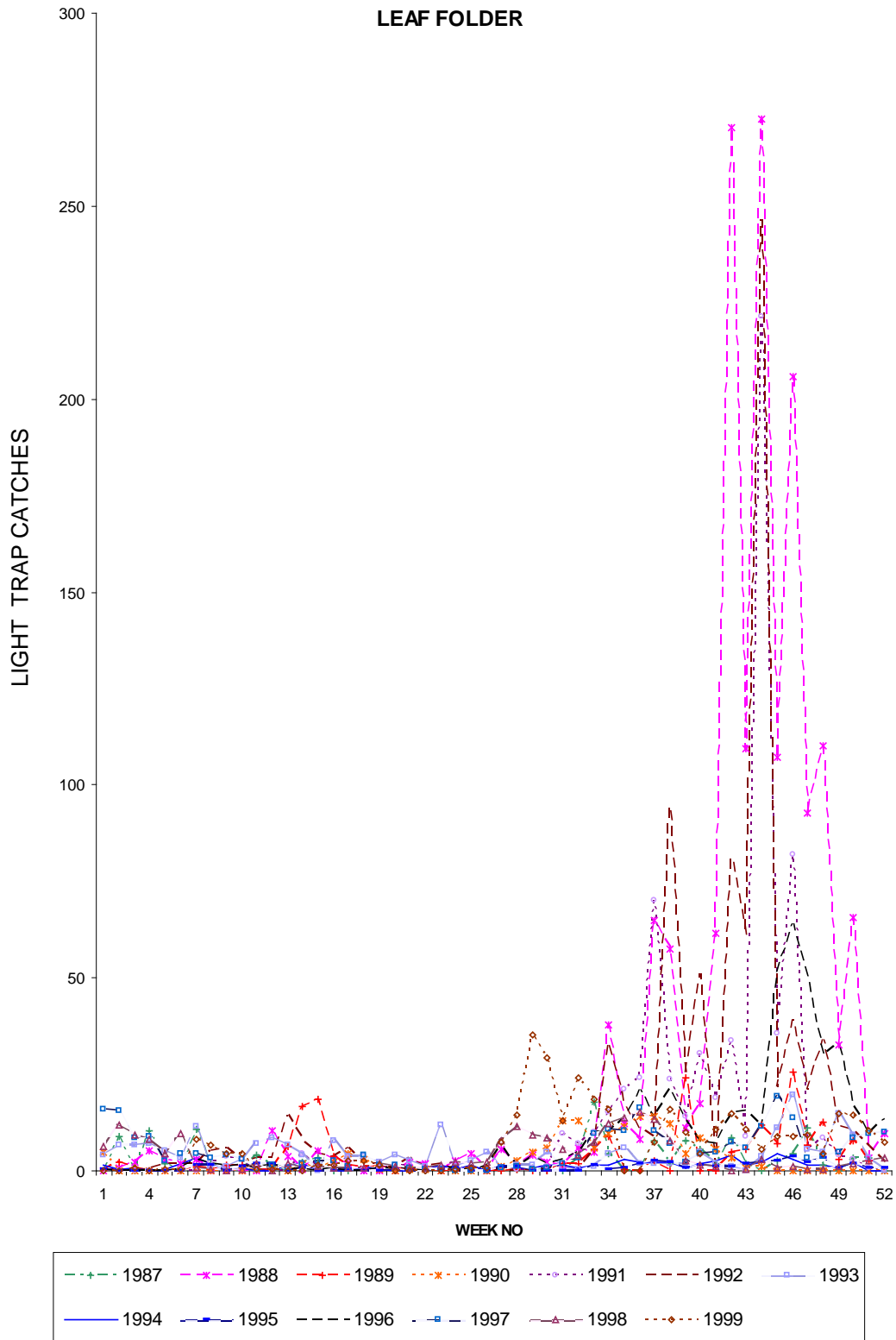
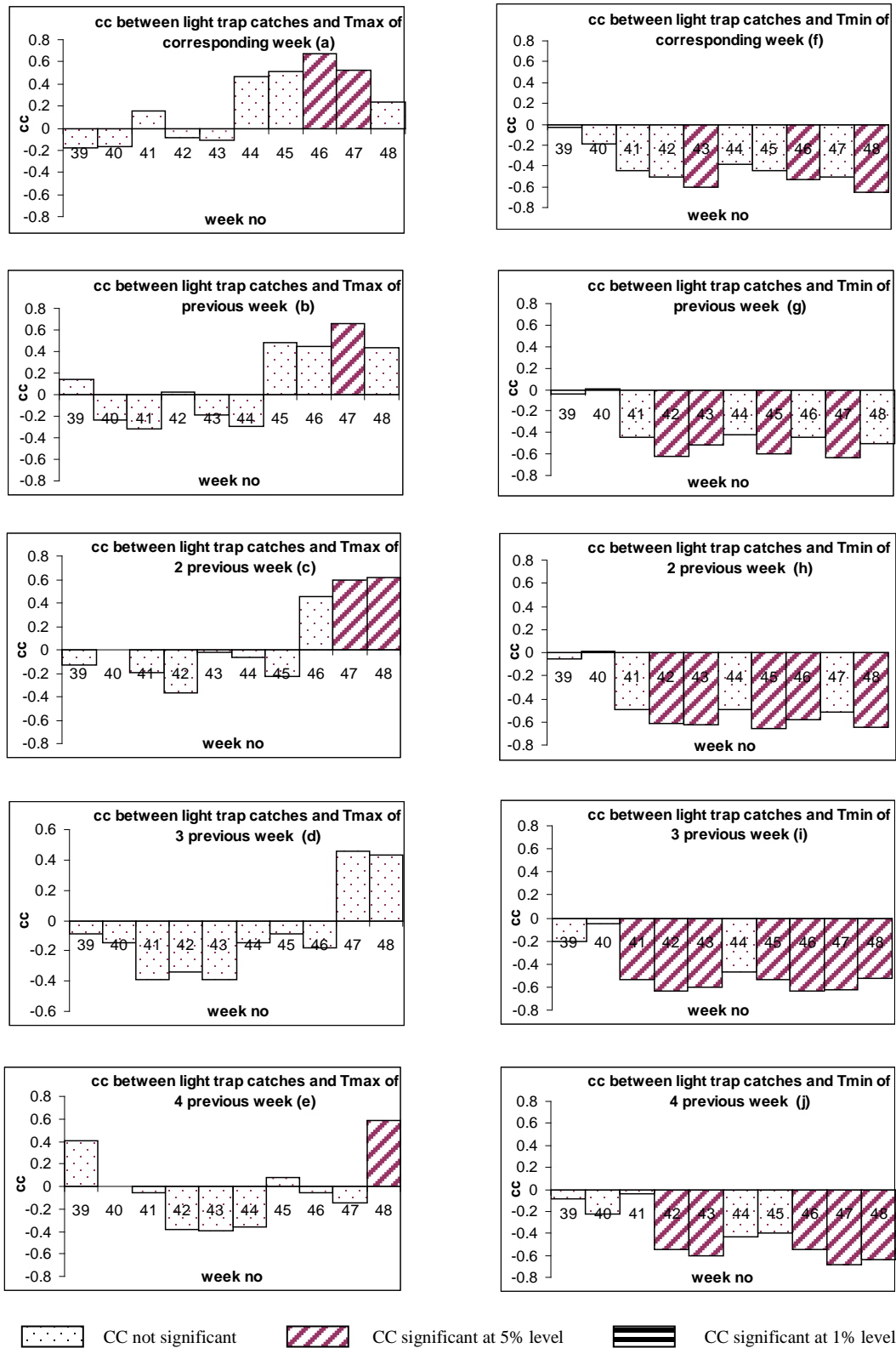
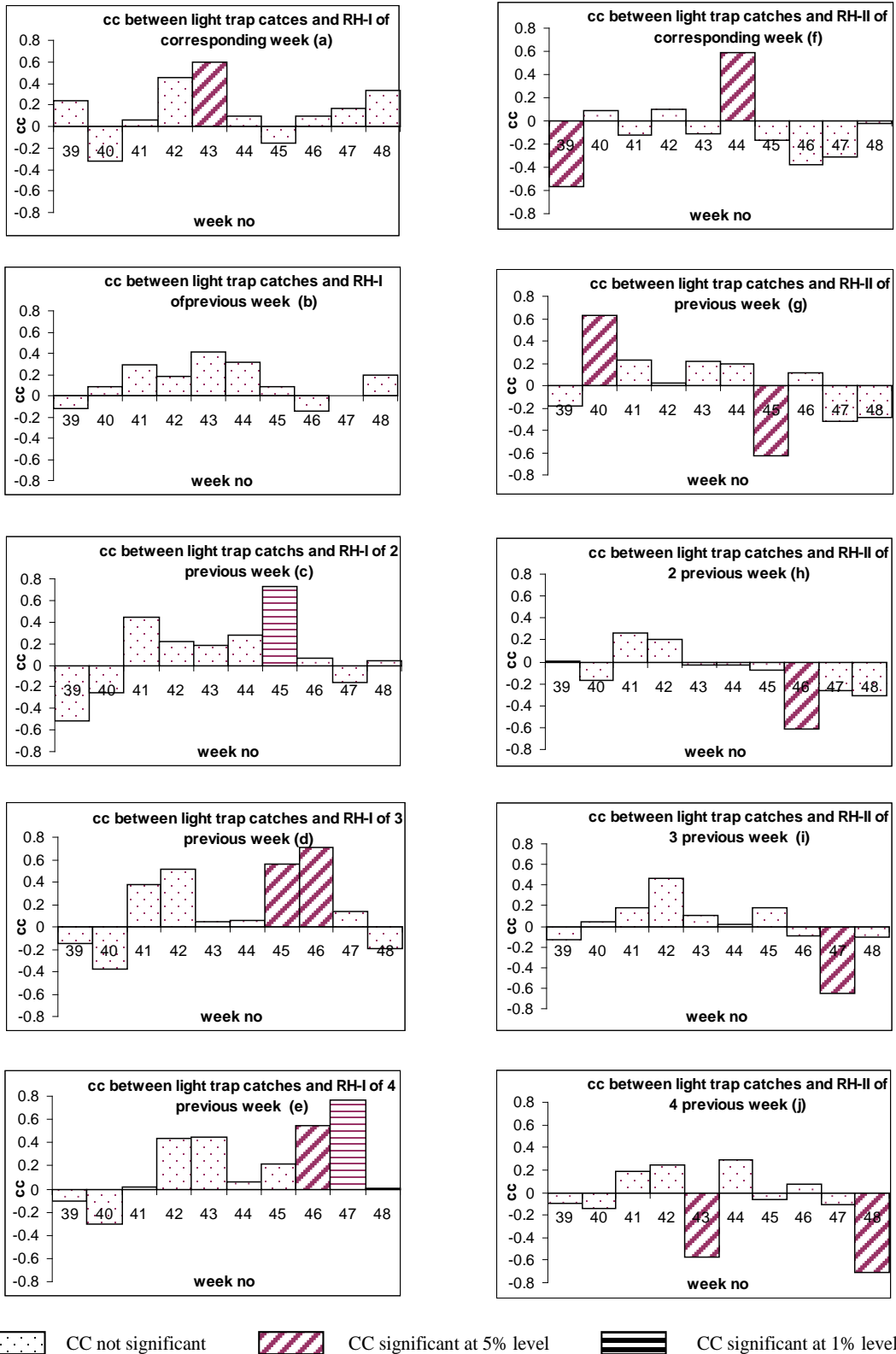


Fig. 1. Variation of weekly leaf folder catches in different rice growing seasons at Pattambi, Kerala State



Figs. 2(a-j). Correlation coefficients between light trap catches and Tmax and Tmin respectively for corresponding week, previous week, 2 week previous, 3 weeks previous, 4 weeks previous



Figs. 3(a-j). Correlation coefficients between light trap catches and RH-I and RH-II respectively for corresponding week, previous week, 2 week previous, 3 weeks previous, 4 weeks previous

(1987-2001) at Pattambi by the Entomologist, Regional Rice Research Station (RARS) and Meteorological data by the Meteorological Office at Pattambi respectively. Leaf folder data were recorded using Chinsurah type light trap which is a mechanical device consisting of a 200W bulb and suitable pest trapping arrangement fitted on a iron mast of 1.5m height. The traps have been designed for catching various insects. The basic structure is formed by a conical or funnel like frame having transparent wall (usually of glass), the upper part being open and the lower part of the funnel or cone which gradually slopes down inwardly to lead to a small basal open where a collecting vessel containing fumigant is snugly fitted. The upper free end is fitted with a device with which the source of light (either electric bulb-200W or petromax) may be suspended. Light energy plays a profound role in the behavioral orientation of insects. Different species of insects responds differently to the different wave length of visible spectrum of electromagnetic energy. The light traps were installed in the rice field at RARS, Pattambi for trapping various rice pests. This is a very effective device against various rice pests and attracts pest from an area of about 2 ha around the trap. The pests are attracted towards light trap in the night and observations are recorded early in the morning by counting each of the pests separately. Weekly average of leaf folder catches is reported in this study (Fig. 1).

In this analysis correlation coefficients (c.c.s) between leaf folder population and individual meteorological parameters for the corresponding and each of the four previous weeks have been worked out and presented in Figs. 2 to 4. The meteorological parameters significant at 5% and 1% levels were selected for further analysis and developing forewarning models. The parameters which were found most predominant by stepwise multiple regression technique was chosen for the development of the multiple regression equations (Table 1).

Meteorological elements such as weekly mean maximum temperature (T_{max}), minimum temperature (T_{min}), relative humidity for 0700 and 1400 hrs LMT (RH-I and RH-II), bright sunshine hours (SSH), total weekly rainfall (RF) were used to work out the association of meteorological parameters on infestation of leaf folder on kharif rice.

3. Weather and leaf folder activity at Pattambi

Pattambi is located at 25 m.a.s.l. in Palghat district of Kerala. The district has a tropical climate with an oppressive hot season and fairly assured rainfall during southwest monsoon season. The average annual rainfall in the district is 2396.6 mm. March is the hottest month

with mean daily maximum temperature at 37.4° C and the mean daily minimum temperature at 24.5° C. The air is highly humid throughout the year, the relative humidity being generally over 70% (I.M.D, 1986).

Leaf folder was found most active in kharif season (June- November). The maximum leaf folder attack was observed between the 39th (24-30th September) to 47th (19-25th November) standard week (std. week) in kharif season (Fig. 1). Damage is caused both by nymph and adult. Both congregate on the leaf sheaths and blades to suck the cell sap which results in browning of leaves or hopper burn. This insect also transmits dwarf and yellow dwarf viruses. The effect of attack is to delay heading as well as panicles formation. Late ripening varieties suffer more as compared to early ripening varieties.

Female deposits 23-27 eggs under epidermis of young leaf sheaths. Incubation period is from 3-5 days. Nymphal period takes about 12-21 days. The adults hide by day time and feed on leaf tissues during the night time. Male lives 3 weeks while female 4 weeks (Nath and Agarwal, 1982). As rice is grown round the year, the leaf folder also multiply in successive generations depending on the favourable conditions (Fig. 1).

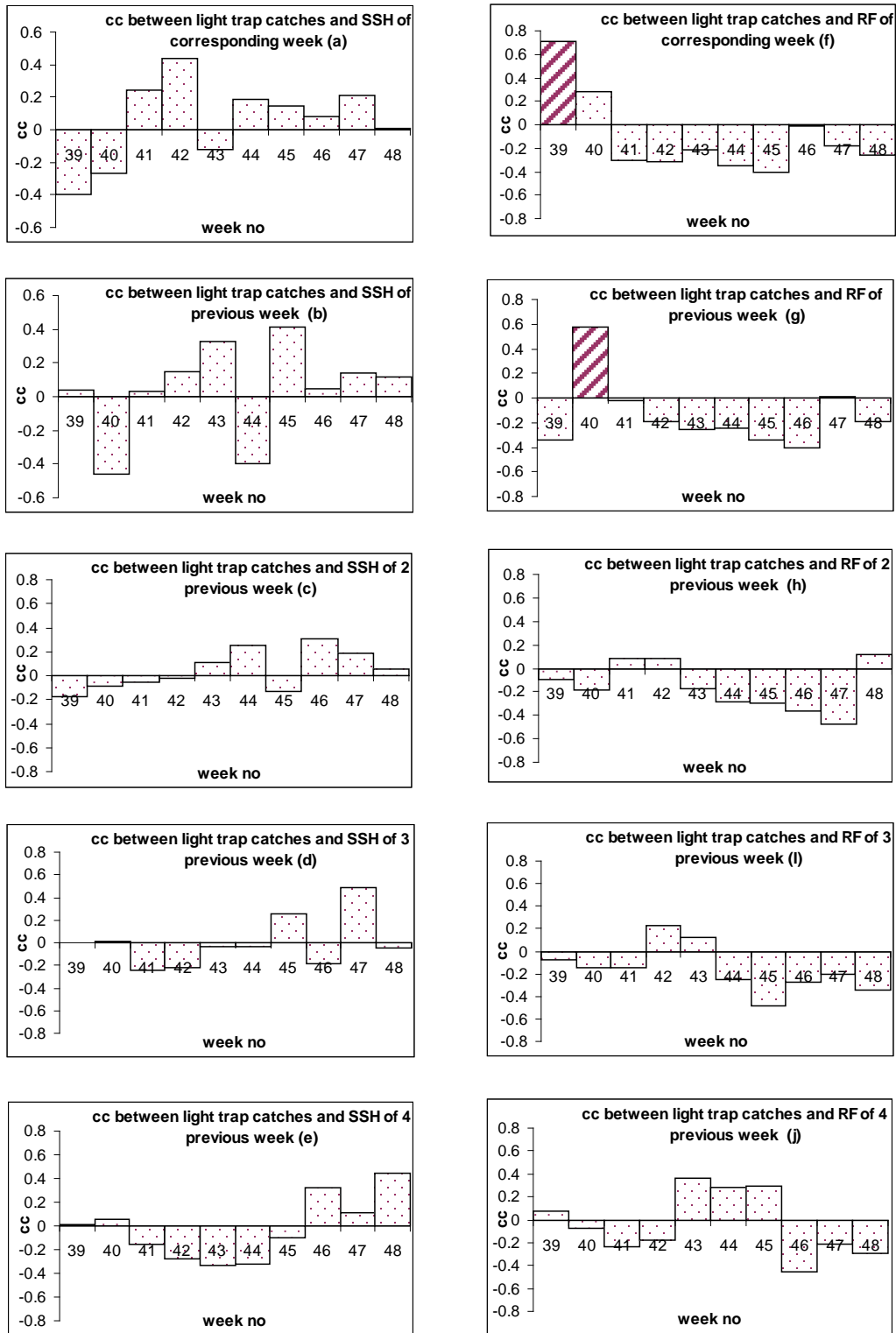
4. Weather and leaf folder relationship

Correlation coefficients worked out between weekly average leaf folder catches and different meteorological parameters that the pest experienced during different generations are discussed below.

4.1. Correlation with maximum temperature (T_{max})

Correlation coefficients (c.c.s) between the weekly average leaf folder population (LFP) and T_{max} during the peak infestation period between 39th to 47th week (both corresponding and each of four previous weeks) show the influence of T_{max} on growth and development of leaf folder [Figs. 2(a-e)]. Out of 50 c.c.s 24 (48%) c.c.s positively and 26 (52%) c.c.s were negatively correlated. 6 c.c.s were significant at 5% level.

It is interesting to note that development of adult leaf folder at 47th week was profoundly influenced by higher T_{max} of the same week. Development of larva of leaf folder at 45th and 46th week is influenced by higher T_{max} at 45th and 46th weeks (c.c. significant at 5% level). It is observed that most of the c.c.s are negatively correlated but not significant till week no 44. c.c.s were found positively and significantly correlated from 45th week onwards. Third generation of leaf folder was profoundly influenced by higher T_{max} . The abundance of green leaf



CC not significant
 CC significant at 5% level
 CC significant at 1% level

Figs. 4(a-j). Correlation coefficients between light trap catches and SSH and RF respectively for corresponding week, previous week, 2 weeks previous, 3 weeks previous, 4 weeks previous

TABLE 1

Regression equation, multiple correlation coefficient (M.C.C.), *t* value and *F* values of leaf folder for different generation with different meteorological parameters

Eqn. No.	Pest generation/Std week no.	Regression Equation	M.C.C	<i>t</i> value	<i>F</i> value
1	1 st generation at 39 th week (24-30 th September)	$P = 9.17 - 0.13X_4 + 0.09X_6$ Where, P = Leaf folder population X_4 = Afternoon Relative Humidity for 39 th std week X_6 = weekly total Rainfall for 39 th std week	0.72*	3.37	5.19
2	2 nd generation at 43 rd week (22-28 th October)	$P = 228.09 - 14.31X_2 + 1.64X_4$ Where, P = Leaf folder population X_2 = Minimum Temperature for 41 st std week X_4 = Afternoon Relative Humidity for 39 th std week	0.76*	3.98	4.5
3	3 rd generation at 47 th week (19-25 th November)	$P = -305.73 + 16.5X_1 - 3.8X_2 - 1.9X_4$ Where, P = Leaf folder population X_1 = Maximum Temperature for 47 th std week X_2 = Minimum Temperature for 43 rd std week X_4 = Afternoon Relative Humidity for 44 th std week	0.82*	4.79	6.3

* Significant at 1% level

hopper has been attributed to high temperature (Pest Surveillance Manual, 1980).

4.2. Correlation with minimum temperature (*Tmin*)

Out of 50 c.c.s worked out between LFP and *Tmin* during the peak infestation period 48(96%) c.c.s were negatively and only 2 c.c.s (4%) were positively correlated. 24 c.c.s were negatively and significantly correlated at 5% level. This negative and significant c.c.s. clearly indicated that leaf folder population at all the generations were mostly controlled by lower *Tmin*.

Tmin lower than average value (avg. *Tmin* = 22.5°C) at 41st week was found beneficial for the egg laying and development of larva and adult at 43rd week. Similarly 43rd, 44th and 46th week's negatively significant c.c.s between LFP and *Tmin* of the corresponding, 1st, 3rd and 4th previous weeks [Figs. 2(f-j)] indicated that development of larva and adult were favoured by lower *Tmin*. Thus peak population was observed during the end of SW monsoon season when higher day temperature and lower night temperature influenced the multiplication of leaf folder at 3rd generation compared to 1st & 2nd generations during SW monsoon seasons.

4.3. Correlation with morning relative humidity (RH-I)

Out of 50 c.c. values, 38 (76%) c.c.s were positively and only 12 (24%) c.c.s were negatively correlated

[Figs. 3(a-e)]. This clearly indicates that higher morning relative humidity is beneficial for leaf folder population.

4.4. Correlation with afternoon relative humidity (RH-II)

Afternoon relative humidity showed profound effect in building up LFP during 39th, 43rd and 47th weeks. Out of 50 c.c. values, 22(44%) were positively and 28(56%) were negatively correlated. 8 of them were significant at 5% level. The lower RH-II of 39th week was found beneficial for adult development at 39th week during 1st generation. The lower RH-II at 45th, 46th and 47th week also had influenced significantly egg laying, larva and pupa development at 3rd generation [Figs. 3(g-i)].

4.5. Correlation with bright sunshine hours (SSH)

It may be seen from [Figs. 4(a-e)] that none of the c.c.s between LFP and SSH were significant. Out of 50 c.c.s 28(56%) were positively and 22(44%) were negatively correlated.

4.6. Correlation with rainfall (RF)

Out of 50 c.c.s 13 (26%) were positively and 37 (74%) were negatively correlated. 2 c.c.s were positively and significantly correlated at 5% level [Figs. 4(f) and Fig. 4(g)]. Light rainfall at 39th and 40th weeks had influenced adult formation of leaf folder during 1st

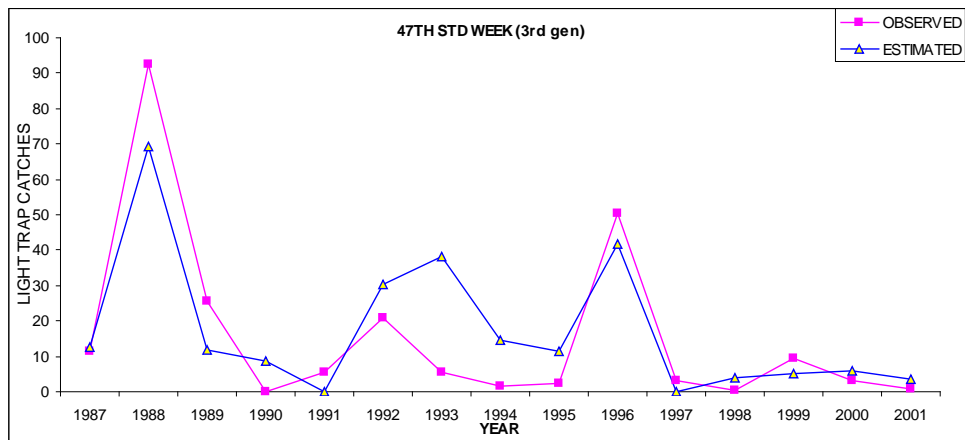
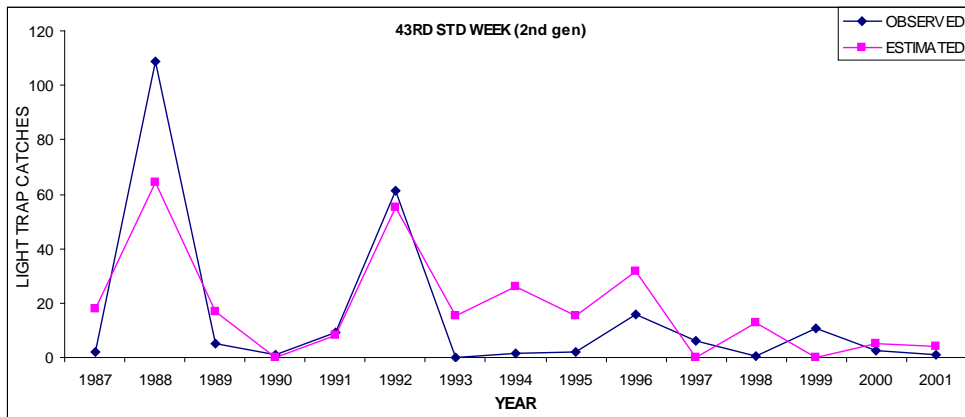
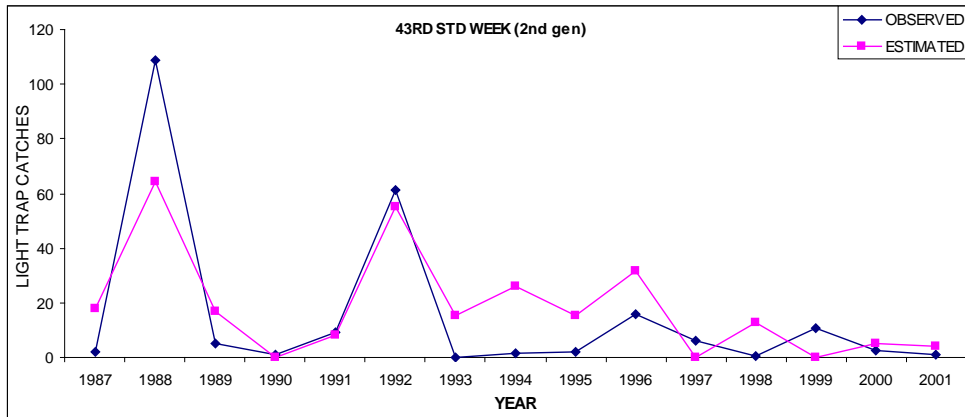


Fig. 5. Weekly mean observed and estimated leaf folder population during first, second and third generations

generation. It may be seen from Figs. 4(h-j) that none of the c.c.s between LFP and RF was significant.

5. Forewarning models

Three multiple regression equations (Table 1) for 1st, 2nd and 3rd generations were developed using

meteorological parameters having significant correlation coefficients for each of the three generations. As development of one generation overlap with other one it is very difficult to distinguish exact duration of one generation from the others. Based on pest activity and their life cycles only three overlapping generations are discussed here. The leaf folder population at 39th week

Pest weather calendar

State : Kerala
 Season : Kharif
 Station : Pattambi

Crop : Rice
 Pest : Leaf folder

Weather warnings	Max. temp. (°C)	> 32.2° C (47 wk)																
	Min. temp (°C)	< 22.5° C (41 wk) < 22.2° C (43 wk)																
	Morning RH (%)																	
	Afternoon RH (%)	< 67.6% (39 wk)					< 67.6% (39 wk)					< 66.5% (44 wk)						
	Sunshine hours																	
	Total rainfall	> 68.84 mm (39 wk)																
Weekly normal weather	Rainfall (mm) total	89	63.1	38.2	37.9	33.8	41.5	65.7	47.2	55.2	78.1	61.7	53.0	51.0	39.5	28.0	10.8	
	Max. temp. (°C)	29	29.2	29.8	30.1	30.5	30.6	30.5	30.8	31.2	31.5	31.4	31.9	32.1	32.4	32.2	32.5	
	Min. temp (°C)	22.7	22.8	23	22.8	22.9	22.9	22.9	22.9	22.9	22.9	22.8	22.7	22.4	22.2	21.9	21.7	
	Sunshine hours	4	4.6	5.7	6.3	6.8	6.3	6.3	6	6.3	5	6.2	6.7	7.5	0.7	7.7	8.1	
	Morning RH (%)	96	96	95	94	94	94	94	95	95	95	94	94	90	89	87	85	
	Afternoon RH (%)	78	76	72	70	67	70	67	69	68	68	67	64	59	57	57	51	
Mean dates of important epochs of crop growth and pest development																		
Standard weeks	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48		
Months	August			September				October					November					

Fig. 6. Pest weather calendar

was negatively and significantly correlated with the RH-II of 39th week ($cc = -0.57$) and positively and significantly correlated with RF of 39th week ($cc = 0.71$). When these two meteorological parameters were subjected to regression analysis with LFP at 39th week the resultant M.C.C. was 0.72 (significant at 1% level) which accounted for 52% variation in LFP (Eqn. 1 in Table 1). The study revealed that lower afternoon relative humidity <67.6% of 39th week and intermittent but not heavy rainfall (weekly total rainfall <68.84 mm *i.e.*, near normal rainfall (normal RF = 65.7 mm of 39th week)) contributed significantly for the development of LFP of rice at 39th week. It may be mentioned that variations in LFP during 1st generation can not be explained more than 52% because of the fact that there are several other factors such as natural enemies, parasites etc. which equally played important role in reducing the development of the pests.

The second generation of leaf folder starts multiplying under favourable weather conditions at 43rd

week. The multiple regression equation developed using the weather parameters and leaf folder population at 43rd week is presented as Eqn. 2 in Table 1. The resultant M.C.C. was 0.76 (significant at 1% level) which accounted for 58% variation in the LFP. Weather conditions which were found favourable for the leaf folder development at 43rd week are: minimum temperature <22.5° C of 41st week and afternoon relative humidity <67.6% of 39th week. This is the week when leaf folder multiplies quickly. Maximum damage to the crop is inflicted during this time. Thus 43rd week may be termed as epicenter week for the outbreak of leaf folder at Pattambi, Kerala.

The third generation of leaf folder starts multiplying at and around 47th week. Multiple regression equation for the third generation was developed using LFP of 47th week and T_{min} of 43rd week, T_{max} of 47th week and afternoon relative humidity of 44th week. When all these

three meteorological parameters were subjected to regression analysis with leaf folder population at 47th week, the resultant M.C.C. was 0.82 (significant at 1% level) which accounted for 67% of variation in leaf folder population (Eqn. 3 in Table 1). Weather conditions which were found favourable for the development of third generation of leaf folder are: maximum temperature >32.3° C of 47th week, minimum temperature <22.2° C of 43rd week and afternoon relative humidity <66.5% of 44th week.

Thus the study clearly indicates that there is a distinctly different weather requirement for egg laying, egg hatching, larva, pupa and adults of a leaf folder. Early studies have also shown that the eggs, first instar larva and adult are highly susceptible to changes in temperature and humidity (A. P. Dept. of Agriculture, 1980). The information on economic threshold value of the pest along with favourable meteorological conditions at all the three generations will help to take decision regarding possible rapid multiplication of pest and crop protection measures to be adopted subsequently.

The multiple regression models developed for each of the generations of leaf folder were validated using meteorological data for 2000-2001. Estimated and observed light trap catches for each of the generations during the study period 1987-2001 are presented in Fig. 5. It may be seen from the Fig. 5 that all the models performed fairly well. Validated results show that forewarning of leaf folder attack could be taken up based on weather information in and around Pattambi, Kerala. However information on host plants, natural enemies, leaf folder population from the field and the weather conditions on real time basis would help to forewarn the farmers well in advance. Observation on pest population from the field along with present and forecast weather based on synoptic situations would also help to forewarn the possibility of rapid multiplication and development of the pest in subsequent generations.

6. Pest weather calendar

Keeping in view of the weather requirement of rice crop as well as weather conditions favourable for development of leaf folder at their successive generations, pest weather calendar has been prepared and presented in Fig. 6. Based on the findings of this study and weather conditions (both favourable and unfavorable) during the peak infestation time *i.e.*, 39th to 47th std weeks for kharif rice crop along with warning to be issued for plant protection purposes at each of the generations, the optimum weather requirements for leaf folder

development are highlighted at the top of the calendar. The middle portion shows the normal weather at Pattambi, Kerala. The bottom portion shows the months and standard weeks along with life history and mean important epochs of pest development and crop growth. This also depicts the important stages of pest like egg laying, larva, and adult. It also shows crop growth stages like, sowing and emergence, transplanting, active vegetative growth, reproductive stage, ripening stage and harvesting respectively.

For issuance of warning on pest incidence as well as for advisories to the farmers for crop protection, observation on leaf folder population from the field and a comparison of actual weather conditions and weather requirements for the development of the pest at each of the generations of pest will help to take plant protection measures in time and to minimize loss due to infestation of the pest. In case of unfavorable weather conditions for leaf folder development strict watch may be kept on pest population and even when the population reaches near economic threshold values the farmers may be advised to postpone spraying operations till further increase in population is noticed.

7. Operational crop protection

The critical factors in the proper application and use of chemicals are temperature and precipitation during the succeeding 24 hours and the speed and direction of wind at the time of spraying. Temperature determines its effectiveness where as precipitation immediately following application can dilute or wash off the chemicals. Such operational crop protection is an interagency collaborative work and is required to be taken up on real time basis. All concerned agencies such as meteorological, entomological and extension departments are required to act quickly based on information on past, present and future weather conditions and field observation on pest population. Active participation of workers from the extension wing of the State Agricultural Department and Agricultural Universities would be required for real time plant protection measures. Dissemination of such information especially the exact time of spraying of pesticide for operational plant protection through TV/Radio/Telephone/Personal contact on real time basis would help to protect crop from infestation of leaf folder attack. Timely application of insecticide, pesticides and fungicides has not only become economical but it can also minimize the amount of noxious chemicals released into the atmosphere. This would also help the farmers to obtain maximum control with a minimum number of chemical sprays.

On the basis of the findings of this study and forewarning models developed for leaf folder of rice, useful operation of agrometeorologically based information and advice for rice protection from leaf folder attack could be introduced successfully in the meteorological sub-divisions of Kerala. Information on probability of rainfall and synoptic situation and observation on leaf folder population from the rice field by the extension workers of the State Agricultural Department /Agricultural University at and around 39th to 47th standard weeks would help to take up decision regarding spraying operations. Information on favourable weather for leaf folder development and weather likely to be experienced in near future could be used for issuing forewarning for leaf folder attack and spraying /dusting operations or negative forecast. *i.e.*, advisory against spraying /dusting operations when the likelihood of pest attack is negligible. Weather experienced by the pest and expected weather in succeeding days (using short and medium range forecast) juxtaposed with the optimum weather requirement for leaf folder for their out break would also help to advise the farming community for the spraying operations.

8. Conclusions

(i) The maximum activity and damage due to high population density of leaf folder was observed during kharif rice season from 39th to 47th std weeks.

(ii) Egg laying, hatching and rapid multiplication of leaf folder start at and around 37th std week under favourable weather conditions. Afternoon relative humidity <67.6% of 39th week and weekly total rainfall <68.84 mm of 39th week triggered the leaf folder multiplication.

(iii) A critical examination of significant correlation coefficient between leaf folder population and meteorological parameters revealed that minimum temperature <22.5° C of 41st std week and afternoon relative humidity <67.6% of 39th std week played an important role in the development and outbreak of 2nd generation of leaf folder at 43rd std week. 43rd week was found to be the epicenter week for outbreak of leaf folder and favourable meteorological condition at this week would favour the development of the pest at 43rd and subsequent weeks.

(iv) Development of third generation of leaf folder were favoured by minimum temperature <22.2° C of 43rd week,

afternoon relative humidity <66.5% of 44th week and higher maximum temperature >32.2° C at 47th week.

(v) The turning points in correlation coefficient with the maximum temperature, rainfall, morning and afternoon relative humidity during the peak infestation period (39th to 47th std weeks) clearly indicate that optimum and favourable weather requirements for adult, hatching of eggs and development of larva are quite different. More studies under controlled temperature and humidity conditions are necessary for determining the exact requirements.

(vi) Under favourable weather conditions egg laying, hatching of eggs and larva development takes place in short interval of time overlapping one with other and causing it difficult to distinguish clearly one generation from that of the other generation. Thus it would be desirable to conduct controlled study under laboratory conditions. Perhaps this is the reason for not explaining more than 67% variation in leaf folder population by the multiple regression equation.

(vii) Forewarning models and pest weather calendar for leaf folder of rice could be used as a useful aid in agrometeorological forewarning and operational crop protection.

Acknowledgements

The authors are thankful to Dr. H. P. Das, LACD Deputy Director General of Meteorology (Agricultural Meteorology) for giving constant encouragement and full facilities for carrying out the work. They are also thankful to the Associate Director of Research, Regional Agricultural Research Station, Pattambi, Kerala for providing the entomological data. They also express their thanks to Dr. K. Karthikeyan and Dr. P. V. Balachandran of Regional Agricultural Research Station, Pattambi, Kerala for their help and guidance.

References

- Andhra Pradesh Department of Agriculture, 1980, "Rice Pest Surveillance Manual", p11.
- India Meteorological Department, 1986, "Climate of Kerala State", 60-62.
- Karthikeyan, K., 2002, "Annual Reports of Regional Agricultural Research Station", Pattambi, Kerala (Personal communication).
- Nath, Vishwa and Agarwal, R. A., 1982, "In Insect Pests of Crops and their control published by Bharati Publications Delhi", p35.

Rangaswamy, G., 1988, "In Diseases of crop plants in India, (ed.) Prentice Hall of India Private Limited", New Delhi, p152.

Rice Pest Surveillance Manual for Extension Workers, 1980, "Andhra Pradesh Department of Agriculture", p11.

Samui, R. P., Banerjee, S. K., Chattopadhyay, N., Sable, J. P., Kartikeyan, K. and Balachandran, P. V., 2002, "Rice pest development in relation to inter and intra-seasonal variation of weather and operational crop protection at Pattambi", Kerala presented in the National Symposium on Priorities and Strategies for Rice Research in High Rainfall Tropics at RARS, Pattambi, Kerala 10-12 October 2002.
