

Weather based forewarning of gall midge attack on rice and operational crop protection using weather information at Pattambi, Kerala

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सार – इस अध्ययन में 1987 से 1999 तक की 13 वर्षों की अवधि में केरल स्थित पट्टम्बी में नियमित रूप से रिकार्ड किए गए कीट विज्ञान संबंधी और मौसम वैज्ञानिक आँकड़ों का उपयोग करते हुए पिटिका मशकाम कीट के आक्रमण की मौसम वैज्ञानिक आधार पर पूर्व चेतावनी देने की संभावना पर विचार किया गया है। पूर्व चेतावनी देने के लिए निदर्शों को विकसित करने हेतु इस अध्ययन में समाश्रयण तकनीक का चरणबद्ध तरीके से उपयोग किया गया है। पिटिका मशकाम कीट के विकास की सभी अवस्थाओं पर अधिकतम और न्यूनतम तापमान सुबह और दोपहर की सापेक्षिक आर्द्रता, तेज धूप के घंटे और सप्ताह की कुल वर्षा का गहन प्रभाव पड़ता है। 1987 से 1999 तक की अवधि के आँकड़ों का उपयोग करते हुए कीट द्वारा इसके विकास की चारों अवस्थाओं में फसल को अधिकतम क्षति पहुँचाने की अवधियों का पता लगाने के लिए मौसम पर आधारित बहुसमाश्रयण निदर्श विकसित किए गए और इनका परीक्षण 2000 से 2001 तक के फसल नाशी कीट संबंधी आँकड़ों और एकत्रित किए गए मौसम वैज्ञानिक आँकड़ों के उपयोग से किया गया है। इस अध्ययन से प्राप्त हुए परिणामों के आधार पर धान के फसलनाशी पिटिका मशकाम कीट के लिए कीट मौसम कलेंडर भी तैयार किया गया। यह कलेंडर पिटिका मशकाम कीट के आक्रमण की पूर्व चेतावनी देने और उस अवधि में धान की फसल को होने वाली हानि से बचाने के लिए उपयोगी सिद्ध होगा।

ABSTRACT. The feasibility of meteorological forewarning of gall midge attack has been made using entomological and meteorological data for a period of 13 years from 1987 – 1999 recorded systematically at Pattambi in Kerala. Stepwise regression techniques are used in this study for developing forewarning models. The maximum and minimum temperatures, morning and afternoon relative humidity, bright sunshine hours and weekly totals of rainfall have profound effect on the development of the gall midge at their successive generations. Weather based multiple regression models for the peak infestation period for each of the four 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 and 2001. Based on the findings of this study pest weather calendar for gall midge of rice was also prepared. This calendar would be useful for early warning and operational rice crop protection from gall midge attack.

Key words – Gall midge, Forewarning, Operational rice protection.

1. Introduction

Rice being a primary food for most of the Asians, over 85% of the world's rice is produced in Asia. It is the principal field crop grown in many states in India. Kerala is one of them where rice is grown all throughout the year. *Kharif* rice is grown extensively all over Kerala in south-west monsoon season and *rabi* rice is grown in some parts under irrigated condition. 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 cause

considerable damage to the crop. Under favourable conditions this crop is infested heavily by many pests. *Kharif* rice is mainly infested by gall midge (*Orseolia oryzae*), leaf folder (*Naphalocrocis medinalis*) and green jassid (*Nephotettix virescens*) year after year. On an average 20-25% damage has been reported due to gall midge at Pattambi (Karthikeyan, 2002). Whereas other pests *viz.*, stem borer and brown plant hopper (BPH) though remain near economic threshold level in most of the years yet become destructive on some occasions. On the other hand *rabi* rice is mainly infested by stem borer (*Scirpophaga intertials*) and rice bug (*Leptocorisa acuta*) at Pattambi. It is reported that the proper plant protection

TABLE 1
Correlation coefficient between gall midge population and weather parameters

Gall midge population for W.N.	Met. Std. W.N	Max.	Min.	RH I	RH II	SSH	R.F
30	26	0.062	-0.687*	0.323	0.017	0.073	0.050
30	27	0.128	-0.580*	-0.117	-0.109	0.451	-0.256
30	28	0.105	-0.512	0.384	-0.000	0.160	-0.255
30	29	-0.220	-0.623*	0.499	0.562*	-0.275	0.183
30	30	-0.058	-0.705**	0.444	0.170	-0.149	-0.097
31	27	-0.104	-0.545*	-0.391	0.053	0.034	0.225
31	28	-0.179	-0.451	0.093	0.094	0.045	-0.110
31	29	-0.010	-0.582*	0.227	0.283	-0.097	-0.322
31	30	0.202	-0.483	0.331	-0.143	-0.071	0.229
31	31	-0.037	-0.238	0.374	0.315	-0.038	0.233
32	28	0.217	-0.021	0.495	0.009	0.102	-0.099
32	29	0.553*	0.054	0.387	-0.302	0.470	-0.523
32	30	0.726**	-0.059	0.412	-0.592*	0.673**	-0.166
32	31	0.361	0.073	0.195	0.039	0.383	-0.196
32	32	0.244	-0.262	0.501	0.192	-0.007	-0.334
33	29	0.399	-0.097	0.475	0.046	0.141	-0.238
33	30	0.288	0.324	0.533	-0.142	0.247	0.167
33	31	0.382	-0.071	0.003	0.005	0.565*	0.066
33	32	0.244	-0.370	0.503	0.157	0.226	-0.366
33	33	-0.687**	-0.423	0.697**	0.792**	-0.681*	0.497
34	30	0.459	0.046	0.417	-0.305	0.392	0.184
34	31	0.322	0.164	-0.200	-0.137	0.449	-0.165
34	32	0.313	-0.082	0.174	0.289	-0.025	-0.577
34	33	-0.496	-0.161	0.620*	0.628*	-0.702**	0.566*
34	34	-0.478	-0.302	0.249	0.280	-0.423	0.026
35	31	0.107	0.220	-0.420	-0.225	0.398	0.039
35	32	0.206	0.144	-0.100	0.184	-0.065	-0.504
35	33	-0.625*	-0.117	0.401	0.556*	-0.619*	0.752**
35	34	-0.201	-0.203	-0.244	-0.234	-0.098	0.053
35	35	0.369	0.062	-0.162	-0.407	0.328	-0.224
36	32	-0.203	-0.661*	0.515	0.351	-0.181	-0.094
36	33	-0.562*	-0.611	0.478	0.395	-0.512	0.337
36	34	0.296	-0.585*	0.289	-0.127	-0.065	0.211
36	35	0.151	-0.553*	0.343	0.079	0.015	-0.161
36	36	0.122	-0.482	0.294	-0.175	0.360	0.226
37	33	-0.468	-0.096	0.371	0.398	-0.669*	0.664*
37	34	-0.215	-0.261	0.209	0.031	-0.501	0.204
37	35	0.314	0.068	0.030	-0.314	0.296	-0.335
37	36	0.568*	0.124	-0.022	-0.599*	0.687**	-0.276
37	37	0.122	0.425	-0.407	-0.009	-0.329	0.023
38	34	-0.294	0.155	0.061	0.027	-0.381	-0.005
38	35	0.307	0.107	-0.025	-0.337	0.323	0.290
38	36	0.735**	0.210	-0.087	-0.654*	0.799**	-0.485
38	37	0.223	0.499	-0.458	-0.110	-0.144	0.004
38	38	0.038	0.138	-0.209	-0.045	0.017	0.072

* Significant at 5% level. ** Significant at 1 % level

TABLE 2

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

Eq. No.	Pest generation/ Std. week No.	Regression Eq.	M.C.C	<i>t</i> value	% Level of significance	F value
1	1 st generation at 32 nd week (6-12 th August)	$P = -521.9 + 18.63X1 - 2.73X5$ Where, P = Gall midge population X1 = Maximum Temperature for 30 th std week X5 = Bright sunshine hours for 30 th std week	0.71	3.37	1	5.19
2	2 nd generation at 33 rd week (13-19 th August)	$P = -288.5 + 3.14X1 + 0.93X3 + 1.58X4 - 0.8X5$ Where, P = Gall midge population X1 = Maximum Temperature for 33 rd std week X3 = Morning Relative Humidity for 33 rd std week X4 = Afternoon Relative Humidity for 33 rd std week X5 = Bright sunshine hours for 33 rd std week	0.82	4.79	1	4.22
3	3 rd generation at 35 th week (27 th August-2 nd September)	$P = -358.1 + 9.69X1 + 1.11X4 - 4.66X5 + 0.25X6$ Where, P = Gall midge population X1 = Maximum Temperature for 33 rd std week X4 = Afternoon Relative Humidity for 33 rd std week X5 = Bright sunshine hours for 33 rd std week X6 = Weekly total rainfall for 33 rd std week	0.81	4.53	1	3.73
4	4 th generation at 38 th week (17-23 rd September)	$P = 726.6 - 20.8X1 - 2.2X4 - 16.7X5$ where, P = Gall midge population X1 = Maximum Temperature for 36 th std week X4 = Afternoon Relative Humidity for 36 th std week X5 = Bright sunshine hours for 36 th std week	0.87	5.17	1	9.33

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 pests at successive generations by finding the possible relationship between the pest 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 observations relating to gall midge and weather experienced by the pest during *kharif* and *rabi* seasons at different generations were recorded using light trap for 15 years (1987-2001) at Pattambi by the Entomologists, Regional Rice Research Station and meteorological data by the Meteorological Office at Pattambi respectively. Light trap is a mechanical device consisting of a 200W bulb and suitable pest trapping arrangement fitted on a iron mast of 1.5m height. Chinsurah type light trap was 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 on light trap in the night and observations are

recorded early in the morning by counting each of the pests separately. Weekly average of gall midge catches is reported in this study.

As a first step in this analysis correlation coefficient (c.c.) between gall midge population and individual meteorological parameters for the corresponding and four previous weeks have been worked out (Table 1). The meteorological parameters significant at 5% and 1% levels were selected for developing forewarning models. The parameters which were found most prominent by stepwise multiple regression technique were chosen for the development of the multiple regression equations (Table 2).

Meteorological elements such as 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 workout the association of meteorological parameters on infestation of gall midge on rice.

3. Weather and gall midge activity

Pattambi is located at 25 m.a.s.l. in Palghat district of Kerala. The district has a tropical climate with an

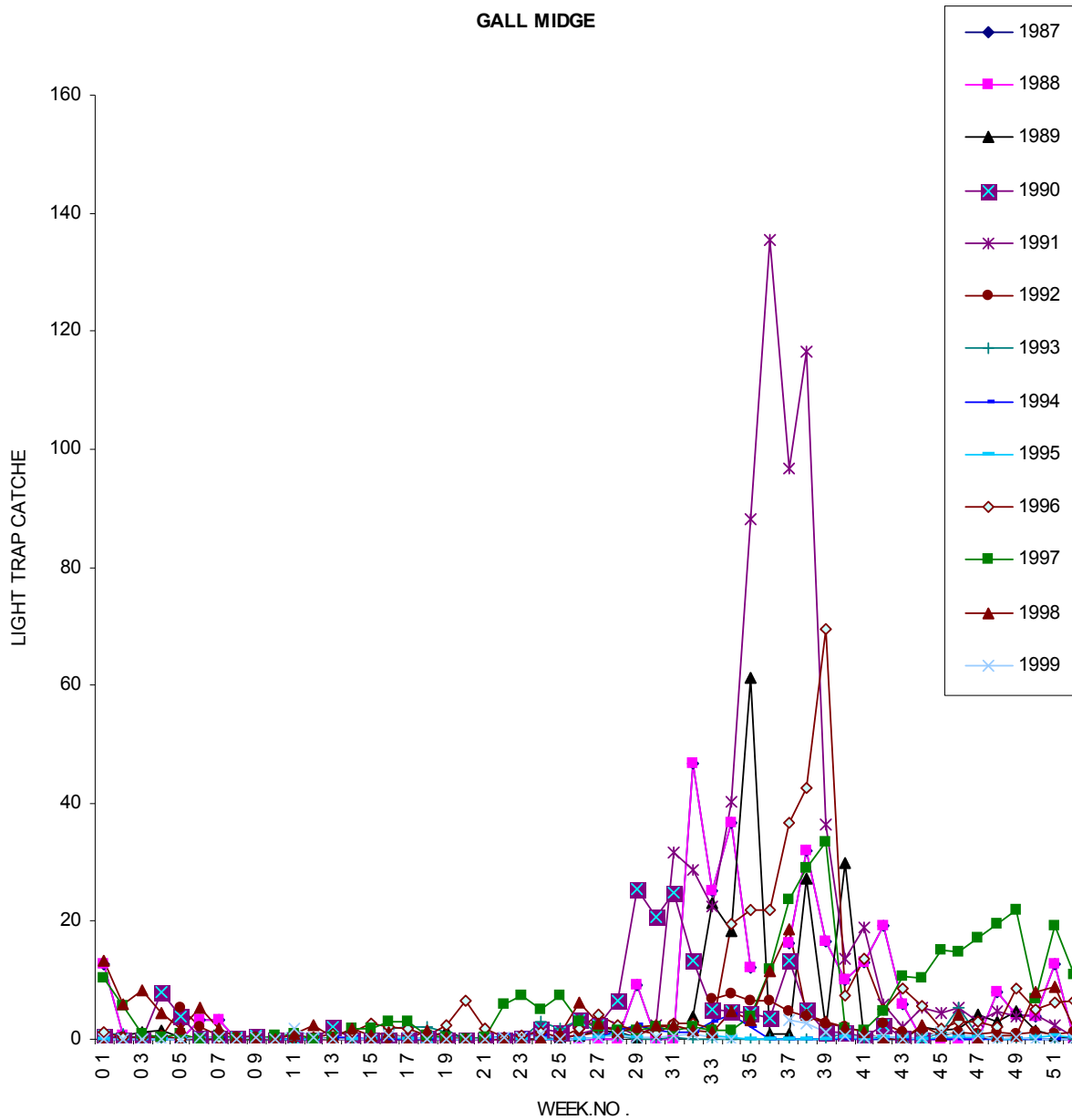


Fig.1. Variation of weekly gall midge catches in different rice growing seasons at Pattambi, Kerala state

oppressive hot season and plentiful and fairly assured rainfall in south-west monsoon season. The average annual rainfall in the district is 2396.6 mm. March is the hottest month with the mean daily maximum temperature of 37.4° C and the mean daily minimum temperature of 24.5° C. The air is highly humid throughout the year, the relative humidity being generally over 70% (IMD, 1986).

The insect breeds on variety of wild grasses and migrates to the paddy crop when it is in the tillering stage.

It attacks the crops in all the three crop growing seasons. In the southern States the maximum attack is observed between the 30th and 38th std week *i.e.*, from fourth week of July (23-29 July) to mid September (17-23 September) (Fig. 1).

It lays eggs in singly or in clusters on the leaves or on stems. During August to November they hatch in 1-3 days under favourable thermal regime. The tiny maggots crawl down to the base of the shoot and enter a young bud

where they feed for 10-13 days and then pupate. The fly emerges after 4-7 days. The life cycle is completed in 15-23 days. The adults live for 3 to 4 days and lay up to 250 eggs. There are 3 to 4 overlapping generations on the *kharif* crop and 5-8 in a year.

4. Weather-gall midge relationship

4.1. Correlation with maximum temperature

Correlation coefficients (c.c.s) between the weekly gall midge population and maximum temperature during the peak infestation period between 30th to 38th week (both corresponding and four previous weeks) show profound influence of maximum temperature on growth and development of gall midge. Out of 45 c.c. values more than 64% (29) c.c. values were positively and 16 c.c. values were negatively correlated (Table 1). Four of them were positively and significantly correlated (two at 1% and two at 5% level). During 29th to 32nd weeks and 36th to 38th weeks gall midge population were positively and significantly correlated. On the other hand during the weeks 33rd to 36th, gall midge population were negatively and significantly correlated with maximum temperature. Thus maximum temperature had played very significant role for the development of gall midge at successive generations.

4.2. Correlation with minimum temperature

It is interesting to note that out of 45 c.c. values worked out between gall midge population and minimum temperature (*T*_{min.}) during the peak infestation period (30 to 38th weeks), 29 c.c. (64%) were negatively correlated. All the 10 significant c.c.s were found negatively correlated. 30th week gall midge population were negatively and significantly correlated with 26, 27, 29 and 30th week's *T*_{min.} Similarly 36th week gall midge population was negatively and significantly correlated with 32, 33, 34 and 35th week's *T*_{min.} except c.c. between 30th week gall midge population and 30th week *T*_{min.} which was significant at 1% level all other c.c.s were significant at 5% level. These negatively significant c.c.s have clearly indicated that lower minimum temperature than the mean temperature had played the profound role in the development of the gall midge whereas higher *T*_{max.} had contributed significantly for hatching and multiplication of gall midge.

4.3. Correlation with morning relative humidity

Morning relative humidity showed positive c.c.s with gall midge population for most of the weeks (Table 1). 37 out of 45 c.c. values (82%) were positively correlated. However, only two c.c.s were positively and significantly

correlated. Gall midge population at 33rd and 34th week's were positively and significantly correlated with RH-I of 33rd week (significant at 1% and 5% levels respectively).

4.4. Correlation with afternoon humidity

Afternoon relative humidity also showed profound effect in building up gall midge population during 30th-38th weeks. Out of 45 c.c.s worked out during the peak infestation period, 26 c.c.s (57%) were positively correlated. Out of 7 c.c.s, which were found significant either at 1% or 5% levels, 4 were positively and 3 were negatively correlated. The turning point in the correlation coefficient around 36th week (36th week's RH-II with 37 and 38th week's gall midge population) was observed in this case with RH-II.

4.5. Correlation with bright sunshine hours

Bright sunshine hours also played very important role. In the beginning it showed positive and significant correlation between 32nd week's gall midge population and 30th week's SSH (significant at 1% level). The turning point in the c.c.s was observed around 33rd to 37th week when c.c.s were found negative. Second turning point in the c.c.s was found again at 37th and 38th weeks. The gall midge population at 37th and 38th week's were found positively and significantly correlated with SSH of 36th week (both significant at 1% level). Thus more hours of bright sunshine at 30th and 37th to 38th weeks were favourable for the gall midge development. On the contrary less hours of SSH at and around 33rd week were favourable for the gall midge activity.

4.6. Correlation with rainfall

Rainfall at 33rd week had the profound effect in building up gall midge population in the subsequent weeks *i.e.*, 34, 35 and 37th weeks. During this time higher amount of rainfall amount provided adequate leaf wetness for multiplication of gall midge. The positive c.c.s. indicate that the development of the pest at and around 35th week was favoured by higher rainfall at 33rd week.

5. Forewarning models

We have developed four multiple regression equations using meteorological parameters having significant correlation coefficients for each of the four generations (Table 2). The gall midge population at 32nd week was positively correlated with the 30th week's meteorological parameters. The c.c. values for maximum temperature and SSH were found significantly correlated (c.c.s for maximum temperature = 0.73 and SSH = 0.67 both significant at 1% level). When these two

meteorological parameters at 30th week were subjected to regression analysis with the gall midge population at 32nd week the resultant MCC was 0.71 (significant at 1% level) which accounted for 50% variation in gall midge population. The study revealed that maximum temperature >28.9° C, and SSH >2.5 hours contributed significantly for higher degree of infestation at 32nd week. The information on economic threshold value of the pest along with favourable meteorological conditions at this generation will help to take decision regarding possible rapid multiplication of the pest and crop protection measures to be adopted subsequently.

The second generation of the gall midge starts multiplying under favourable weather conditions at 33rd std week. The multiple regression equation was developed using the weather parameters and gall midge populations at 33rd week and the same is presented as Eqn. 2 in Table 2. The resultant MCC was 0.82 (significant at 1% level) which accounted for 68% variation in the gall midge population. Weather conditions which were found favourable for the gall midge development are: maximum temperature <29.6° C, higher morning relative humidity >94%, higher afternoon relative humidity >75% and lower sunshine hours <3.9 hours at 33rd week.

The third generation of gall midge starts multiplying in and around 35th std. week. This generation overlaps with the 2nd generation under favourable weather conditions. During this period the weekly total rainfall of 33rd std. week gave highest correlation coefficient 0.75 (significant at 1% level) with 35th std. week's gall midge population. The highest correlation coefficient with gall midge population of 35th std. week was found to be -0.62 (significant at 5% level) for maximum temperature, 0.56 (significant at 5% level) with RH-II and -0.62 for SSH of 33rd std. week. When all these four meteorological parameters at 33rd std. week were subjected to regression analysis with the gall midge population at 35th std. week the resultant MCC was 0.81 (significant at 1% level) which accounted for 65% of variation in gall midge population. Development of the gall midge during the 3rd generation was favoured under lower maximum temperature < 29.6° C, higher afternoon relative humidity > 75%, lower sunshine hours < 3.9 hours and higher weekly total rainfall > 86.0mm at 33rd std. week. This is the time when gall midge multiplies quickly and maximum damage to the crop is inflicted during this time. Thus 33rd week may be termed as epicentre week for the outbreak of gall midge at Pattambi condition. The development was found to be profoundly influenced by the weather condition when adult of 2nd generation lay eggs at 33rd week and subsequently hatches. Thus a close watch on light trap catches of gall midge along with close monitoring of meteorological parameters would help to

forewarn possibilities of multiplication of gall midge at 34th to 35th week. The multiple regression equation for the third generation of gall midge is presented as Eqn. 3 in Table 2.

Fourth generation of gall midge developed at or around 38th std. weeks. Correlation studies show that gall midge population at 38th week was positively correlated with maximum temperature ($r = 0.74$ significant at 1% level), negatively correlated with afternoon relative humidity ($r = -0.65$ significant at 5% level) and positively correlated with bright sunshine hours ($r = 0.80$ significant at 1% level) of 36th std week. Thus favourable weather conditions at 36th std. week were found to play very important role for the multiplication and development of gall midge at 4th generation. When all these meteorological parameters of 36th std. week were subjected to regression analysis with the gall midge population at 38th std. weeks the resultant MCC was found to be 0.87 (significant at 1% level) which accounted for 75% variation. The equation is shown as Eqn. 4 in Table 2. Development of adult gall midge at 38th week was influenced by higher maximum temperature > 32.5° C, lower afternoon relative humidity < 71% and higher SSH > 5.3 hours at 36th week. Under favourable weather condition at 33rd week when adult lays eggs and subsequently develops into adult at 35th week, it once again lays eggs at and around 35th week. Larva starts developing under favourable weather condition at 36th week and develops into adult at 38th week. This study clearly indicates that there is a distinctly different weather requirement for adult, egg laying, hatching of eggs and also for the larva. Earlier studies have shown that the eggs, first in star larva and adult are highly susceptible to changes in relative humidity. The eggs required a relative humidity of over 90% for normal development. The first in star larva requires a relative humidity of over 95% associated with moist surfaces for successful infestation of rice plants (Shastry *et al.*, 1972). Adult gravid female required a relative humidity of over 70% for normal longevity and egg laying. Rao *et al.* (1971b) also found that the threshold temperature for the development of the rice gall midge were between 16° C to 34° C.

The multiple regression models developed for each of the generations of gall midge were validated using meteorological data for 2000-2001. Estimated light trap catches for 2000 and 2001 are presented in Fig. 2. All the regression models performed fairly good. Validated results show that forewarning of gall midge attack could be taken up based on weather information in and around Pattambi, Kerala. However, information on host plants, natural enemies, gall midge population from the field and weather information on real time basis would help to forewarn the farmers well in advance. Observations on

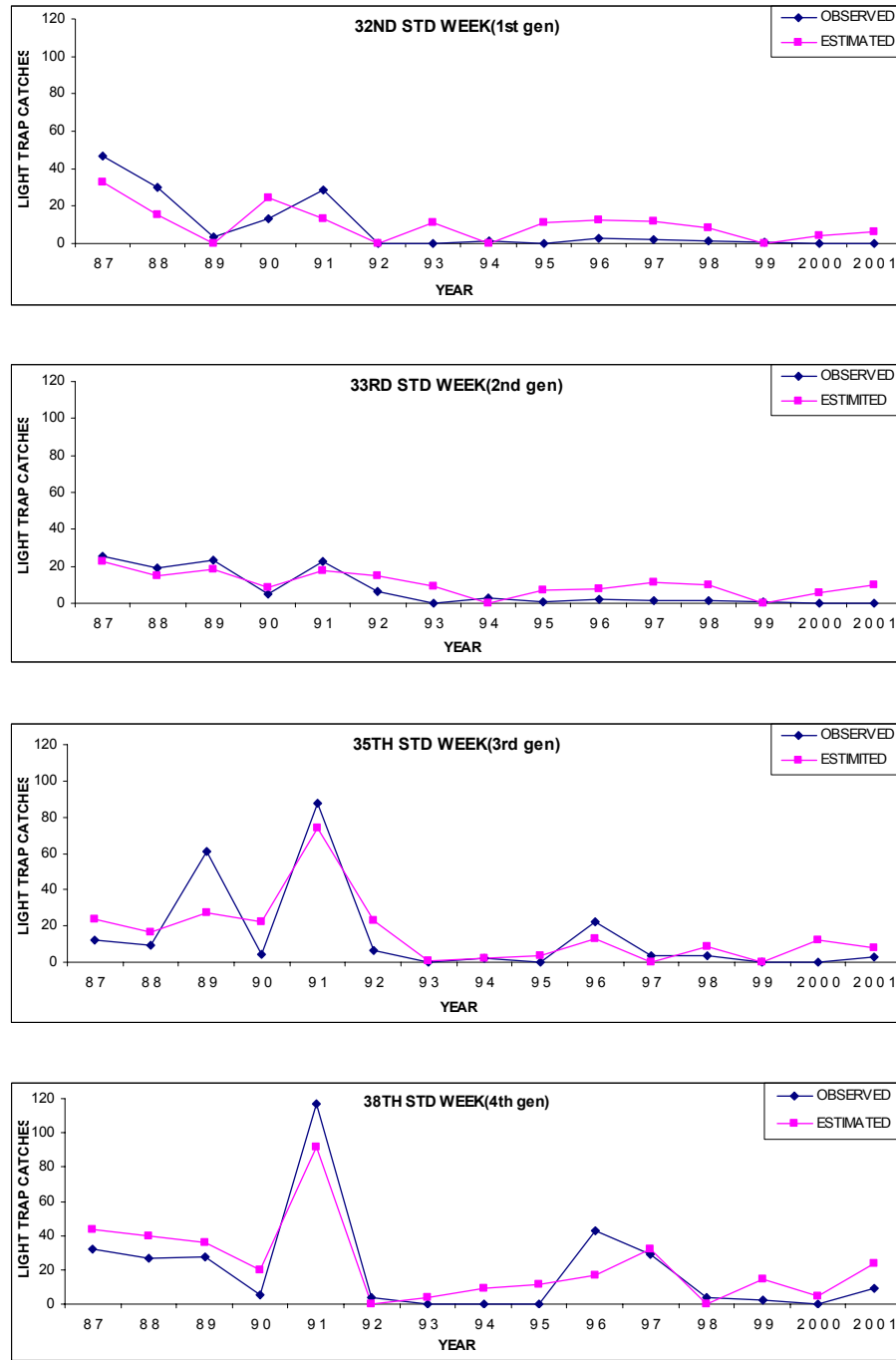


Fig. 2. Weekly mean observed and estimated gall midge population during first, second, third and fourth generations.

pest population from the field, present and forecast weather based on synoptic situations would also help to forewarn the possibilities of pest development in subsequent generations.

6. Pest weather calendar

Keeping in view weather requirement of rice crop as well as weather conditions favourable for the development

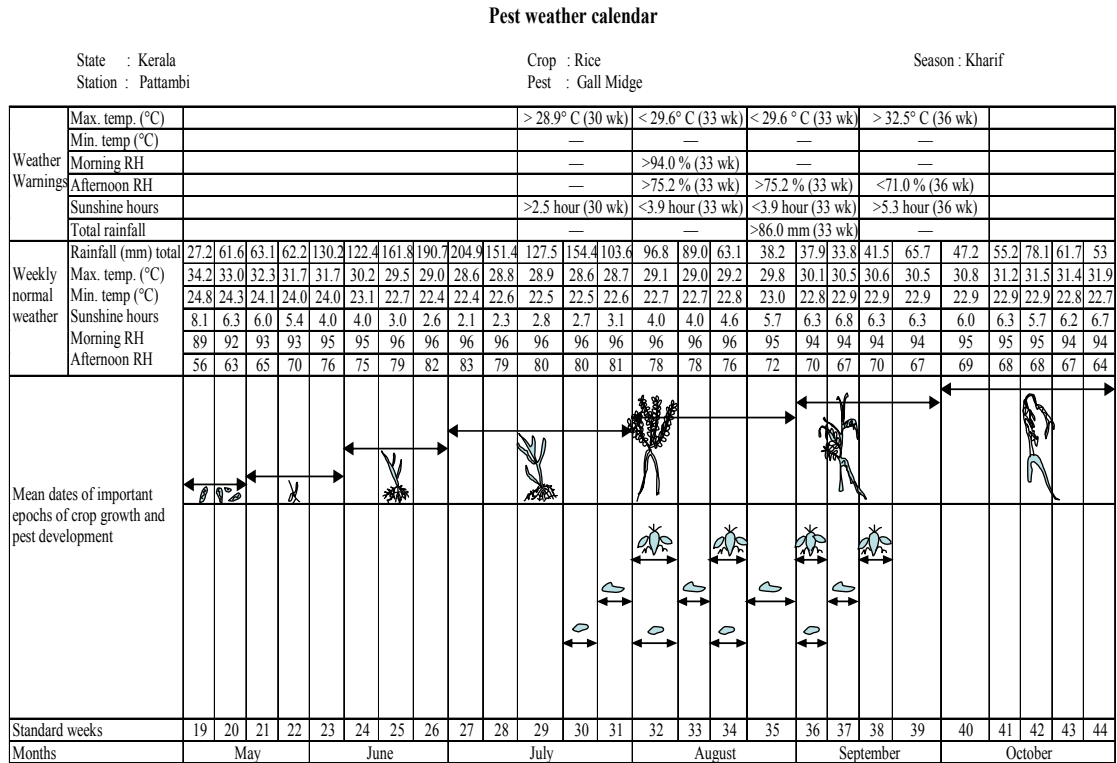


Fig. 3. Pest weather calendar

of gall midge at their successive generations, a pest weather calendar has been prepared and presented in Fig. 3. Based on the findings of this study and weather conditions (both favourable and unfavourable) during the peak infestation time *i.e.*, 30 - 38th standard weeks along with warning to be issued for plant protection purposes at each of the generations, the optimum weather requirements for gall midge 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 the life history and mean date of important epochs of pest development and crop growth. This also depicts the important stages of pest like egg laying, larva, pupa 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 gall midge 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 issue advisories for

spraying on real time basis. This would help to take up plant protection measures in time and minimise loss due to infestation of the pest. In case of unfavourable weather conditions for gall midge 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

Timely application of insecticide, pesticides and fungicides has not only become economical but it can also minimise 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. 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. Temperatures determine its effectiveness whereas 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

TABLE 3

Weather requirements for Spraying and Dusting Operation. (After WMO 1991)

Weather Factor	Spray	Dust
Wind (ms ⁻¹)	0.8	0.4
Dew	Undesirable	Desirable
Precipitation	Undesirable	Undesirable
Convection	None of slight	None of slight
Relative Humidity	Not important	Optimum 90% or more
Temperature (°C)		
Lower limit	About 2	Not important
Upper limit	About 32 with low Relative Humidity	Not important

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 gall midge attack.

On the basis of the findings of this study and forewarning models developed for gall midge of rice, useful operation of agro meteorologically based information and advise for rice protection from gall midge attack could be introduced successfully in the meteorological sub-division of Kerala. Information of probability of rainfall and synoptic situation from weather forecasting office along with observation on gall midge population from the rice field by the extension workers of the State Agril. Department/Agril. University at and around 30-38th standard weeks would help to take up decision regarding spraying operations. Information on weather requirement of gall midge development and weather likely to be experienced in future could be used for issuing forewarning for gall midge attack and spraying/dusting operations (Table 3) 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 two days juxtaposed with the optimum weather requirement for gall midge for their outbreak

would also help to advise the farming community for the spraying operations.

8. Conclusions

(i) Maximum activity and damage due to high population density of gall midge was observed in kharif season during 30th to 38th std. weeks.

(ii) Out of 7 to 8 generations in a year, 3 to 4 generations appear in kharif season. Maximum temperature >28.9° C, and bright sunshine hours >2.5hours at 30th week triggered the multiplication of gall midge.

(iii) A critical examination revealed that 33rd week is the epicentre week for out break of gall midge at Pattambi condition. Max temperature <29.6° C, morning relative humidity >94%, afternoon relative humidity >75% and bright sunshine hours < 3.9 hours at 33rd standard week played the most important role in the development and outbreak of 2nd generation at 33rd week. These weather condition associated with higher weekly total rainfall >86.0mm at 33rd week also favoured the development of 3rd generation of gall midge.

(iv) Development of pest at 38th weeks were influenced by higher maximum temperature >32.5° C, lower afternoon relative humidity <71% and higher SSH >5.3 hours.

(v) The turning points in correlation coefficient with the maximum temperature, afternoon humidity and bright sunshine hours during the peak infestation period (30-38th

week) clearly indicate that optimum and favourable weather requirements for adult gall midge at and around 33rd week and for hatching of eggs and development of larva at and around 32nd and 36th weeks are quite different. Higher maximum temperature, higher bright sunshine and lower afternoon humidity from the mean value during hatching and larva stage are favourable. On the contrary lower maximum temperatures, lower bright sunshine hours and higher afternoon humidity from that of mean values at adult stage of the pest are favourable for multiplication and the development of the pest. However, more studies under controlled temperature and humidity conditions are necessary for determining the exact values. Perhaps this is the reason for not explaining more than 50 to 75% variation in gall midge population by the multiple regression equations.

(vi) Forewarning models for each of the four generations and pest weather calendar for gall midge of rice could be used as an useful aid in agro meteorological forewarning and operational crop protection.

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