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Forewarning incidence of American boll worm (*Heliothis armigera* H.) of cotton at Akola in Vidarbha region of Maharashtra

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सार – कपास की फसल में अमेरिकी गोलक शलभ बोल वॉर्म (हीलियोथिस आर्मीजेरा) के नाशक जीवों की संख्या का अध्ययन किया गया। ये वर्षा (RF), अधिकतम तापमान (Tmax) न्यूनतम तापमान (Tmin), प्रातःकालीन सापेक्षिक आर्द्रता (RH I), सायंकालीन सापेक्षिक आर्द्रता (RH II) और तेज धूप के घंटों (BSS) जैसे मौसम प्राचलों से प्रभावित होते हैं। इनको सांख्यिकीय सहसंबंध का डा. पंजाबराव देशमुख कृषि विद्यापीठ, अकोला में अभिलेखित किए गए आँकड़ों के साथ अध्ययन किया गया हैं। हीलियोथिस की भारी जीव संख्या के कारण होने वाली सबसे अधिक गतिविधियां और नुकसान 35वें से 50वें मानक सप्ताहों के दौरान होता हुआ देखा गया। 40वें मानक सप्ताह की अवधि में नाशक जीवों की अत्याधिक संख्या, 38वें सप्ताह के अधिकतम तापमान (40वें सप्ताह) और न्यूनतम तापमान (37वें सप्ताह), प्रातःकालीन व सायंकालीन सापेक्षिक आर्द्रता में महत्वपूर्ण भूमिका निभाती हैं। फसल में फूल आने से लेकर गोलक (बॉल) बनने की अवस्थाओं तक फसलें हीलियोथिस से प्रभावित रहती हैं। अकोला में अधिकतम तापमान लगभग 32° से. और न्यूनतम तापमान 23° से. से कम, प्रातःकालीन सापेक्षिक आर्द्रता 88% से कम, सायंकालीन सापेक्षिक आर्द्रता 60% से कम और तेज धूप के घंटे 6.5 घंटे/प्रतिदिन से अधिक ऐसे संकट पूर्ण मौसम प्राचल हैं जो अकोला में हीलियोथिस बीमारी के फैलने के लिए उत्तरदायी हैं।

ABSTRACT. A study on pest population of American boll worm (*Heliothis armigera* H.) in cotton crop as influenced by weather parameters like rainfall (RF), maximum temperature (*T*max), minimum temperature (*T*min), morning relative humidity (RH I), evening relative humidity (RH II) and bright sunshine hours (BSS) and its statistical correlation was undertaken with data recorded at Dr. Punjabrao Deshmukh Krishi Vidhyapeeth, Akola. The maximum activity and damage due to high population of *Heliothis* was observed during 35th to 50th standard weeks. Maximum temperature (40th week) and minimum temperature (37th week), morning and evening relative humidity during 38th week play an important role in pest infestation during 40th standard week. Flowering to boll formation stages of the crop suffered heavy incidence of *Heliothis*. Critical weather parameters causing the outbreak of *Heliothis* in Akola was maximum temperature around 32 °C and minimum temperature around 23 °C, morning relative humidity below 88%, evening relative humidity below 60% and hours of bright sunshine above 6.5 hrs / day.

Key words – *Heliothis*, Cotton, Weather, Correlation and regression model.

1. Introduction

Cotton, an important fibre crop, is extensively grown in the dry farming tract of India. Despite being the largest growing country, yield per hectare is very low as compared to that of other cotton growing countries. Amongst the various factors insect pests contribute significantly towards limiting cotton production. Cotton crop alone receives 55% of the pesticides sprayed to control pest damage. In recent times integrated pest management (IPM) is being followed to tackle the pest complex in cotton. Pesticide spray is one of the key components of IPM even today. There is wide scope to prevent the losses of crops due to pests by taking appropriate plant protection measures in time, based on weather information, thereby minimise the number of sprays.

Cotton crop is damaged every year by different pests like aphids, jassids, thrips and bollworms in Maharashtra particularly in the Vidarbha region. Among boll worms all the four species, *viz*., American boll worm (*Heliothis armigera* H.), tobacco cut worm (Spodoptera litura), pink boll worm (*Pectinophora gossypiella* S.) and spotted bollworm (*Earias vitella*) are the most prevalent pests and damage the crop here. An aggregate loss of 20-25% to cotton is caused by various pests in India (Sohi, 1964). The losses caused by boll worms have been earlier reported by Fletcher and Misra (1919), Prayag (1928), Deshpande and Nadkarny (1936), Patel *et al*. (1954) and

Kaushik *et al.* (1969). American boll worm inflicts heavy losses every year (Tedas *et al*., 1994). H. armigera has also been reported to cause heavy loss to chickpea, pigeon pea, sorghum and cotton during last few decades in the country (Singh and Singh, 1974, Saharia and Dutta, 1975, Lal *et al*., 1981 and Dhaliwal & Arora, 1998). The newly hatched larvae of Heliothis cause heavy damage to flowers, flower buds and bolls by feeding on them. The infested bolls and flower buds drop prematurely. It has been estimated that a single larva can destroy about 3-4 buds each day and 7-8 larvae could kill one adult plant. In the absence of bolls and buds, larvae start feeding on leaves. An attempt has been made in this paper to investigate whether any statistical relationship exists between American boll worm infestation and meteorological factors and also to develop forewarning models for predicting the outbreak of these pests at Akola where the damage caused by the pest was maximum.

2. Data and methodology

Pest data for American boll worm infestation collected for 11 years (2000-2010) at Dr. Punjabrao Deshmukh Krishi Vidhyapeeth, Akola (24° 42' N, 77° 02' E) were used in the study. The crop was sown on and around 26th standard week. Pest observations were recorded daily on one block of experimental plot where insecticides and pesticides were not used during the entire period of crop growth. Weekly population of the pest was used for the study. The daily meteorological parameters *viz*., rainfall (RF), maximum temperature (*T*max), minimum temperature (*T*min), morning relative humidity (RH I), evening relative humidity (RH II) and bright sunshine hours (BSS) averaged over different standard meteorological weeks during the entire crop period and weekly total rainfall were utilised in the study. Since the previous weeks' meteorological parameters equally influence the development of the pest, meteorological data four weeks prior to the reported infestation, was considered for analysis. Correlation analysis between the pest population and meteorological factors prior to four weeks were carried out for the years 2002 to 2008.

Simple correlation coefficient (CC) between pest population and the meteorological parameters has been worked out for the standard weeks when higher infestation was observed. Student's '*t*' test (Fisher and Yates, 1938) was applied to test the significance. The week's individual weather parameters having highest correlation coefficients which are statistically significant were selected. All these statistically significant parameters were subjected to multiple correlation coefficients combining all the selected parameters for these selected weeks and a '*F*' test was performed for testing its significance. Regression equations were developed for the peak infestation week using the significant weather parameters having highest correlation coefficients. The multiple regression models thus developed were validated using subsequent two years data (2009-10). Graphical analysis between significant weather parameters and pest population were made.

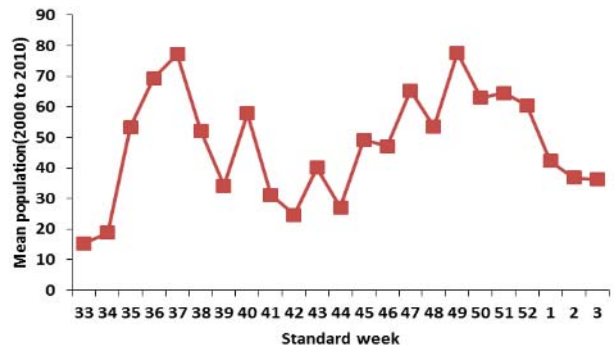


Fig. 1. Weekly variation of *Heliothis* population at Akola

3. Results and discussion

3.1. *Climate and Heliothis activity at Akola*

The climate of Akola is characterised by hot summer and dryness throughout the year except in southwest monsoon season. The average annual rainfall is 846.5 mm and July is the rainiest month with the average rainfall of 247.5 mm. In the remaining part of the year *i.e.*, from January to May and October to December, rainfall is appreciably low compared to the rainfall during the monsoon season. May is the hottest month with the average maximum temperature of 42.4 °C. In the month of November, December and January temperatures were appreciably low. The pest data for the years under study revealed that *Heliothis* attack on cotton was mainly confined between first week of September and second week of December. During the crop season two generations of *Heliothis* were observed with the peak population in the first generation between 35th and 40th standard weeks and the second generation between 46th and 50th standard weeks which correspond to flowering and boll formation stages, respectively. The maximum *Heliothis* attack was observed at 37th standard week (10-16th September) followed by 40th standard week (1-7th October) corresponding to flowering to early boll formation stages of the crop (Fig. 1) in the first generation. Tedas *et al.* (1994) and Chattopadhyay *et al.* (2003) observed maximum pheromone catches of the *Heliothis* armigera in cotton field in Akola from middle of August to end of September. Pazhanisamy and Deshmukh (2011) reported that peak catches of American boll worm were observed during 37th (34.77 moths / trap / week), 43rd (11.25 moths / trap / week) and 48th (11.75 moths / trap / week) weeks. Pest population during individual years showed considerable variations (Table 2) as a result of

TABLE 1

Correlation coefficient (CC) between population of American boll worm at 40th std. week and weather parameters at Akola

Std. week	Weather parameters					
	*T*max	*T*min	RH I	RH II	BSS	RF
40	0.81*	-0.77*	-0.87*	-0.67	0.71	-0.33
39-40*	0.76*	-0.04	-0.67	-0.54	-0.01	0.04
38-40	0.73	-0.58	-0.94**	-0.91**	0.29	-0.66
37-40	0.14	-0.97**	-0.07	-0.53	0.48	-0.40
36-40	-0.95**	-0.93**	-0.01	0.89**	-0.93**	0.24

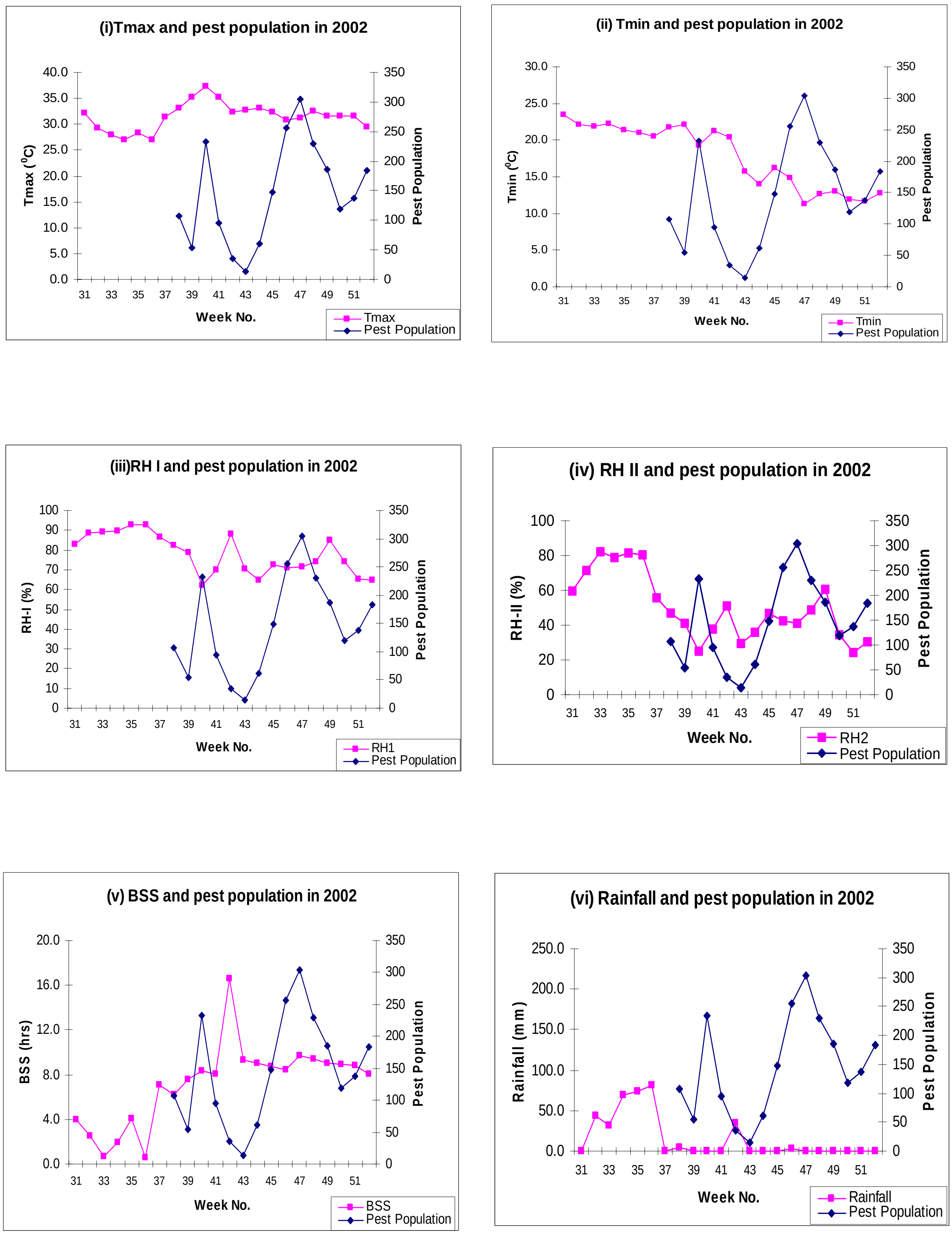
CCs significant at 5 % level*, CCs significant at 1% level**
*Week No.39-40 indicates that pest population of 40th week and based on weather parameters of 39th week

TABLE 2

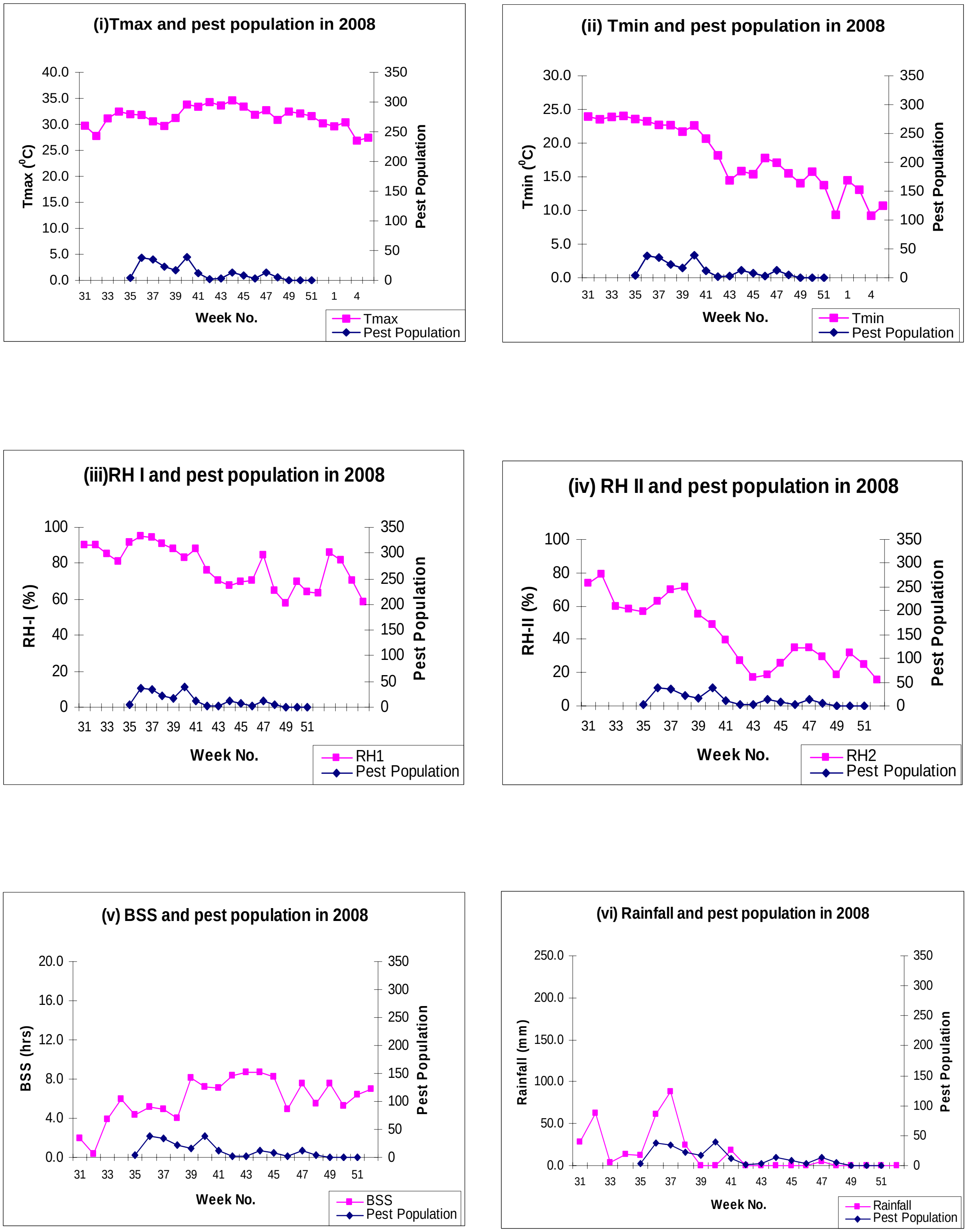
Weekly variation of *Heliothis* population (total number of moth catches / week) in different years at Akola

Week	Year								
	2000	2001	2002	2003	2004	2005	2006	2007	2008
33		34		3				2	
34	3	44		22				22	
35	35	154		130				23	4
36	48	205		128		4		19	38
37	39	108		290		4		29	35
38	56	20	107	146		2		31	23
39	54	2	54	105		3		21	17
40	47	19	233	94	24	2		42	39
41	28	8	95	72	18	1		35	12
42	32	32	35	56	14	3		23	2
43	188	25	14	52	4	4		31	3
44	22	12	61	50	6	6		47	13
45	81	14	148	41	5	9		88	8
46	6	7	256	29	0	21	6	95	3
47	11	9	304	43	53	20	65	70	13
48	19	33	230	54	24	17	39	60	5
49	10	66	186	39	13	34	72	201	
50	18	65	119	22	16	33	56	175	
51	15	48	137	26	45	22	85	138	
52	21	29	184	29	69	12	87	52	
1	49	17	111	9	25				
2	19	21	103	15	26				
3		31	91	16	7				

Blank indicates no catches of moth in the particular week.



Figs. 2a(i-vi). Variation of weather parameters and pest population at Akola during 2002 (year of maximum population)



Figs. 2b(i-vi). Variation of weather parameters and pest population at Akola during 2008 (year of minimum population) weather variations / aberrations. Maximum population of *Heliothis* was recorded in 2002 at 47th standard week followed by 2003 at 37th standard week and minimum population was recorded in 2008.

3.2. *Correlation with weather parameters*

Correlation coefficients worked out between weekly moth catches of *Heliothis* and different weather parameters are given in (Table 1) are discussed below. Correlation studies indicated that different weather parameters influenced the pest population differently. In the present study pest population at 37th standard week, did not show significant correlation with weather parameters whereas population of *Heliothis* at 40th standard week was found to be positively correlated with max. temperature and negatively correlated with min. temperature of most of the previous four weeks. Morning and evening relative humidity were negatively correlated with pest population. Bright sunshine hours showed high positive correlation with the pest incidence though were not significant statistically (r = 0.71). Similarly rainfall during 38th standard week was negatively correlated (r = -0.66) with population at 40th standard week.

3.2.1. *Correlation with maximum temperature (Tmax)*

*T*max during 37th and 40th standard weeks were positively correlated with the weekly *Heliothis* population. However, correlations for 39th and 40th week were significant with pest population in the 40th standard week, culminating in development of adult *Heliothis* by 40th standard week. Balasubramanian *et al*. (1982) reported similar positive correlation with the maximum temperature (r = 0.742) in case of incidence of boll worm.

3.2.2. *Correlation with minimum temperature (Tmin)*

During all the five weeks *i.e*., 36th to 40th standard weeks, *T*min showed negative correlation with pest population of 40th standard week. Significant correlations were noticed for 36th, 37th and 40th standard weeks. Thus, lower minimum temperature than the average value could be beneficial for the egg hatching and development of larva and adult at 40th standard weeks. Chattopadhyay *et al*. (1999) observed negative correlation between *Heliothis* population and minimum temperature.

3.2.3. *Correlation with morning relative humidity (RH I)*

RH I between 36th and 40th standard weeks was negatively correlated with pest population at 40th standard week with significant values for 38th and 40th week. Singh and Singh (1978), Vaishampayam and Veda (1980), Chattopadhyay *et al*. (1999) and Chattopadhyay *et al.* (2001) reported negative correlation of morning relative humidity with *Heliothis* population.

3.2.4. *Correlation with evening relative humidity (RH II)*

RH II between 36th and 40th standard weeks also showed similar trend showing negative correlation with *Heliothis* population during 40th standard week with significant value for 38th standard week. Chattopadhyay *et al*. (2003) also reported negative correlation of evening relative humidity with *Heliothis* population.

3.2.5. *Correlation with bright sunshine hours (BSS)*

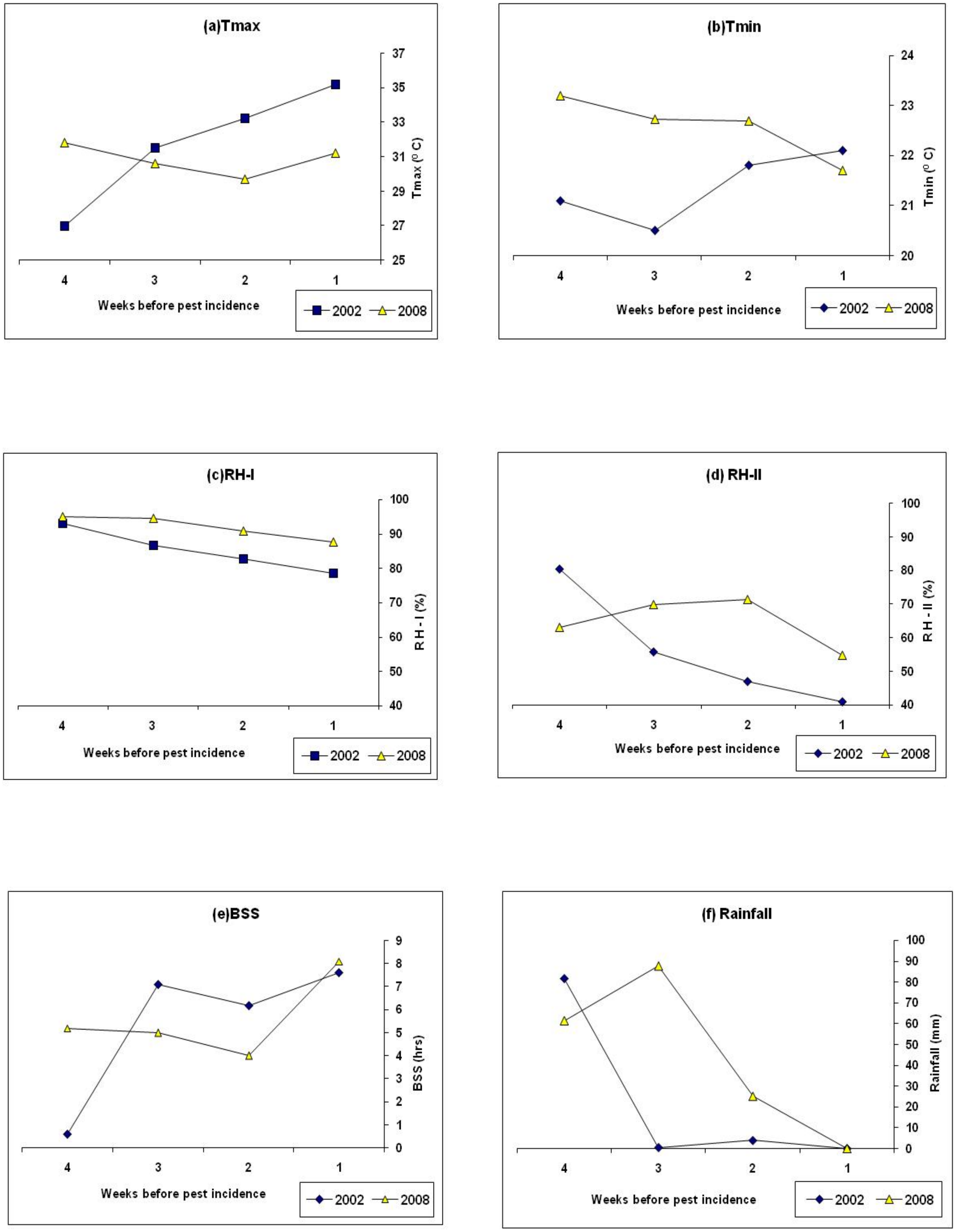
BSS during most of the antecedent standard weeks showed positive correlation with pest population during 40th standard week. Correlation for BSS during 40th standard week was high, though not statistically significant. Tedas *et al*. (1994) also reported positive correlation between bright sunshine hours and Heliothis.

3.2.6. *Correlation with rainfall (RF)*

Rainfall in most of the earlier standard weeks showed negative correlation with pest population at 40th standard week, though not statistically significant. Chaudhary *et al*. (1999) and Chattopadhyay *et al.* (2003) also reported negative correlation of rainfall with *Heliothis* population. In the study period rainfall is decreased drastically from 37th standard week through 41st standard week leading to dry spell conditions starting from 37th standard week. The dryness might have influenced higher population at 40th standard week.

3.3. *Favourable weather for development of Heliothis*

A critical examination of various weather parameters [Figs. 2(a&b) & 3(a-f)] showed that pest population increases substantially when the maximum temperature was above 32 °C and minimum temperature was below 23 °C, morning relative humidity below 88% and evening relative humidity below 60%. Chattopadhyay *et al.* (2003) found that drop in minimum temperature below 23 °C under prolonged dry conditions resulting in decrease of morning relative humidity below 88%, evening relative humidity below 60% during squaring to boll formation of the crop, particularly from September to December, are favourable for outbreak of *Heliothis* on cotton. Temp. limits for development of eggs range from 14-38 °C (WMO, 1996) and our results are within these limits. The



Figs. 3 (a-f). Variation of different weather parameters in the weeks before incidence of *Heliothis* in 40th std. week in outbreak year (2002) and non-outbreak year (2008)

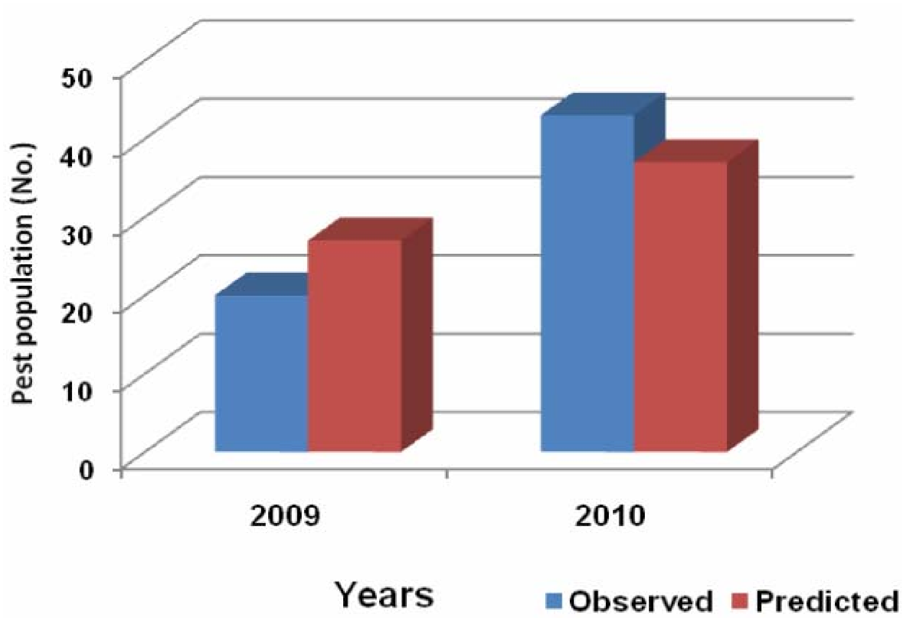


Fig. 4. Observed and predicted population of *Heliothis* during 40th Std. week

presence of western disturbance as an upper air system which normally lay over north Pakistan and adjoining Punjab from 26th September to 2nd October seems to have lead to such favourable weather conditions, *i.e.*, drop in minimum temperature for the outbreak of *Heliothis*. In the present study period also, between 3rd September to 7th October, there were 10 such western disturbances in 2002 (outbreak year). These critical limits of weather variables were mostly met out in outbreak year 2002 and non-outbreak year 2008 [Figs. 3 (a-f)]. The maximum temperature during previous four weeks showed increasing trend towards the maximum infestation week at 40th standard week in 2002 and 2008. Minimum temperature showed declining trend towards the maximum infestation at 40th standard week during 2008, whereas, during 2002 there was slight increasing trend, however, all these weeks minimum temperature was below 23 °C in 2002. Both RH I and RH II showed decreasing trend during 2002 and 2008. BSS showed increasing values during 2002 and 2008. Rainfall amount also showed decreasing trend during 2002 and 2008.

3.4. *Forewarning model*

The highest correlation coefficient between the pest population at 40th standard week and weekly mean of weather parameters were noticed with 37th standard week for minimum temperature, 38th standard week for both the morning and evening relative humidity in Akola. The values of the correlation coefficients for different weather parameters along with their significance at different levels are given in Table 1. The multiple regression equation which describes the average relationship between the pest population and significant weather parameters is derived and expressed as below:

$$Y = 2550.972 - 63.82\, X_1 - 13.95\, X_2 + 3.06\, X_3 \quad (R^2 = 0.97)$$

where,

Y = Pest population at 40th standard week,

X_1 = minimum temperature for 37th standard week,

X_2 = morning relative humidity for 38th standard week and

X_3 = evening relative humidity for 38th standard week. The multiple correlation coefficient was 0.97 which was significant.

The multiple regression models developed for predicting the outbreak of *Heliothis* at Akola were validated using weather parameters for 2009 and 2010. Observed and predicted values of *Heliothis* population are presented in Fig. 4. Validated results showed that forewarning of *Heliothis* attack could be taken up based on weather information at Akola in Vidarbha.

4. Conclusions

(*i*) The maximum activity and damage due to high population of *Heliothis* at Akola was observed during 35th to 50th standard weeks.

(*ii*) Maximum temperature was positively correlated with pest incidence and minimum temperature was negatively correlated. Morning and evening relative humidity were negatively correlated with pest population.

(*iii*) Continuous dry conditions and fall in minimum temperature around 23 °C were found congenial for outbreak of *Heliothis* on cotton at Akola in Vidarbha region of Maharashtra. Absence of rain due to withdrawal of southwest monsoon or break monsoon situation along with the fall in minimum temperature are favourable for outbreak of *Heliothis*.

(*iv*) Based on this information including regression models and also pest weather calendars already developed for Akola region, it would be possible to forewarn the incidence of Heliothis using real time weather information.

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