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Forecasting of *Helicoverpa armigera* populations and impact of climate change

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ABSTRACT

Helicoverpa armigera (Hubner) is a polyphagous insect pest and has been reported to feed on at least 181 plant species belonging to 45 botanical families in India. This insect pest has become of national importance because of huge losses caused to the high value crops such as cotton, soybean, tobacco, pulses, vegetables and cereals etc. Forecasting of the pest occurrence and peak activity periods is the prerequisite for an economically viable, environmentally sound and easily adaptable pest management programme. Adult population of *H. armigera* has been monitored successfully throughout India with the help of pheromone traps. By using the pheromone trap data, egg and larval count in the fields, damage caused to the crops and meteorological data, especially rainfall and temperature, region-specific prediction models have been developed and validated for Andhra Pradesh, Karnataka, Uttar Pradesh and Punjab. Rainfall has been found to be important factor in forecasting *H. armigera* in Andhra Pradesh and Karnataka. Temperature played the major role in the prediction model developed and validated for Uttar Pradesh. Whereas in Punjab, the peak population of *H. armigera* during March-April is dependent on temperature and humidity in February, while the high population during October depended on the rainfall during the rainy season.

Key words: Forecasting, *Helicoverpa armigera*, Monitoring, Pheromone trap

Helicoverpa (= *Heliothis*) *armigera* (Hubner) (Lepidoptera: Noctuidae) is a major pest of several crops in the old world semi-arid tropics. In India alone this highly polyphagous insect feed on at least 181 plant species spread across 45 botanical families (Manjunath *et al.* 1989). Along with polyphagy the following ecological and physiological features contribute to boosting the pest status of *H. armigera*: -high fecundity, multivoltinism, ability to migrate long distance and diapause under become unfavourable conditions (Fitt 1989, Zalucki *et al.* 1986). This insect has developed a high level of resistance to many of the commonly used insecticides (Kranthi *et al.* 2002). *Helicoverpa* causes an estimated loss of US $ 927 million in chickpea and pigeonpea and possible over US $ 5 billion on different crops worldwide (Sharma 2001). A conservative estimate is that over US $ 1 billion is spent on insecticides to control this pest. Heavy losses caused by *H. armigera* are mainly due to the feeding preference of the larva for plant parts that are high in protein content, particularly the reproductive structures and growing points, eg cotton buds and bolls, corn ear, tobacco buds, sorghum panicles, flowers and pods of pulses resulting in a direct reduction in the crop yield. In addition to the huge economic losses caused directly by this pest, there are several indirect costs accruing from the deleterious effect of pesticides on the environment as also human and animal health.

The population density of this pan-tropical pest vary greatly across seasons and among years but the reasons for these area-wide fluctuations in abundance are unknown by virtue of its biological make-up (Pimbert and Srivastava 1991). *H. armigera* is particularly well adapted to dealing with ephemeral environments and shares many traits found in r-selected species and we might therefore expect its regional abundance to be determined mainly by abiotic (eg climatic) rather than by biotic factors (Southwood 1977 a, b).

DEVELOPMENT OF PHEROMONE TRAPPING SYSTEM FOR *H. ARMIGERA*

The development of a trapping system for monitoring *H. armigera* male moths using virgin females started in 1977 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Later on Tropical Products Institute (Now Natural Resources Institute) of London subsequently provided synthetic pheromone mixtures [(Z) 11–hexadecenal and (Z) 9–hexadecenal (97:3)] that attracted many more

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Fig 1 Standard pheromone trap used for monitoring *Helicoverpa* population

moths. The dispenser, dose and design of pheromone traps were standardized at ICRISAT (Pawar *et al.* 1988). Eventually, small burette stoppers (earlier rubber septa), on which 2 mg of the pheromone was adsorbed, were adopted as the standard lures which attracted moths for several months but the first four weeks were the optimum use period. Dry traps, particularly funnel types, were more effective than sticky traps. A white coloured pheromone trap was most efficient and was adopted as the ICRISAT standard trap (Fig 1). Traps placed just above the crop canopy in sorghum, millet, pigeonpea, chickpea and groundnut caught more moths than at other heights (Table 1).

ICRISAT in collaboration with the AICPIP, developed a network of pheromone traps in different agro-climatic zone of India in 1981 (Pawar *et al.*1983). The data from this network has been used to study the temporal and spatial variations in the abundance of the gram pod borer, *H. armigera* in India (Srivastava *et al.* 1990). The catches were generally higher and had more sharply defined peaks, at northern locations. In view of definite trend of population build-up of *H. armigera* at northern locations, it is possible to escape peak infestation period by growing early-maturing cultivars or by early sowing of crop. This phenomenon of host avoidance is effective both in chickpea and pigeonpea and can be fully exploited to escape *Helicoverpa* damage effectively (Dias *et al*. 1983, Yadava *et al*. 1983). Similarly, ICRISAT in collaboration with the pulse entomologists of Pakistan had developed a network of pheromone traps in the regions where chickpea is more likely to be at risk in Pakistan. In Pakistan, maximum catches were recorded during the first fortnight of April. In south Pakistan, moths were trapped throughout the crop-growing season (Srivastava *et al.* 1991). In Nepal, the *H. armigera* moths were caught in pheromone traps from first week of January to the last week of April with the peak population from fourth week of February to the first week of March, affecting the chickpea (Sah *et al*. 1988).

Table 1 Mean catches of *H. armigera* in ICRISAT standard traps fixed at different heights above ground level in ICRISAT mandate crops, 1982–83

Crop	Crop height (m)	Moths/trap per night in traps at			SEm±
		1 m	2 m	3 m	
Sorghum	1.8	0.2	1.0	1.4	0.24
Millet	1.5	0.4	1.7	1.0	0.31
Groundnut	0.3	3.9	1.6	1.0	0.20
Pigeonpea	2.1	0.2	9.8	29.0	1.26
Chickpea	0.3	8.3	7.2	4.6	0.23

Source: Pawar *et al.* (1988)

RELATIONSHIP BETWEEN PHEROMONE TRAP CATCHES AND CORRESPONDING FIELD POPULATION

The pest monitoring is only reliable, if the relationship between the pheromone trap catches and the corresponding field population estimates are good and consistent across time. Nyambo (1989) reported that in western cotton-growing areas of Tanzania, there was one week drift between the timing of peak moth catches and the increase in egg density. The correlation between larval counts and pheromone trap catches, recorded in the same week and 1 week earlier than the timing of larval counts were significantly positive for all the years (1981–88) under study at Patancheru (Srivastava *et al.* 1992) (Table 2). Kehat *et al*. (1982) reported that peaks in pheromone trap catches of *H. armigera* were invariably followed by an increase in the numbers of egg and larvae in the field. Rothschild *et al*. (1982) reported a significant positive relationship between pheromone trap catches and egg counts of *H. armigera*. Chhabra and Kooner (1993) reported that the peak activity of the noctuid coincided with the pod formation and harvest of the legume crops. Verma and Sankhyan (1993) found that the pheromone trap catch in preceding week coincided with larval activity on different hosts in the current week. The relationship between

Table 2 Correlations between pheromone trap catches and estimated larval population of *H. armigera* at ICRISAT, Patancheru, during June 1981–May 1988

Year	Correlations between larval population and pheromone trap catches of *H. armigera*	
	In same week	1 week earlier*
1981–82	0.43	0.30
1982–83	0.60	0.53
1983–84	0.42	0.36
1984–85	0.75	0.74
1985–86	0.63	0.59
1986–87	0.73	0.73
1987–88	0.74	0.68

Source: Srivastava *et al.* (1990)

Tabulated value of *r* at 50 df at 5% = 0.273.

*Larval counts at week $_{n=0}$ and catches at week $_{n-1}$.

pheromone trap catches and egg and larval counts (early instars) of *H. armigera* have been worked out on chickpea (Srivastava and Srivastava 1995). The correlation between pheromone trap catches of week $_{n-1}$ and egg count for week $_{n=0}$ were positive and significant (r = +0.35 in 1986 and r = +0.69 in 1987). The correlation between egg counts of week $_{n-1}$ and larval counts for week $_{n=0}$ were also significant and positive, r = +0.89 and +0.94 in 1986 and 1987, respectively. Dayakar and Rao (2000) have also reported that pheromone trap catches are positively correlated with the number of eggs laid and the subsequent larval population in pigeonpea. Similarly, the relationship between pheromone trap catches and egg and larval counts of *H. armigera* have been worked out on short-duration pigeonpea (Joshi and Srivastava 2007). The correlation between pheromone trap catches of week $_{n-1}$ and egg counts for week $_{n=0}$ were positive and significant, r = +0.847 in *kharif* 2001 and +0.851 in *kharif* 2002. The correlation between egg count and larval count for same week were also highly significant and positive, r = + 0.975 and + 0.994 during *kharif* 2001 and 2002, respectively. The possibility that moonlight and the different phases of the lunar cycle (within and between months and years) might influence pheromone trap catches was investigated. However, unlike for light traps, moon luminance levels apparently have no effect on pheromone trap catches (Dent and Pawar 1988). In light trap, highest catches are recorded at the night of new moon, whereas lowest catches are recorded at the night of full moon.

DEVELOPMENT OF PREDICTION MODEL FOR FORECASTING OF *H. ARMIGERA*

The next step of monitoring is forecasting. Forecasting mainly depends on monitoring of insect pests, their emergence and occurrence over time and space, climate, geographical distribution, topography, phenological stages of the plants, natural enemies, life-tables and the cropping system. The forecasting system for the pest is mainly developed by using various mathematical models based on biotic and abiotic factors. These models may be deterministic, statistical, simulation, schematic or geographical. It is better, if such models have the input of indigenous technical knowledge of farming community to provide location-specific models for polyphagous pests which needs to be fine-tuned based on local factors before field application.

In India, the first attempt to develop a prediction model for *H. armigera* was made by National Centre for Integrated Pest Management (NCIPM), New Delhi by using 16 years (1981–96) data on pheromone trap catches recorded at ICRISAT and corresponding weather parameters. A thumb rule has been developed to predict *H. armigera* population using surplus/deficit rainfall in different months in Andhra Pradesh (Das *et al.* 2001). The thumb rule predicted the severity of pod borer attack in Andhra Pradesh during 1997–98. The surplus or deficit of monsoon rainfall (total rainfall from June to September), which is referred here as A and surplus or deficit rainfall during November, is referred here as B. A and B can be calculated as:

A = actual rainfall during four monsoon months in a year-normal rainfall during the year.

B = actual rainfall during November in a year-normal rainfall of that month.

Positive (+) values of A and B indicate surplus rainfall and negative (–) value indicate rainfall deficit. The +ve and –ve values of A and B parameters at ICRISAT, Patancheru

Table 3 The rainfall during monsoon and November, and its relationship with the level of *H. armigera* damage (ICRISAT, Patancheru)

Year	A	B	Moth catch in pheromone traps	Severity of Damage
1982	–27.3	–11.7	1505	Moderate
1983	+265.6	–22.5	301	Low
1984	–113.1	–17.1	*	Moderate
1985	–240.0	–23.5	1680	Moderate
1986	–86.4	+13.3	2570	Severe
1987	–177.3	+216.5	2409	Severe
1988	–273.9	–23.5	*	Moderate
1989	+285.5	–23.5	*	Low
1990	–91.5	–12.1	1798	Moderate
1991	+36.9	–20.5	913	Low
1992	–55.4	+53.5	2205	Severe
1993	–36.4	–23.5	1391	Moderate
1994	–73.8	–13.9	1122	Moderate
1995	+122.7	–10.5	974	Low

Source: Das *et al.* (2001)

* complete data not available

A, actual rainfall during four monsoon months in a year – normal rainfall during the year.

B, actual rainfall during November in a year – normal rainfall of that month.

and corresponding pheromone trap catches and severity of damage for 14 years (1982–95) are given in Table 3. During November, December and January, chickpea and pigeonpea are the major crop hosts of *H. armigera*. Population density (total moth catch during, November, December and January per pheromone trap) varied from 301 to 2 570. These were classified into three categories as: low = <1 000, moderate = 1 000–2 000 and high/severe = >2 000. The thumb rule for predicting the level of *H. armigera* attack can be used as follows:

A+B–Low incidence	A+B+Moderate incidence
A–B–Moderate incidence	A–B+Severe incidence

A combination of monsoon surplus and November deficit (A+B–) indicated a low population density (1983, 1989, 1991 and 1995). Both the monsoon and November deficit (A–B) indicated moderate population density (1982, 1984, 1985, 1988, 1990 and 1994), while monsoon surplus and November surplus (A+B+), which was supposed to result in moderate attack, did not occur in any year. This simple approach has been fine tuned and November rain has been included as input in B to predict the disastrous situation in crop damage (A–B+) by *H. armigera* in different districts of Andhra Pradesh devastating cotton, pigeonpea, chillies and sunflower crops during 1997–98 (Table 4). The information on November rainfall can be obtained in advance from Indian Meteorological Department (IMD) and National Centre for Medium Range Weather Forecasting (NCMRWF). After monsoon the rainfall data during that period can be used to study the level of *H. armigera* attack (low to moderate to high) in the coming winter (Das *et al*. 2001). Crop protection managers can utilize this information for application of pesticides and release of biological control agents for better management of this pest.

This thumb rule has also been validated in chickpea–pigeonpea-based ecosystem at Gulbarga, Karnataka using the data on monthly rainfall and per cent pod damage and one modification was introduced to compute B parameter. The rainfall value of October was taken in place of November. It was found that the population observed of only one year (1990) out of 10 years is deviating from the predicted population (Table 5).

Thus, it is clear from the results that a single model is insufficient to forecast for entire country. Location-specific and season-specific models are required to be developed for operational purpose. Venkataiah and Subbaratnam (1992) reported that male catches in pheromone traps at Medchal, Andhra Pradesh, had a positive correlation with maximum and minimum temperature and a negative correlation with morning and evening relative humidity. The weekly population of *Helicoverpa* male adult recorded through pheromone traps during six years from 1983 to 1988 at Indian Institute of Pulses Research (IIPR), Kanpur was analyzed with different weather parameters in collaboration with NCIPM. The build-up of moth population in long-duration

Table 4 A and B parameters, crops affected and level of damage by *H. armigera* in different districts of Andhra Pradesh

District	A	B	Level of damage	Crops affected
Warangal	–305.5	+17.1	Severe	Cotton, pigeonpea, chillies, sunflower
Khammam	–142.0	+9.2	Severe	Cotton
Karimnagar	–321.0	+29.5	Severe	Cotton, pigeonpea, chillies
Rangareddy	–213.5	+17.1	Severe	Cotton, pigeonpea
Mehboobnagar	–250.1	+18.5	Severe	Cotton, pigeonpea

Source: Das *et al.* (2001)

Table 5 A and B parameters, and percentage pod damage by *H. armigera* in different years at Gulbarga, Karnataka

Year	A	B	Predicted Damage	Percentage pod damage	Level of damage
1989	+140.9	–40.5	Low	25.8	Low
1990	+42.6	+88.8	Moderate	90.7	Severe
1991	–232.7	–63.6	Moderate	43.1	Moderate
1992	–180.5	+12.6	Severe	100	Severe
1993	–156.7	+96.0	Severe	71.8	Severe
1994	–354.7	+145.4	Severe	65.3	Severe
1995	–197.5	+70.6	Severe	80.2	Severe
1996	+9.9	+36.0	Moderate	54.6	Moderate
1997	–126.0	+23.2	Severe	99.6	Severe
1998	+266.6	+178.4	Moderate	32.5	Moderate

Source: Trivedi *et al.* (2005)
low pod damage, < 30%; moderate pod damage, 30–60%; severe damage, > 60%

Table 6 Validation of simple prediction rule for *H. armigera* in long-duration pigeonpea at Kanpur

Year	Rainfall (1–9 SW)	Base moth population (5–7 SW)	Sudden rise in min. temp. (7–8 SW)	Expected pest population in (10–14 SW)	Maximum population observed	Level of field infestation
2001–02	Yes (4–9 SW)	Low (4)	No sudden rise	Low	50 (12 SW)	Low
2002–03	Yes (4–8 SW)	Yes (28)	Yes	High	282 (13 SW)	High
2003–04	Yes (3–5 SW)	Yes (20)	No sudden rise	Moderate	122 (13 SW)	Moderate
2004–05	Yes (3–5 SW)	Yes (6)	No sudden rise	Low	18 (12 SW)	Low

Source: Vishwa Dhar *et al.* (2008); SW, Standard week

pigeonpea was predicted as sudden rise in the minimum temperature (>5°C) around 7–8 standard weeks associated with the considerable adult moth population during 5–7 standard weeks, followed by built-up of egg and larval population could result in major rise in larval population around 11–12 standard weeks. Based on the analysis of eight years data (1989–90 to 1995–96 and 2000–01) on pheromone trap catches with different parameters, a modified weather-based rule was developed as a sudden rise in the minimum temperature (>5°C) around 7–8 standard weeks and rainfall during 1–9 standard weeks along with a considerable adult moth catches (above 15/weeks) during 5–7 standard weeks, trigger a major rise in the pest population during 10–14 standard weeks. This rule was verified taking 14 years of data (1982–95 and 2000–01) on pest population which holds true in at least 10 out of 14 years (Vishwa Dhar *et al*. 2008). Further, the same rule was validated for predicting the build-up of moth population of *H. armigera* at least 4–5 weeks in advance in long-duration pigeonpea during 2001–04 at Kanpur. This confirmed its authenticity in predicting the pod borer infestation. Table 6 clearly indicates very high moth population when all the three factors agree as against the predicted high population and *vice-versa* when one or two factors agree showing low or moderate population, similar to predicted values.

Similarly, a statistical prediction model for *H. armigera* in short-duration pigeonpea for 38th and 39th std. weeks have been developed at IIPR in collaboration with Indian Agricultural Statistical Research Institute (IASRI), New Delhi. The population of *Helicoverpa* through pheromone traps for 13 years (1985–98) was analyzed with different parameters up to 5 lag week. The weather variables used were X_1=maximum temperature, X_2=minimum temperature, X_3=maximum RH and X_4=minimum RH. For each variable two indices have been developed (z), ie one as simple total of values of weather parameters in different weeks and the other one as weighted total, weight being correlation co-efficients between variable to forecast and weather variables in respective weeks. The first index represents the total amount of weather parameters with reference to its importance in different weeks in relation to the variable to forecast. On similar lines, composite indices were computed with product of weather variable (taken two at a time) for joint effect on population build-up. Based on data up to 1997–98 regression equation developed for predicting *Helicoverpa* damage in short-duration pigeonpea for 38th and 39th std. weeks are as follows.

$Y = -22.13 + 0.052Z_{12} + 0.03Z_{13}$ (R^2=0.68) for 38th std. week

$Y = -76.23 + 0.052Z_{13} - 0.0\,Z_{45} + 1.33\,Z_1$ (R^2=0.91) for 39th std. week

The observed values for pod borer infestation during 1998–99 and 2001 are found very close to the forecast value for these years showing the accuracy of the model.

Forewarning system have been developed for Punjab, depending on climatic conditions and cropping system in a particular region (Trivedi *et al.* 2005). In Punjab, the pheromone trap data recorded from 1983–90 showed two major peaks (March–April and October, Figs 2, 3) of *H. armigera* moth catches in a year. During March-April, chickpea is the main crop, while during October, cotton is grown over large areas. The peak in *H. armigera* moth populations during March-April and October can be predicted in advance by using a multiple regression model based on different weather parameters and population of *H. armigera* in the past. The results of regression analysis of *H. armigera* population and weather data during 1986–1990 indicated that *H. armigera* abundance depends on the total moth catch per trap during October-February (P_{O-F}), mean monthly relative

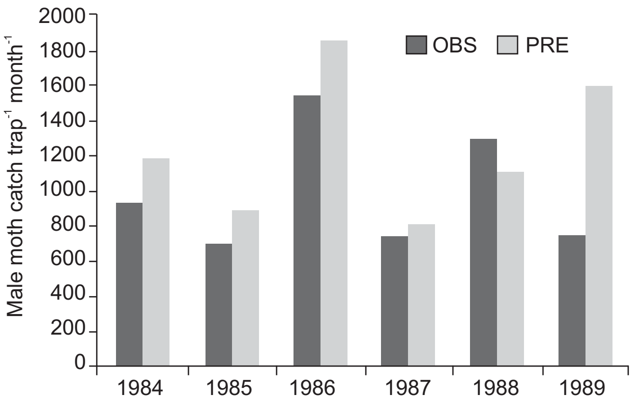

Fig 2 Observed and predicted *Helicoverpa armigera* moth population during March-April in Punjab
OBS, Observed; PRE, predicted
Source: Trivedi *et al.*2005

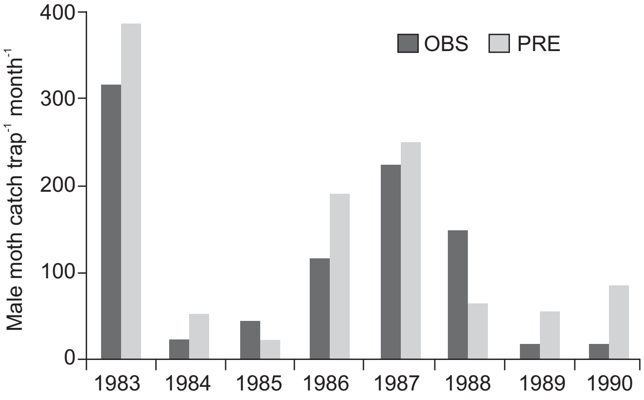

Fig 3 Observed and predicted *Helicoverpa armigera* moth population during October in Punjab
OBS, Observed; PRE, predicted
Source: Trivedi *et al.*2005

humidity in the afternoon during previous February (RHE_F) and mean monthly minimum temperature of previous February ($Tmin_F$) : ($R^2 = 0.75$).

$$P_{M-A} = -1032.65 + 2.06\ P_{O-F} - 34.26 RHE_F + 516.74 Tmin_F$$

The observed and predicted values of population density during March–April are shown in Fig 1. Apart from weather parameters, the total cumulative population from October to February is another important parameter. The insect enters diapause in October due to severe winter and emerges after February. Similarly, the population density during October (P_0) can be predicted in advance using multiple regression involving weather parameters as well as pest populations of the preceding months as follows.

$$P_0 = -5.39 +.\ 12 P_{M-A} + 1.28\ P_J - 0.51\ R_{J-J}\ (R^2 = 0.87)$$

P_{M-A}, Pest population density during March and April; P_J, pest population density during June; R_{J-J}, total amount of rainfall during June and July.

The observed and predicted values of population density during October are shown in Fig 2. A part of the population during March–April also undergoes diapause due to low winter temperature (5–10°C). The adults migrate at temperature above 40°C, and re-emerge during September–October. This low population activity continues during colder and warmer months, which influences population build-up. There is a close agreement between the two ($R^2 = 0.87$), viz Ludhiana, Punjab. March–April peak is dependent on temperature and humidity during February, while the October peak depends on the amount of rainfall during the rainy season. The pest abundance at the same location depends on different weather parameters during different seasons.

Monitoring of the adult population with the help of pheromone traps and immature stages by scouting in the field and study of life-table of insect pests in field condition is the pre-requisite for developing forecasting and forewarning models of insect pests. Presently, the IPM strategy developed and validated by the scientists of All India Co-ordinated Research Project on Pigeonpea and Chickpea at many locations in different agro-ecological zones of the country invariably include the pheromone traps @ 10–15/ha as a monitoring tool.

POSSIBLE IMPACT OF GLOBAL WARMING ON MONITORING AND FORECASTING OF *H. ARMIGERA*

The occurrence of climate changes is evident from the observations of increase in global average air and ocean temperature, widespread melting of snow and ice, and rising global mean sea level as recorded in the Fourth Assessment Report of IPCC (2001). Global warming will lead to extension of geographical range of *H. armigera* and increased risk of outbreaks, rapid population growth and more number of generations, changes in insect-host synchrony and availability of alternate hosts, changes in activity and abundance of natural enemies, changes in expression of host plant resistance, and reduced effectiveness of different biopesticides and synthetic insecticides. Very low and very high temperatures will be critical in determining the geographical distribution of *H. armigera* (Sharma 2001). Global warming will possibly shift the northern boundary of *H. armigera* by 500 to 700 km, while the southern edge of ranges may have little effect as this pest is currently distributed throughout Australia and Pacific islands, but with little chance to invade the Antarctica (Sharma 2009). The abrupt climate change during the cropping season or in the preceding period triggers the outbreak of *H. armigera.* The off-season rains during May–June in north India promote the growth of alternate hosts. It also helps in carryover and population increase during the off seasons. In Andhra Pradesh, *H. armigera* outbreaks have been recorded in years experiencing un-seasonal rains/hurricanes during November–December (Sharma 2009).

Migration in *H. armigera* has been reported in response to poor conditions for feeding, survival and reproduction (Fitt 1989). The migration of *H. armigera* in India mostly occurs along with south-easterly winds during February–April, and/or in response to cyclones during October–December in southern India (Pedgley *et al*. 1987).

Global warming may also lead to drought stress in some part of the country. This will ultimately lead to the water stress to the plants which in turn influences the plant-insect relationship. The direct as well as the indirect effect of water stress influences the level of plant resistance. The water stress changes the plants and its thermal environment in such a way that the stressed plants become more susceptible and suitable to the phytophagous insects. Venugopal *et al.* (1992) reported that among the different abiotic factors correlated with the incidence of *H. armigera* in Guntur, Andhra Pradesh, only rainfall showed negative correlation. Yadav and Lal (1988) have also reported negative correlation between larval population of *H. armigera* on chickpea (*Cicer* *arietinum* L.) and relative humidity. Similarly, Pimbert and Srivastava (1991) reported that prolonged rainfall deficits promoted the growth of *H. armigera* populations in Andhra Pradesh, India.

In India, Bt cotton has been grown on about 7.6 million ha in 2008 and on average, the conservative estimates for small farmers indicated the yield increase by 31% and insecticide application decreased by 39% mainly against *H. armigera* (James 2008). Epistatic and environmental effects on transgenic expression influence the stability, efficacy and durability of genetically modified crops (Sachs *et al*. 1996). Higher temperatures and prolonged drought lead to increased susceptibility of Bt cotton to bollworms (Sharma *et al*. 2002). This will lead to more population of *H. armigera* and may ultimately effect the forecasting of this insect pest.

Since the temperature and rainfall appeared to have pivotal role on changes in geographical range, population dynamics and migration of *H. armigera*, which will ultimately affect the monitoring and forecasting system of *H. armigera* based on the pheromone trap catches. Hence, there is a need to record regularly the population dynamics of this insect in the field as well as pheromone trap catches in respect to climate change due to global warming. The hot spots of the individual insect pest and its migration pattern needs to be worked out. Remote sensing and geographic information system can be helpful in developing forecasting system of insect pest. To achieve this goal entomologist, agricultural meteorologist, agronomist and statistician have to work as a team; only then some workable prediction models can be developed.

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