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SPATIAL AND TEMPORAL CHANGES IN THE ABUNDANCE OF *HELICOVERPA* (= *HELIOTHIS*) *ARMIGERA* (HUBNER) IN INDIA*

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Abstract—A pheromone trap network was used to study the temporal and spatial variations in the abundance of the pod borer, *Helicoverpa* (= *Heliothis*) *armigera* (Hubner) in India. The pattern of pheromone trap catches of *Helicoverpa armigera* was similar within any given agro-climatic zone but there were also obvious changes with latitude in patterns of trap catches. The catches were generally higher and had more sharply defined peaks, at northern locations than at southern locations. The catches at the eastern locations were lower than those elsewhere. The practical applications of this information for pest control are discussed.

Key Words: Pheromone trap, *Helicoverpa armigera,* agro-climatic zone

Résumé—Un réseau de pièges à phéromone a été établi pour étudier les variations spatio-temporelles dans l'abondance des populations de *Helicoverpa* (= *Heliothis*) *armigera* (Hubner) en Inde. Cet article présente une synthèse des résultats obtenus pour la période 1981–1988. L'activité de cette noctuelle nuisible est semblable au sein de chaque zone agro-climatique étudiée et varie en fonction de la latitude. Les piégeages sont plus importants, avec des pics bien définis, dans le Nord que dans les zones du Sud de l'Inde. A l'Est du pays les résultats des piégeages indiquent que les populations de *Helicoverpa armigera* sont peu abondantes dans le temps. L'intérêt de ces résultats pour les programmes de lutte contre cet insecte nuisible est mis en évidence.

Mots Cléfs: Pièges à phéromone, *Helicoverpa armigera,* zones agro-écologiques

INTRODUCTION

Helicoverpa (= *Heliothis*) *armigera* (Hubner), (Lepidoptera: Noctuidae) is an important pest of several crops in the semi-arid tropics of the Old World. It has been recorded feeding on at least 181 cultivated and wild plant species belonging to 45 families (Manjunath et al., 1989). This insect feeds on all five of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) mandate crops—sorghum, millet, groundnut, pigeonpea and chickpea (Bhatnagar et al., 1982). *H. armigera* is a major pest of pigeonpea and chickpea in India, where these pulses significantly contribute to the protein intake of the human population.

ICRISAT, in collaboration with the All India Coordinated Pulses Improvement Project (AICPIP), developed a network of pheromone traps in different agro-climatic zones of India in 1981 (Pawar et al., 1983). Almost all of the co-operators were agricultural entomologists who operated the traps on research farms attached to universities or agricultural institutes. One of the

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objectives of this network was to monitor *H. armigera* populations throughout the year at many locations in order to determine the seasonal incidence of this pest and the maximum threat periods for our target crops in each location. Information was also generated to identify crop durations and sowing dates that might help the crop's most susceptible stage avoid peak infestations of *H. armigera*.

The data obtained from 23 such locations (each having 3 or more year's data) are reported here.

MATERIALS AND METHODS

The Government of India has divided the Indian Union into 16 agro-climatic zones based on rainfall, geo-morphological features, vegetation, cropping patterns and land use (Fig. 1). Each zone can be further divided into agro-climatic sub-zones, depending upon specific agro-ecological conditions.

Co-operative work between ICRISAT and the Tropical Products Institute (TPI), London, UK (now part of the Overseas Development Natural Resources Institute, ODNRI) led to the development of pheromone traps which are very effective in attracting and trapping the male moths of *H. armigera*. ICRISAT standard pheromone traps (Pawar et al., 1984) are supplied to network collaborators across India. The synthetic pheromone used was a mixture of (Z)-11-Hexadecenal and (Z)-9-Hexadecenal in 97:3 ratio (Nesbitt et al., 1980). Until 1983, large white rubber septa with 1 mg pheromone load were used as dispensers in this network. Unfortunately, these septa were not readily obtainable so they were replaced by burette stoppers, which were readily available, smaller and relatively cheaper from 1983 onwards. These stoppers impregnated with 2 mg pheromone were found to be as effective as the large white rubber septa containing 1 mg pheromone (Pawar et al., 1988).

The data received from the co-operators were converted to $\log_{10}(x + 1)$ and mean weekly catches averaging 3–7 years were calculated. The cropping year was considered from June (when the monsoon begins) to May and mean weekly catches per trap were used for plotting graphs for different locations. The number of years for which data were available for each of the locations are indicated in Table 1.

Table 1. Study period and standard errors of the pheromone trap catches of *Helicoverpa armigera* for locations in different agro-climatic zones in India

Location	Zone No.	Period	S.E.±*		
			Min.	Max.	Mean
Solan	2	1983–1988	0.051	0.502	0.127
Pantnagar	2	1982–1988	0.038	0.342	0.167
Faizabad	2	1981–1988	0.052	0.279	0.131
Dholi	2	1981–1988	0.029	0.299	0.092
Shillong	3	1983–1986	0.018	0.294	0.103
Ludhiana	5	1983–1988	0.069	0.286	0.180
Hisar	5	1982–1988	0.061	0.309	0.174
Gwalior	5	1981–1988	0.051	0.243	0.128
Kanpur	5	1981–1988	0.053	0.268	0.134
Navgaon	6	1982–1988	0.109	0.374	0.207
Banaskantha	6	1983–1988	0.056	0.433	0.201
Anand	6	1982–1988	0.062	0.257	0.154
Jabalpur	9	1981–1988	0.047	0.317	0.158
Thane	9	1983–1988	0.047	0.232	0.114
Sambalpur	10	1983–1987	0.019	0.256	0.068
Nagpur	11	1982–1988	0.070	0.272	0.158
Akola	11	1983–1988	0.044	0.467	0.211
Badnapur	11	1981–1988	0.086	0.325	0.170
Gulbarga	11	1983–1988	0.031	0.338	0.172
Guntur	12	1982–1988	0.041	0.281	0.145
Patancheru	13	1981–1988	0.048	0.229	0.143
Paiyur	14	1983–1988	0.039	0.197	0.114
Coimbatore	14	1981–1987	0.060	0.290	0.154

*The minimum, maximum and mean standard errors show the range of standard errors of pheromone trap catches in all the 52 weeks, over the years.

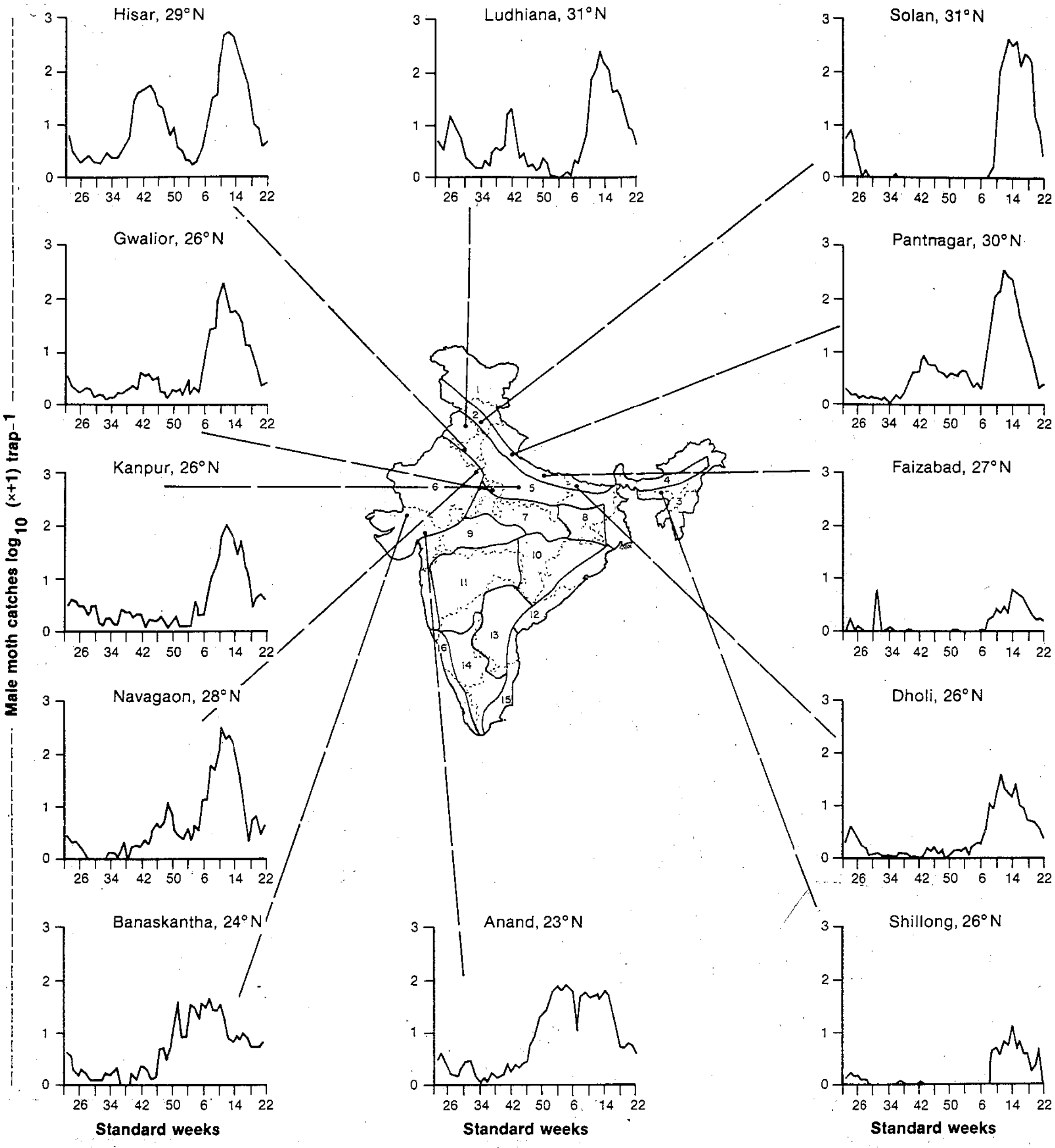

Fig. 1. Mean weekly catches [$\log_{10}(x + 1)$] per trap from standard week 23 (4 June) to week 22 (3 June) from 12 locations in the ICRISAT *Helicoverpa* pheromone network in agro-climatic zones of north and part of central India, June 1981–May 1988. 1. Humid northwestern Himalayas, 2. Himalayan foot hills, 3. Humid high rainfall northeastern zone, 4. Humid Assam Bengal plains, 5. Sub-humid and humid Satluj-Ganga alluvial zone, 6. Northwestern semi-arid and arid zone, 7. Central semi-arid vindhyan zone, 8. High rainfall, high run-off Chhotanagpur plateau and adjoining areas of West Bengal and Orissa, 9. Assured rainfall deep black soil Malwa plateau and Narmada basin, 10. Chhatisgarh plateauic zone, 11. Variable rainfall south-central deccan plateau zone, 12. Southeastern brown red soil zone, 13. Southern variable rainfall, mixed soil zone, 14. Southern bi-modal rainfall zone, 15. Eastern Coromandal coastal zone, 16. Western Malabar coastal zone.

RESULTS AND DISCUSSION

The mean weekly catches per trap for different locations across India are presented in Figs 1 and 2. It is obvious that different locations in any given agro-climatic zone were characterized by almost similar patterns of trap catches. Apparent discrepancies in flight patterns within a given agro-ecological zone can be explained in terms of the zone's subdivisions i.e. on the basis of smaller

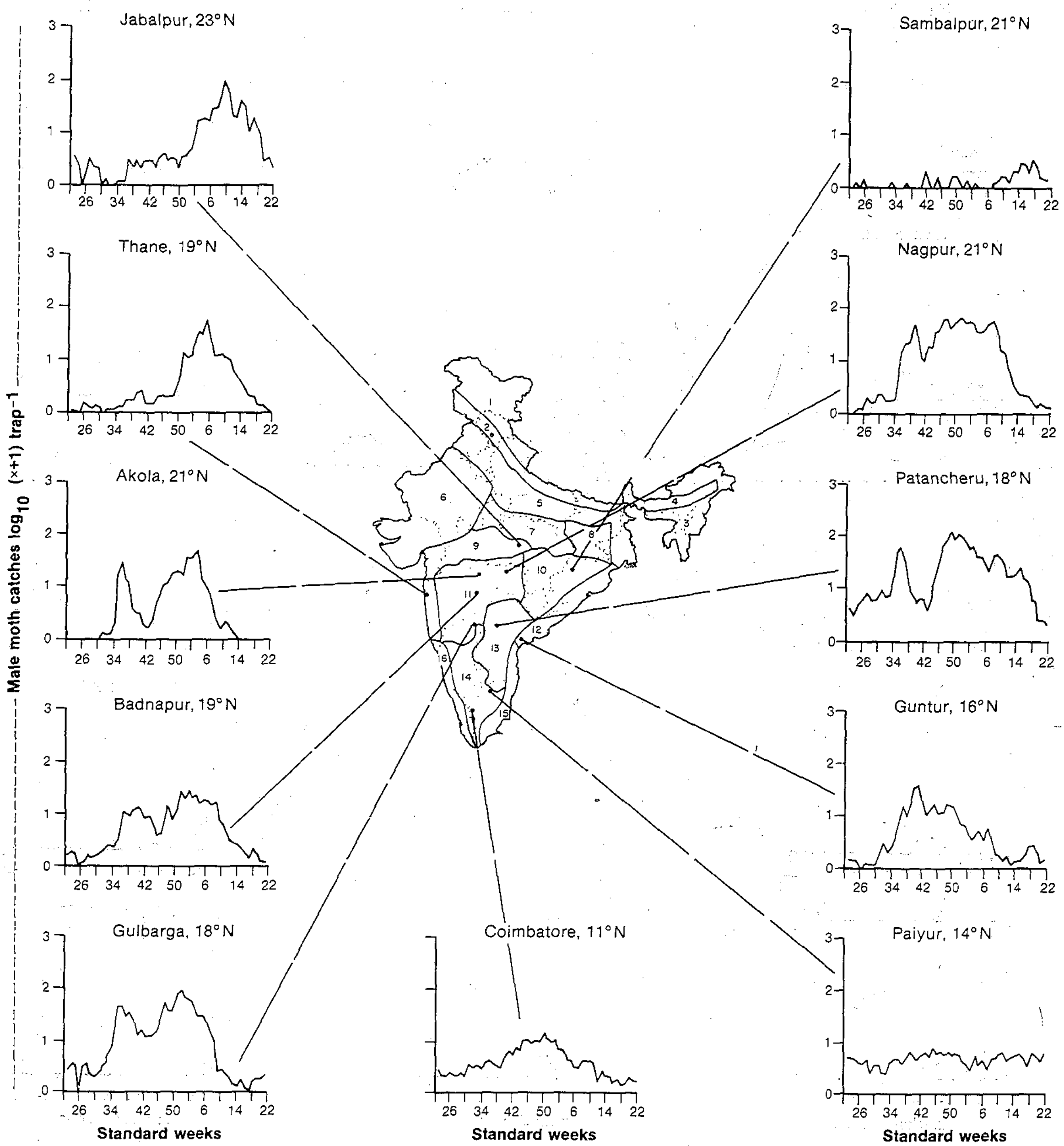

Fig. 2. Mean weekly catches [$\log_{10}(x + 1)$] per trap from standard week 23 (4 June) to week 22 (3 June) from 11 locations in the ICRISAT *Helicoverpa* pheromone network in agroclimatic zones of south and part of central India, June 1981–May 1988. 1. Humid northwestern Himalayas, 2. Himalayan foot hills, 3. Humid high rainfall northeastern zone, 4. Humid Assam Bengal plains, 5. Sub-humid and humid Satluj-Ganga alluvial zone, 6. Northwestern semi-arid and arid zone, 7. Central semi-arid vindyan zone, 8. High rainfall, high run-off Chhotanagpur plateau and adjoining areas of West Bengal and Orissa, 9. Assured rainfall deep black soil Malwa plateau and Narmada basin, 10. Chhatisgarh plateauic zone, 11. Variable rainfall south-central deccan plateau zone, 12. Southeastern brown red soil zone, 13. Southern variable rainfall, mixed soil zone, 14. Southern bi-modal rainfall zone, 15. Eastern Coromandal coastal zone, 16. Western Malabar coastal zone.

agro-ecological groupings. For example Solan and Pantnagar, which are part of the semi-arid upper region of zone 2, have almost similar patterns of trap catches, but differ from those of Faizabad and Dholi, which lie in the sub-humid central region of this Himalayan foot hill zone. The *Helicoverpa* flight patterns observed in Ludhiana and Hisar, which lie in the sub-humid upper region of zone 5 were similar, but differed from the flight patterns recorded in Kanpur and

Gwalior, which lie in the central region of the humid Satluj Ganga alluvial zone (zone 5).

The flight patterns of *H. armigera* as well as the duration and timing of peak catches at individual locations were almost similar over the years, but the magnitude of the peaks varied. Overall, the variability of the data was relatively small, as can be seen from the minimum, maximum and mean standard errors of the mean trap catches for each location (Table 1).

There were obvious changes with latitude in patterns of trap catches. In general, in the more northerly traps, peak catches occur around standard week 15 (mid-April). Local *H. armigera* populations are thought to have bred mainly on chickpeas. Catches during these peaks often averaged more than 100 moths per trap night. At some of these northerly locations, there was also a smaller peak in catches around week 43 (late October). These moths were considered to have bred on short duration pigeonpea, cotton and wild host plants. The cold winters in these northern locations limit *H. armigera* activity from November to February, as night temperatures can drop below 0°C. Temperature is known to influence the rate of development of eggs of *H. armigera* (Reed, 1965) and its larvae, with optimum temperatures for survival between 25–28°C (Jayaraj, 1982). Pupal development is also lengthened by the low temperatures that prevail during the winter months in northern locations like Hisar and Ludhiana.

Diapausing pupae of *H. armigera* attain a uniform physiological state before undergoing metamorphosis in response to the better environmental conditions that follow the cold northern winter. The emergence of moths from pupae formed over a long period, thus becomes concentrated around the time when climatic conditions become less harsh for the insects and its food plants (Sachan, 1987). This partly explains the large peak in *Helicoverpa* abundance observed shortly after the winter in the northern locations of India e.g. Hisar and Ludhiana.

In most southern locations (e.g. Coimbatore and Paiyur), the pheromone trap catches were generally lower than those recorded at northerly locations, and without well defined peaks. At these locations, night temperatures (< 10°C) during winter are not low enough to limit *Helicoverpa* activity. *Helicoverpa* populations thus tend to remain active throughout the year. However, high temperatures in summer may also affect egg, larval and pupal development and survival. The dry summer high temperatures in peninsular India are associated with low humidities. The combined effects of low humidity and high temperature on mating and oviposition may be responsible for the annual population decline observed at all locations. For example, night time relative humidities in Patancheru (zone 13) during April and May (standard weeks 14–22) fall as low as 50%. This is well below the level suggested by Roome (1975) to inhibit mating. In addition to the debilitating effects of the physical environment on the pest's survival during the summer season, the dearth of crop hosts can further limit the abundance of *H. armigera* at this time of the year.

Central zone catches show flight patterns that present features of both northern (e.g. Akola) and southern (e.g. Nagpur and Badnapur) locations (Figs 1 and 2). In general, the catches in Eastern India (e.g. Faizabad, Dholi, Shillong and Sambalpur) were lower than elsewhere. The low numbers of *H. armigera* caught in traps in these areas may be due to the relative scarcity of the pest's preferred host plants in East India (Anon, 1982, 1988).

According to Jayaraj (1982), who studied the oviposition and feeding preferences of *H. armigera*, pigeonpea is the preferred host for oviposition followed by field bean, chickpea, tomato, cotton and sorghum. The larval feeding preference in descending order is pigeonpea, field bean, cotton, sunflower, sorghum, chickpea and tomato. The distribution and abundance of *H. armigera* in each agroecological zone are obviously partly determined by the presence and relative abundance of its preferred host plants. According to the Directorate of Economics and Statistics of the Indian Ministry of Agriculture, the absolute and relative acreages of the pest's preferred crops have remained broadly similar within each agroecological zone for the entire study period, 1981–1988 (Anon, 1982, 1988). One of the important biotic factors that can influence the distribution and abundance of *H. armigera* has thus, generally remained constant within and between zones, throughout the time interval considered here. Other environmental factors are therefore probably responsible for the inter-year variations in the magnitude of the peaks in trap catches.

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 illuminance levels apparently have no effect on pheromone trap catches (Dent and Pawar, 1988). Long term trends in pheromone trap catches and egg counts on crops also show no periodicity coincident with moon phase and degree of illuminance (Reed, unpubl. data).

Climatic factors may explain the inter-year variations in maximum trap catches. Pimbert and Srivastava (Unpubl. data, 1990) postulated that there is a positive relationship between rainfall deficits and outbreaks of *H. armigera* in South India on the basis of an analysis carried out on 8 years data. The effects of rainfall shortages and drought on the pheromone trap catches of all locations are now being studied using the All India Geographic Information System on drought developed by the National Remote Sensing Agency (NRSA) in Hyderabad, India (Pimbert and NRSA, unpubl. data). This research should show if the inter-year variations in trap catches are due to the effects of erratic rainfall patterns in the semi-arid parts of India. The information obtained would provide an ecological basis for developing long term pest forecasting systems for *H. armigera*.

However, in the more immediate future the pheromone traps may be useful in forecasting increases in egg and larval numbers in crops, by monitoring adult population changes in traps. One of the most important criteria for any trap monitoring system used for short term pest forecasting is that the relationships between trap catch and a corresponding field infestation estimate must be consistent across time and space. The relationship between mean pheromone trap catches and larval populations estimated from counts on all hosts are shown for one of the southern locations in Fig. 3. The data were obtained by ICRISAT's pest surveillance team who carried out weekly counts of larvae on 50 plants per ha, covering a total area of about 500 ha. Correlations between pheromone trap catches and larval populations averaged for 1981–1988 are high and positive: +0.82 for the same week and +0.76 when catches of week (n = 1) were related with larval counts for week (n = 0). However, when data are analysed on an annual basis a more composite picture emerges. For 3 out of the 7 years for which data are available on the relationship between trap catches and larval population estimates, correlations are poor (Table 2). Good correlations were only observed during the years 1984–1985 to 1987–1988. The pheromone traps therefore provide reliable information for pest monitoring and forecasting only in 4 out of 7 years at Patancheru (zone 13).

However, the AICPIP entomologists have reported consistent positive relationships

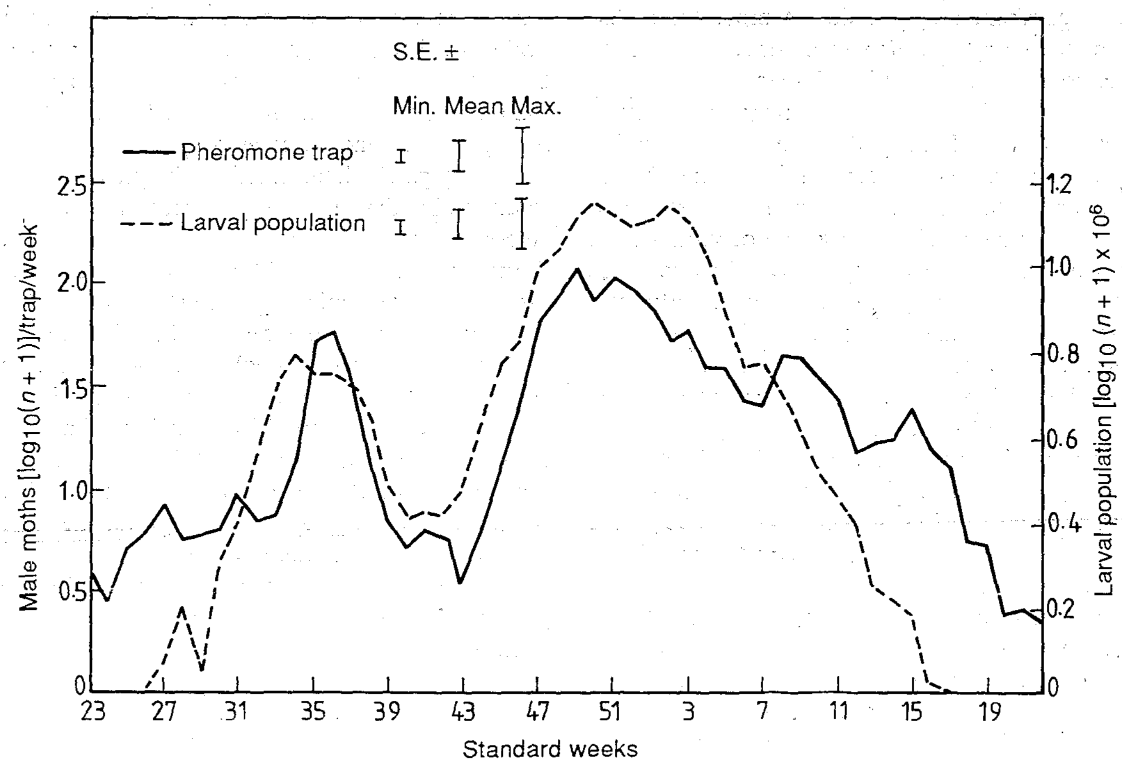

Fig. 3. Mean pheromone trap catches of *Helicoverpa armigera* and the larval populations, estimated from counts on all hosts per standard week, ICRISAT Center, Patancheru, June 1981–May 1988.

Table 2. Correlation between pheromone trap catches and larval population estimates of *Helicoverpa armigera* at ICRISAT Center, Patancheru, 1981 June to 1988 May

	Same week	Catches one week earlier (n = 0–1) and larval estimates (n = 0)
1981–1982	0.43	0.30
1982–1983	0.60	0.53
1983–1984	0.42	0.36
1984–1985	0.75	0.74
1985–1986	0.63	0.59
1986–1987	0.73	0.73
1987–1988	0.73	0.68

between pheromone trap catches and immature stages of *H. armigera* in the field at Kanpur (S. S. Lal, pers. commun). In Udaipur (Rajasthan) a good relationship was also found between pheromone trap catches and egg and early instars of *H. armigera* in chickpea fields (Srivastava and Srivastava, unpubl. data). However, for many of the locations studied here no reliable data on the relationships between trap catches and field infestation estimates for several years running are available at present.

CONCLUSION

The pheromone trap network has generated a consistent picture of the flight patterns of *H. armigera* in each agro-climatical zone of India.

The pheromone trap data generated so far can be used to help entomologists design cultural pest control for some of the localities considered here. Crop maturities and sowing dates of pigeonpea and chickpea may be manipulated to ensure that the pest sensitive stage of the pulses (flowers and pods) do not coincide with the peaks in *Helicoverpa* activity. AICPIP entomologists have begun recommending pest control strategies based on the information derived from the pheromone trap network in India. Thus, in and around Kanpur (sub-humid and humid Satluj—Ganga alluvial zone) entomologists demonstrated that farmers can reduce the risk of heavy pest damage by growing a pigeonpea variety named "Bahar". By maturing relatively early in the season "Bahar" largely escapes from the post-winter population build-up of *H. armigera* that is responsible for the heavy crop losses in that particular agroecological zone (Fig. 1; Lal and Sachan, 1987). Moreover, AICPIP entomologists now plan to extend the pheromone trap network in areas where correlations between trap catches and larval field populations are consistently high and positive over several years (R. S. Paroda, pers. commun.). Traps will thus be used to monitor the local abundance of *H. armigera* populations and provide an effective warning system for farmers.

An attempt is now being made to correlate more precisely the pest population fluctuations with the factors that are likely to influence them in each agro-ecological zone e.g. the direct and indirect effects of rainfall, migration, etc.

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