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Forecasting of Spotted Bollworm (*Earias vitella* (Fab.) (Lepidoptera: Noctuidae) Occurrence in Cotton

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Abstract.- Spotted bollworm, *Earias vitella* (Fab.) (Lepidoptera: Noctuidae) causes huge losses to cotton crop each year. As a relative hardy species among insects, *E. vitella* tolerates a wide range of environmental conditions and so is prevalent in many regions of the world. To facilitate predictions of its occurrence in the cotton crop, forecasts were using three years of data collected from pheromone traps and accumulated degree days (DD). Moth populations were observed in the second week of August, and in the first and last weeks of September. The DD model predicted that the first, second and third generations of *E. vitella* produced each year would occur at the accumulation of 2755, 3210 and 3665 Celsius DD respectively. The predicted DD of population peaks matched closely to observe DD results. These observations were consistent in successive generations with a cycle of 263 Celsius DD (predicted) on a yearly average of 241 Celsius DD (observed). The capture of 8 moths/trap/night accumulated a range of 2161-2255 DD in the second week of July (equals the minimum ETL), whereas, 11 moths/trap/night accumulated a range of 2288-2370 DD in the third week of July, accurately predicted the start of application of IPM practices to control this pest. These results enable forecasting of seasonal *E. vitella* population peaks providing additional information vital for development of a successful integrated pest management programme for the spotted bollworm.

Key words: Forecasting, degree days, *Earias vitella*, population, pheromone traps.

INTRODUCTION

Integrated pest management (IPM) is an insect pest control strategy that utilizes a variety of different methods for monitoring insect numbers to identify the optimal time for action to be taken in a bid to prevent the pest populations from increasing beyond the break even pest density. The degree days (DD) forecasting method has been successfully used in the past for forecasting several economic pests, such as *Lygus* bugs (Sevacherian *et al*., 1977), codling moth (Johnson, 1988) and the peach tree borer (Johnson, 1989). In the formulation of forecasting models, developmental data from a range of temperatures, help to determine the insect developmental threshold (Herms, 1998). Insect stages are known to have varying developmental thresholds in pink bollworm (Beasley and Adams, 1996), and corn earworm, *Heliothis zea* (Coop *et al*., 1993). Threshold and development time differ with geography, insect species and their strains. Simple linear regressions of development rate and temperature are widely used for predicting and forecasting insect development within the range of temperature typically encountered in the field (Higley *et al*., 1986). In these models, threshold temperatures and the thermal constants are useful indicators of an insect's distribution and abundance. Such studies in *E. vitella* are scarce in the literature.

The ability to predict a pest's occurrence, abundance and distribution is crucial in strategically developing a tactical pest control plan (Maelzer and Zalucki, 2000). Pheromone traps have previously been used to predict the occurrence of pink spotted bollworm, *P. scutigera* (Holdaway) (Page *et al*., 1984) and corn earworm, *Helicoverpa zea* (Boddie) (Drapek *et al*., 1997). Toscano *et al*. (1979) predicted the population cycles of pink bollworm with pheromone baited traps in Imperial valley, California by accumulating degree days.

Earias species are a group of Paleoarctic, Ethiopian, Asiatic and Australasian pests that cause extensive damage to cotton, *Gossypium hirsutum* L. The distribution of this group covers a large geographical range (Arora *et al*., 2006). Two of the most economically important pests of this group, *E. vitella* (Fab.) and *E. insulana* (Boisd), cause damage to multiple parts of the cotton plant leading to shedding of as much as 12-16 % squares, 1-1.3% flowers and 7-9% bolls (Dhawan *et al*., 1990). To control these pests, farmers rely heavily on

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insecticides whose application is often based on inaccurate pest scouting. To facilitate cotton farmers in the area of these studies, improved knowledge of when pest numbers will peak and how many DD it will need to occur is imperative. This study demonstrates efforts to generate data for forecasting models based on seasonal trap catches and accumulated degree days (ADD) in a bid to improve control measures at the given economic threshold level (ETL) and help in strengthen the current IPM strategies.

MATERIALS AND METHODS

Development threshold and accumulated degree days

Culture of spotted bollworm was maintained on cotton squares in the laboratory under controlled temperature and humidity conditions (25±2°C and 65±5% R.H.). Developmental stages were recorded in incubators, maintained at 15, 20, 25, 30 and 35ºC and set with photoperiod (14 h D: 10 h L) and relative humidity (60-65%). Forty eggs of bollworm were counted under a binocular stereo-microscope and placed in 8 oz cups containing small tender leaves, squares and flowers to feed the newly emerged larvae. Five replicates each of 40 eggs were undertaken. Cups were kept in incubators and set at the desired temperatures. Fresh food was provided daily for 4-6 days during which observations of egg hatchings were recorded. Newly hatched larvae were shifted with camel hair brush to small tender leaves, squares and flowers. Rates of development for different insect stages (Y) were plotted against temperature (X) and calculated as the reciprocal of the mean number of days required to complete development. The lower development thresholds (LDT), or base temperatures, were calculated as the intercept of the fitted lines and X-axis and as a/b from linear equations (Kim *et al*., 2001). Field temperature data were obtained from an adjacent weather station at Ayub Agriculture Research Institute (AARI), Faisalabad, Pakistan. Annual degree days for the whole years were calculated using MICROSOFT EXCEL by determining daily minimum and maximum temperatures (ºC), the base temperature for the insect and the following conditions set by Pedigo (2002).

A. If daily maximum and minimum temperatures exceed the lower threshold, but not the upper then:
   DD accumulation = [(Max+ Min)/2] – Lower Threshold
B. If daily maximum temperature exceeds lower threshold, daily minimum is less than lower threshold then:
   DD accumulation = [(Max + Lower Threshold)/2] – Lower Threshold
C. If daily maximum temperature exceeds upper threshold, daily minimum exceeds lower threshold then:
   DD accumulation = [(Upper Threshold + Min)/2] – Lower Threshold.
D. Daily maximum temperature is less then lower threshold no degree day accumulations.

The DD for each day were converted into Accumulated Degree Days (ADD) for three years, each year starting from the 1st January and ending on the 31st December.

Pheromone trap catches

Pheromone traps were installed throughout the year starting from the 1st January at three different experimental field each of 4.5 ha size, at Nuclear Institute for Agriculture and Biology, NIAB, Faisalabad, Pakistan. The purity of lures was maintained up to 98% and checked through capillary column gas chromatography, SP.2100, 60 m by 0.25 mn (Kehat *et al*., 1982). Traps were comprised of plastic containers (12 cm diameter, 20 cm height), funnels (3.5 cm diameter) and pheromone dispensers (inside centre of plastic rooftop). A small piece of plastic impregnated with dimethyl- dichlorovinyl phosphate (DDVP) was used inside the container to kill the trapped males. Pheromone dispensers and DDVP pieces were replaced every 4 to 5 weeks. Four to five traps per 4.5 ha were used and suspended 50 meters apart from each other and placed within the top 15 cm of cotton foliage. Traps were re-baited at lures after one month intervals and moths captured in each trap were counted daily.

Statistical analysis

The data were analyzed using ANOVA technique and multiple comparisons of means through Duncan's multiple new range test (Steel and Torrie, 1984). The means were converted into graphics for easy comparisons between years, population of moths, and degree days.

RESULTS AND DISCUSSION

Insect development rate and thresholds

The development of *E. vitella* from egg through larva, pupa and pre-oviposition stage had a significant and linear relationship with temperature at 15, 20, 25, 30 and 35ºC respectively (R^2 values equal 0.9829, 0.9858, 0.9908, 0.9977 at P < 0.01). Linear relationships were observed between temperature and both the rate of complete insect development and generation period (R^2 values equal 0.9909 and 0.9924 at P < 0.01). LDT for eggs, larvae, pupae and complete development were 10.8, 10.1, 9.8 and 8.8ºC, respectively (Table I). Our results partially agree to Nietschke *et al*. (2007) who reported the base threshold developmental temperature of other species from the order lepidoptera, averaged about 10.1ºC.

Table I.- Linear regression equations of mean proportional growth by temperature and lower development threshold (LDT) for different stages of spotted bollworm.

Stage	Linear Equation	R^2	LDT(°C)
Egg	Y=0.0185 X – 0.2003	0.9829	10.83
Larva	Y=0.0056 X – 0.0566	0.9858	10.11
Pupa	Y=0.0059 X – 0.0575	0.9908	9.75
Preoviposition	Y=0.0151 X – 0.1332	0.9977	8.82
Development period	Y=0.0025 X - 0.0250	0.9909	10.00
Generation period	Y=0.0021 X - 0.0212	0.9924	10.09

Accumulated degree days

Many population prediction models exist for a variety of organisms (Gabriella and Douglas, 1998) and for implementation within different geographical regions (Borchert *et al.*, 2003). These models depend partly on the accumulation of degree days starting from a certain period, method of DD calculation, regression equations, location of study, development thresholds of insects and population dynamics. Degree days were accumulated from 1st January (Regan *et al*., 1991; Chu and Henneberry, 1992) and from the 1st February (Beasley and Adams, 1996) for prediction of *P. gossypiella* and from the 1st March (Teixeira and Polavarapu, 2001) for prediction of blueberry maggot flies. In the present study, accumulation of DD for *E. vitella* was started from 1st January by using the insect's base developmental temperature of 10ºC.

Moth population

Analysis of variance for the mean number of moths captured/trap/night were highly significant (P < 0.01) between the years (F = 651.075). Results in table-II showed that during 1998 the first peak (P_1) in the moth population occurred in the 2nd week of August, the second peak (P_2) in the 1st week of September and the third peak in the last week of September. Population trends during 1999 increased abruptly in July and P_1 occurred in the 1st week of August, P_2 in the 1st week of September and the third peak (P_3) in the last week of September. The population during 2000 remained below those recorded during 1998 and 1999. Results on population of *E. vitella* (Baloch *et al*., 1990) match closely with present observations, where P_1 occurred during the first week of August, P_2 about 20 days later and P_3 in mid September.

Relationship between trap populations and degree days

The vertical lines crossing through moth population per trap over three years (Fig. 1) indicate successive generations that occurred with a lap of 455 DD. Our results match closely with Nietschke *et al*. (2007) who reviewed the average DD requirements for an insect generation in the order lepidoptera are 559.1, similar to the findings of the present study. By adding the lap (455 DD) at the first generation peak point (2755 DD), successive generations are shown to occur around at the accumulation of 3210 and 3665 DD during 1998, whereas the moth peaks happened nearly at 2761, 3150, 3508 DD. Similar trends in moth population peaks were recorded at 2755, 3269 and 3644 DD during 1999 and at 2813, 3330 and 3674 DD, respectively during 2000. The overall results (Table-III) indicate that successive peaks appear with the

Table II.- **Mean per trap population of bollworm moth and accumulated degree days (ADD) in un-sprayed cotton from July, 1 to October, 13 in different years.**

Weeks	1998		1999		2000	
	Population (per trap)	ADD	Population (per trap)	ADD	Population (per trap)	ADD
07.07	6.0 h	2142	7.5 k	2164	4.6 h	2026
14.07	8.0 gh	2218	11.8 j	2255	7.0 h	2161
21.07	10.7 g	2348	15.0 ij	2370	11.3 g	2288
28.07	16.6 f	2406	20.6 h	2506	15.9 ef	2418
04.08	25.3 e	2497	33.8 cd	2639	18.7 de	2548
11.08	34.9 c	2633	45.8 a	2755	27.8 b	2680
18.08	40.0 b	2761	41.1 b	2882	35.1 a	2813
25.08	16.8 f	2896	14.3 j	3014	14.0 fg	2943
01.09	29.9 d	3023	22.6 gh	3141	16.0 ef	3077
08.09	59.4 a	3150	35.9 c	3269	18.1 def	3211
15.09	36.3 bc	3274	23.0 gh	3394	20.9 cd	3330
22.09	18.1 f	3389	19.0 hi	3519	16.3 ef	3448
29.09	28.9 de	3508	30.9 de	3644	25.3 b	3560
06.10	26.0 de	3626	28.0 ef	3754	26.0 b	3674
13.10	27.0 de	3739	26.0 fg	3856	24.0 bc	3786

Means sharing same letters are statistically non-significant (*P < 0.05*) according to Duncan's multiple range test.

Table III.- **Comparison of observed and predicted dates of occurrence of spotted bollworm generations and their relevant accumulated degree days.**

Year	Generation	Observed		Predicted	
		Date	Degree days	Date	Degree days
1998	First	Aug 18	2761	Aug 18	2755
	Second	Sep 08	3150	Sep 11	3210
	Third	Sep 29	3508	Oct 08	3665
		SE = ± 216		SE = ± 263	
1999	First	Aug 11	2755	Aug 11	2755
	Second	Sep 08	3269	Sep 05	3210
	Third	Sep 29	3644	Sep 30	3665
			SE = ± 258		
2000	First	Aug 18	2813	Aug 15	2755
	Second	Sep 15	3330	Sep 08	3210
	Third	Oct 06	3674	Oct 05	3665
			SE = ± 250		
Yearly Average			SE = ± 241		SE = ± 263

cycle of approximately 263 Celsius DD (predicted) and on an average 241 Celsius DD (observed). These peaks indicate three generations of this insect in a cotton season. Contrary to these results, Sharma *et al*. (1985) documented eleven generations under laboratory conditions while Arora *et al*. (2006) found many overlapping generations during a year under field conditions.

Requirements of degree days for various threshold levels

For the purpose of arthropod control, knowledge of forecasting models (Maelzer and Zalucki, 2000) the economic threshold levels (Knight and Light, 2005) is essential. Qureshi and Ahmed (1989) and Naik *et al*. (1997) identify the significant economic threshold level of *E. vitella*

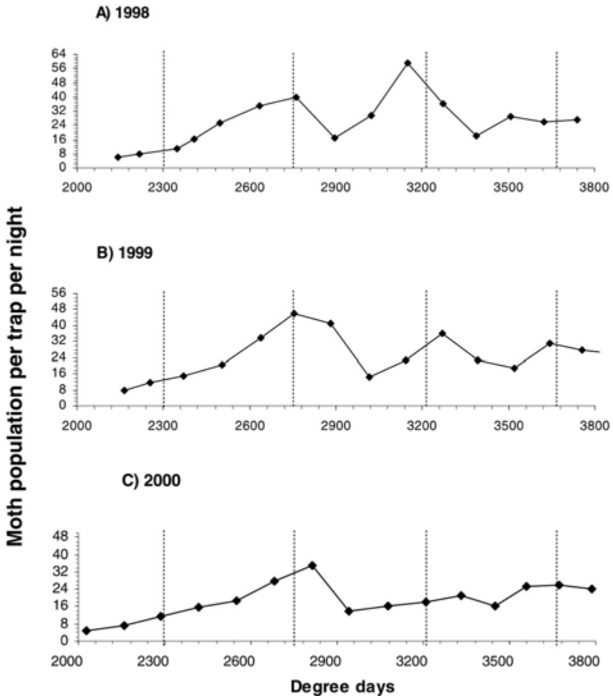

Fig. 1. Comparison of *E. vitella* moth population peaks based on degree days accumulated in years from 1998 to 2000 in unsprayed cotton.

through the use of pheromone trap catches. Our results over three years (Table II) show a correlation between trap catches and accumulated degree days. This finding agrees with Toscano *et al*. (1979) where there was positive relationship between population peaks from 1973 to 1975 and the accumulation of a certain number of DD. A mean trap catch of 9-12 moths per trap per night of spotted bollworm was associated with economic injury level infestation (Qureshi and Ahmed, 1991). In our studies the rapidly increasing trend in moth population, starting with 8 moths per trap per night on the 14th July, accurately predicted when to start the application of IPM practices.

CONCLUSIONS

The overall studies concluded that the capture of 8 moths/trap/night accumulated a range of 2161-2255 DD in the second week of July (equals the minimum ETL); whereas, 11 moths/trap/night accumulated a range of 2288-2370 DD in the third week of July, accurately predict the start of application of IPM practices to control this pest. Findings of this study introduce a durable temperature based population model for spotted bollworm, *E. vitella* by documenting fluctuations in moth population and their relevant DD. Knowledge of these variables will be helpful in devising control strategies and deciphering trends that may have application in ecological pest management.

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