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Forecasting Adult Populations of *Helicoverpa armigera* on Chickpea Using Pheromone Trap

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Abstract: Chickpea pod borer, *H. armigera* infestation forecasting models revealed that 4th March ± 6 days, 13th April ± 4 days and 7th June ± 16 days were calculated to be the predicted dates for start, peak and end of trap catch populations respectively according to Calendar date method. Similarly, by Degree-day accumulation method, 181.2 ± 39.7, 480 ± 85.5, and 1379.6 ± 319.3 degree-days were calculated as to be the predicted degree-days for start, peak and end of trap catch populations respectively. In April 1999, insect peak population was seen on 14th April (fallen in agreement within the range of the calendar date model) and accordingly the plant protection measures were adopted.

Key words: Pheromone, *Helicoverpa armigera*, forecasting, degree-day, *Cicer arietinum*

Introduction

Chickpea (gram) (*Cicer arietinum* L.)is an important grain legume crop of Pakistan normally grown rainfed in the post rainy season (Oct-Mar) on an area of about 1.1 million hectares with an annual production of 0.767 million tones (Anonymous, 1998a). Average yield of chickpea is low because of the reason that diseases and insect pests are the main yield limiting factors. By far the most economically important insect pest of chickpea is the pod borer, *Helicoverpa armigera* Huebn. Substantial yield losses due to this pest have been reported for example, in chickpea growing areas of Pakistan, up to 90% pod damage due to *H. armigera* has been recorded in unprotected chickpea fields in the irrigated and rain-fed areas (Ahmed *et al.*, 1986; Anonymous, 1998b).

Chickpea growers in Pakistan can not afford the use of expensive and hazardous chemical insecticides. Therefore, there is a need to explore less expensive, non-hazardous, environmentally suitable means of integrated pest management (IPM). Integrated pest management is an art of combining factors (sowing of pest resistant cultivars, optimum spacing, crop rotation, inter-cropping, use of pheromones, timely weeding and recommended use of appropriate biological/chemical insecticides at right time) that could result in substantial reduction in losses due to pests.

As one of the components of IPM, pheromones are the compounds used in interspecific communication to regulate the behaviour of insects e.g. to attract the opposite sex, aggregation of both the sexes, sexual stimulation and trail following. Many workers reported practical applications of pheromones such as, 1) use in trapping insects for monitoring/detecting, population suppression, disruption in mate-finding, 2) population survey for need-based use of insecticides (Silverstein, 1981; Schouest and Miller, 1994; Harris *et al.*, 1997). Pheromone traps are used to determine 1) a threshold level of trap catch population indicating the need for insecticide application, 2) the peak periods of adult populations in order to develop insect infestation prediction models (Ahmed *et al.*, 2000a, 2000b) and 3) more complex relation between trap catches, eggs and larval counts or damage estimates (Dent, 1985; Srivastava and Srivastava, 1995). Day-degree models have been used to predict the onset of insect flight activity and pheromone trap catch of Lepidoptera, although such models are more commonly used for forecasting emergence and correct timing of insecticide application (Baker *et al.*, 1982; Potter and Timmons, 1983).

Present study was conducted to determine the possibility to use pheromone trap populations to monitor and predict the population density of *H. armigera* in cognizance with the integrated pest management (IPM) of this insect pest infesting chickpea in northern Punjab.

Materials and Methods

Pheromone trap: The present population study on chickpea pod borer, *Helicoverpa armigera* through pheromone was initiated in 1983 and continued up to 1998 (16 years study) at National Agricultural Research Center (NARC), Islamabad. The pheromone trap used in this study was that of standard type (Pawar *et al.*, 1988). Synthetic sex pheromone, a mixture of (Z)-11-Hexadecenal and (Z)-9-Hexadecenal in 97:3 ratio (Nesbitt *et al.*, 1980) impregnated with 2.0 mg pheromone in a rubber septum was used. Three pheromone traps were operated in 3 different blocks of chickpea crop(each block of 2.2 hectare) at NARC, Islamabad. The trapped moths were checked, counted and removed daily. The rubber septum was replaced with new one after every 28th day.

Prediction of adult emergence (start, peak and end of trap catch) temperature dependent development and prediction on the basis of degree-day accumulation and calendar date methods: Three pheromone traps (each 100 m apart from one another) were operated from 1983 to 1998 (16 years) on chickpea crop at National Agricultural Research Center, Islamabad. In all the cases, weekly averaged data of the 3 traps catches of male *H. armigera* were analyzed for each year from 13th Feb to 26th June during the entire study period (from 1983-1998).

In case of lepidopterous insects, the degree-day models for adult are usually used to predict the start of emergence (flight activity) which is indicated by the pheromone trap catch (Bakers *et al.*, 1982; Potter and Timmons, 1983). Adult emergence prediction model can be used for timely and economical insecticidal spray operation for control of chickpea pod borer. For the calculation of degree-day, daily temperature (maximum and minimum) data obtained from the meteorological section of National Agricultural Research Center, Islamabad were used. Degree-days were calculated following the averaging method as follows:

$$\text{No. of degree-days (DD)} = \frac{A + B}{2} - C$$

Where A = Daily maximum temperature
B = Daily minimum temperature
C = The lower developmental threshold (base temperature)

The base temperature was taken to be 9.5°C(tentative) which was around the temperature calculated for other Lepidopterous insects (Bues *et al.*, 1989). The degree-days were rounded off to whole numbers with no decimal. For predicting start of emergence, December and January were taken as tentative Biofix (where no biological event occurs) for the sake of convenience. The average temperature during these months remained below 9.5°C. In case of degree-day accumulation, statistical analysis of the data recorded from 1st Dec of the preceding year to the date of 1st trap catch, peak trap catch and end of trap catch of respective year was done with the help of Microsoft Excel 97 computer programme.

Monitoring the trend of oviposition (egg laying) in relation with trap catch population in chick pea crop: Sampling for monitoring oviposition *H. armigera* were initiated in the last week of March every year (usually near the start of oviposition and hatching) from 1995 to 1998 chickpea seasons. Thrice a week, twenty five plants were randomly pulled out from the unsprayed chickpea plot. The eggs plant^{-1} were counted and recorded. The sampling was carried out up to the 4th week of May (the time when chickpea crop attained full maturity). Statistical analysis of the data was done with the help of using Microsoft Excel 97 computer programme.

Results

Prediction of *H. armigera* adult population (start, peak and end of trap catch) : The data illustrates a comparative account of calendar date and degree-day (DD) accumulation methods for predicting start of trap catch over 16 years (Table 1). The earliest trap catch was noted on 13th February 1993 and the latest 13th March (1990, 1995, 1998) and the start of trap catch for other years was in between 13th February and 13th March. The average date of 1st trap catch was calculated to be 4th March. For the sake of depicting stable inferences from 16 years of trap catch populations, it was clearly noted that the date of first trap catch (in most of the years) was noted near 4th March. The calendar date method in which the pheromone trap data was recorded covered a period of 19 weeks starting from 13th Feb. to 26th June every year. On the basis of 16 years (Table 1) the average date of 1st trap catch was calculated to be 4th March. Therefore, with the help of calendar date method, the predicted date of 1st traps catch (within 6.0 days from the average date) was noted to be 4th March.

Minimum degree-day (DD) accumulation (from 1st Dec. 1996 to 1st March 1997) was 115 with 91 temperature observation days and the maximum DD accumulation (from 1st Dec. 1989 to 13th March 1990) was 258 with 103 temperature observation days. The average DD accumulation for the 1st trap catch for 16 years (1983 to 1998) was 181.2 (base temperature 9.5^{o}C). The average degree-day (DD) was calculated to be 181.2 with standard deviation (SD=39.7) can be used to predict accurately the start of trap catch of *H. armigera* adult in chickpea field (Table 1). Relationship between DD accumulation (from 1st December to the date of 1st trap catch) and number of observation days was non-significant (Fig.1) and the regression equation obtained for the relationship was:

$$y=0.4307x + 141.38, R^2=0.0082.$$

A comparison between the calendar date and DD accumulation methods for predicting the peak trap catch is shown (Table 2). The date of peak trap catches varied from the 7th (the date of earliest trap catch) to 29th April (the date of latest trap catch) (Table 2). The average date of peak trap catch was calculated to be 13th April. On the basis of 16 years observation and record, it was noted that the calendar date method predicted the peak trap catch within 4.0 days from the average date (13th April). The degree-day (DD) accumulation (from 1st December to the date of peak trap catch) varied from 330 (1989) to 631 DD (1985). The average DD was 480. The average DD (480) with standard deviation (SD=85.5 DD) can be used to predict peak trap catch period. The regression analysis between number of temperature observation days and DD accumulation was significant (R^2= 0.2051, $P<0.05$) (Fig. 2). The average date of end of trap catches was 7th June within a range of 15.6 days (Table 3). The DD accumulation from 1st December of the preceding year to the date of end of trap catch varied from 967 (1989) to 1747 DD (1985). The average DD was noted to be 1379.6. The end of trap catch can also be predicted at 1379.6 DD accumulation with SD=319.3. Regression trend between the number of temperature observation days and DD was highly significant (R^2= 0.7902, $P<0.001$) (Fig. 3).It is evident from 16 years of trap catch population (Tables 1, 2 and 3) that *H. armigera* adults start appearing in the crop within 6.0 days (on an average basis) from 4th March, the peaks within 4.0 days (on an average basis) from 13th April and end of trap catch can be observed within 15.6 days (on an average basis) from 7th June.

Regression analysis between the number of *H. armigera* adults (on the basis of trap catch population) and the number of eggs plant^{-1} shows that the relationship between the two parameters was found highly significant in all the years (1995 to 1998) (Fig.4-7). The linear regression equations were $y=0.0272x-0.4723$ $R^2=0.6824$ at $P<0.001$ d.f.=16, $y=0.0401x-0.8011$ $R^2=0.7611$ at $P<0.001$ d.f.=21, $y=0.0441x+0.1698$ $R^2=0.5521$ at $P<0.001$ d.f.=25 and $y=0.0331x+0.5374$ $R^2=0.8168$ at $P<0.001$ d.f.=20 for 1995, 1996, 1997 and 1998, respectively.

Discussion

Prediction of *H. armigera* adult population (start, peak and end of trap catch): The earliest trap catch was noted on 13th February 1993 and the latest 13th March (Table 1). The average date of 1st trap catch was calculated to be 4th March. The calendar date method, thus, predicted 1st traps catch to be within 6 days from the average date 4th March (4th March $\pm$ 6.0 days). The author tested this prediction model in 1999 chickpea season and observed 1st capture (first trap catch) during the night between 9th and 10th March, 1999. The degree-day (DD) (181.2) with standard deviation (SD=39.7 DD) can be used to predict accurately the start of trap catch of *H. armigera* adult in chickpea field (Table 1). There was non-significant relationship between DD accumulation and number of days to 1st trap catch (Fig. 1).

Calendar date method predicted the peak trap catch within 4.0 days from the average date (13th April $\pm$ 4 days) (Table 2). The author also tested peak prediction dates of trap catches in 1999 and observed adult population peak on 14th April during 1999 chickpea season (Ahmed and Khalique, personal communication). The average degree-day (DD) was 480 (SD=85.5 DD which can be used to predict peak trap catch period. The peak trap catch period is associated with maximum egg laying period of the insect and it is the time to time application of plant protection measures before the start of severe infestation of the crop. The application of *Bacillus thuringiensis* (*Bt*) based insecticides are usually recommended 4 to 5 days before the peak trap catches (13th April) e.g., as per author's calculation, the date of *Bt* based insecticide application should be around 8th April in this case for control of chickpea pod borer (*H. armigera*) under normal environmental conditions other than severe drought. The regression analysis between number of days to peak trap catch and DD accumulation was at $p<0.05$ (Fig. 2).

Degree-day (DD) accumulation from 1st December of the preceding year to the date of end of trap catch varied from 967 DD (1989) to 1747 DD (1985) (Table 3). The average DD was noted to be 1379.6. The end of trap catch can also be predicted at 1379.6 DD accumulation with SD=319.3. Regression trend between the number of trap catches and DD was highly significant ($P<0.001$) (Fig. 3). Similar studies on the onset of flight date of European corn borer, *Ostrinia nubilalis* were conducted by Palaniswamy *et al.* (1990) who reported that the degree day (DD) accumulations for onset of flight date of European corn borer *Ostrinia nubilalis* were 312, 318, 397 and 430 DD for the years 1985 through 1988, respectively. Hoffman and Dennehy (1989) studied phenology, movement and within-field distribution of the grape berry moth, *Endopiza viteana* (Clemens) and reported that from 1976 to 1986 (11 years), the average date of first male trap catch of the moth ranged from 6th to 31st May, the average being 20th May. They further stated that the average degree day accumulation from 1st March to the first trap catch was 150.1 (base 10°C) and recommended that degree day accumulation method was more accurate for predicting peak trap catch. Coop *et al.* (1992) reported peak trap catch of corn earworm *Helicoverpa zea* between 8th June and 27th August 1989 with average degree

Table 1: Comparison of two methods for predicting the 1st trap catch of *H. armigera*

	Predicted dates and degree-day accumulation			
	Calendar date method		Degree-day method	
Year	Observed date of 1st trap catch	Average date of 1st trap catch	Number of ** days for DD calculation	Degree-day (DD) from 1st Dec of preceding year to the date of 1st trap catch
1983	7-Mar-83	4-Mar (3)*	97	130.00
1984	11-Mar-84	4-Mar (7)	102	180.00
1985	1-Mar-85	4-Mar (3)	91	210.00
1986	6-Mar-86	4-Mar (2)	96	209.00
1987	2-Mar-87	4-Mar (2)	92	218.00
1988	9-Mar-88	4-Mar (5)	77	182.00
1989	15-Feb-89	4-Mar (17)	99	121.00
1990	13-Mar-90	4-Mar (9)	103	258.00
1991	7-Mar-91	4-Mar (3)	97	154.00
1992	2-Mar-92	4-Mar (2)	93	187.00
1993	13-Feb-93	4-Mar (19)	75	164.00
1994	5-Mar-94	4-Mar (1)	95	228.00
1995	13-Mar-95	4-Mar (9)	106	180.00
1996	6-Mar-96	4-Mar(2)	97	202.00
1997	1-Mar-97	4-Mar (3)	91	115.00
1998	13-Mar-98	4-Mar (9)	103	161.00
Average	4th March	4-Mar (6.0)		181.2
SD	± 8.2 days			39.7

* Figures in parentheses are the values obtained due to difference between the average date of 1st trap catch (4th March) and the actual date of 1st trap catch.

Table 2: Comparison of two methods for predicting peak trap catch of *H. armigera* predicted dates and degree-day accumulation

	Predicted dates and degree-day accumulation			
	Calendar date method		Degree-day method	
Year	Observed date of 1st trap catch	Average date of 1st trap catch	Number of ** days for DD calculation	Degree-day (DD) from 1st Dec of preceding year to the date of 1st trap catch
1983	10-Apr-83	13-Apr (3)*	131	341.00
1984	13-Apr-84	13-Apr (0)	135	520.00
1985	13-Apr-85	13-Apr (0)	134	631.00
1986	9-Apr-86	13-Apr (4)	130	419.00
1987	8-Apr-87	13-Apr (5)	129	500.00
1988	11-Apr-88	13-Apr (2)	128	491.00
1989	6-Apr-89	13-Apr (7)	132	330.00
1990	29-Apr-90	13-Apr (16)	141	555.00
1991	7-Apr-91	13-Apr (6)	128	402.00
1992	15-Apr-92	13-Apr (2)	137	502.00
1993	21-Apr-93	13-Apr (8)	142	586.00
1994	10-Apr-94	13-Apr (3)	131	552.00
1995	16-Apr-95	13-Apr (3)	137	439.00
1996	13-Apr-96	13-Apr (0)	135	532.00
1997	12-Apr-97	13-Apr (1)	133	401.00
1998	17-Apr-98	13-Apr (4)	138	479.00
Average	13-Apr	13-Apr (4.0)		480.00
SD	± 5.8 days			85.5

* Figures in brackets are the values obtained due to difference between the average date of 1st trap catch (13th April) and the actual date of 1st trap catch.

** Figures are the number of days counted from the 1st Dec of the preceding year to the date of 1st trap catch of respective year.

day was 469 using a lower threshold of 12.6 °C these studies corresponded with our findings.

H. armigera adults start appearing in the crop within 6.0 days from 4th March (4th March ± 6 days), the peak trap catch population can be observed within 4.0 days from 13th April (13th April ± 4 days) and end of trap catch within 15.6 days from 7th June (Table 1, 2 and 3). Degree-day accumulation results can be used to predict the adult population of *H. armigera* in chickpea field under Islamabad climatic conditions.

One of the main criteria for any monitoring system used for forecasting trap captures, eggs and larval population should have consistency between the trap catch and corresponding infestation estimate. Eighteen years of working experience of the authors on chickpea indicated that there was observed a clear relationship between the chickpea phenology and pest behaviour showing that this insect appeared to have an instinctive behavioural association with the developmental stages of chickpea crop.

Highly significant linear regression and coefficient of determination $R^2=0.6825$ at $P<0.001$ d.f.=16, $R^2=0.7611$ at $P<0.001$ d.f.=21, $R^2=0.5521$ at $P<0.001$ d.f.=25 and $R^2=0.8168$ at $P<0.001$ d.f.=20 for, 1995, 1996, 1997 and 1998, respectively were observed between *H. armigera* trap catch population and number of eggs plant^{-1}) (Fig. 4-7). These results correspond to the statement of Latheef *et al.* (1991) who reported a weak, but linear relationship between the number of corn earworm (*Helicoverpa zea*) eggs and trap catches when corn was at the whorl stage of growth. Izquierdo (1996) observed positive correlation between egg densities and trap catches of *H. armigera* on tomato and carnation crops.

Table 3: Comparison of two methods for predicting end of trap of *H. armigera*

	Predicted dates and degree-day accumulation			
	Calendar date method		Degree-day method	
Year	Observed date of 1st trap catch	Average date of 1st trap catch	Number of ** days for DD calculation	Degree-day (DD) from 1st Dec of preceding year to the date of 1st trap catch
1983	30-Jun-83	7-Jun (23)*	212	1495.00
1984	18-May-84	7-Jun (20)	170	1099.00
1985	15-Jun-85	7-Jun (8)	197	1747.00
1986	29-Jun-86	7-Jun (22)	211	1723.00
1987	26-Jun-87	7-Jun (19)	208	1721.00
1988	26-May-88	7-Jun (13)	207	1960.00
1989	24-Jun-89	7-Jun (17)	177	967.00
1990	19-May-90	7-Jun (29)	170	1053.00
1991	16-Jun-91	7-Jun (9)	198	1451.00
1992	21-May-92	7-Jun (14)	173	1007.00
1993	23-May-93	7-Jun (16)	174	1164.00
1994	11-May-94	7-Jun (27)	162	984.00
1995	13-Jun-95	7-Jun (6)	195	1424.00
1996	17-Jun-96	7-Jun (10)	200	1626.00
1997	8-Jun-97	7-Jun (1)	190	1187.00
1998	12-Jun-98	7-Jun (5)	194	1465.00
Average	7-Jun	07-Jun (15.6)		1379.6
SD	±16.6			319.3

* Figures in brackets are the values obtained due to difference between the average date of 1st trap catch (7th June) and the actual date of 1st trap catch.

** Figures are the number of days counted from the 1st Dec of the preceding year to the date of 1st trap catch of respective year.

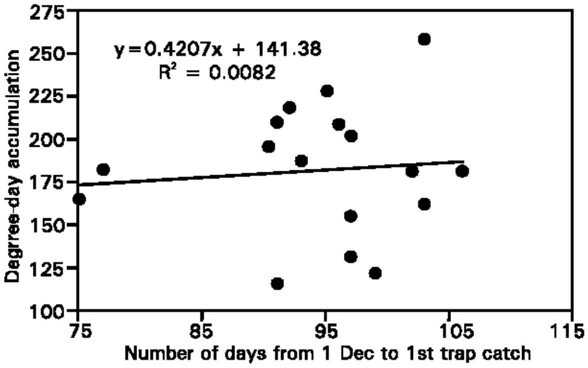

Fig. 1: Trend of degree-day vs no. of days to 1st trap catch

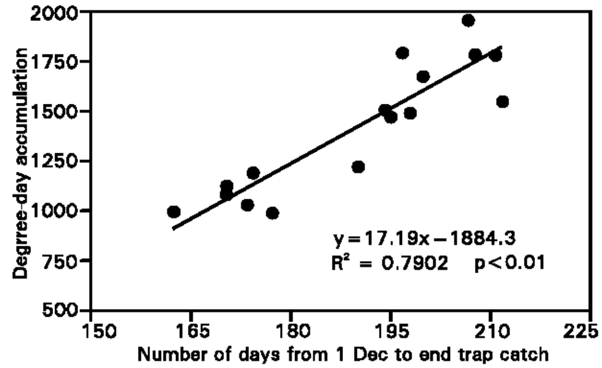

Fig. 3: Trend of degree-day vs no. of days to the end of trap catch

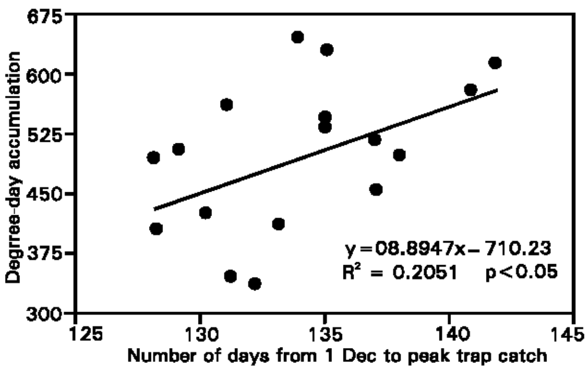

Fig. 2: Trend of degree-day vs no. of days to peak trap catch

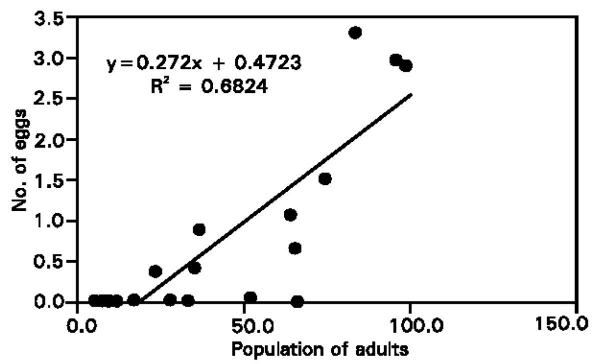

Fig. 4: Relationship between no. of eggs & trap catch population (1995)

Palaniswamy *et al.* (1990) reported that there was no observed correlation between egg mass densities and pheromone trap catch of European corn borer, *Ostrinia nubilalis* (Huebn.) and this observation of Palaniswamy did not correspond with our findings. Srivastava and Srivastava (1995) monitored *H. armigera* by pheromone trap in chickpea and stated that trap catches of the moth were invariably followed by the peaks in egg and larval counts in 1986 and 1987, they also reported positive correlation (r=0.35 in 1986 and r=0.69 in 1987) between moth catches and egg counts. The author also observed a significant positive correlation between trap catches and eggs (r=0.83, r=0.87, r=0.75 and r=0.90 in 1995, 1996, 1997 and 1998, respectively

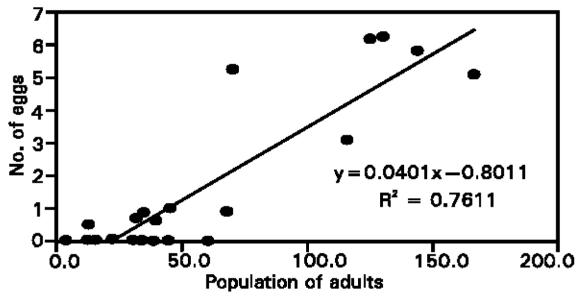

Fig. 5: Relationship between no. of eggs & trap catch population (1996)

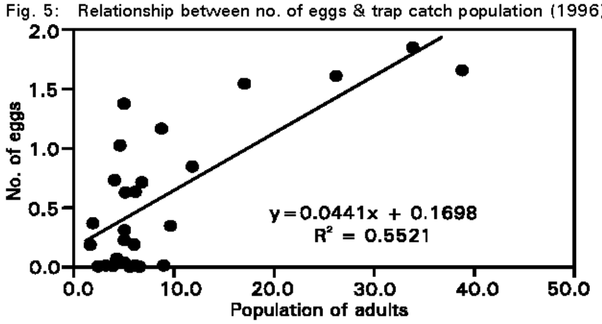

Fig. 6: Relationship between no. of eggs & trap catch population (1997)

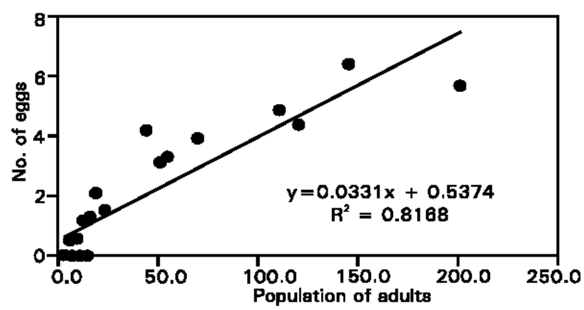

Fig. 7: Relationship between no. of eggs & trap catch population (1998)

and thus agreed with the finding of Srivastava and Srivastava(1995). Thorpe *et al.* (1993) reported a similar observation stating a significant relationship between trap catch and egg mass density of gypsy moth, *Lymantrai dispar* and observed significant slopes with R^2 values of 0.60 and 0.65 for the low and high lure traps, respectively.

Chickpea pod borer, *H. armigera* infestation predicting models were developed (using Calendar date and Degree-day accumulation methods), 4th March ± 6 days, 13th April ± 4 days and 7th June ± 16 days were calculated to be the predicted dates for start, peak and end of trap catch, respectively. Similarly, 181.2 ± 39.7 degree-day, 480.0 ± 85.5 degree-day and 1379.6 ± 319.3 degree-day were also calculated to be the predicted degree-days for start, peak and end of trap catch respectively. During 1999, chickpea season, these models were tested and accordingly the start, peak and end of trap catches were recorded on 9th March, 14th April and 2nd May (within the range of the calendar date model) and accordingly the plant protection measures were adopted and successful plant protection was obtained.

Relationship between trap catch population and no. of eggs laid on chickpea crop revealed that the most critical period during which insect could cause severe damage to the crop was calculated to be from 7th April to 23rd April (at full podding stage of the crop) on the basis of 4 years observations from 1995-1998. Hence, during this period plant protection measures were adopted. Significant regressions were also obtained between *H. armigera* adults populations and the number of eggs $plant^{-1}$.

Pheromone trap based calendar date and degree-day models have been used to predict the onset of insect flight activity and pheromone trap catch of lepidoptera, although such models are more commonly used for forecasting emergence and correct timing of insecticide application. With the help of this study, infestation of chickpea pod borer can be managed by minimum number of insecticidal sprays starting from 13th April (the average peak trap catch) being the right time and right stage of the insect to be targeted.

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