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Degree-Day Forecasting Method: A Tool for Increasing the Precision of Chemical Control for Managing Peach Flat-Headed Borer, *Sphenoptera dadkhani* (Oben.) (Coleoptera: Buprestidae)

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Abstract.- Studies were conducted to develop an IPM plan for the control of peach flat-headed borer using degree-day forecasting to predict the adult emergence time of the borer and thus determine the proper time for initiating the chemical control measures. Adult emergence in the observed years started in the first week of April with a degree-day (DD) accumulation of 567-573 and continued upto the first week of May. Cumulative degree-day (CDD) summations to first emergence in the second generation ranged from 2355-2374 and lasted till the second week of August. Third generation emergence was observed when 4545-4580 DD were accumulated. A difference of 5-15 days in the start of emergence for all the three generations was observed. Similarly, for peak emergence, a difference of more than one month was observed during the study years. CDD calculations, on the other hand could be translated into a difference of 1-3 calendar days. Thus DD can be used as an accurate predictor for initiating the control measures that can lead to precise control of the pest. Trials conducted to evaluate the efficacy of different insecticides indicated that all the tested insecticides significantly controlled the adult population. A single spray of Confidor or Ematac at the time of first adult emergence (when 570 DD were accumulated) was very effective and reduced the adult population by more than 85%.

Keywords: Peach flat-headed borer, *Sphenoptera dadkhani*; degree days forecasting method, chemical control.

INTRODUCTION

Prunus spp. fruits *i.e.*, peach, plum and apricot are the most important deciduous fruits grown in Peshawar region for domestic consumption as well as for export. The production of peaches and plum in Peshawar valley is severely hampered by Peach flat-headed borer (PFB), *Sphenoptera dadkhani* (Oben.) and there are increasing complaints from the orchard growers regarding the devastation of their orchards due to this pest. Little work is available on this pest in Peshawar region but some studies conducted in the past have clearly documented that severe infestation of this pest has been a leading cause of mortality of Prunus trees in this region (Chughtai *et al*., 1984). Raqib (2003) reported that maximum levels of gummosis damage by this borer was recorded in plum (70.4%) followed by peach (53.3%) and apricot (42.5%) in Peshawar. Survey revealed that more than 82% of the plum and peach orchards were found infested with PFB (Zahid, 2014). Females of PFB lay eggs on rough surfaces and crevices of trunk and old branches (Chughtai *et al*., 1984). The larvae bore into the bark and make shallow and irregular galleries. They feed on the cambium and can completely girdle and kill young or newly grafted trees in a short period of time. Several interconnected galleries loosen the bark and block the flow of sap, causing death of the limb. Badly riddled bark breaks loose, exposing the wood and, in a case of severe infestation, the branches and even entire trees die. The attack is evident from the oval exit holes made by the adults. The adults after emergence feed on leaves of the host. During the initial stages of attack, fruit-setting is negatively affected, and in the advanced stages, fruit-setting ceases and the trees often die (Chaudhary *et al*., 1993; Lakra *et al*., 1980). Use of synthetic chemicals can be an effective method to control PFB but the time of insecticide application is very

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crucial. Successful control can be achieved only if the chemicals are applied before the start of oviposition. This is the most vulnerable stage in the biology of the pest when the adults are exposed on the plant surface feeding on the foliage and moving on the bark to find oviposition sites. Chemical application at this stage can lead to direct mortality of the adults. Visually, it is very difficult to observe the emergence of adult beetles due to their smaller size and inconspicuous activity. Another option is to use calendar dates for scheduling the onset of control measures which may coincide with adult emergence time but this may not be accurate depending on the temperature fluctuations within years. Like other poikilotherms, development of PFB is dependent on the ambient temperature, thus completion of pupation period and emergence of adults is likely to vary with the outside temperatures. Physiological time or degree days (DD) can effectively be used to predict developmental stages of an insect pest. DDs are being used as a basic component of many insect pest management programs (Kowalsick and Clark, 2006; Riedl *et al*., 1976; Wilson and Barnett, 1983). Degree day is an accumulation of heat units above a threshold for a 24 h period. These DDs are cumulated over time starting from a fixed calendar time or a biofix. Commonly used methods for calculation of DDs include average method, Single Sine wave method and double Sine wave methods. Information on relationship of adult emergence pattern with physiological time is lacking about this pest in our region. The current studies were therefore undertaken to develop a DD model for forecasting the adult emergence time for *Sphenoptera dadkhani* (Oben.) and test the efficacy of insecticides for the control of this pest.

MATERIALS AND METHODS

Development of degree day model for predicting the emergence of S. dadkhani *(Oben.)*

DD studies were undertaken in borer infested plum orchard at the experimental farm of NIFA, Peshawar during 2008, 2009 and 2012. Ten heavily infested plum trees of uniform age (15 years old) were selected randomly. Each tree served as an experimental unit. One main scaffold branch of each tree was wrapped with a transparent polythene sheet (1m length) for trapping and counting the adults. Weather-worn sheets were replaced as needed. Normal agronomic practices were carried out in the orchard. Adult emergence was recorded on weekly basis in the passive season and daily as the first emergence was observed in the active season. Daily DD summations were calculated from first January using the spread sheet developed by Snyder (2005) based on the calculations of Zalom *et al*. (1983). Single-sine method, which measures the area under a sine curve with amplitude specified by each pair of daily maximum and minimum temperatures, was used to determine the cumulative degree days (CDD). Daily maximum and minimum air temperatures were obtained from the weather station at Agricultural Research Institute, Tarnab, Peshawar (situated within 1km of the experimental site). DD accumulation was started from January 1 and was matched with the actual field observation of adult emergence. Since the data on developmental threshold temperature (base temperature) is not available for this pest, the method of Arnold (1959) was used, in which DD to first emergence are computed for a number of base temperatures (0, 2, 4, 6, 7, 8 and 10°C) for different years. The base temperature showing the least coefficient of variation between years was considered as the most suitable base temperature.

Table I.- List of synthetic insecticides tested for the control of *S. dadkhani* (Oben.)

Trade name	Chemical name	Dose/10 L	Active ingredient (g/l)
Fyfenon 57EC	Malathion	50 ml	570
Ematac 1.9EC	Emamectin benzoate	30 ml	19
Curacron 500EC	Profenofos	50 ml	500
Regent 5%SC	Fipronil	50 ml	50
Lorsban 40EC	Chlorpyrifos	50 ml	400
Confidor 20%SL	Imidacloprid	30 ml	200
Thiodan 35EC	Endosulfan	50 ml	352
Control	(no treatment)	----	----

Field efficacy of different synthetic insecticides against S. dadkhani *(Oben.)*

Seven insecticides (Table I), when applied against the first generation of PFB, were tested for their efficacy. Sixty four plum trees of uniform age (7-8 years old) were selected at the experimental

Table II.- Coefficient of variation of several base temperatures evaluated for Use in degree day model.

	1st Generation						
Dates	**0ºC**	**2ºC**	**4ºC**	**6ºC**	**7ºC**	**8ºC**	**10ºC**
03.04.2012	1239.9	1054.4	882.6	719.9	643.1	573.9	446.27
02.04.2008	1180.9	1008.6	844.6	699.4	631.4	567.6	437.05
07.04.2009	1322.0	1127.7	926.5	741.4	651.8	573.9	443.94
C.V.	0.06	0.06	0.05	0.03	0.02	0.006	0.011

farm of NIFA, Peshawar. Each tree served as an experimental unit. The experiment was laid out as CR factorial with eight treatments (seven insecticides and an untreated control) each at two levels (single or two sprays) and replicated four times. The first spray was applied when 570 degree days were accumulated since January 1st. The spray was done on the whole trees using a shoulder mounted PIR spray pump. The second insecticidal spray was done in the same manner two weeks after the first application. All the gummosis present on the stem and main branches was removed before chemical application. Before spray, the trees were checked for already present exit holes upto to a height of 2 m from ground level (as maximum damage is confined to a height of 2 m from ground level), which were then marked with a colored pen. In order to standardize the borer damage, number of exit holes was recorded as holes/m^2. Effect of insecticides on borer damage and thus emergence of subsequent generation was evaluated by recording freshly made exit holes when the second generation adults had completed emergence. The data on exit holes was transformed using a log transformation and subjected to ANOVA for testing the significance of insecticides, application frequency and their interaction.

RESULTS

DD model for predicting the emergence of adult S. dadkhani *(Oben.)*

Emergence time of the first generation of adults and associated DD summations at 7 potential base temperatures are listed in Table II. As is evident from the table, the base temperature of 8°C (46.4°F) yielded the lowest average coefficient of variation in DDs, and was therefore considered as the appropriate base temperature for use in degree day calculations. Population dynamic studies of the adult *S. dadkhani* (Fig.1) showed that the adult emergence began during the first week of April and lasted till the first week of May in different years. Total number of adults emerged per tree (each trap represents a tree) across all the three generations were lowest during 2012 (10.3 ± 8) as compared with those emerged during 2008 or 2009 (13.1±3.4 and 12.1±4.1, respectively). Averaged across the years, total number of adults emerged per tree were highest in the first generation (17.9±6.0) and lowest in the third generation (8.6±6). Maximum number of adults trapped on a single day was 4.9±1.05 and this peak emergence was observed within 3-4 days of first adult emergence.

Adult emergence in the observed years started in first week of April with a DD accumulation of 567-573 (Table III). Adult emergence peaks were observed within 3-5 days of the first emergence (DD ranging from 598-606). Emergence of adults continued until the last week of April during 2008 and 2012 and first week of May in 2009 corresponding to a DD accumulation of 868-938. Total number of adults observed per tree were 15.4, 14.3 and 24.6 (n=10) in 2008, 2009 and 2012, respectively.

The second generation adults started emergence in the first or second week of July with a considerable variation in emergence dates between years. CDD summations to first emergence ranged from 2355-2374. Adult emergence peaked in the 3rd week of July (CDD: 2519-2535) in the years 2008 and 2009. Maximum emergence in 2012 was observed in the 2nd week of July on a DD accumulation of 2508. Last emergence in 2nd generation was noted in first week of August (CDD: 2903), second week of August (CDD: 2958) and last

Table III.- Emergence Pattern of adult Peach flat-headed borer, *Sphenoptera dadkhani* (Oben.) and associated accumulated degree days.

Years		1st Generation emergence Start	Peak	Last	2nd Generation emergence Start	Peak	Last	3rd Generation emergence Start	Peak	Last
2008	Dates	2-Apr	5-Apr	26-Apr	9-Jul	16-Jul	3-Aug	2-Nov	8-Nov	16-Nov
	CDD	567	598	868	2374	2519	2903	4580	4645	4730
2009	Dates	7-Apr	11-Apr	5-May	14-Jul	21-Jul	9-Aug	7-Nov	16-Nov	26-Nov
	CDD	573	606	938	2366	2534	2957	4570	4639	4701
2012	Dates	3-Apr	6-Apr	29-Apr	2-Jul	9-Jul	27-Jul	17-Oct	22-Oct	2-Nov
	CDD	573	603	928	2355	2508	2899	4545	4614	4747

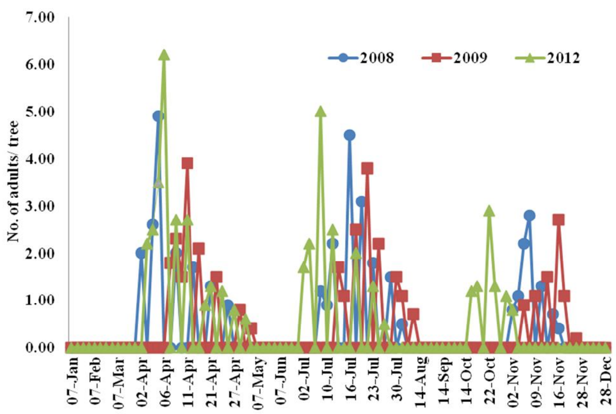

Fig. 1. Population dynamics of *Sphenoptera dadkhani* (Oben.) in three different years.

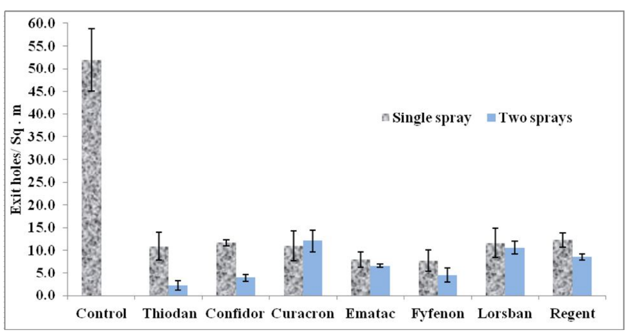

Fig. 2. Impact of insecticidal application in reducing the damage caused by *S. dadkhani* (Oben.)

week of July (CDD: 2899) with a total of 15.7, 14.6 and 15.2 adults per tree in 2008, 2009 and 2012, respectively.

Adults in the third generation started emerging out from the infested trees when 4545-4580 degree days had been accumulated during the third week of October to the first week of November in the three different years. Peaks of adult emergence were observed on 8th November (2008), 16th November (2009) and whereas on 22nd October in 2012 corresponding to DD summations of 4614-4645. The adult emergence continued till 3rd or 4th week of November (CDD: 4730 and 4701) with a total of 93 and 75 adults in the years 2008 and 2009, respectively. In 2012, last emergence was recorded on 2nd November (CDD: 4747) with a total of 86 adults per tree.

Field efficacy of different synthetic insecticides against S. dadkhani *(Oben.)*

A significant effect of insecticides ($F_{7, 48} = 67$, $p < 0.0001$) in reducing the population of adult PFB as indicated by the appearance of new exit holes was observed. All the insecticides tested in this study were able to exert a significant reduction in the adult population as compared with untreated control (Fig. 2). Two sprays were more effective in reducing the borer population when averaged across the insecticides ($F_{1, 48} = 7.8$, $p<0.007$). The interaction of insecticide*application frequency was not significant ($p>0.05$).

In case of Curacron, Fyfenon, Lorsban and Regent, two sprays led to a greater reduction in the borer damage as compared with one spray. However, a significant difference in borer damage between one or two sprays for Thiodan, Ematac and Confidor was not recorded. Even a single spray of these chemical was able to reduce the damage by more than 85%.

DISCUSSION

The study indicates that the adults of PFB may start emerging in the first week of April, first week of July and third week of October depending on the ambient temperature. Three adult emergence times with distinct peaks in each year clearly demonstrates that the insect has three generations in a year. An overlap in adult emergence periods was not found in all the three generations which were well separated temporally. Chughtai *et al*. (1984) also recorded three generations of the pest in Peshawar valley during April-June, July-Oct and November to April next. They found that in the beginning of March larvae resume feeding, transform into pupae and over-wintering generation adults emerge out about the first week of April. Maximum adult population was observed in the first generation while the minimum adults were recorded in third generation. There was an obvious year to year variation for the adult emergence pattern. Although the emergence pattern showed variation based on calendar dates, there was a lesser variation if CDD are considered. A difference of 5-15 days in the start of emergence was found for all the three generations. Similarly, for peak emergence, a difference of more than one month was observed within the study years. CDD calculations, on the other hand can be translated into a difference of 1-3 calendar days. Thus instead of using calendar dates, CDD can accurately be used for predicting the emergence pattern of *S. dadkhani* (Oben.).

The control of *S. dadkhani* (Oben.) is difficult because most of its life cycle is spent concealed beneath the bark of host tree and it is found outside the bark only in its adult stage. The adults after emergence feed on fresh leaves of the host tree and start egg laying within 3-4 days of emergence. Thus, the adult stage is exposed and is a weak link in the pest biology. Control tactics targeted at the adults of PFB may provide a good control of this notorious beetle before it starts egg laying. But it is necessary that the control measures must coincide with the time when the adults are present on the plant surface. Spray schedules based on calendar dates cannot provide accurate information for chemical applications because of the variations in the environmental conditions, especially temperature. In this case, a forecasting model based on DD calculations is a good solution. Thus beginning the control measures when 570 DD have been accumulated can ensure that the first generation adults will be targeted.

Studies conducted to evaluate the efficacy of different insecticides showed that if spray time is carefully selected, all the tested chemicals can give a good control of the pest. Repeating the insecticide application after two weeks lead to a better control in some of the insecticides. This was particularly true for the organophosphate (OP) insecticides used in the current study indicating a residual effect of the poison until two weeks after application. Since emergence period of the borer adults is spread over a period of 4-5 weeks, a second spray ensures a continuous insecticidal cover during the time, borer adults are expected to be around.

However, even a single spray worked as good as two sprays in case of Thiodan, Ematac and Confidor. Thiodan, being a chlorinated hydrocarbon insecticide, is persistent therefore even a single spray provided enough residual cover. Confidor is a systemic insecticide which is absorbed by the plant tissues and can be effective for a longer period of time. Emamectin benzoate has been shown to be translocated within the wood when injected into the tree and has been found to persist for months (Takai *et al*., 2004). All the chemicals were sprayed after physical removal of gummosis present and thus exposing the already present exit holes to penetration by the insecticides. This penetration followed by the translocation of the insecticide within the tree may be responsible for avoiding future damage even when a single spray was used. Since the use of organochloride has environmental concern, a single spray of Emamectin benzoate or Confidor; or two sprays of OP insecticides at the time of emergence of first generation adults as predicted by the forecasting model are recommended. The insecticidal treatment against the second generation adults has not been recommended but doing so may eliminate any pest population having survived from the first generation.

CONCLUSION

Emergence of *S. dadkhani* (Oben.) adults coincided with degree accumulation of 567-574, 2355-2374 and 4545-4580 for the first, second and third generations respectively. Degree day can be used as an accurate predictor for initiating the control measures as compared with using calendar schedule for PFB. Thus, if chemical control program is started following degree day forecasting method, there are better chances of finding exposed adults which can lead to a better control of the PFB. A single spray of Confidor or Ematac if applied when 570 DD have been accumulated (emergence time of first generation adults) can successfully control the damage caused by this pest.

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REFERENCES

ARNOLD, C.Y., 1959. The determination and significance of the base temperature in a linear heat unit system. *Proc. Am. Soc. Hortic. Sci*., **74**: 430-445.

CHAUDHARY, O.P., RATAUL, H.S. AND SANDHU, G.S., 1993. Management of flat-headed borer, *Sphenoptera dadkhani* (Oben.) on peach in India. *Int. J. Pest Manage*., **39**: 75-79.

CHUGHTAI, G.H., KHAN, B. AND KHAN, M.R., 1984. Biology and control of peach flat headed borer in Peshawar region, NWFP. *Front. J. agric. Res.,* **9**: 110-116.

KOWALSICK, T. AND CLARK, S., 2006. *Using growing degree days for insect pest management*. Information brochure. Horticulture Research laboratory, Cornell Cooperative Extension, Cornell University, pp. 4.

LAKRA, R.K., GUPTA, D.S. AND BHANOT, J.P., 1980. Nature and extent of damage and varietal susceptibility of peaches to peach borer, *Sphenoptera lafertei* (Thoms.). *Indian J. Ent*., **42**: 233-239.

RAQIB, A., 2003. *Integrated management of borers in stone fruit orchards of Peshawar region* (Final Report). Pak-Swiss Project for Horticultural Promotion (PHP). First Ann. Tech. Rep. Pak. Sci. Foundation Project, 2011-2012:19.

RIEDL, H., CROFT, B.A. AND HOWITT, A.J., 1976. *Forecasting codling moth Phenology based on pheromone trap catches and physiological time models. Canad. Entomol.,* **108**: 449-460.

SNYDER, R.L., 2005. Degree days. *Regents of the University of California*. Retrieved from :*<http:// biomet.ucdavis.edu/ Degree Days/Deg Day.htm>*.

TAKAI, K., SUZUKI, T. AND KAWAZU, K., 2004. Distribution and persistence of Emamectin benzoate at efficacious concentrations in pine tissues after injection of a liquid formulation. *Pest. Manage. Sci*., **60**:42-48.

WILSON, L. T. AND BARNETT. W. W., 1983. Degree-Days: An aid in crop and pest management. California Agriculture, pp. 37:4-7.

ZAHID, M., 2014. *Integrated management of peach flat-headed borer,* Sphenoptera dadkhani *(Oben.) damaging trees of stone fruit orchards*. Final Tech. Report, PSF Project No. PSF/NSLP/KP-NIFA (171): 01-58pp.

ZALOM, F.G., GOODELL, P.B., WILSON, L.T., BARNETT, W.W. AND BENTLEY, W.J., 1983. *Degree-days: The calculation and use of heat units in pest management*. University of California, DANR Leaflet No. 21373.

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