Research Article

Population Dynamics and Forecasting of Cotton Pink Boll Worm (*Pectinophora Gossypiella*, (Saundars) Lepidoptera: Gelechiidae) in Punjab, Pakistan

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Abstract | Pink boll worm (*Pectinophora gossypiella*, *S. Lepidoptera*: Gelechiidae) is one of the most destructive pests of cotton. Observations were recorded about pest infestation. Metrological data was collected of each district's head quarter on daily basis for the year 2017. For accumulation of degree days model, Huber's method was adopted and data for calculation of generations by accumulating progressive degree days was observed highly significant i.e., *P>0.0001*. In the present study, the accumulation of degree days for its forecasting was calculated from 1st January by using the metrological data and base line temperature and found 7 generations of pink boll worm to be found in all districts. Data for moths trapped in sex pheromone traps was noted as highly significant i.e., *P>0.0001*. Peaks of moth catches in 14 districts were observed in the month of September to October while for pest survey P= 2 X 10-16 were highly significant meaning that all variables had significant result in response to ETL. The results by pest survey of pink boll worms in cotton fields depicted that the spots above economic threshold level (AETL) was varying between 0.4% in districts viz., D G Khan and Rajanpur to a maximum of 5.0% in district Vehari. Below economic threshold level (BETL) was varying between 0.4% in districts D G Khan and Rajanpur to a maximum infestation found in district Vehari at 23.1%. The population peaks indicate the overlapping seven generations of pink boll worm out of which 5 active generations were in cotton season giving the thresh hold time of start of emergence of 1st generation and its 50% emergence.

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Introduction

Cotton (*Gossypium hirsutum* L.) is the most important crop of Pakistan. It contributed 1% share in GDP of Pakistan and 5.2% in the agriculture value addition with and annual production of 10.671 million bales in 2016-17 (Zalucki and Furlong, 2005). Cotton crop is attacked by a hundred of insect pests

but only a few have potential threat of damaging (Jeremy, 2017). Almost 150 species of insect pests have been reported to attack this crop in sub-continent (Agrawal, 1987). Among the chewing pest's pink boll worm (*Pectinophora gossypiella*, S. Lepidoptera: Gelechiidae) is one of the most destructive pests of cotton (Sarwar, 2017). Since the introduction of genetically engineered Bt cotton due to its insecticidal proteins some major pests of cotton like American (*Helicoverpa armigera*) and spotted (*Earias vitella* (Fab.) and *Earias insulana* (Boisd) and pink boll worm (*Pectinophora gossypiella*, S. Lepidoptera: Gelechiidae) were effectively controlled but now the resistance in pests against Bt has decreased the benefits (Wan *et al*., 2017). Resistance has been reported in pink boll worm against Bt proteins in China (Wan, 2012). Amongst the integrated pest management approach, pest monitoring is considered to be the best one for the control of this dangerous pest. Process of pest monitoring is based on the tools like pest survey, light and pheromone traps and sticky traps of various colors (Yenumula and Prabhakar, 2012). Pest monitoring can be helpful for a number of objectives like: (a) prediction of coming generations (Zalucki and Furlong, 2005); (b) ecological studies (Pathak, 1968; Crummay and Atkinson, 1997) (c) tracking migration of insects (Hirao *et al*., 2008); (d) starting date for biofix or phenology models; (Drake *et al*., 2002); (e) timing of pest arrivals in agro-ecosystems (Knutson and Muegge, 2010); (f) starting field scouting and sampling procedures and (g) timing of pesticide application (Klueken *et al*., 2009; Lewis, 1981). Researchers have forecasted the peaks of pink bollworm population using pheromone traps in USA by the degree days' accumulation (Lewis, 1981; Merrill *et al*., 2011; Toscano *et al*., 1979).

The study of population dynamics of a particular pests it is relating with metrological data for forecasting the population peaks could be very helpful for an effective ICT based IPM tool. This study covers the pest monitoring and forecasting of pink boll worm in Punjab, Pakistan by using the data of field surveys, pheromone traps and metrological data.

Materials and Methods

Metrological data

Metrological data was collected of each district's head quarter on daily basis from the website of Pakistan Meteorological Department (Zalucki and Furlong, 2005).

Accumulation of degree days and development of threshold

Annual degree days for the whole years were calculated using Microsoft Excel by determining daily minimum and maximum temperatures (°C), and the base temperature for the insect (pink boll worm). The DD for each day were converted into Accumulated Degree Days (ADD) for year 2017, starting from the 1st January and ending on the 31st December. For accumulation of degree days Huber's method (Zalucki and Furlong, 2005) was adopted: Lower development threshold: 55.0°F (12.8°C) Upper development threshold: 86.0°F (30.0°C) (Table 1).

Table 1: *Degree-day accumulations required for each stage of development.*

Season	DD (°F)	DD (°C)
Start of spring emergence:	500.0	277.8
Peak of spring emergence:	1180.0	655.6
End of spring emergence:	2200.0	1222.2
Summer generation time (adult to adult)	800.0	444.4

**Start date: January 1, 2017.*

Pheromone traps

Pheromone traps were installed in each tehsil @ 2 per tehsil and regular observations on moth catches were recorded on daily basis. Pheromone traps were installed throughout the year starting from the 1st January in each tehsil in the cotton field. Traps were comprised of plastic containers (12cm diameter, 20cm height), funnels (3.5cm diameter) and pheromone dispensers (inside center of plastic rooftop). A cotton swap soaked with bifenthrin 10 EC was used inside the trap as killing agent of the trapped pink boll worm moths. Pheromone dispensers and cotton swaps were replaced every 15 days. Traps were placed within the top 15cm of cotton foliage. Traps were re-baited at lures after one-month intervals and moths captured in each trap were counted daily.

Random pest survey

Pest scouting teams were consisting of one agriculture officer, one field assistant/pest surveyor with one or two gardeners for pest scouting in each tehsil. Data was collected from 14 districts and their 46 tehsils of cotton zone (core area) of Punjab. Each team conducted pest scouting 5 days per week covering 8-10 spots per day (40-50 spots per week) from April to October. Observations were recorded about pest infestation. In core cotton areas, each Union Council (UC) was covered at least on weekly basis in order to have more accurate picture of pest infestation in

that particular Tehsil/District. The teams and their survey were counterchecked by district and divisional supervisors. For pest scouting of pink boll worm 100 cotton bolls were collected randomly from a field and dissected with a fine blade to check the infestation of this pest. 5 % infestation was considered as economic thresh hold level (ETL) for pink boll worm.

Statistical analysis

The data was 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

Calculation of generations of pink boll worm according to degree days model

Data for calculation of generations by accumulating progressive degree days is highly significant i.e. P>0.0001. First generation of pink boll worm started emerging on 5 April and 4 April @ 277.8 DD (degree days) in district Bahawalnagar and Rahimyar Khan, respectively (Figure 1A and 1B). The 50% emergence of PBW @ 655.6 DD in both districts were on 30 April and 28 April, respectively. The linear graph of generations exhibits almost the same trend of pink boll worm up to 7th generations in both districts (Figure 1A and 1B) because both districts are adjacent and have almost same metrological situation. Generations of pink boll worm forecasted with the help of degree days in the districts D.G Khan and Khanewal exhibit that an early emergence initiated in D.G Khan starting from 27.03.2017 as compared to Khanewal where emergence starts from 10.04.2017 (Figure 1C and 1D). Similarly, the 7th generation@ 3556 DD was also reached early in district D.G Khan on 15.09.2017 as compared to Khanewal i.e. 26.10.2017 (Figure 1C and 1D). The reason for early generations in D.G Khan is due to the existence of this district at the distal end of the south Punjab with a significantly different metrological data. Similarly, an early emergence was observed in Layyah on 24.03.2017 compared with 9.04.2017 in Lodhran. 7th generation reached in Layyah on 03.10.2017 and in Lodhran on 17.10.2017 (Figure 1E and 1F) with a difference of 14 days (earlier in Layyah as Layyah is also a district of D.G Khan Division). Almost same emergence of pink boll worm moth in districts Multan and Muzaffargarh was forecasted at almost same time (Figure 1G and 1H). But 7th generation in district Muzaffargarh reached 15 days earlier on 9.10.2017 as compared with Multan where 7th generation was reached on 24.10.2017 (Figure 1G and 1H). As the two districts are adjacent and are present on the two brinks of river Chenab so the metrological data is not different for most of the generations calculated by progressive degree days. Generations according to progressive degree days for districts Okara and Pakpattan are illustrate significant difference in the start of emergence of pink boll worm moths between the two districts i.e. 7.04.2017 in Okara and 16.05.2017 in Pakpattan (Figure 2A and 2B). Similarly, all generations in the district Pakpattan are delayed from that of in Okara (Figure 2A and 2B) due to the difference in metrological data. Generations of PBW according to progressive degree days in Rahimyar Khan and Rajanpur showed that from emergence to 7th generations all set of dates in Rahimyar Khan are much earlier than that of in Rajanpur with a maximum difference of up to 22 days (Figure 2C and 2D).

Rahimyar Khan is another distal end of south Punjab province having its boundaries with another province Sindh and a desert on its south which is causing early generations of pink boll worm. It is evident that the generations according to degree days in Sahiwal and Vehari are almost same at the start of the emergence but there is a difference of 14 days while reaching at the 7th gen eration i.e. 3.10.2017 in Sahiwal and 17.102017 in Vehari (Figure 2E and 2F).

Population monitoring of pink boll worm with sex pheromone traps

Data for moths trapped in sex pheromone traps is highly significant i.e. P>0.0001. Moth catch data in Bahawalnagar and Bahawalpur (Figure 3A and 3B) are on lower ebb between 2nd and 3rd generations and start increasing after that showing peak at the 7th generation. Moth capture data of district D.G Khan and Khanewal shows population peak in district D.G Khan at 50% emergence whereas in district Khanewal the moth catches reached at maximum at 7th generation (Figure 3C and 3D). The moth catch data of the two districts Layyah and Lodhran is different significantly as Layyah showing population peak at the start of emergence whereas moth population gradually increased from 4th generation to a maximum at 7th generation in Lodhran (Figure 3E and 3F).

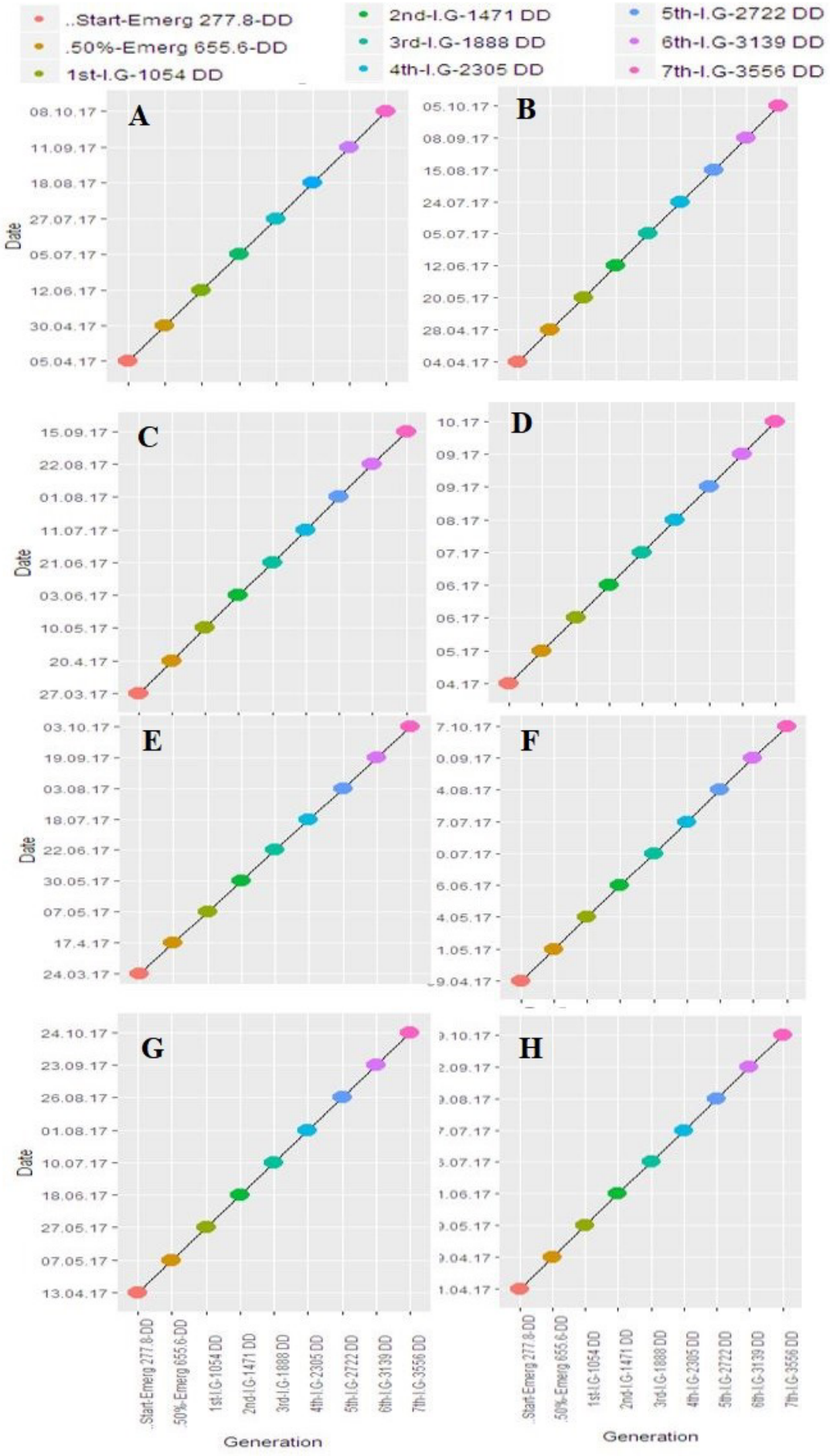

Figure 1: *Pink boll worm generations forecasted on the basis of progressive degree days in different districts (A: Bahawalnagar, B: Bahawalpur, C: DG Khan, D: Khanewal, E: Layyah, F: Lodhran, G: Multan, H: Muzaffargarh).*

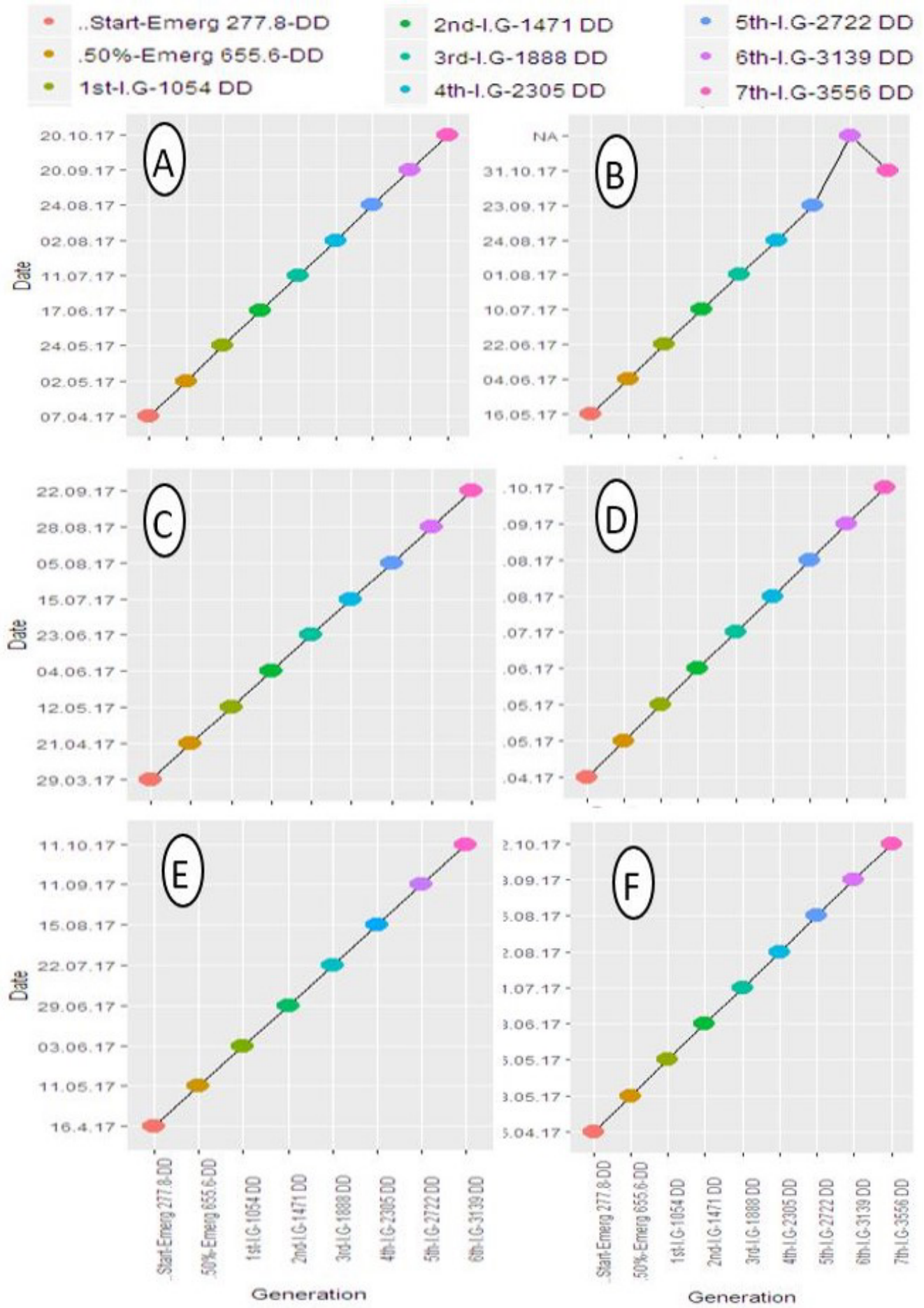

Figure 2: *Pink boll worm generations forecasted on the basis of progressive degree days in different districts (A: Okara, B: Pakpattan, C Rahimyar Khan, D: Rajanpur, E: Sahiwal, F: Vehari).*

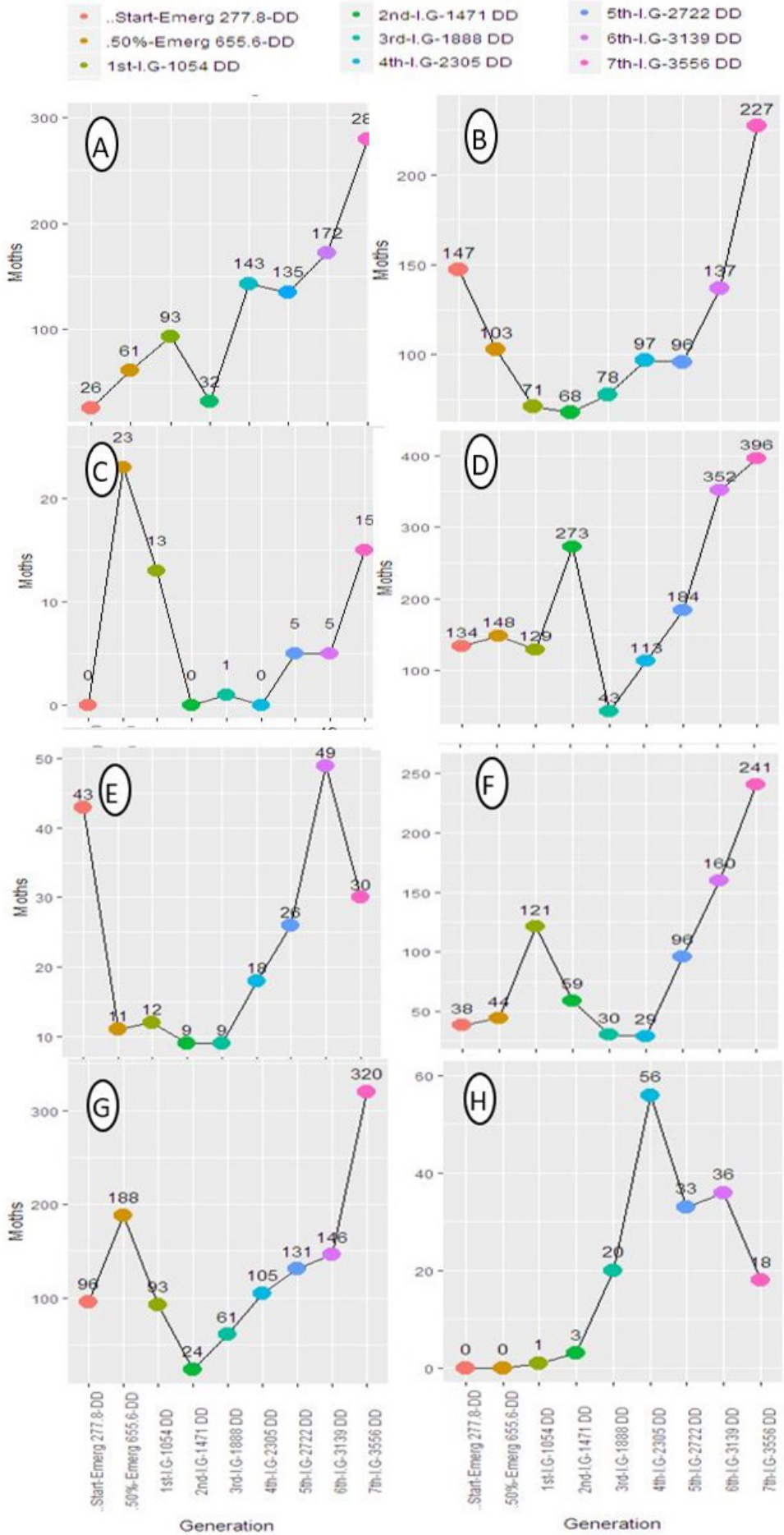

Figure 3: *Pink boll worm moth catches in pheromone traps between the generations in different districts (A: Bahawalnagar, B: Bahawalpur, C: DG Khan, D: Khanewal, E: Layyah, F: Lodhran, G: Multan, H: Muzaffargarh).*

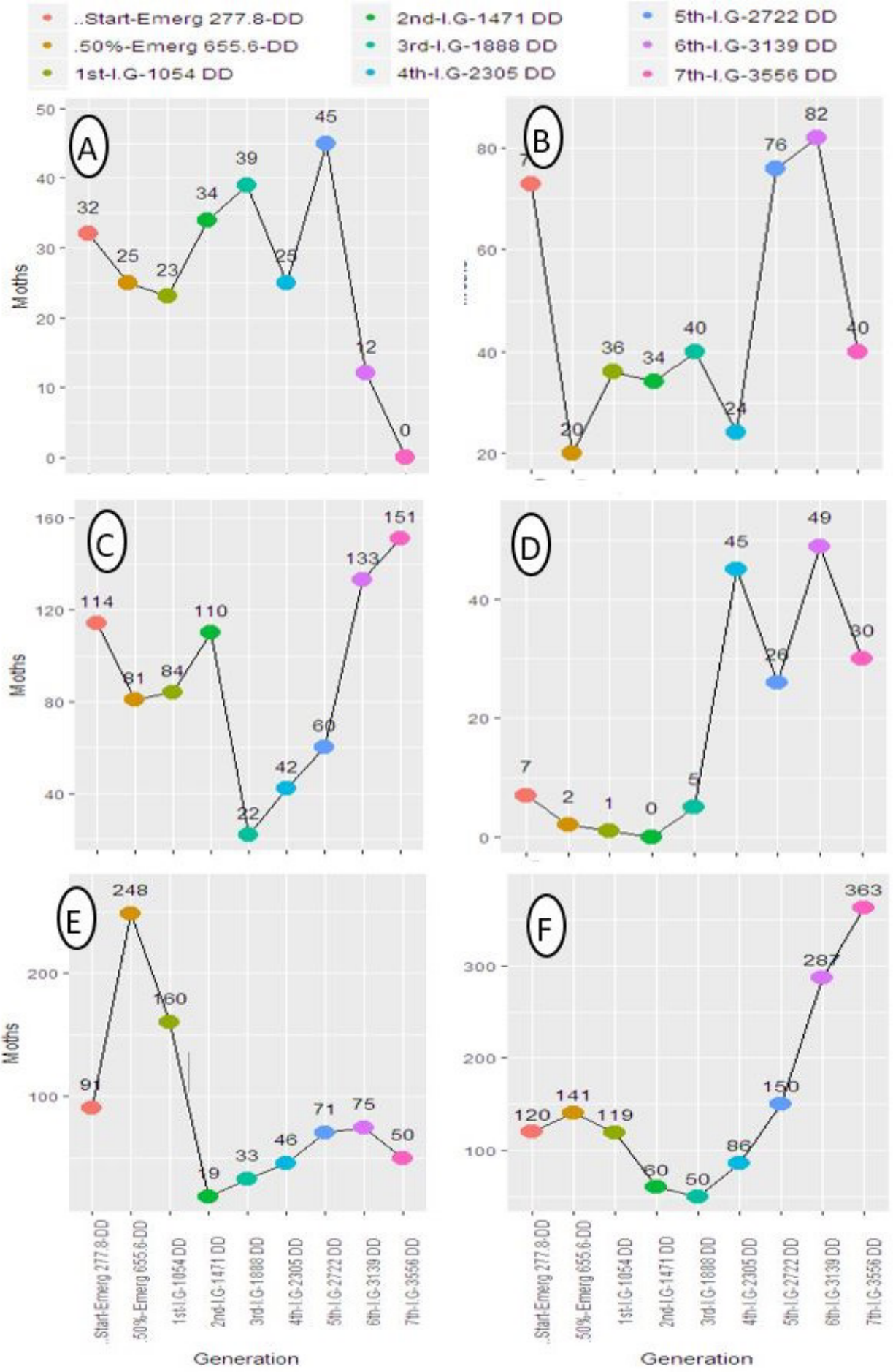

Figure 4: *Pink boll worm moth catches in pheromone traps between the generations in different districts (A: Okara, B: Pakpattan, C Rahimyar Khan, D: Rajanpur, E: Sahiwal, F: Vehari).*

In Layyah moth catches started increasing after 3rd generation and reached at maximum at 6th generation whereas in Lodhran moth catches started increasing after 4th generation and got a peak at 7th generation (Figure 3F and 3F). Regarding pink boll worm moth catches in pheromone trap the peak population was recorded in Multan was at 7th generation and in Muzaffargarh at 4th generation (Figure 3G and 3H). Moths trapped in pheromone traps in Okara decline after 5th generation as compared with Pakpattan where moth catches gradually increase after 4th generation to a maximum at 6th generation (Figure 4A and 4B). Male tarps in sex pheromone traps were recorded maximum at 5th generation in Okara and at 6th generation in Pakpattan (Figure 4A and 4B). Maximum moth population trapped in pheromone traps in Rahimyar Khan was recorded at 7th generation and in Rajanpur at 6th generation (Figure 4C and 4D). Whereas in Sahiwal and Vehari, both districts showing peak of moth captured in pheromone traps at 6th generation (Figure 4E and 4F).

Population monitoring of pink boll worm by pest survey of cotton crop in the field

District P-value = 2 X 10^{-16} are highly significant meaning thereby that all variables have significant result in response to ETL. The results by pest survey of pink boll worms in cotton fields depict that the spots above economic threshold level (AETL) is varying between 0.4% in districts DG Khan and Rajanpur to a maximum of 5.0% in district Vehari.

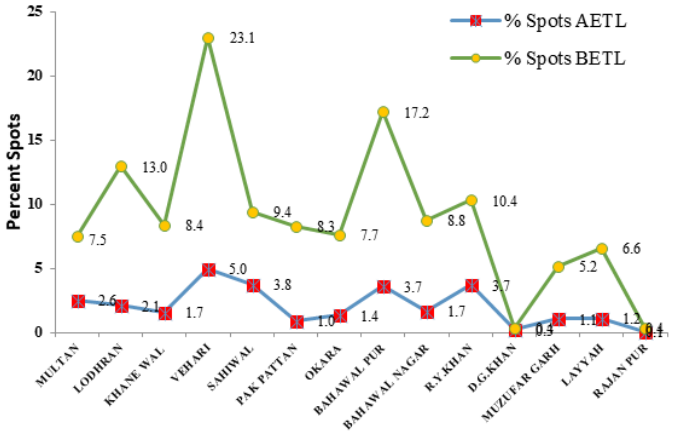

Figure 5: *District wise infestation of Pink boll worm.*

Similarly, below economic threshold level (BETL) is varying between 0.4% in districts DG Khan and Rajanpur to a maximum infestation found in district Vehari at 23.1% followed by Bahawalpur at 17.2%. The vertical lines crossing through moth population specify consecutive generations of pink boll worm. And the same is endorsed by the pest survey and generations deduced using metrological data by accumulating the degree days (Figure 5).

Population forecasting models are there for many organisms (Gabriella and Douglas, 1998). Hamed and Nadeem (2010) reported that for spotted boll worm 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. Borchert *et al.* (2003) reported forecasting of a particular pest can be different on the basis of different geographical reasons. Beasley and Adams (1996) accumulated degree days from the 1st February for prediction of pink boll worm and from the 1st March for prediction of blueberry maggot flies (Teixeira and Polavarapu, 2001). Accumulated DD for spotted boll worm from 1st January by using the base developmental temperature. In the present study the accumulation of degree days for its forecasting was calculated from 1st January by using the metrological data and base line temperature and found 7 generations. Five generations of pink boll worm were in the peak cotton season (Teixeira and Polavarapu, 2001). The difference in the number of moth catches in the districts is mainly due to varying number of tehsils in each district. Off season management of pink boll worm includes turning of heaps of cotton sticks, disposal of cotton ginning waste from cotton ginning factories, oil mills and brick kilns etc., which also can affect the emergence of moths from their hibernating habitats. Most of the moth catches peaks in 14 districts were observed in the month of September to October. Our results closely relate with Borchert *et al.* (2003) who reported that during 1998 the first peak in the moth population of spotted boll worm occurred in the 2nd week of August, the second peak 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 first peak occurred in the 1st week of August, second peak was observed in the 1st week of September and the third peak was recorded in the last week of September. Our results closely resemble with that of reference (Manjunatha *et al.*, 2009) who studied the incidence of PBW on different Bt and Non Bt hybrids and reported that all the Bt cotton hybrids registered significantly lower per cent of rosette flowers (0.01-1.57%) due to PBW throughout the season. Later it was gradually increased and

reached to peak level at 140 DAS with damage ranging from 8.72 to 11.57 per cent. Our data results are in contradiction with that of Vadodara and Kheda districts, the infestation of PBW was found up to 94 percent and 27 percent irrespective of the Bt cotton varieties (Sharma *et al*., 1985). Our results match closely with reference (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. The population peaks indicate the overlapping 7 generations of pink boll worm in a cotton season also giving the thresh hold time of start of emergence of 1st generation and its 50% emergence. Contrary to these results Sharma *et al*. (1985) documented eleven generations of spotted boll worm under laboratory conditions while Sharma *et al*. (1985) found many overlapping generations of spotted boll worm during a year under field conditions.

Conclusions and Recommendations

The overall studies concluded that the moth capture accumulated at range of degree days, pest survey and generations predicted on the basis of degree days model used in this study, almost precisely predict the pink boll worm attack on the cotton crop in Punjab. On the basis of forecasting by this method PBW red alerts can be issued to the farmer community so that they can start integrated pest management measures to control this pest.

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Novelty Statement

The moth capture accumulated at range of degree days, pest survey and generations predicted on the basis of degree days model used in this study, almost precisely predict the pink boll worm attack on the cotton crop in Punjab. On the basis of forecasting by this method PBW red alerts can be issued to the farmer community so that they can start integrated pest management measures to control this pest.

Author's Contribution

Syed Ismat Hussain: Conceived the idea and introduction
Khalid Mehmood: Wrote abstract and introduction
Mudassar Khaliq: Wrote methodology and discussion
Habib Anwar, Syed Muhammad Zaka and Ateeq ur Rehman: Wrote methodology
Muhammad Shahid, Syed Atif Hasan Naqvi and Ummad ud Din Umar: Did SPSS analysis and discussion
Muhammad Asif Zulfiqar: Result and discussion

Conflict of interest

The authors have declared no conflict of interest.

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