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Monitoring of Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee) Adult Populations in Brinjal (*Solanum melongena* L.) Using Light Traps

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ABSTRACT

Brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guennee) is an important and widely distributed insect pest of brinjal (*Solanum melongena* L.). In this study, populations of BSFB were monitored using a kerosene lantern as a light trap at Multan and Sahiwal during 2012 and 2013. Moths trapped were recorded daily from the first week of April to the end of November. However, data were accumulated at weekly intervals to establish the relationship between moths trapped and fruit infested and for two weeks for population growth trends. Number of moths trapped was quite low at both locations during both years in April, May and November. Moth populations increased at a slow rate during early sampling dates (April, May, up to mid July) and a sharp increase in number of moths trapped was recorded thereafter at both locations during both years. After August, the number of moths began to decline and reached a very low level in November. During 2012, at Multan, the mean number of moths fluctuated around 0.95, 1.74 and 7.3 moths per week for the first eight weeks, next nine weeks, and next four weeks, respectively. At Sahiwal, the mean moth population per week was 0.52 for the first thirteen weeks and 2.7 for the next eight weeks. During 2013, at Multan, the mean moth population per week was 1.6, 2.33 and 4.33 for the first six weeks, next seven weeks and next seven weeks, respectively. At Sahiwal, the mean moth number per week was 0.55 for the first eight weeks, 1.9 for the next five weeks and 4.0 for the next four weeks. The population was relatively lower at Sahiwal than at Multan. The population increase was faster at Multan than at Sahiwal. A significant positive relationship was noted between number of moths per week in traps (independent variable) and brinjal fruit infestation by BSFB (dependent variable) for pooled data of 2012 and 2013 at Multan ($y = -4.65 + 0.779x$; $P = 0.000$; $R^2 = 81.9$) and Sahiwal ($y = 2.37 + 0.763x$; $P = 0.000$; $R^2 = 71.6$), for pooled data of 2012 for Multan and Sahiwal ($y = -0.07 + 0.735x$; $P = 0.000$; $R^2 = 78.0$), for pooled data of 2013, for Multan and Sahiwal ($y = 1.10 + 0.702x$; $P = 0.000$; $R^2 = 70.1$) and for pooled data of both locations and both years ($y = 0.56 + 0.716x$; $P = 0.000$; $R^2 = 71.6$). BSFB monitoring with light traps is practical, economical and convenient as compared to conventional pest scouting techniques for this pest.

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Authors' Contributions
MA, QY, MA conceived and planned the study, and wrote the article. Crops were planted and data collected at Multan by QY and ADA and at Sahiwal by QY and MA.

Key words
Aubergine, eggplant, monitoring, moth population, fruit infestation.

INTRODUCTION

Vegetable production is often a very profitable business and requires a short duration for financial turnover (Shahabuddin and Dorosh, 2002; Ishtiaq *et al*., 2005; Zaman *et al*., 2010). Small land holders in Pakistan mostly prefer to grow vegetables so that they can earn more profit than that in other agricultural businesses (Sultan *et al*., 2007). Eggplant or brinjal (*Solanum melongena* L.) is one of the most important vegetables in areas like South-East Asia (Thapa, 2010) with hot-wet climactic conditions (Hanson *et al*., 2006). It belongs to the family Solanacae and is one of the most commonly grown vegetables in this family (Kantharajah and Golegaonkar, 2004). Its worldwide cultivation is more than 1,85,3023 ha and production is 48.4 million metric tons. In Pakistan, area under its cultivation is 9,000 ha and production is 87,000 tons per annum (FAO, 2014).

Different insect pests feed on brinjal from the early growth stage to harvesting. Among the insect pests of this vegetable, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is a major pest (Chakraborty and Sarkar, 2011; Saimandir and Gopal, 2012) prevailing worldwide in brinjal producing countries (Dutta *et al*., 2011). It is the most important insect pest of brinjal in Asia especially in India, Pakistan, Srilanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos, Vietnam (AVRDC, 1994), Africa, Sahara and South-East Asia (CABI, 2007). It causes severe yield loses in South Asia (Thapa, 2010) which may reach up to 85 to 90 percent (Misra, 2008; Jagginavar *et al*., 2009).

Different management practices are used in the

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field for reducing infestations of this injurious insect pest. BSFB moth mass trapping using pheromone traps has been used by a number of scientists but synthetic pheromones and their installation are very expensive and cannot be afforded by small landholders in Pakistan. One alternative for lepidopteran mass trapping is the use of light traps. Moths are nocturnal in habit. Light traps are a very effective way of catching moths with less effort and nominal cost (Fiedler and Schulze, 2004). Moths can easily be monitored by using light traps which is a standard and worldwide applied method for sampling night flying insects (Southwood and Henderson, 2000). In India, light traps are used to monitor the size of moth populations and migration patterns (Palatty *et al.*, 2013). Sayama *et al.* (2012) used light traps to study the seasonal activities of moths of different species from April to August. They found that most of the moth species were abundant and active in the summer (July and/or August) while some were found active only in the autumn. Light trap sampling should be done throughout the night in order to get maximum catch and avoid bias (Jan and Linsenmair, 2006). The analyses of catches in light trap are helpful to define the ETL (economic threshold level) and suggest an appropriate time for pest management (Ramamurthy *et al.*, 2010). This work was carried out to study BSFB moth populations in brinjal and to determine the relationship between the number of moths caught in light trap and fruit infestation. The results will help make monitoring and scouting of BSFB based on moth catches in traps economical and easier.

MATERIALS AND METHODS

The study was carried out at two locations, *i.e.*, COMSATS Institute of Information Technology, Sahiwal (30°39′52″N 73°6′30″E). and Mouza Bibi Pur, Multan (30°11′52″N 71°28′11″E), in 2012 and 2013. Seeds of brinjal variety Nirala were obtained from Ayyub Agriculture Research Institute, Faisalabad. The nursery was sown in 12 inch earthen pots on February 10, 2012 and February 15, 2013 for both locations. Seedlings were transplanted to rows 0.5 m apart in a plot of 0.202 ha (1/2 acre) at each location. Transplantation was done on March 13, 2012 and March 18, 2013, at each location. Light traps were installed at both locations on March 22 in the middle of each block.

The light traps were made of a kerosene metal lantern with a glass chimney. The lamps were hung at a height of 140.2 cm over a metal tray (36.6 cm diameter and 18.3 cm depth). The tray was filled with water and kerosene oil in a 10:1 ratio. The lantern was lit from dusk to dawn. The numbers of BSFB adults in the tray were recorded daily in the morning at 8:00 am starting from mid-April to the end of November. Adults were collected by sieving the water and kerosene mixture through a tea strainer. Adult BSFB's collected in the sieve were placed on a filter paper, separated from other insects and counted. Twenty plants were randomly marked in the plots and BSFB fruit infestation was recorded from these plants in each block every 15 days during the period of adult population monitoring. All marketable fruits from these 20 randomly selected plants were plucked. Infested and healthy fruits were sorted out by observing exit and entry holes. Percent BSFB fruit infestation was calculated using the following formula:

Percent BSFB fruit infestation= Fruits infested by *L. orbonalis* / Total no. of fruits x 100

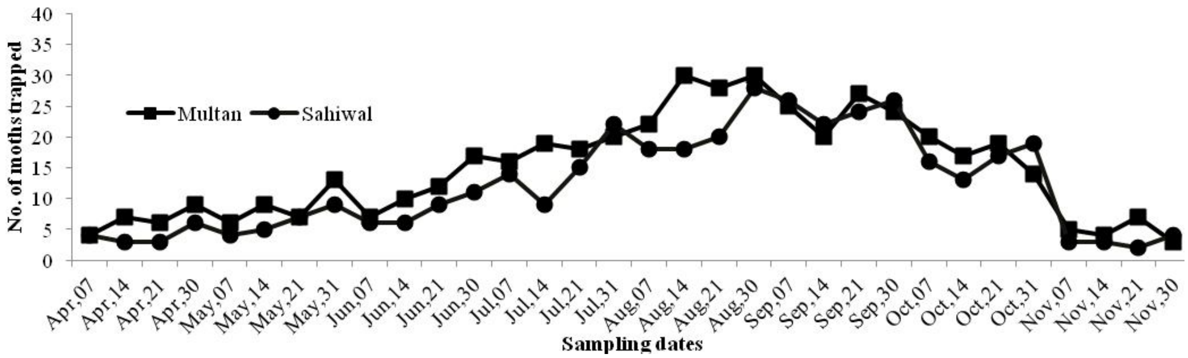
Graphs were plotted to indicate adult BSFB population dynamics at each location on a weekly basis, and for 10 days in certain samples. Data of cumulative number of moths trapped in seven or 10 days were used in graphical presentations. Comparisons of BSFB adult population dynamics were also made between locations and years. Trend lines were drawn by using Microsoft Office Excel (2007) on the graphs to show moth population growth and decline. Regression analysis was also performed (Minitab, 2013) to determine the relationship between BSFB moth populations and percent fruit infestation.

The same procedure was adopted for both locations during both years.

RESULTS AND DISCUSSION

Moth population dynamics at Multan and Sahiwal 2012

A description of moth numbers trapped at Multan and Sahiwal during 2012 and 2013 is expressed on the basis of population increase and decrease rather than on the time interval, *i.e.*, weeks. The number of BSFB in traps during 2012 at Multan and Sahiwal are presented in Figure 1A. Data are presented for cumulative weekly number of moths caught in traps. The number of moths in traps increased very slowly from April 7 to May 31. During this period moth numbers fluctuated between four and 13 and the mean number of moths was 0.95 moths per week. The numbers ranged between seven and 22 during the next nine weeks with a mean of 1.74 moths per week. Number of moths trapped increased sharply from August 7 to 30. During these four weeks, moth numbers ranged between 28 and 30 and averaged 7.3 per week. Trapped moths started to decrease on August 30 and a sharp decrease in numbers was recorded from August 30 to October 31. Moth numbers during this eight week



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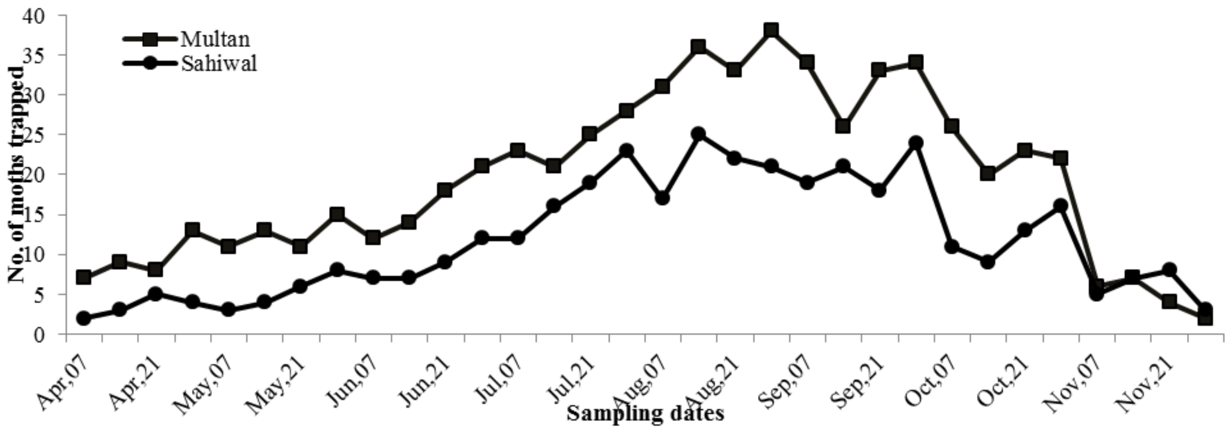

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Fig. 1. Number of brinjal shoot and fruit borer (*L. orbonalis*) moths in light traps in brinjal (*S. melongena*) at Multan and Sahiwal during 2012 (A), 2013 (B).

period ranged from 17 to 27, with an average of 2.5 moths per week. Populations were very low (three to seven moths) during November. At Sahiwal during 2012, the number of BSFB moths in traps increased but fluctuated from time to time until the population reached a peak. From April 7 to July 7 the increase in moth populations was slow and the number of moths in first 13 weeks was between three and 14. From July 14 to August 30 a relatively sharper increase in moth populations was recorded as compared to that occurring in the previous 13 weeks. Trap counts during these seven weeks ranged between nine and 28 moths. Populations declined after August 30, and from September 7 to October 31, a sharp decrease was noted. Populations were very low in November, *i.e*., three moths per four weeks.

At Multan during 2012, the number of moths in traps increased slowly with up and down fluctuations from week to week. Populations increased slowly during the first eight weeks, relatively faster in the next nine weeks and the fastest in the next three weeks. Mean number of moths was 0.95, 1.74 and 7.3 moths per week during the first eight weeks, next nine weeks and next four weeks, respectively. A decrease in moths in trap was noted from August 30 to November 30, with a little higher population on three samples dates, *i.e.,* September 21, October 21 and November 21. The moth population at Sahiwal also increased slowly in first thirteen weeks with a mean moth population during this period of 0.52 moths per week. From July 14 to August 30 an increase in populations as compared to that during previous weeks occurred. The mean number of moths per week was also 2.7 during these eight weeks. Number of moths during November was very low at Sahiwal.

At both locations, the number of moths trapped in April, May and November were quite low. This could be due to growth stages of the crop. In early (April) and late stage (November) there are few flowers on the crop, which could have made it less attractive to the moths. When moths in traps were compared between the two locations, population trends were similar at both locations with a few more moths in traps at Multan than at Sahiwal. A possible reason for this difference could be the different cropping patterns in the two areas. In the Sahiwal area, mostly potato is grown and there may be lower populations of BSFB as compared to that in the Multan area, where brinjal is grown around the city and in mango orchards. Since more area is occupied by brinjal in Mulan there could be more BSFB moths in the area, which resulted in more moths in traps.

2013

At Multan and Sahiwal during 2013, a slow increase in moth catches was recorded early in the season (Fig. 1B). From April 7 to May 14, moth numbers ranged from seven to 13. Trap catches during these six weeks fluctuated around a mean of 1.6 moths per week. From May 21 to July 7 a relatively sharp increase in moths in traps was recorded as compared to that occurring in the previous six weeks. The number of moths in traps ranged from 11 to 23 and averaged 2.33 per week during these seven weeks. The highest increase in number of moths in traps was noted from July 14 to August 30. The population of moths during this sampling period ranged from 22 to 34 and averaged 4.33 per week. Catches declined after August 30, and quite low counts, *i.e.*, two to six moths per week, were noted during November. At Sahiwal during 2013, the moth population increased in steps at a slow pace in the early sampling period. A slow increase in number of moths trapped was recorded from April 7 to May 31. The mean number of moths in this eight week period was 0.55 per week. Population increased rapidly between June 7 and July 7 as compared to the previous eight weeks. The number of moths in traps during these eight weeks ranged between seven and 12, with a mean of 1.9 moths per week. From July 14 to August 14 the sharpest increase in populations of moths was recorded. During these five weeks, populations were between 16 and 25 and the mean number of moths was 4.0 per week. After this period, the number of moths in traps started to decline. The number of moths in trap from August 21 to October 14 ranged from nine to 22, with a mean of 2.6 moths per week. Populations of moths in trap increased from October 21 to 31. During this time counts fluctuated between 13 and 16 moths. The population was very low during November.

At Multan during 2013, moth population in the trap started to increase slowly in the early sampling period (first six weeks). A relatively higher numbers of moths were found in traps during the next seven weeks. The highest population trapped was recorded from mid-July to the end of August. Thereafter the population started to decline. The population increased almost continuously from the beginning of sampling (April 7) to the end of August. The number of moths fluctuated around a weekly mean population of 1.43, 2.33 and 4.33 per week during April 7 to May 14 (six week period), May 21 to July 7 (seven week period) and July 14 to August 30 (seven week period), respectively. The number of moths increased on a number of sampling dates during the period when population was declining up to November. Number of moths in trap at Sahiwal during 2013 increased slowly during the first eight weeks (from April 7 to May 31) and next five weeks (from June 7 to July 7) with a mean weekly population of 0.55 and 1.9 moths per week, respectively. The maximum increase in moths trapped was recorded from July 14 to August 14 when the mean weekly catch was four moths. Populations increased consistently from the start of sampling to the date when the peak number of moths was recorded. The only exception to this was the number of moths recorded on August 7, when the moth population dropped suddenly. These low numbers could be the result of changing weather conditions during that period. However, in general there was a declining trend in populations but the decline in populations was not uniform. The reason for a higher number of moths in traps on these sampling dates is not clear, but such deviations in biological data are normal. When the number of moths in traps were compared between Multan and Sahiwal, populations were mostly lower at Sahiwal as compared to that in Multan during 2012 (Fig.1) and 2013 (Fig.2) throughout the study period. However, the number of moths at Sahiwal was slightly higher in 2012 on August 7, September 21 and October 21, and during 2013 on November 21 and 30. During 2012, the moth population trend was almost similar for both locations except that the difference in number of moths in traps between the two locations was more on certain sampling dates, *i.e.*, April 30, July 7, August 7 and 30. During 2013, the difference in moths per trap at the two locations was more on August 7, and 30 and September 7 and 21. Population peaks at the two locations were also different during 2013 only. The highest population at Multan was noted on August 30 whereas at Sahiwal it was noted on August 14. However, population peak during 2012 occurred on the same sampling date, *i.e.*, August 30. These findings confirm the results of studies conducted by Sayama *et al.* (2012), who found that the number of moths in light traps fluctuated around the year and reached a peak in the summer from July to August. The trend in moth population trapped was quite similar for both years at Multan (Fig. 2A). However, counts were lower during 2012 as compared to 2013, except on November 14 and 30, when number of moths in traps was slightly higher in 2012 than 2013. The number of moths in traps was similar for the years 2012 and 2013 from April 7 to July 7 at Sahiwal (Fig. 2B). However, the number of moth for the two years fluctuated. After July 7, the population for the two years fluctuated considerably and no clear trend was noted. Anju and Khatri (2010) also reported that BSFB moth populations fluctuated throughout the year.

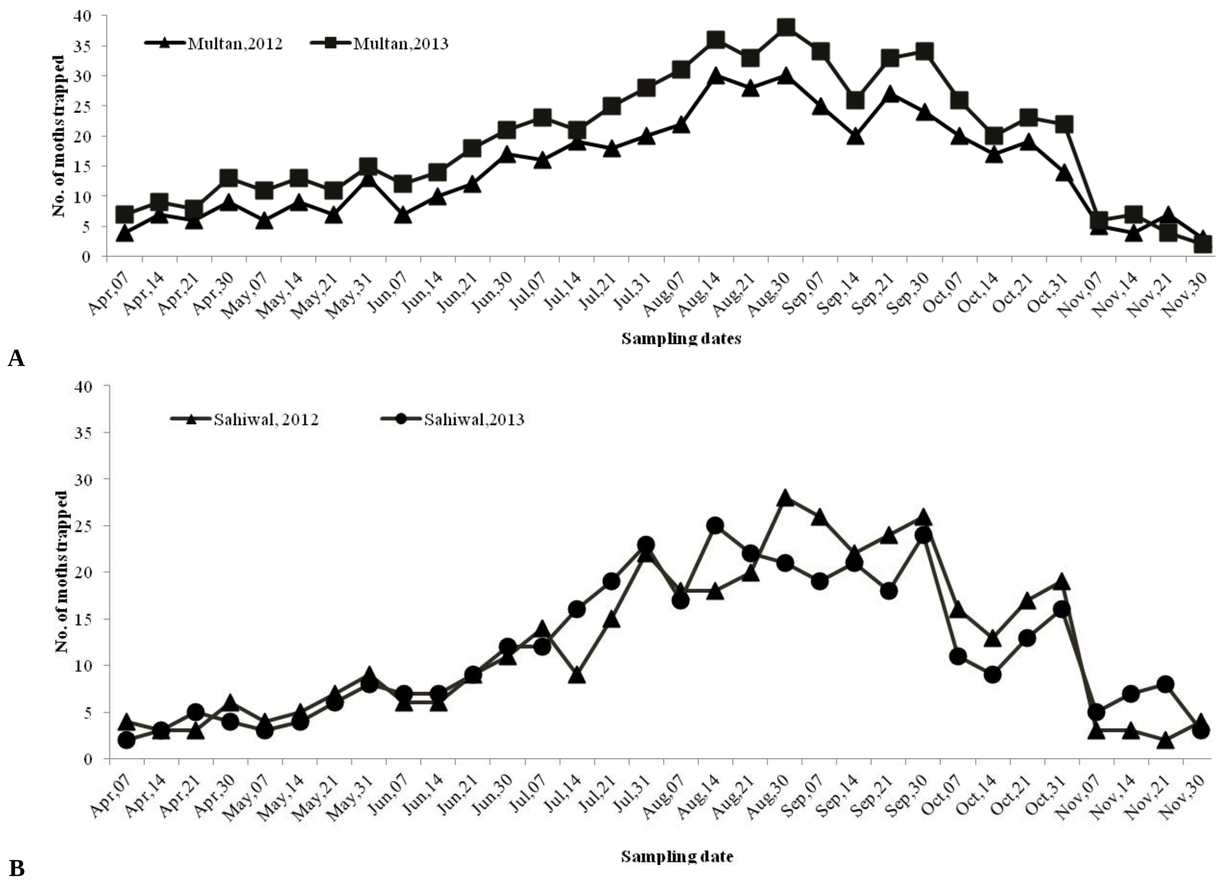
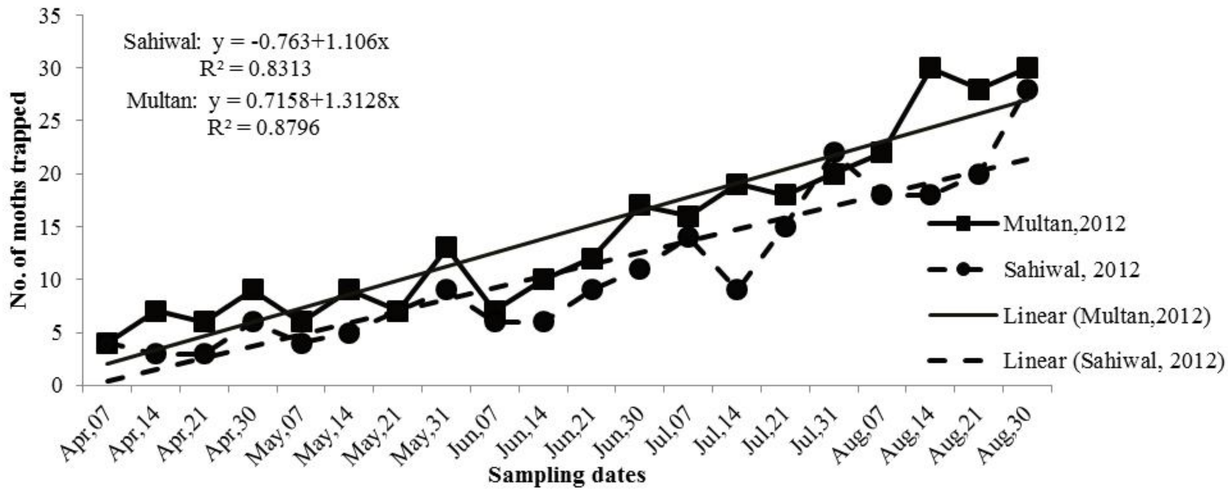


Fig. 2. Brinjal shoot and fruit borer (*L. orbonalis*) moth catches in light traps in brinjal (*S. melongena*) at Multan (A) and Sahiwal (B) during 2012 and 2013.

BFSB population growth trend

During 2012, moth population increase was linear at Multan and Sahiwal (Fig.3A) from the beginning of sampling (April 7) to the peak recorded (August 30). Although the moth population increase from April 7 to August 30 at Sahiwal (R^2=0.8313) and Multan (R^2= 0.796) was linear the slop for Multan (1.3128) was steeper than that for Sahiwal (1.106), which indicated that the population increase was faster at Multan than at Sahiwal. The decrease in moth catches from September 7 to November 30 was also linear (Fig. 3B) for both locations (Multan R^2= 0.845 and Sahiwal R^2= 0.809). However, the population decrease was relatively sharper at Sahiwal (slope= -2.346) as compared to Multan (slope= -2.206). During 2013, the moth population increase was again linear at Multan (R^2= 0.917) and Sahiwal (R^2= 0.867) from April 7 to August 30 (Fig. 4A). However, populations increased faster at Multan (slope= 1.569) than at Sahiwal (slope= 1.245). The population decrease from August 21 at Sahiwal and from September 7 at Multan was also linear (Fig. 4B). There were more fluctuations in decreasing populations at Multan (R^2= 0.749) than at Sahiwal (R^2= 0.853). At Multan moth numbers decreased at a faster rate (slope= -3.0804) than at Sahiwal (slope= -1.439).

When the population increase at Multan during 2012 and 2013 was compared very little difference was noted in the rate of increase in moth numbers from April 7 to August 21 for both years (Fig. 5A). The rate of population increase was slightly greater during 2012 (slope= 1.569) than in 2013 (slope= 1.313). However, the rate of population decrease (Fig. 5B) was faster in 2013 (slope= -3.0804) than in 2012 (slope=-2.206). A comparison of moth population increase at Sahiwal during 2012 and 2013 (Fig. 6A) indicated that the rate of increase was similar in both years (during 2012, slope= 1.106; during 2013 slope = 1.245). Moth numbers (Fig. 6B) decreased more during 2012 (slope = -2.346) as compared to 2013 (slope= -1.439).



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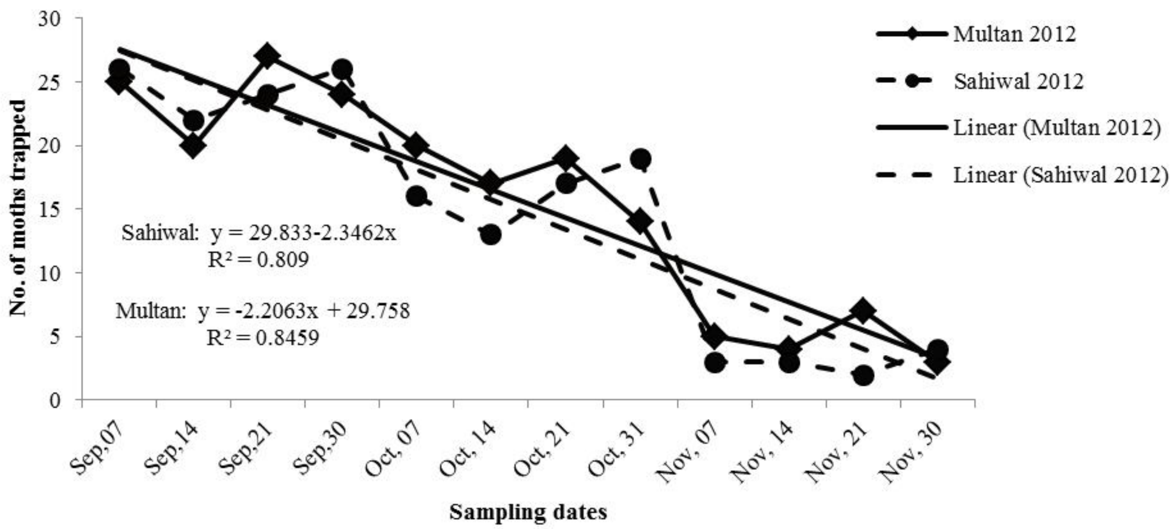

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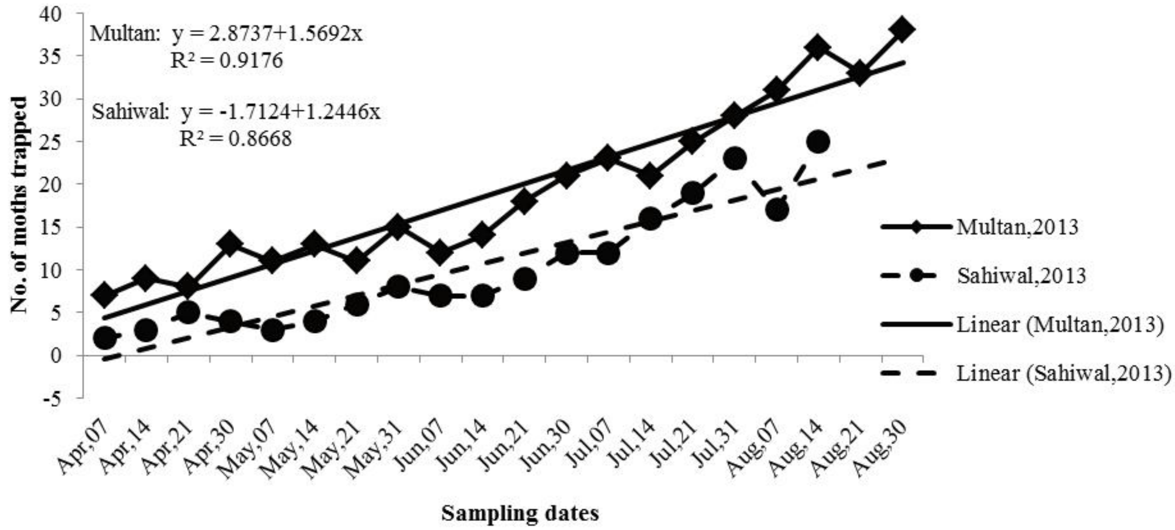
Fig. 3. Brinjal shoot and fruit borer (*L. orbonalis*) moth population increasing trend during April-August (A), and decreasing trend during September-November (B) at Sahiwal and Multan during 2012.

Table I.- Regression equation and predicted number of moths for economic threshold of Brinjal Fruit and Shoot borer (*L. orbonalis*) for different locations, years, and combinations.

Location and year	Regression equation	*p*	R^2 (%)
Multan, 2012	y = - 1.93 + 0.775 x	0.000	81.5
Multan, 2013	y = - 8.41 + 0.817 x	0.000	84.4
Multan, 2012 + 2013	y = - 4.65 + 0.779 x	0.000	81.9
Sahiwal, 2012	y = 2.14 + 0.684 x	0.000	72.0
Sahiwal, 2013	y = 2.82 + 0.830 x	0.000	75.5
Sahiwal, 2012 + 2013	y = 2.37 + 0.763 x	0.000	71.6
Multan, 2012 + Sahiwal 2012	y = - 0.07 + 0.735 x	0.000	78.0
Multan, 2012 + Sahiwal 2013	y = 1.10 + 0.702 x	0.000	70.1
Multan, 2012 + Multan, 2013 +Sahiwal, 2012 + Sahiwal 2013	y = 0.56 + 0.716 x	0.000	71.6



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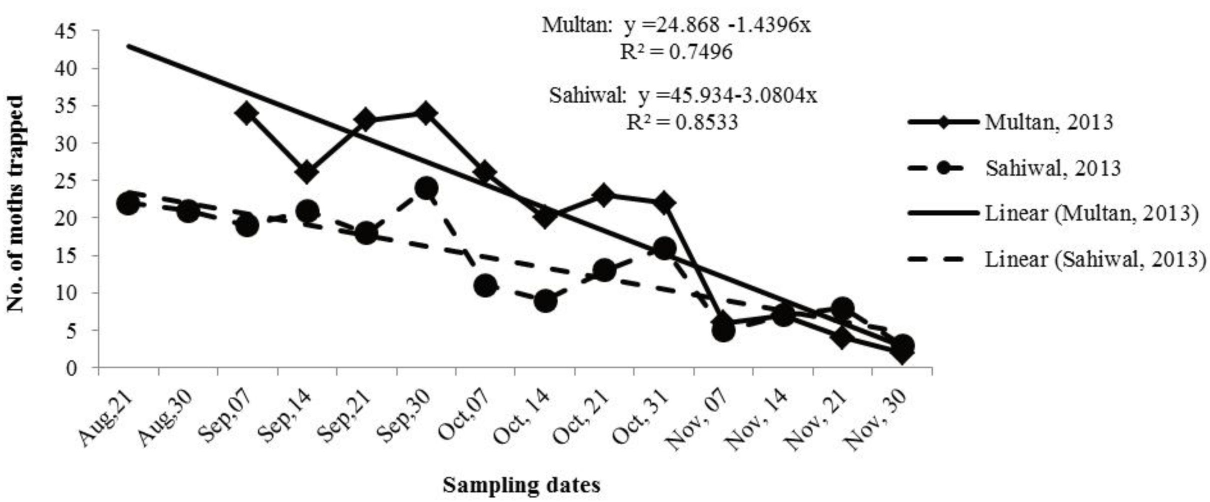

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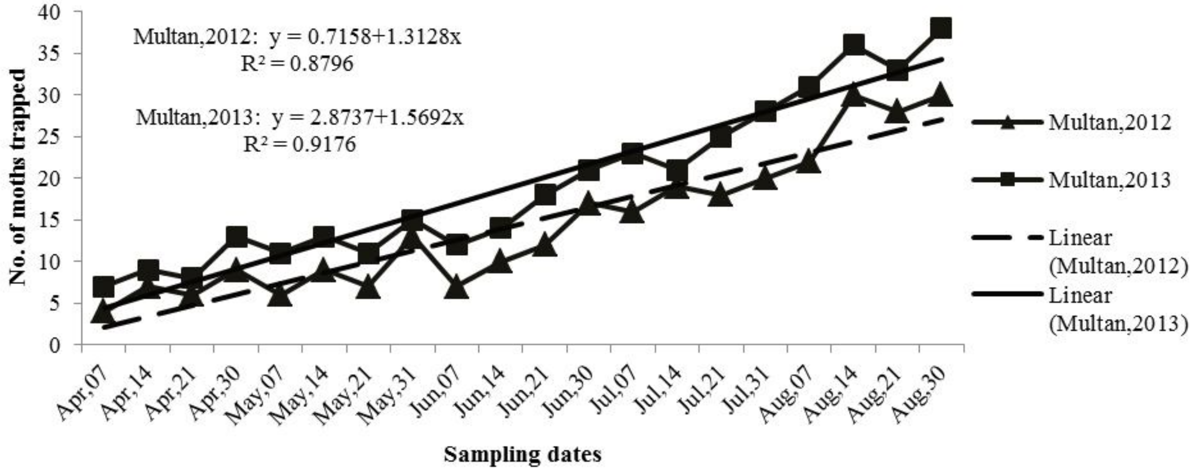
Fig. 4. Brinjal shoot and fruit borer (*L. orbonalis*) moth population increasing trend during April-August (A) and decreasing trend during September-November (B) at Sahiwal and Multan during 2013.

Moth in traps and fruit infestation

The mean moth population for every two weeks along with brinjal fruit infestation from April 15 to November 30 during 2012 for Multan is presented in Figure 7A. Percent fruit infestation by BSFB showed almost the same trend as the moth population throughout the sampling period. However, the number of moths trapped was lower than fruit infestation on all sampling dates, except on July 30, when it was slightly higher than the fruit infestation. At Sahiwal during 2012, moth number in trap and fruit infestation fluctuated throughout the sampling period (Fig.7B). The number of moths was higher than fruit infestation from April 15 to May 30 and July 30 to November 15. A regression analysis between number of moths in trap (as an independent variable) and percent fruit infested (as the dependent variable) for years, location, and combinations thereof was performed for applicability of the results to a wider area. The regression equation and R^2 values are given in Table I. The regression was significant (P = 0.00) for the relationship between the two variables. The relation between trapped moths and fruit infestation at Sahiwal was not as strong (R^2 =72.0) as that at Multan (R^2 = 81.5).

During 2013 at Multan, moth catches were consistently higher than fruit infestation on all sampling dates (Fig. 7C). However, percent fruit infestation closely



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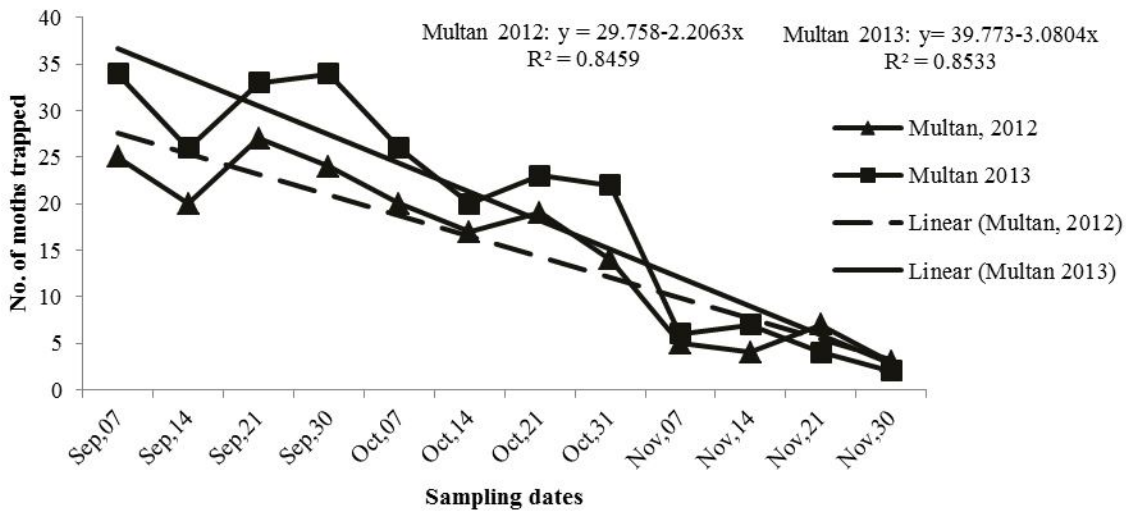

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Fig. 5. Brinjal shoot and fruit borer (*L. orbonalis*) moth population increasing trend during April-August (A) and decreasing trend during September-November (B) at Multan during 2012 and 2013.

followed the trend of mean number of moths for two weeks for most of the season. Regression analysis revealed a reasonably strong relationship (R^2= 0.844) between the two parameters. At Sahiwal during 2013, the mean number of moths in trap and fruit infestation fluctuated throughout the sampling period in 2013, as it did in 2012 (Fig. 7D). From July 30 to September 30, and October 30 to November 30, percent fruit infestation was lower than the number of moths in trap. Percent fruit infestation was higher than the number of moths in traps during the period of high moth catch and fruit infestation (July 30 to September 30). During 2013, as in 2012, the relationship between number of moths and fruit infestation was weak (R^2 = 75.5) at Sahiwal as compared to that at Multan (R^2 = 84.4). The combined data of Sahiwal and Multan for 2012 had a higher R^2 value than that for 2013. For Multan, pooled data of two years (2012 and 2013) had a higher R^2 value as compared to that at Sahiwal. When the regression was calculated for pooled data of both locations and both years the R^2 was 71.6.

Monitoring of moth activity can be used as a source of information to initiate pest management practices. Different workers have reported a positive correlation between lepidopteran larval infestation and adult catches in traps (Knight, 2001; Walker *et al*., 2003; Martin *et al*., 2011). Sulifoa and Ebenebe (2007) also reported a positive correlation between *Plutella xylostella* moths trapped and larval infestation in cabbage. Shelton

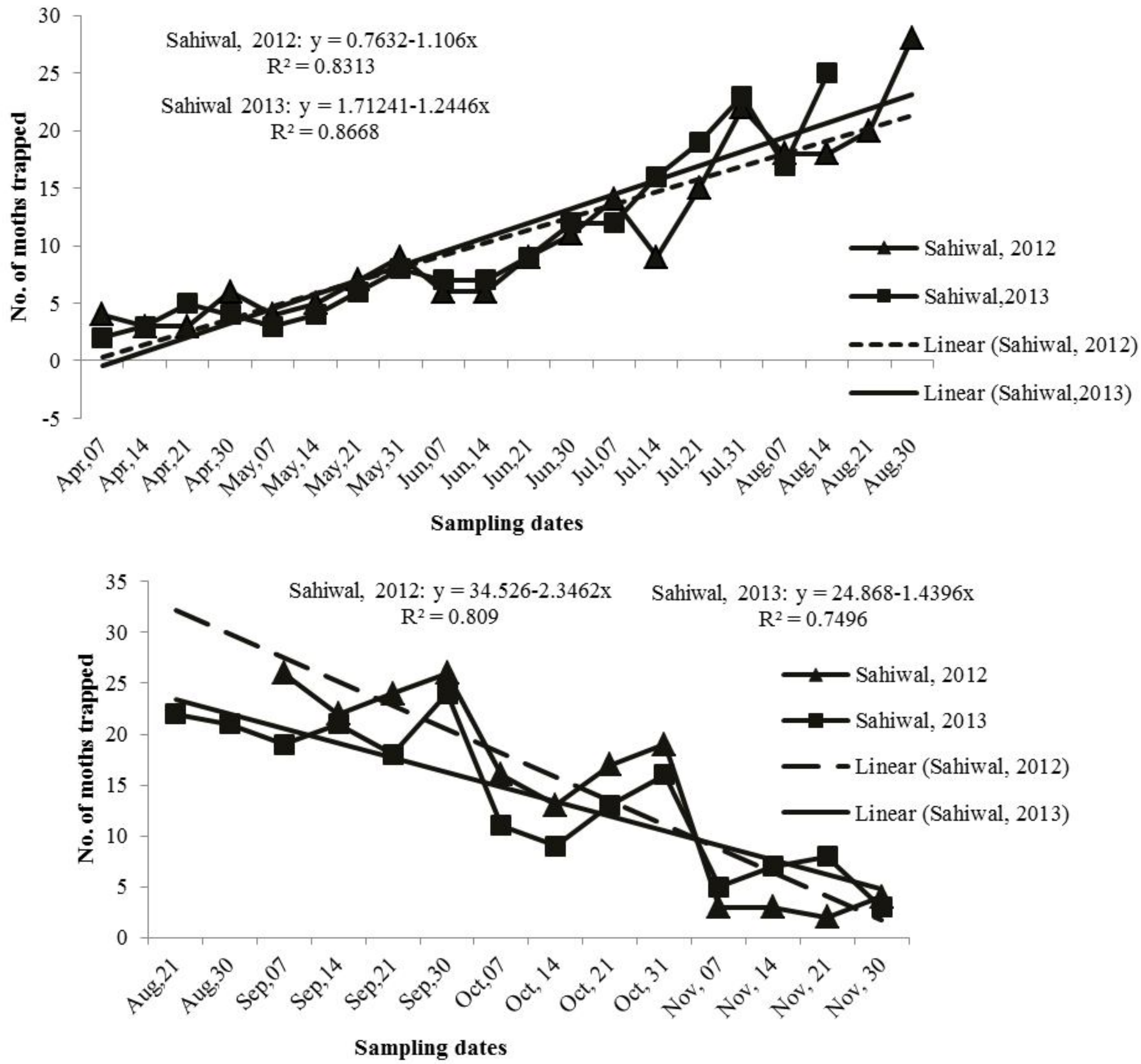

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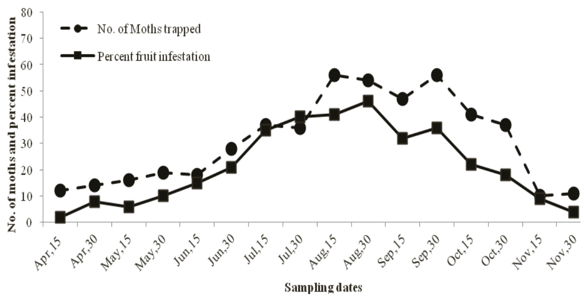
Fig. 6. Brinjal shoot and fruit borer (*L. orbonalis*) moth population increasing trend during April-August (A) and decreasing trend during September-November (B) at Sahiwal during 2012 and 2013.

and Wyman (1979) found that the potato tuber worm moth catch in pheromone trap was directly correlated with larval infestations. Khalique and Feeroza (2012) studied the relationship between the number of trap catches of *Helicoverpa armigera* and chickpea infestation and concluded that this study can help in designing IPM strategy well in time. Results of monitoring of chickpea borer adult populations suggests that IPM against *Helicoverpa armigera* should begin in mid-January (Hossain, 2008). Amin and Gergis (2006) suggested that the integration of lepidopteran moth monitoring with other insect pest control methods can improve environmentally friendly management of insect pests in cotton. According to the results of our study, the economic threshold level (ETL) based on the fruit infestation can be determined on the basis of number of moths trapped. The result of Multan, by combined regression of moths and fruit infestation during 2012 and 2013 ($y = -4.65 + 0.779X$) revealed that 19 moths caught in 15 days will result in a 10 percent fruit infestation, which is the ETL for BSFB (PW and QCP, 2014). At Sahiwal 10 moths caught in 15 days will result in 10



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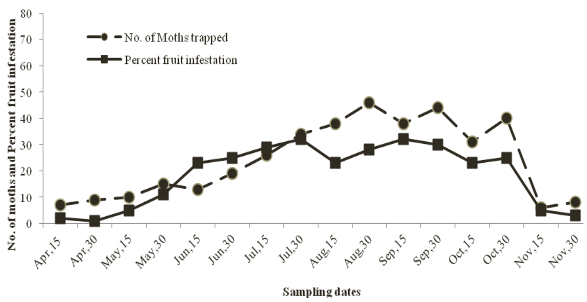

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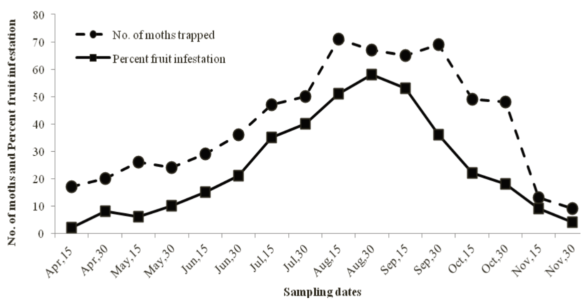

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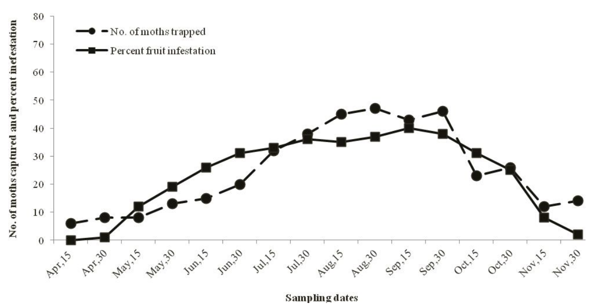

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Fig. 7. Number of brinjal shoot and fruit borer (*L. orbonalis*) moths in traps and brinjal (*S. melongena*) fruit infestation at Multan (A) and Sahiwal (B) during 2012 and at Multan (C) and Sahiwal (D) during 2013.

percent fruit infestation (y = 2.37 + 0.763X). If area wide application of results is desired, the area wide ETL can be obtained by combining the results for both location and years, which results in 13 moths per trap per 15 days (y = 0.56 + 0.716X). The results of our study can help to decide the appropriate time to initiate management practices against BSFB infestation in brinjal fields.

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