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Optimizing Transplanting Dates for the Management of Brinjal Shoot and Fruit Borer and Better Crop Yield under Field Conditions

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ABSTRACT

Brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) causes severe crop yield losses. Utilization of the ecological approach through different sowing times might provide its long-term control and safety to the environment. In the present study, effect of four sowing dates was evaluated on the infestation of *L. orbonalis* on brinjal at two locations in the Pothwar region of Pakistan. The study revealed that sowing dates influenced infestation by brinjal shoot and fruit borer. Shoot infestation significantly varied on brinjal at both locations sown at different dates. The maximum average shoot infestation of 9.7% was observed on late sown crop (10th of April) while the minimum average shoot infestation (8.9%) was recoded on crop sown on 20th of March. Square infestation on brinjal plants sown at different times was at par at both the locations and was found slightly higher at farmer field. The maximum average fruit infestation (52.8 %) was observed at URF Koont on early sown crop (1st of March) while the minimum (46.3 %) was observed on crop sown on 20th of March. At Rawat, the maximum mature infestation (54.5%) was observed on late sown crop (30th of April) while the minimum mature fruit infestation (47.8%) was recorded on crop sown at 20th of March. Similarly, the percentage of damaged fruit was higher (54.1%) on crop sown at 30th of April at Rawat while the minimum damage of 49.6% was observed on the crop sown on 20th of March. At URF Koont, the percentage of damaged fruit was statistically at par among all the four treatments. Yield losses were statistically at par at URF Koont ranging from 24.6% to 25% in all the treatments. However, the minimum yield loss of 22% was recorded on crop sown at 20th of March. At URF Koont, the maximum yield loss of 17% was recorded on early sown crop (1st of March) while the minimum yield loss of 13.1% was observed on crop sown at 20th of March. It is therefore, concluded that change in sowing dates can reduce the pest infestation and result in the enhancement of yield.

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Authors' Contribution
WM and HJ designed the study, executed experimental work, analyzed the data and prepared the manuscript. TM and MA supervised the experimental work, analyzed the data and edited the manuscript.

Key words
Leucinodes orbonalis, sowing time, crop yield, fruit infestation, eggplant

INTRODUCTION

In Pakistan, brinjal is cultivated over 8,368 hectares with an average production of 83,832 tons including 4,460 hectares from Punjab with 54,223 tons production (GOP, 2017). Its year-round production results into pest problems from nursery to harvesting. Brinjal shoot and fruit borer (*Leucinodes orbonalis*) is considered as the most devastating insect pest of brinjal crop and damages almost all plant parts especially fruiting parts (Mall *et al*., 1992; Rajiv, 2018; Aslam *et al*., 2019a). Its damage may reach up to 78% on shoots and 66% in fruits (Singh and Singh, 2000) with total yield losses to the tune of 70-90% (Reddy and Srinivasa, 2004).

Almost all the available insecticides have been used for its control (Khaire *et al*., 1986; Ogah, 2011) which have negative impacts on environment and human health. This accentuates the need for alternate methods including cultural control, crop rotation, biological control, resistant varieties and alteration of sowing time (Kuppuswamy and Balasubramanian, 1980; Aslam *et al*., 2019b; Javed *et al*., 2019a, b; Mukhtar and Kayani, 2019).

Synchronization of sowing time may be helpful for getting higher yields and reduction in pest populations as change in sowing and plantation time helped avoiding the oviposition of certain pests and attack of migrants (Hill, 1990). This change was also found helpful in reducing pest attack and resulted in proliferation of their natural enemies. A reduction in aphid population in cowpea fields was reported by changing sowing time and using the clean seed. In Uganda, IPM practices performed more efficiently when combined with proper sowing time and maintaining plant population. Adjustment in planting time helped in escaping vulnerable stages of plant before pest infestation

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(Adipala *et al*., 2000; Karungi *et al*., 2000; Barzman *et al*., 2015; Vetek *et al*., 2017; Surendra, 2019). Pests having specific season pattern can easily be controlled by adjusting sowing time. This method is helpful for those pests which bore into the plant tissue and are difficult to control with the application of insecticides or biocontrol agents (Swezey *et al*., 2007; Stoleru and Sellitto, 2016). Better pest management can be achieved by integrating "alteration in sowing times" tactic with other control strategies rather than a single management approach (Adipala *et al*., 2000). Saeed and Razaq (2014) reported that change in sowing time was not helpful on the onset of pest incidence in canola crop but early sown crop was less infected with aphid as compared with late-sown crops resulting in to higher yield in early sown crop. Studies have also shown that modification of management practices like change in sowing time, plant population, dose of fertilizer and other inputs and crop rotation affected infestation of insect pests. These changes are helping in fine tuning the system, which can be used for better pest management (Lamine, 2011). In another study, Verma (2019) reported that rice borer attack was minimized by early transplantation of rice nursery in fields and the same practice was adopted by cotton growers to reduce the attack of pink bollworm. On the other hand, late sown maize suffered less from losses by borers. Similarly, Kalyan and Ameta (2017) found that early sown soybean faced higher pest attack of whitefly and soybean girdle beetle as compared with the late sown crop while incidence of *Spodoptera litura* and *Helicoverpa armigera* was significantly less in early sown crop. This revealed that alteration in sowing time can be evaluated for the management of brinjal shoot and fruit borer.

Keeping the foregoing in view, the present studies were conducted to optimize sowing time of brinjal crop at two locations of Pothwar region of Pakistan for the better management of brinjal shoot and fruit borer in the area.

MATERIALS AND METHODS

The study was conducted in the field during the Kharif cropping season of 2018 at two locations in the Pothwar region of Pakistan i.e. University Research Farm (URF), Koont and a farmer field in Rawat, Rawalpindi. The nursery of brinjal cv. Nirala was raised in the green house in germination trays. The nursery was transplanted on different dates with 20 days interval. The treatments were as followed: T_1, 1st of March; T_2, 20th of March; T_3, 10th of April and T_4, 30th of April in.

Each treatment was replicated four times with 50 healthy plants in each replication maintaining plant to plant and row to row distances of 45 cm and 75 cm respectively. Randomized Complete Block Design was followed at both the locations. Meteorological data were collected from Pakistan Meteorological Department, Islamabad for calculation of correlation between climatic factors and pest population.

Data were recorded regarding plant height, number of total shoots, squares, flowers, immature and mature fruits at weekly intervals from 24th of April to 30th of September. For this purpose, ten plants were randomly selected from each replication and were examined thoroughly. Percentage shoot, squares, flowers and fruit infestation was calculated after counting the damaged parts using the formula given below

$$\text{Percent damaged parts} = \frac{\text{Number of damaged parts}}{\text{Total number of parts observed}} \times 100$$

For yield estimation, mature fruit from ten randomly selected plants were collected and weighed on electronic balance in the laboratory after separating the healthy and damaged fruits individually. The yield of ten plants and percent yield loss by brinjal shoot and fruit borer was estimated through following calculations.

Yield of 10 plants (kg) = (Average number of mature fruits/plant × Average healthy fruit weight (grams) × 23 × 10) / 1000

$$\text{Percent yield loss} = \frac{\text{Average damaged fruit yield}}{\text{Average total mature fruit yield}} \times 100$$

Statistical analysis

Analysis of variance regarding pest infestation and yield parameters was carried out using Statistix 8.1 package (Analytical Software, 2005). Means were separated using LSD test at 5% probability level. Percent infestation by brinjal fruit and shoot borer was correlated with environmental factors i.e. temperature (°C), relative humidity (%) and rainfall (mm).

RESULTS

Seasonal pest infestation

The observations during twenty three weeks of fruiting period for infestation caused by brinjal shoot and fruit borer recorded at two locations showed that pest infestation started in the 1st week of June at farmer field, Rawat and in the 2nd week of June at URF Koont when average temperature was 29.36°C and relative humidity was 32.62% (Fig. 1). Pest infestation was found at its peak in the last week of July till last week of August. Maximum infested fruits (2.28/plant) were observed during the last week of July at URF Koont and 3.18/plant were observed during the 2nd week of August at the farmer field. The extent of fruit infestation reduced with the reduction of fruiting capacity of the crop.

Table I. Correlation coefficient (r) of *L. orbonalis* infestation (%) on different plant parts of brinjal with abiotic factors at two locations (Lower case for P- values).

Location	URF Koont			Farmer field Rawat		
Parameter	**Av. Temp. (°C)**	**R.H. (%)**	**R. F. (mm)**	**Av. Temp. (°C)**	**R.H. (%)**	**R. F. (mm)**
Square infestation (%)	0.499 (0.015)	-0.440 (0.035)	-0.201 (0.357)	0.220 (0.311)	-0.217 (0.319)	-0.142 (0.517)
Shoot infestation (%)	0.470 (0.023)	0.410 (0.051)	0.135 (0.537)	0.364 (0.087)	0.746 (0.000)	0.360 (0.090)
Flower infestation (%)	0.665 (0.000)	-0.480 (0.020)	-0.189 (0.385)	0.299 (0.165)	-0.489 (0.017)	-0.267 (0.217)
Immature fruit infestation (%)	0.405 (0.055)	0.580 (0.003)	0.211 (0.333)	0.411 (0.050)	0.582 (0.003)	0.147 (0.501)
Mature fruit infestation (%)	0.176 (0.420)	0.628 (0.001)	0.289 (0.180)	0.206 (0.345)	0.702 (0.000)	0.264 (0.222)

Av. Temp., average temperature; R.H., relative humidity; R.F., rain fall

Table II. Effect of sowing dates on % infestation of square, flower, shoot and fruit by *Leucinodes orbonalis* (Guenee) on two locations.

Location	Parameters	1st of March	20th of March	10th of April	30th of April	LSD
URF Koont	Plant height (cm)	34.4±0.20 a	33.0±0.14 b	30.4±0.23 c	28.9±0.26 d	0.44
	Shoot infestation (%)	9.0±0.09 ab	8.9±0.29 b	9.7± 0.27a	9.0±0.26 ab	0.85
	Square infestation (%)	1.1±0.22 a	1.2±0.51 a	1.6±0.27 a	1.4±0.54 a	0.76
	Flower infestation (%)	1.6±0.49 a	1.4±0.48 a	1.7±0.50 a	1.7±0.43 a	1.05
	Immature fruit infestation (%)	55.1±0.99 a	48.2±1.32 c	51.7±0.77 b	52.6±0.32 ab	2.72
	Mature fruit infestation (%)	52.8±3.26 a	46.3±1.20 a	50.7±1.41 a	51.9±2.17 a	7.3
	Weight loss (%)	47.1±0.98 a	47.5±1.16 a	48.6±0.56 a	47.4±1.06 a	1.82
Farmer field Rawat	Plant height (cm)	45.4±0.26 a	44.5±0.22 b	37.6±10 c	34.9±0.11 d	0.47
	Shoot infestation (%)	13.9±0.21 b	13.7±0.14 b	15.6±0.23 a	16.3±0.25 a	0.66
	Square infestation (%)	1.5±0.19 a	1.2±0.08 b	1.3±0.16ab	1.2±0.15 b	0.24
	Flower infestation (%)	1.2±0.17 a	1.2±0.14 a	1.0±0.19 a	1.2±0.43 a	0.62
	Immature fruit infestation (%)	57.1±0.52 a	51.1±1.06 b	53.6±0.94 ab	53.5±1.33 ab	3.64
	Mature fruit infestation (%)	52.9±0.56 a	47.8±2.20 b	52.7±0.73 a	54.5±0.90a	4.21
	Weight loss (%)	50.9±2.22 ab	49.6±0.78 b	53.2±0.87 ab	54.1±1.41 a	4.41

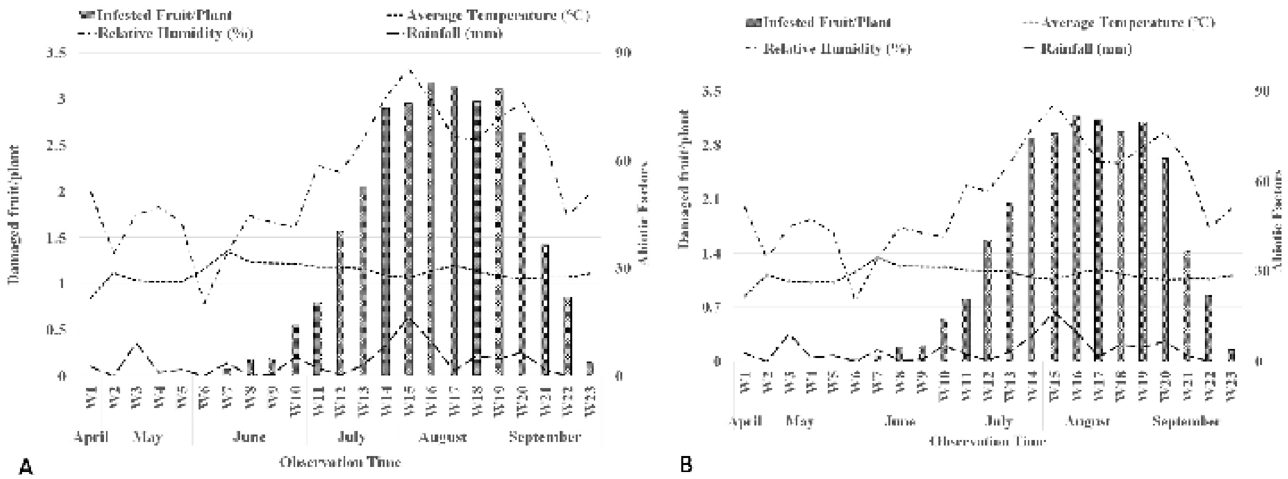

Fig. 1. Influence of abiotic factors on the incidence of shoot and fruit borer on mature fruits during Kharif 2018 at Rawat, Rawalpindi (A) and at URF, Koont (B).

Correlation of climatic factors with % infestation caused by L. orbonalis

The coefficient of correlation (r) of climatic factors with different parameters observed during this study at two locations is given in Table I. Average temperature had positive correlation with square infestation, shoot infestation, flower infestation, immature and mature fruit infestation at URF Koont and farmer field Rawat. Per cent relative humidity had negative correlation with square and flower infestation but positive correlation with shoot, immature and mature fruit infestation both at URF Koont and farmer field Rawat. Rainfall also had negative correlation with square and flower infestation but positive correlation with shoot, immature and mature fruit infestations at URF Koont and farmer field Rawat (Table I).

Effect of sowing time on % infestation of different plant parts

The study revealed that sowing time influenced infestation by brinjal shoot and fruit borer. Plant height was significantly higher at both locations when the crop was sown at 1st of March 2018 followed by the crop sown at 20th of March (Table II). Shoot infestation significantly varied on brinjal crop at both locations sown at different time intervals. The maximum average shoot infestation of 9.7% was observed on late sown crop (10th of April) while the minimum average shoot infestation (8.9%) was recoded on crop sown on 20th of March. Square infestation on brinjal plants sown at different times was at par at both the locaions but was found slightly higher at Rawat field. No special pattern was recorded in square and flower infestation for all the treatments on both locations. Average infestation of immature fruit was greatly influenced by the change in sowing time and significant results were observed. The maximum immature fruit infestation of 55.1% and 57.1% was observed at URF Koont and Rawat respectively on the early sown (1st of March) brinjal crop. Mature fruit infestation was non-significant at URF Koont but significant at farmer field Rawat. Maximum average fruit infestation (52.8 %) was observed at URF Koont on early sown crop (1st of March) while the minimum (46.3 %) was observed on crop sown on 20th of March. At Rawat, the maximum mature infestation (54.5%) was observed on late sown crop (30th of April) while the minimum mature fruit infestation (47.8%) was recorded on crop sown at 20th of March. Similarly, the percentage of damaged fruit was higher (54.1%) on crop sown at 30th of April at Rawat while the minimum damage of 49.6% was observed on the crop sown on 20th of March. At URF Koont, the percentage of damaged fruit was statistically at par among all the four treatments (Table II).

Crop yield and yield loss

The comparison of harvestable yield of brinjal crop in the present study sown at different times and per cent yield loss resulted from *L. orbonalis* infestation is given in Figure 2. Yield losses were statistically at par at URF Koont ranging from 24.6% to 25% in all the treatments. However, the minimum yield loss of 22% was recorded on crop sown at 20th of March. At URF Koont, the maximum yield loss of 17% was recorded on early sown crop (1st of March) while the minimum yield loss of 13.1% was observed on crop sown at 20th of March. The harvestable yield/10 plants (kg) was significantly different at both the locations with maximum yield of 38.6 kg and 17.0 kg/10 plants during the whole cropping season on the crop sown at 20th of March at Rawat and URF Koont respectively. The minimum yield (27.1 kg/10 plants/season) was observed on the crop sown on 30th of April in Rawat while it was the minimum (13.1 kg) on the crop sown on 1st of March at URF Koont (Fig. 3).

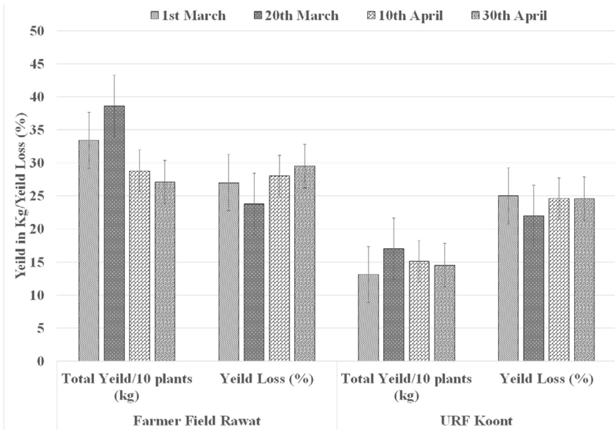

Fig. 2. Influence of sowing dates on yield and yield loss of marketable brinjal fruit caused by *L. orbonalis* at two locations of Rawalpindi, Punjab.

DISCUSSION

Weather is an important factor for plant growth and incidence of pests and diseases. The developmental rhythms of plant growth are greatly influenced through climatic change ultimately affecting pest populations. Coincidence of plant growth stage or age with pest attack can be adjusted by altering the agronomic practices like sowing time for minimizing crop losses. The results of the present study regarding seasonal pest infestation were in supporting with the findings of Jat *et al*. (2002). They observed the first fruit damage during the 4th week of August at 29°C and peak fruit infestation was found during the last week of September when the relative humidity was 77%. The difference of time period is due to the shift of sowing season and the climatic conditions were almost same as have been observed in the present study. The studies of Naik *et al*. (2008) also reported the initiation of infestation after 6 weeks of transplantation and the maximum infestation was recorded on 10th week after transplantation as has been observed in the present findings during the last week of July. Singh and Singh (2000) reported a decline in fruit infestation in the month of October which also confirmed the present findings.

Pest incidence has been reported to be affected by weather conditions. In the present study, positive correlation of relative humidity and temperature was found with mature fruit infestation. Nandi *et al*. (2017) and Kumar *et al*. (2017) have also reported positive correlation of brinjal shoot and fruit infestation with temperature. They have also reported positive correlation between relative humidity and pest infestation on harvestable fruit while Yadav *et al*. (2015) reported a negative correlation which is only observed between flower and squares infestation in the present study. This variation may be due to the difference in crop stage or severity of the pest and the present findings supported the observations of Tripathy *et al*. (1997). According to their observation, borer infestation was the maximum in the first week of June when there was mean temperature of 27°C and relative humidity of 79%. Similar results were observed in our study during the 1st week of September when the mean temperature was 29.63°C and relative humidity was 65.33% and after that, the pest infestation decreased in a similar pattern revealing that pest is active during summer season after the onset of rain falls. Findings of Kumar *et al*. (2017) and Singla (2014) were in accordance with the results of the present study showing maximum infestation of about 86% in the third week of September as compared with 79% observed in the present study in the 1st week of September. Their findings also revealed that soot infestation started in earlier plant age and fruit infestation started at later stage and increased with time.

The findings of the present study are also supported by those of Mahesh and Men (2007) who reported that the maximum infestation was caused in rainy season (August-September) meaning that the fruit harvested before maximum infestation period may save the farmer from severe losses irrespective of sowing time. Gebregergis *et al*. (2018) also described the preference of pests for tender leaves and soft fruits which are mostly available on late sown crops. This point of view is highly supporting our findings that alteration in sowing time can increase or decrease the pest infestation and capital cost to control these pests according to the crop. The same concept of crop protection from invaders was given by Egonyu *et al*. (2009). Ara *et al*. (2007) reported that pest incidence on brinjal crop was most relative to new flush and fresh fruits which was also observed in our study that sowing time affected the availability of fresh flushes and fruit for pest infestation. In early sowing, pest infestation started early and declined with reduction in new flushes and fruiting while in late sowing, infestation started lately and continued to later stages as compared with early sowing.

Yield reduced on late sowing crop with 29% reduction due to pest infestation as compared with 23% reduction on early sown crop (Fig. 2). The findings are supported by those of Adipala *et al*. (2000) who reported that combination of agronomic practices and alteration of sowing time with IPM programs are helpful in the reduction of pest populations and increase in yield of crops. It is therefore, concluded from the present study that change in sowing dates can reduce the pest infestation and result in the enhancement of yield.

Statement of conflict of interest

The authors have declared no conflict of interest.

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