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Research Article

EVALUATION OF TOMATO VARIETIES AGAINST RESISTANCE TO FRUIT BORER (*Helicoverpa armigera hub*.)

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ABSTRACT

Sixteen tomato varieties were evaluated against fruit borer (*Helicoverpa armigera*) to find out borer resistant tomato varieties. The eight varieties were collected from Bangladesh Agricultural Research Institute (BARI) and eight varieties from the farmer's field of South-west Bangladesh. This field experiment was conducted in a protected net house suitable for inoculation of the fruit borer at germplasm center of Khulna University for two years (2018 and 2019). Data were collected on fruit physical characters, and borer infestation. The genotypes BARI Tomato-18, BARI Tomato-16, Ruma-VF, Pusa Ruby and Guli had the minimum weight of infested fruit (3.57%, 3.63%, 4.83%, 7.17% and 7.67%, respectively) as well as the minimum number of infested fruits (both were bellow10%) with the minimum number of larvae of *H. armigera* (0.23, 0.28, 0.27, 0.54 and 0.60 larvae plant^{-1}, respectively). BARI Tomato-8, BARI Tomato-17 and Paltola were found as more susceptible (29.71%, 26.01% and 28.95% infestation, respectively) than the others. Maximum fruit weight plant^{-1} was recorded from the genotypes BARI Tomato-18, BARI Tomato-19, Surakha and Paltola (2603g, 2687g, 2755g and 2731g respectively) and among these BARI Tomato-18 and Suraksa gave maximum fresh yield plant^{-1} (2512.77 g and 2476.53 g, respectively). The fruit infestation rate was significantly and positively correlated with fruit weight loss plant^{-1} (r = 0.971), larvae plant^{-1} (r = 0.789), fruit diameter (r = 0.567) and individual fruit weight (r = 0.545). On the other hand, the fruit shape index (r = -0.44) and the number of fruit plant^{-1} (r = -0.498) were significant and negatively correlated with fruit infestation rate. It could be concluded that BARI Tomato-18 and BARI Tomato-16 are resistant as well as high yielding varieties.

Keywords: Fruit borer, Resistant, Susceptible, Tomato varieties

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the important and remunerative vegetable crops, which is grown everywhere in the world belongs to the family Solanaceae. Bangladesh has an average yield of 13.68 t ha^{-1} and area covered was about 28130 ha (FAOSTAT, 2018). It is a rich source of vitamins, minerals and lycopene. The lycopene is a phytochemical that protects us from cancer (Mutanen et al., 2011). Tomato plants are attacked by various insects-pests however, fruit borer (*Helicoverpa armigera.* Hub) is the most serious one. Fruit borer larvae perforate the fruit and eats up the inner portion of the fruit. It is responsible for significant yield loss of up to 55% (Talekar et al., 2006) and up to 46.8% in Bangladesh (Alam et al., 2007). Fruit borer damaged crop is estimated about 5 billion US dollar $year^{-1}$ in the world (Sharma, 2001). It is a very hazardous pest, but the borer control operation mainly depends on chemicals which is harmful to human health. In Bangladesh tomato is grown both in summer and winter season but winter is the major tomato growing season and early November is the best time for tomato planting (Hossain et al., 1986). The average winter temperatures are around 13.9-26.5^{0}C, rainfall 44mm and humidity 73 % (BBS 2018). Tripathi and Sharma (1985) noted that temperature of 12-21^{0}C is most favorable for *H. armigera* development. Due to environmental and health problems caused by pesticides (Ignacimuthu, 2007), alternative control measures that are eco-friendly and economically acceptable, should be focused. For that reason, the entomologists gave great importance to IPM (integrated pest management) program. Among the steps of IPM, usage of resistant varieties is the premier (Khanam et al., 2003).

The *Lycopersicon spp*. expresses resistance approximately 19 arthropod pest species of tomato (Kennedy, 2003). Sticky and toxic chemicals are released by glandular trichomes on tomato leaves result mortality of the larvae (Srinivasan and Uthamasamy, 2005). Trichome density and leaf pubescence could be a physical barrier to natural movement and development of the fruit borer (Selvanarayanan and Narayanasamy, 2006a). It is very essential to cultivate a resistant and tolerant cultivar against insect-pests especially tomato fruit borer. Therefore, it is necessary to find out borer resistant tomato varieties to avoid the use of insecticides. Therefore, this research was carried out to screen out sixteen tomato genotypes showing resistant and susceptible responses to the fruit borer, and to identify the fruit morphological characteristics influencing the infestation rate of tomato fruit borer.

MATERIALS AND METHODS

The experiment was conducted in the field of germplasm centre of Khulna University during the winter season from October 2017 to March 2018 in 1st year and October 2018 to March 2019 in the 2nd year. The average winter temperatures in 1st year was around 13.9-26.5^{0}C, rainfall 44mm and humidity 73 % (BBS 2018) and in 2nd year, temperature 9.9-30.7^{0}C, rainfall 58mm and humidity 75 % (BBS 2019).

Plant materials

Sixteen tomato varieties, including 8 improved varieties viz; BARI Tomato-2, BARI Tomato-8, BARI Tomato-14, BARI Tomato-15, BARI Tomato-16, BARI Tomato-17, BARI Tomato-18 and BARI Tomato-19 developed by Bangladesh Agricultural Research Institute (BARI) and 8 available genotypes collected from the farmers in South-west Bangladesh, viz; Bonkim Ruby, Pusa Ruby, Suraksa, Patharkuchi, Ruma VF, Ruma 19, Guli and Paltola were evaluated on their performance against tomato fruit borer.

Experimental Design

The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. Total numbers of plots were 48 and plot size was 2.25 m x 1.8 m consist of 15 tomato plants with spacing 45 cm X 60 cm. The experimental field was covered by the mosquito nets with the help of bamboo so the plant was protected from other insect-pests except the fruit borer because the fruit borer was artificially inoculated in the net house thus the crop was completely free from insecticidal application. Normal agronomic practices such as ploughing, manuring, irrigation and staking were conducted uniformly.

Data Collections

The twenty randomly picked fruits from each replication of each variety were harvested and measured for length and diameter with the help of digital slide caliper. Then the average was taken in mm. The fruit shape index was recorded on the basis of the ratio of their respective fruit length and fruit diameter. The average number of fruits was recorded by counting the fruits of sample plants. The weight of thirty randomly picked fruits from each replication of each variety was measured and then the average was taken as individual fruit weight. Fruit yield (fresh and damaged) of eight randomly selected plants of each variety from the three replications recorded at each picking were cumulated and the average yield plant^{-1} was worked out. Similarly, the fresh fruit was weighed and weight of fresh fruit per plant was calculated. The total number of fresh fruits and infested fruits of each variety were counted at each harvesting stage. Fruits were considered as fresh and infested based on fruit borer infestation. The number of larvae plant^{-1} was recorded by randomly selecting eight plants per variety in each plot. Data were recorded weekly till the infestation of fruit borer was over and the mean was calculated. %age of fruit infestation was calculated on weight and number basis. A rating system for fruit damage developed by Kashyap and Verma (1987) was followed for estimating resistance and susceptibility of selected tomato varieties.

Statistical analysis

The data were statistically analyzed for ANOVA using STAR package computer program. Significance of differences among the treatment means was evaluated by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The sixteen tomato varieties were significantly differed from each other in respect of fruit characters and fruit borer infestation.

Fruit length (mm)

The highest average fruit length (60.58 mm) was recorded in BARI Tomato-15 followed by BARI Tomato-17 (52.00 mm) while the minimum fruit length of 29.83h mm was recorded in Ruma 19 and it was statistically at par with Guli (31.13mm). Fruit length was positively non-significant co-related with fruit infestation (in 1st year r=0.214 and in 2nd year r=0.166) (Table 1). On the contrary, infestation rate decreased with increasing fruit length (Daboul et al., 2011; Thakur et al., 2017).

Table 1. Fruit length fruit diameter and fruit shape index of different tomato varieties in relation to the infestation of fruit borer

Variety	Fruit length (mm)			Fruit diameter (mm)			Fruit shape index		
	1st Year	2nd Year	Average	1st Year	2nd Year	Average	1st Year	2nd Year	Average
BARI Tomato-2	43.67^{de}	36.00^{g}	39.83^{e}	49.67^{b-d}	35.48^{f-h}	42.57^{cd}	0.89^{b-d}	1.02^{bc}	0.96^{cd}
BARI Tomato-8	50.00^{bc}	39.83^{d-f}	44.92^{d}	48.67^{b-d}	38.67^{d-f}	43.67^{cd}	0.73^{d}	0.78^{f}	0.75^{f}
BARI Tomato-14	65.67^{a}	55.50^{a}	60.58^{a}	55.00^{b}	45.33^{bc}	50.17^{b}	1.03^{a-c}	1.03^{bc}	1.03^{bc}
BARI Tomato-15	38.33^{ef}	35.90^{g}	37.12^{e}	52.33^{bc}	46.00^{b}	49.17^{b}	1.20^{a}	1.23^{a}	1.21^{a}
BARI Tomato-16	52.00^{bc}	43.33^{cd}	47.67^{cd}	43.33^{de}	35.33^{f-h}	39.33^{de}	1.20^{a}	1.23^{a}	1.21^{a}
BARI Tomato-17	55.67^{b}	48.33^{b}	52.00^{b}	72.67^{a}	62.67^{a}	67.67^{a}	0.76^{d}	0.77^{f}	0.77^{ef}
BARI Tomato-18	50.67^{bc}	43.83^{cd}	47.25^{cd}	44.00^{de}	38.67^{d-f}	41.33^{c-e}	1.17^{a}	1.13^{b}	1.14^{ab}
BARI Tomato-19	53.00^{bc}	45.82^{bc}	49.41^{bc}	41.67^{de}	36.88^{e-g}	39.27^{de}	1.27^{a}	1.24^{a}	1.26^{a}
Bonkim Ruby	43.67^{de}	37.67^{e-g}	40.67^{e}	54.33^{bc}	44.67^{bc}	49.50^{b}	0.80c^{d}	0.84^{ef}	0.82^{ef}
Pusa Ruby	41.33^{ef}	36.33^{fg}	38.83^{e}	45.33^{cd}	38.33^{d-g}	41.83^{d}	0.91^{b-d}	0.95^{cd}	0.92^{cd}
Suraksa	40.33^{ef}	37.33^{e-g}	38.83^{e}	47.00^{b-d}	41.67^{cd}	44.33^{c}	0.86^{b-d}	0.89^{de}	0.88^{d-f}
Patharkuchi	38.33^{ef}	36.33^{fg}	37.67^{e}	37.33^{ef}	34.33^{gh}	35.83^{fg}	1.05^{ab}	1.05^{bc}	1.05^{ab}
Ruma VF	41.00^{ef}	38.67^{e-g}	39.83^{e}	32.67^{f}	31.67^{i}	32.17^{g}	1.26^{a}	1.22^{a}	1.24^{a}
Ruma-19	29.33^{g}	30.33^{h}	29.83^{f}	32.33^{f}	34.67^{gh}	33.50^{fg}	0.91^{b-d}	0.87^{de}	0.89^{de}
Guli	35.67^{f}	28.00^{h}	31.83^{f}	42.67^{de}	31.67^{i}	37.17^{ef}	0.84^{b-d}	0.88^{de}	0.86^{d-f}
Paltola	48.67^{cd}	40.33^{de}	44.50^{d}	46.67^{cd}	39.67^{de}	43.17^{cd}	1.04^{a-c}	1.02^{bc}	1.03^{bc}
Treatment mean	45.50	39.54	42.52	46.79	39.54	43.16	0.9923	1.02	1.00
LSD (p≤0.01)	5.84	3.80	2.97	8.11	3.82	4.79	0.2481	0.080	0.1360
Co-relation with fruit infestation rate									
(r- Value)	0.203^{ns}	0.166^{ns}	0.1783^{ns}	0.5170**	0.5685**	0.5674**	- 0.381**	-0.439**	-0.4402**

Means in the same column followed by same letter(s) did not differ significantly at p<0.01 by DMRT and LSD=Least Significant Difference

Fruit diameter (mm)

The maximum fruit diameter was found in BARI Tomato-17 (67.67 mm), followed by BARI Tomato-14 (50.17 mm) and the minimum fruit diameter was recorded in Ruma-VF (32.17 mm). There was a positive and significant correlation between fruit

diameter and per cent fruit infestation rate at 1st year, 2nd year and average of two years (0.5069, 0.4889 and 0.5274 respectively) (Table 1). The results are in conformity with findings of Amutha and Manisegaran, (2005), Rath and Tripathy (2006), Daboul et al. (2011), Ambule et al. (2015), who also reported that increased diameter provide higher infestation. Fruit diameter may help the borer to stay on the fruit.

Fruit shape index

In case of the average of two years, the fruits of BARI Tomato-19 had the highest fruit shape index (1.26), which was statistically at par with Ruma-VF (1.24), BARI Tomato-15 (1.21) and BARI Tomato-16 (1.21). The fruits of BARI Tomato-8 recorded the lowest fruit shape index (0.75). In the present study, significantly negative correlation was found between fruit shape and fruit infestation for both the years (r= -0.38 and -0.43, respectively) (Table 1). This is in conformity with findings of Thakur et al. (2017) and Sharma et al. (1985), who reported round shaped varieties are more susceptible than lengthen variety. The varieties with lower fruit shape index like BARI Tomato-8 and BARI Tomato-17 being more susceptible to fruit borer infestation on the other hand, BARI Tomato-19 with higher fruit shape index was resistant.

Number of fruits plant^{-1}

In case of an average of the two years, the maximum amount of fruit plant^{-1} was found in Suraksa (53.94) and Guli (51.09). The minimum number of fruit plant^{-1} was found in BARI Tomato-17 both in the first (14.61) and second (9.6) year and an average of the two years (12.11). The number of fruits plant^{-1} was significantly and negatively correlated with the infestation rate (r=-0.4985) (Table 2). This finding is in a line with findings of Khanam et al. (2003) and Ambule et al. (2015). Between the two years, the number of fruit plant^{-1} was comparatively higher in 1st year than that was in the 2nd year.

Table 2. Number of fruit plant^{-1} and individual fruit weight of different tomato varieties in relation to the infestation of fruit borer

Variety	Number of fruit plant^{-1}			Individual fruit weight (g)		
	1st Year	2nd Year	Average	1st Year	2nd Year	Average
BARI Tomato-2	32.40^{g}	24.97^{i}	28.68^{g}	66.77^{de}	42.23^{f-h}	54.50^{e-ge}
BARI Tomato-8	36.61^{fg}	28.48^{g-i}	32.54^{f}	81.00^{c}	50.43^{c-f}	65.72^{c}
BARI Tomato-14	24.99^{h}	25.90^{hi}	25.45^{g}	103.67^{b}	78.13^{b}	90.90^{b}
BARI Tomato-15	46.25^{b-d}	37.17^{b-e}	41.71^{d}	63.47^{ef}	51.43^{cd}	57.45^{d-f}
BARI Tomato-16	49.62^{bc}	42.47^{ab}	46.05^{b}	61.63^{ef}	47.73^{c-f}	54.68^{e-g}
BARI Tomato-17	14.61^{i}	9.63^{j}	12.11^{h}	129.31^{a}	92.27^{a}	110.79^{a}
BARI Tomato-18	44.65^{c-e}	42.10^{a-c}	43.38^{b-d}	66.50^{de}	53.27^{cd}	59.88^{c-e}
BARI Tomato-19	51.97^{b}	37.87^{b-e}	44.92^{b-d}	62.97^{ef}	55.63^{c}	59.30^{c-e}
Bonkim Ruby	39.78^{ef}	29.60^{f-i}	34.69^{ef}	72.70^{cd}	49.57^{c-f}	61.13^{c-e}
Pusa Ruby	51.85^{b}	35.13^{d-g}	43.49^{b-d}	59.83^{ef}	43.10^{e-g}	51.47^{fg}
Suraksa	59.41^{a}	48.48^{a}	53.94^{a}	54.63^{fg}	46.80^{d-f}	50.72^{g}
Patharkuchi	40.95^{d-f}	32.37^{e-g}	36.84^{e}	46.43^{gh}	34.83^{hi}	40.63^{h}
Ruma VF	37.09^{fg}	35.43^{c-f}	36.26^{e}	39.60^{h}	38.07^{g-i}	38.83^{h}
Ruma 19	58.93^{a}	32.50^{e-h}	45.71^{bc}	28.20^{i}	32.33^{i}	30.27^{i}
Guli	61.85^{a}	40.33^{b-d}	51.09^{a}	43.40^{h}	31.17^{i}	37.28^{h}
Paltola	51.33^{b}	33.17^{e-g}	42.25^{cd}	73.63^{cd}	50.80^{c-e}	62.22^{cd}
Treatment mean	43.89	33.49	38.69	65.86	49.86	57.85
LSD ($p \leq 0.01$)	6.41	6.67	3.53	9.17	8.25	6.71
Co-relation with fruit infestation rate						
r- Value	-0.3996**	-0.602**	-0.4985**	0.5968**	0.4357**	0.5450**

Means in the same column followed by same letter(s) did not differ significantly at $p<0.01$ by DMRT and LSD=Least Significant Difference

Individual fruit weight

The highest individual fruit weight was found in BARI Tomato-17 in both the years as well as in the average (129.31g, 92.27g and 110.79g respectively) and the variety Ruma-19 showed significant minimum fruit weight (28.20g, 32.33g and 30.27g respectively) for 1st year, 2nd year and average. There was positive and significant correlation between individual fruit weight and % fruit infestation rate in the1st year, 2nd year and an average (0.59680, 0.4357 and 0.5450, respectively) (Table 2). Daboul et al. (2011) observed a negative correlation between fruit weight and infestation rate that is opposed to the present result.

Total fruits weight plant^{-1}

The maximum weight of fruit plant^{-1} (3777 g) was observed in Paltola followed by the BARI Tomato-19 (3270 g) and Suraksa (3243 g) whereas the minimum weight of fruit plant^{-1} was found in Ruma VF (1466 g) during the 1st year. During the 2nd year, the maximum weight of fruit plant^{-1} was found in Suraksa (2268 g) that was statistically similar to BARI Tomato-18 (2241 g) and the minimum in BARI Tomato-17 (885 g). The two years average, weight of fruit plant^{-1} was significantly higher for genotype Suraksa, Paltola and BARI Tomato-19 (2755 g, and 2731 g and

2687 g, respectively) these were statistically identical and lower for Ruma-19 (1356 g). The average yield of Tomato was comparatively higher in 1st year (2659 g plant^{-1}) than that of 2nd year (1588 g plant^{-1}) (Table 3). Variation of weight of fruit plant^{-1} was generally marked among tomato genotypes as reported earlier by Ahmad et al., 2007 and Usman et al. 2013 as influenced by biotic and abiotic factors.

Table 3. Total fruit weight plant^{-1} and Fresh fruit weight plant^{-1} of different tomato varieties in relation to the infestation of fruit borer

Variety	Total fruit weight plant^{-1}			Fresh fruit weight plant^{-1}		
	1st Year	2nd Year	Average	1st Year	2nd Year	Average
BARI Tomato-2	2161^{e}	1054^{fg}	1608^{f}	1928.0^{e-g}	887.19^{fg}	1407.65^{gh}
BARI Tomato-8	2966^{b-d}	1440^{d-f}	2203de	2330.6^{c-e}	1070.67^{e-g}	1701.00^{fg}
BARI Tomato-14	2587^{d}	202^{ab}	2304^{cd}	2107.0^{d-f}	1686.0^{bc}	1896.33^{d-f}
BARI Tomato-15	2929^{b-d}	1910^{a-c}	2419^{b-d}	2347.33^{c-d}	1554.67^{b-d}	1951.00^{d-f}
BARI Tomato-16	3057^{b-c}	2029^{ab}	2543^{a-c}	2967.25^{ab}	1938.61^{ab}	2452.94^{ab}
BARI Tomato-17	1890^{ef}	885^{g}	1388^{f}	1561.51^{gh}	662.52^{g}	1112.02^{h}
BARI Tomato-18	2965^{bd}	2241^{a}	2603^{ab}	2876.44^{ab}	2149.09^{a}	2512.77^{a}
BARI Tomato-19	3270^{b}	2105^{ab}	2687^{a}	2993.33^{a}	1854.19^{ab}	2423.70^{ab}
Bonkim Ruby	2891^{b-d}	1469^{d-f}	2180de	2650.07^{a-c}	1299.46^{c-f}	1974.77^{d-f}
Pusa Ruby	3092^{bc}	1515^{c-e}	2304^{cd}	2907.77^{ab}	1392.41^{c-e}	2150.0^{b-d}
Suraksa	3243^{b}	2268^{a}	2755^{a}	2962.50^{ab}	1990.56^{ab}	2476.53^{a}
Patharkuchi	1901^{ef}	1139^{e-g}	1520^{f}	1739.74^{f-h}	1016.44^{e-g}	1377.67^{h}
Ruma VF	1466^{g}	1350^{d-f}	1408^{f}	1406.26^{h}	1275.86^{c-f}	1341.06^{h}
Ruma 19	1662^{fg}	1050^{fg}	1356^{f}	1494.50^{g-h}	897.03^{f-g}	1195.77^{h}
Guli	2682^{cd}	1256^{d-g}	1969^{e}	2495.62^{b-d}	1153.31^{d-f}	1824.33^{ef}
Paltola	3777^{a}	1685^{b-d}	2731^{a}	3057.67^{a}	1175.00^{d-f}	2116.67^{c-e}
Treatment mean	2659	1588	2124	2364.12	1375.21	1869.65
LSD ($p \leq 0.01$)	417	431	264	496	450	319
Co-relation with fruit infestation rate						
r-Value	0.1731ns	-0.289*	-0.010ns	-0.124ns	-0.532**	-0.3207*

Means in the same column followed by same letter(s) did not differ significantly at $p<0.01$ by DMRT and LSD=Least Significant Difference

Fresh fruit weight plant^{-1}

Fresh fruit means the fruit are not infested by fruit borer, the fresh fruit were separated and weighted. In 1st year, the variety Paltola, BARI Tomato-19, BARI Tomato-16, Suraksa and Pusha Ruby gave the significantly higher fresh fruit weight of 3057.67 g plant^{-1}, 2993.33 g plant^{-1}, 2967.2 g plant^{-1}, 2962.50 g plant^{-1} and 2907.77 g plant^{-1} respectively, while Ruma VF gave significantly lower fresh fruit yield plant^{-1} of 1406.26 g plant^{-1}. In the 2nd year, significantly higher fresh yield was obtained from the genotype BARI Tomato-18, BARI Tomato-16, BARI Tomato-19 and Suraksa (2149.09 g plant^{-1}, 1938.61 g plant^{-1}, 1854.19 g plant^{-1} and 1990.56 g plant^{-1} respectively), whereas lower was observed in genotype BARI Tomato-17 662.52 g plant^{-1}. The mean fresh yield for the two years was significantly higher for genotype BARI Tomato-18 (2512.77 g plant^{-1}) and Suraksa (2476.53 g plant^{-1}) and lower for BARI Tomato-17 (1112.02 g plant^{-1}) (Table 3). The observed variation in fresh yield among the tested

variety, may be due to the response of their genotypes to tomato fruit borer attack. Fresh yield was negatively correlated with fruit infestation in both 1st and 2nd year (r = -0.124ns and -0.532, respectively) that means the genotypes with lower infestation provide higher yields (Table 3). Genotype BARI Tomato-18 and Suraksa had less fruit infestation and gave maximum fresh yield, while BARI Tomato-17 yielded minimum because of high fruit infestation. Similar results were also reported by Ashfaq et al., 2012 and Usman et al., 2013, who showed that resistant genotypes show higher yield than susceptible genotypes against the fruit borer.

Number of fruit borer larvae plant^{-1}

The observed fruit borer larval population plant^{-1} on different tomato genotypes are given in Table 4. On average, of two years data, the highest number of larval population plant^{-1} was found in the paltola (2.57 larvae) and that was the minimum on genotypes BARI Tomato-18 (0.31 larvae) and Ruma VF (0.38 larvae). Correlation between larvae of borer plant^{-1} and fruit infestation was highly significantly positive for both the years as well as mean for the two years (r = 0.749, 0.767 and 0.789, respectively). This type of findings was also reported by several researchers (Sajjad et al., 2011; Ashfaq et al., 2012; Usman et al., 2013; Ambule et al. 2015; Thakur et al., 2017; Amin et al., 2017).

Table 4. Fruit borer larvae plant^{-1}and % fruit weight loss of different tomato varieties in relation to the infestation of fruit borer

Variety	Fruit borer larvae plant^{-1}			% weight of infested fruit		
	1st Year	2nd Year	Average	1st Year	2nd Year	Average
BARI Tomato-2	0.66^{de}	1.11^{d-g}	0.88^{d-g}	10.78^{b-e}	15.84^{b-d}	13.30^{b-e}
BARI Tomato-8	1.85^{b}	2.50^{ab}	2.18^{ab}	21.57^{a}	25.70^{ab}	23.63^{a}
BARI Tomato-14	0.98^{cd}	1.34^{c-e}	1.17^{ce}	18.55^{a-c}	16.65^{bc}	17.57^{a-d}
BARI Tomato-15	1.54^{bc}	1.83^{bc}	1.69^{bc}	19.81^{ab}	18.58^{bc}	19.20^{a-c}
BARI Tomato-16	0.28^{e}	0.51^{f-h}	0.40^{fg}	2.92^{e}	4.45^{e}	3.63^{fg}
BARI Tomato-17	0.46^{de}	0.71^{e-h}	0.59 $^{e-g}$	17.46^{a-d}	25.22^{ab}	21.33^{ab}
BARI Tomato-18	0.23^{e}	0.38^{h}	0.31^{g}	2.97	4.20^{e}	3.57^{g}
BARI Tomato-19	0.77^{de}	1.09^{d-g}	0.93^{d-f}	8.45^{de}	11.98^{c-e}	10.23^{d-g}
Bonkim Ruby	0.55^{de}	0.85^{d-h}	0.70^{d-g}	8.34^{de}	11.75^{c-e}	10.03^{d-g}
Pusa Ruby	0.54^{de}	0.79^{d-h}	0.67^{d-g}	5.99^{e}	8.32^{c-e}	7.17^{e-g}
Suraksa	1.00^{cd}	1.45^{cd}	1.23^{cd}	8.65^{de}	12.31^{c-e}	10.50^{d-g}
Patharkuchi	0.69^{de}	1.07^{d-h}	0.89^{d-g}	8.58^{de}	10.64^{c-e}	9.63^{d-g}
Ruma VF	0.27^{e}	0.48^{gh}	0.38^{fg}	4.04^{e}	5.68^{de}	4.83^{e-g}
Ruma 19	0.96^{d}	1.19^{c-f}	1.08^{de}	10.05^{c-e}	14.42^{c-e}	12.23^{c-f}
Guli	0.60^{de}	0.85^{d-h}	0.73^{d-g}	6.97e	8.39^{c-e}	7.67^{e-g}
Paltola	2.58^{a}	2.56^{a}	2.57^{a}	19.04^{a-c}	30.74^{a}	24.90^{a}
Treatment mean	0.87^{b}	1.17a	1.02	10.89^{b}	14.04	12.46
LSD ($p \leq 0.01$)	0.57	0.70	0.58	9.74	10.47	8.63
Co-relation with fruit infestation rate						
r-Value	0.749**	0.767**	0.789**	0.9148**	0.981**	0.971**

Means in the same column followed by same letter(s) did not differ significantly at $p<0.01$ by DMRT and LSD=Least Significant Difference

Percent weight loss

The data presented in Table 4 revealed that the average performance for two years showed, the significantly identical lowest fruit weight loss was found in BARI Tomato-18 (3.57%), BARI Tomato-16 (3.63%) and Ruma VF (4.83%). The highest fruit weight loss was found in genotypes Paltola (24.90%), BARI Tomato-8 (23.63%) and BARI Tomato-17 (21.33%). Highly significant positive correlation was observed between % yield loss and fruit infestation for both 1st year (r = 0.9148) and 2nd year (r = 0.981) and means for the two years (r = 0.971). The findings of the present study are in accordance with Usman et al. (2013), Amin et al. (2017), who reported that higher infestation provides higher % fruit weight loss.

Percent of infested fruit

Infestation due to fruit borer among different varieties varied significantly. The minimum number of infested fruits was recorded for BARI Tomato-16 and BARI Tomato-18 while the maximum amount of fruit damage was found in BARI Tomato-8 and Paltola for both the years and ultimately the average (Table 5). Clissold et al. (2006) indicated that feeding of early larval instars obstructed by tough leaves.

Table 5. Rank on two years mean infested fruit (%), and Rating on resistance of sixteen tomato varieties

Variety	% Infested Fruit			Rank	Rating
	Years		Average		
	2018	2019			
BARI Tomato-2	13.25^{d-f}	20.04^{b}	16.65^{c-e}	11	Moderately resistant
BARI Tomato-8	27.13^{a}	32.30^{a}	29.71^{a}	16	Moderately susceptible
BARI Tomato-14	17.48^{c-e}	20.09^{b}	18.79^{cd}	12	Moderately susceptible
BARI Tomato-15	18.17^{cd}	20.82^{b}	19.50^{bc}	13	Moderately resistant
BARI Tomato-16	3.51^{i}	5.19^{e}	4.36 ^{h}	2	Resistant
BARI Tomato-17	21.40^{bc}	30.60^{a}	26.01^{ab}	14	Moderately susceptible
BARI Tomato-18	3.57^{i}	5.01^{e}	4.30^{h}	1	Resistant
BARI Tomato-19	10.40 $^{f-h}$	14.61^{b-d}	12.51^{d-f}	8	Moderately resistant
Bonkim Ruby	10.10^{f-h}	14.11^{b-e}	12.11^{e-g}	7	Moderately resistant
Pusa Ruby	7.11^{g-i}	9.93^{c-e}	8.53^{f-h}	4	Resistant
Suraksa	10.53^{fg}	14.84^{b-d}	12.69^{d-f}	9	Moderately resistant
Patharkuchi	8.20^{f-i}	13.15^{b-e}	10.68^{e-h}	6	Moderately resistant
Ruma VF	4.89^{hi}	6.79^{de}	5.85^{gh}	3	Resistant
Ruma 19	12.29^{e-g}	17.75^{bc}	15.03^{c-f}	10	Moderately resistant
Guli	8.46^{f-i}	9.37^{c-e}	8.92 $^{f-h}$	5	Resistant
Paltola	24.99^{ab}	32.92^{a}	28.95^{a}	15	Moderately susceptible
Treatment mean	12.60	16.72	14.66		
LSD (p≤0.01)	5.57	9.4	6.58		

Means in the same column followed by same letter(s) did not differ significantly at p<0.01 by DMRT and LSD=Least Significant Difference

Antibiotic effects of phenols and acidity of tomato fruits are also achieved to the host plant resistance against tomato fruit borer (Kashyap and Verma, 1987; Banerjee and Kallo, 1989; Selvanarayanan and Narayanasamy, 2006 a). BARI Tomato-16, BARI Tomato-18, Pusa Ruby, Ruma VF and Guliwere found to be a resistant having infestation less than 10% and BARI Tomato-2, BARI Tomato-15, BARI Tomato-19, Bonkim Ruby, Suraksa, Patharkuchi and Ruma 19 were found to moderately resistant with infestation rates falling between 10 to 20%. BARI Tomato-8, BARI Tomato-14, BARI Tomato-17, and Paltola were moderately susceptible with 20.1 to 30.0% fruit damage (Table 5). Among the sixteen varieties, none of the tested varieties were completely resistant to the attack of fruit borer. The results of the present study were supported by the researchers (Khanam et al., 2003; Selvanarayanan and Narayanasamy, 2006b; Sajjad et al., 2011; Usman et al., 2013; Ambule et al., 2015; Amin et al., 2017; Thakur et al., 2017).

CONCLUSION

It can be concluded that none of the tested genotypes were free from *H. armigera* infestation. BARI Tomato-18 and BARI Tomato-16 gave better results as borer resistance with higher fruit shape index and fresh yield plant^{-1}. BARI Tomato-8, BARI Tomato-17 and Paltola was more susceptible containing higher infestation as well as higher % yield loss by fruit borer. BARI Tomato-18 and BARI Tomato-16 may be included in IPM system.

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