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Biophysical characters of tomato varieties in relation to resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner)

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Abstract
The study on relation of morphological characters to the fruit infestation of *H. armigera* was conducted on the farm, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP. On the selected eight tomato varieties morphological characters of tomato plant as well as fruits were measured and compared. The percent fruit damage varied from 15.57 to 45.30 per cent recording the highest fruit infestation in 'Red Gold' and lowest in 'Solan Lalima'. Tomato fruit borer infestation was significantly positively correlated with fruit diameter (r= 0.526), leaf area (r= 0.686) and leaf hairs (r= 0.497); while negative correlation was found with fruit length (r= -0.694), fruit shape (r= -0.772) and pericarp thickness (r= -0.453). The correlation analysis of fruit infestation with plant height, stem diameter, fruit infestation, fruit weight and fruit yield/plant was found to be non-significant.

Keywords: *H. armigera*, fruit infestation, morphological characters, correlation analysis

Introduction
Tomato, *Solanum lycopersicum* L. (Family: Solanaceae) is the world's largest consumed vegetable next to potato and sweet potato and tops the list of canned vegetables. It is grown around the world for fresh marketing and processing [13]. Out of several biotic limiting factors in tomato production, the fruit borer; *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera), is the most important one. In India, Solan district of Himachal Pradesh produces bulk of tomatoes and is often called the 'tomato bowl' of the hill state with more than 42 per cent of total area and 44 per cent of total production [1]. The crop is devastated by the fruit borer *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) which is noted as polyphagous pest. The larvae feed on leaves and bore into the growing shoots, buds and tender fruits affecting the fruit quality and yield. For controlling this pests chemical control is the first and foremost approach but indiscriminate use of broad spectrum synthetic chemicals has led to various environmental and health hazards.

Alternatively, insect pests can effectively be controlled using integrated pest management (IPM) strategy and the planting of pest resistant varieties is one of the key parts of IPM to control pests. The use of pest resistant varieties and the pest preference to host plants are important to know under field conditions to make further depth study because the use of chemicals with the planting of pest resistant varieties can effectively reduce the cost of insecticides and would be environmentally friendly. Plant morphological characteristics such as trichomes and thickness of the cuticle affect *H. armigera* larval movement and feeding rate [20].

The morphological and biophysical characteristics of tomato shoot and fruits are associated with attraction, feeding and oviposition of the pest thus, the identification of biophysical characteristics from insect resistant varieties is most practical significance. Therefore, the present investigations was undertaken to find out the source of resistance against fruit borer.

Materials and methods
Field screening of tomato varieties
Based upon preliminary screening data (Thakur., *et al* unpublished data) eight varieties of tomato were planted in field trials to screen for *H. armigera* resistance in the experimental farm of the Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP).

These varieties were: Palam Pink, Solan Vajar, Solan Lalima, Naveen 2000+, Yash, Rakshita, Red Gold and Heem Sohna. Nursery grown seedlings of these varieties were transplanted in field with15 plants of each entry following standard cultural practices to raise the tomato crop in mid hills, except no chemicals were sprayed on the crop in order to make the crop fully prone to insects.

Plants were monitored weekly starting one week after transplanting. At each observation, the number of *H. armigera* egg and larvae per plant from five randomly-selected plants in each plot were recorded. Once tomato fruit appeared on the plants, the numbers of damaged and undamaged fruits were recorded weekly from five randomly selected plants in each plot to calculate percent of fruit infestation.

Analysis of biophysical characteristics of tomato varieties

Fruit morphological characters:

The morphological characteristics of fruits of different tomato varieties like fruit weight, fruit length, fruit diameter, fruit pericarp thickness, fruit shape and yield were studied to correlate them with plant reaction against the tomato fruit borer. The weight of randomly picked ten immature fruits of different tomato varieties from each replication was taken on digital weighing balance. Fruit length and fruit diameter and the pericarp thickness were recorded with the help of Vernier caliper. Their fruit shape index was worked out from the ratio of fruit length and fruit diameter as per the method suggested by Roy and Choudhary [14]. Fruit yield per plant (healthy and damaged) of five randomly selected plants of each variety from the three replications recorded at each picking were cumulated and the average yield/plant was worked out.

Plant physical characters: Physical characters of different tomato varieties were recorded at 30, 50 and 70 days after transplanting from 10 randomly selected plants. Plant height was measured from the ground level to the highest tip of the plant with the help of measuring scale in centimeter while, stem diameter was recorded at 10 cm above with the help of digital vernier caliper in millimeter (mm) and the mean value was worked out. Leaf samples to measure leaf area of different tomato varieties from three replications were collected from upper, middle and lower portion of 10 randomly selected plants of each variety from three replications. Samples were taken to the laboratory and the area (mm^2) of leaves was measured using digital leaf area meter. Trichomes on the leaf surface were counted on a tomato leaf surface per unit ($10mm^2$) area using a binocular microscope from upper, middle and lower leaves.

Statistical analysis: Data on morphological characteristics of different varieties of tomato to determine the significance of differences were analyzed by using Randomized Block Design (RBD) - one way analysis of variance (ANOVA) as suggested by Gomez and Gomez [8]. In addition to show the interrelationships between fruit borer infestation and mean values of each studied physical character statistical analysis program (SPSS) was used.

Results and Discussion

Varietal infestation screening: There were significant differences among the eight tomato varieties with respect to *H. armigera* larval population per plants and per cent tomato fruit damaged by *H. armigera* larvae (Table1). In Table 1 the per cent tomato fruit borer infestation varied significantly among the different tomato varieties. It ranged from 15.57% (Solan Lalima) to 45.30% (Red Gold). The infestation in 'Red Gold' was statistically at par with the infestation observed in 'Heem Sohna' (39.34%), 'Palam Pink' (34.16%) and 'Yash' (34.13%), while the infestation in 'Solan Lalima' was statistically at par with 'Solan Vajar', 'Naveen 2000+' and 'Rakshita' with per cent fruit infestation of 27.94%, 16.11% and 21.01%, respectively.

Table 1: Per cent fruit infestation and fruit weight loss by tomato fruit borer larvae in different tomato varieties

S. No.	Varieties	Fruit borer infestation (%)
1	Palam Pink	34.16 (35.45)
2	Solan Vajar	27.94 (30.74)
3	Solan Lalima	15.57 (22.76)
4	Naveen 2000+	16.11 (23.03)
5	Yash	34.13 (34.89)
6	Rakshita	21.01 (26.280
7	Red Gold	45.30 (42.20)
8	Heem Sohna	39.34 (38.43)

CD $_{(p= 0.05)}$: Per cent fruit infestation: 9.27

*Figures in parentheses are Angular transformed values.

Influence of physical leaf and plant characteristics on fruit infestation

A perusal of data in presented in Table 2 revealed that the mean of fruit length ranged from 41.95 to 49.45 mm. The highest fruit length (49.45 mm) was obtained in 'Naveen 2000+' (moderately susceptible variety) while the minimum fruit length of 41.95 mm was recorded in 'Palam Pink' (susceptible variety). Fruit diameter of different tomato varieties was also recorded with the help of vernier caliper at an immature stage. The largest fruit diameter of 53.10 mm was obtained in 'Heem Sohna' (susceptible variety), whereas the smallest fruit diameter 47.01 mm was observed in 'Solan Lalima' (moderately susceptible variety). The fruit shape recorded on the basis of ratio of their respective fruit length and fruit diameter which revealed that the fruit of 'Solan Vajar' (moderately susceptible variety) were oval in shape and with fruit shape index of 1.03 and the fruits of 'Heem Sohna' (susceptible variety) were spherical and with value of 0.88. In the present findings fruit pericarp thickness ranged from 4.07 mm 'Palam Pink' (susceptible variety) to 6.25 mm 'Heem Sohna'. The weight of immature fruits of eight tomato varieties s studied ranged from 55.84 g to 66.42 g recording lowest in 'Solan Vajar' (moderately susceptible variety) and highest in 'Heem Sohna' (susceptible variety). The mean fruit yield/plant of each variety was evaluated by combining their individual yield obtained after each picking. It ranged from 3.52 to 0.79 kg/plant. The highest yield/plant was recorded in 'Naveen 2000+' (moderately susceptible variety) while in 'Solan Vajar' (0.79 kg) (less susceptible variety) which was statistically at par with 'Palam Pink' (1.26 kg). Fruit yield recorded in other varieties were, 'Solan Lalima' (2.38 kg), 'Yash' (2.58 kg) and 'Rakshita' (2.75 kg).

The fruit infestation of different varieties when subjected to correlation analysis with fruit physical characters (Table 3) revealed that tomato fruit borer infestation was significantly positively correlated with fruit diameter (r= 0.526). Present results find support from the studies carried out by Canerday *et al.* [3] and Cosenza and Green [5] who reported that tomato cultivars having small fruits were less susceptible. Our results are also at par with those of Naqvi *et al.* [10] who reported positively significant correlation between brinzal fruit diameter and degree of fruit infestation by shoot and fruit borer *Leucinodes orbonalis* (Guen). A negative correlation

was found between fruit length and fruit damage (r= -0.694) in the present study. This is in agreement with the results obtained by Daboul *et al*. [6] who reported that with increase in fruit length infestation rate decreased and in agreement with the findings of Elanchezhyan *et al* [7] who reported that the resistant reaction of two hybrids of brinjal was due to the presence of extra longish fruits with a light purple colour. A negative correlation (r= -0.772) was found between fruit shape and fruit infestation with round shaped varieties like 'Heem Sohna', 'Red Gold' and 'Palam Pink' being more susceptible to fruit borer infestation. This is in conformity with the results of Sharma *et al* [18] who reported that the possible reason for high susceptibility of brinjal hybrids to shoot and fruit borer was due to round shaped fruits The pericarp thickness of the fruits of different varieties was found to be negatively correlated (r= -0.453) with fruit borer infestation. The tough skin of the fruits might be responsible for resistance to fruit borer [15, 18]. While Chandrashekhar *et al* [4] who studied the morphological and biochemical factors of resistance in eggplant against and reported highly significant and positive correlation between pericarp thickness of brinzal fruits and fruit infestation by *L. orbonalis* stating that it might have provided better grip to the mandibles of *H. armigera* larvae. In the present findings, fruit weight was found to be positively correlated with the fruit infestation but the correlation was non-significant (r= 0.320). Fruit yield/plant was found to be negatively correlated with the fruit damage but the correlation was recorded non-significant (r= -0.002). This is contrary to the results of various researchers who reported that *H. armigera* population was negatively correlated with tomato yield [2, 9, 16, 25]. The difference might be due to the effect of environmental factors (high humidity after rains) which might have resulted in the diseases like buckeye rot and fruit rot which ultimately affected the yield.

Table 2: Fruit physical characters and tomato fruit borer infestation of different tomato varieties tolerant and susceptible to tomato fruit borer

Average fruit physical characters and fruit borer infestation						
Varieties	**Fruit length (L) (mm)**	**Fruit diameter (D) (mm)**	**Fruit shape index (L/D)**	**Fruit pericarp thickness (mm)**	**Fruit weight (g)**	**Fruit Yield (kg/plant)**
Palam Pink	41.95	50.36	0.83	4.07	61.81	1.26
Solan Vajar	43.38	41.88	1.03	5.20	55.84	0.79
Solan Lalima	44.26	47.01	0.94	5.27	59.11	2.38
Naveen 2000+	49.45	48.67	1.01	6.07	65.05	3.51
Yash	44.47	49.25	0.90	4.63	60.97	2.58
Rakshita	47.77	47.30	1.01	5.88	59.53	2.75
Red Gold	42.66	50.93	0.84	4.45	63.08	3.15
Heem Sohna	43.71	53.10	0.82	6.25	66.42	3.15
CD $_{(p=0.05)}$	3.36	1.81	0.06	0.30	5.43	0.72

Table 3: Coefficient of correlation between physical characteristics of tomato fruit and tomato fruit borer infestation

Tomato fruit borer infestation	**Fruit diameter (mm)**	**Fruit length (mm)**	**Fruit shape index**	**Fruit pericarp thickness (mm)**	**Fruit weight (g)**	**Fruit Yield (kg/plant)**
	0.526*	-0.694*	-0.772*	-0.453*	0.320	-0.002

* $p \leq 0.05$

Plant physical characters:

Plant height of different tomato varieties at different ages ranged from 24.50 cm to 35.56 cm (Table 4) at 30 days after transplanting (DAT), 46.90 cm to 61.50 cm at 50 DAT and 56.63 cm to 84.66 cm at 70 DAT . In the present studies, susceptibility of the tall varieties to the attack of the tomato fruit borer may be attributed to congenial niche and more shelter for egg laying. The stem diameter did not vary significantly among the varieties at different ages. Highest mean of leaf area (20.23 cm^2) was recorded in 'Heem Sohna' and lowest (15.68 cm^2) in 'Solan Lalima'. Trichome density could be another physical plant factor attributed to resistance [11]. Genotypic differences and environmental factors affect the growth and development of leaf hairs [22]. Therefore, the trichome density was recorded which differed significantly in different varieties. In selected tomato varieties number of leaf hairs ranged from (16.55/10mm^2) in the variety 'Heem Sohna' to the lowest number in 'Rakshita' (9.50/10mm^2).

In Table 5, no significant correlation of infestation was recorded with plant height (r = 0.085) which is in contrary to the studies carried out by Daboul *et al*. [6] and Khanam *et al*. [9] who found the tomato fruit borer infestation to be positively correlated with the plant height. A negative and non-significant correlation (r= -0.363) was found between stem diameter and fruit infestation. There was a significant positive correlation between leaf area (r= 0.686) and fruit infestation which is in agreement with Daboul *et al*. [6] who found that leaf area directly affecting the fruit damage since more leaf area provide broader coverage for egg laying to the fruit borer. More number of hairs stimulates more egg laying by the female of the moth and it was clearly observed in the present study where the correlation between the fruit infestation and number of leaf hairs was found to be significantly positive (r= 0.497). This is in agreement with the results of Daboul *et al*. [6], Khanam *et al*. [9], Rath and Nath [12], Sivaprakasam [21] and Srivastava *et al*. [24] who reported that the more number of eggs were laid on hairy cultivars as compared to cultivars which had a less trichome density. However the study carried out by Williams *et al*. [27] revealed that the foliage of wild tomato *Lycopersicon hirsutum f. glabratum* had a high density of trichomes, which contain 2-tridecanone, a naturally occurring insecticide that resulted in the larval mortality of tomato fruit borer. Similar results were obtained by Satpute *et al*. [17] and Srinivasan and Uthamasamy [23] who reported that certain sticky and toxic chemicals are released by the trichomes that cause mortality of the larvae. On the basis of present studies, various plant factors that influence the infestation level of fruit infestation can be modified and manipulated in high yielding varieties and thus tolerant strains can be obtained that provide protection against pest as well as high economic yield. Further research is to be conducted in developing such strains. Multi location testing of the resistant tomato varieties against varying populations of fruit borers would be useful in confirming the stability of resistance and further utility in crop improvement programme.

Table 4: Plant physical characters and tomato fruit borer infestation of different tomato varieties at different ages tolerant and susceptible to tomato fruit borer

Average plant physical characters and fruit borer infestation				
Varieties	**Plant height (cm)**	**Stem diameter (mm)**	**Leaf area (cm^2)**	**No. of leaf hairs/ $10mm^2$**
Palam Pink	42.67	8.75	16.99	15.61
Solan Vajar	53.46	9.15	15.92	12.16
Solan Lalima	52.16	8.58	15.68	14.22
Naveen 2000+	57.30	9.04	17.75	13.94
Yash	58.74	8.81	19.50	11.44
Rakshita	54.47	8.82	18.16	9.50
Red Gold	54.96	8.91	19.98	16.33
Heem Sohna	54.66	9.49	20.23	16.55
CD $_{(p = 0.05)}$	4.09	NS	2.22	3.31

Table 5: Coefficient of correlation between tomato plant physical characters and tomato fruit borer infestation

Tomato fruit borer infestation	**Plant height**	**Stem diameter**	**Leaf area**	**Leaf hairs**
	0.085	- 0.363	0.686*	0.497*

* $p \leq 0.05$

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