

Insect and Diseases Resistance in Tomato Entries

A. K. M. Quamruzzaman, Ferdouse Islam, Sharmilla Rani Mallick

Olericulture Division, Horticulture Research Center, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

Email: akmqzs@gmail.com

How to cite this paper: Quamruzzaman, A.K.M., Islam, F. and Mallick, S.R. (2021) Insect and Diseases Resistance in Tomato Entries. *American Journal of Plant Sciences*, 12, 1646-1657.
<https://doi.org/10.4236/ajps.2021.1211115>

Received: September 25, 2021

Accepted: November 14, 2021

Published: November 17, 2021

Copyright © 2021 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The study was conducted with 75 tomato entries at the farm of Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during the winter season of 2020-21 to evaluate insect and disease reaction. Among the various insect and diseases of tomatoes, the late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation are most common in Bangladesh. The TYLCV infection was observed 0% to 27% infection, while 47 entries showed zero percent infection. The range of bacterial wilt infection was 0% to 10% and zero percent infection was observed in 62 entries. In case of leaf miner infestation and fruit borer infestation, the range was 0% to 43% and 0% to 10%, respectively. Considering tolerance to late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation, fruit size, fruit shape, plant growth nature, cluster nature of fruit, type of fruit ten entries AVTO 1010, AVTO 1706, AVTO 1713, AVTO 1829, AVTO 1909, AVTO 1911, AVTO 1915, AVTO 1921, AVTO 1954 and SLA 011 were found zero percent late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation. So, these ten entries can be selected for disease and insect tolerant tomato varieties development as well as developing disease and insect tolerant hybrid tomato varieties.

Keywords

Insect, Diseases, Late Blight, TYLCV, Bacterial Wilt, Leaf Miner, Fruit Borer, Infestation, Resistance, Tomato

1. Introduction

Tomato (*Solanum lycopersicum*) is one of the most important vegetables of Bangladesh and the world too. The tomato is an important source of antioxi-

dant. The essential phytonutrients found in the tomato fruit are lycopene, β -carotene, α -tocopherol, polyphenols and ascorbic acid, and antioxidant activity depends on cultivar, environmental parameters, method of production and processing. The regular ingestion of an adequate amount of fresh tomatoes or processed tomato products has been inversely correlated with the development of widespread human diseases [1] [2] [3] and with an increase in plasma lipid peroxidation levels [4] [5]. This protective effect has been mainly attributed to the carotenoid constituents of the fruits, particularly lycopene and β -carotene which act as antioxidants in detoxifying free radicals [2] [6] [7] [8]. [9] reported that both fresh and processing tomatoes constitute significant amounts within produced vegetable crops.

Among the various insect and diseases of tomatoes, the late blight, TYLCV (Tomato yellow leaf curl virus), bacterial wilt infection and leaf miner, fruit borer infestation are most common in Bangladesh. The polyphagous nature of different insects, and development of insecticide resistance, provide challenges to effective management. Resistance in tomato is important for management of fruit borer. The highest levels of arthropod resistance are widely reported in wild varieties such as *L. hirsutum* Dunal. [10]. Attempts have been made to identify sources of resistance in *L. esculentum* [11] [12]. Breeding tomatoes for insect resistance is generally limited to identification of sources and mechanisms of resistance. Emphasis should be placed on development of commercial insect and disease resistant cultivars with desirable yield and market attributes [13].

Heavy use of insecticides to control these pests has resulted in the development of resistance in some pest populations [14], enhancement of the destructiveness of the leaf miner due to loss of its natural enemies [15], and may also pose environmental problems. Morphological and physical characteristics of plants are associated with attraction, feeding, and oviposition of insect pests [16]. Thus, plant phenology may influence pest populations because of factors such as maturation date, which vary according to plant cultivar. In addition, pest population development is favored by high temperatures and plant cultivars that vary in their development time may experience differing levels of pest pressure [17]. Under field conditions, temperature and relative humidity have been shown to affect populations of tomato pests such as aphids (Aphidoidea) and whiteflies (Aleyrodidae) [18].

Therefore, development and deployment of cultivars with resistance to the important insect pests of tomato are needed. However, Bangladesh Agricultural Research Institute (BARI) has released varieties that are higher yielder, but some varieties are prone to several pests and diseases. Beside this growers' demand is good quality hybrid varieties having tolerance to different major insects and diseases. In this context, BARI needs to be developed tomato varieties possess traits of virus and wilt resistance. In 2020, The World Vegetable Centre has supplied 43 tomato advanced entries to BARI. This study was undertaken to screen tomato germplasm from AFACI supplied germplasm, advanced varieties, cultivars, and native entries for resistance against late blight, TYLCV, bacterial wilt infec-

tion and leaf miner, fruit borer infestation and for other morphological attributes in order to develop insect, diseases resistant cultivars.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted at the Olericulture Division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) during 2020-21. The experimental field was at 23.9920°N Latitude and 90.4125°E Longitudes having an elevation of 8.2 m from sea level under agro-ecological zone (AEZ) 28. The average minimum and maximum temperature were 18.0°C and 29.0°C and the average relative humidity was 58.2%. The soil of the experimental field was sandy clay loam in texture having a pH range around 6.0.

Air temperatures and relative humidity of the experimental area

Average monthly minimum air temperatures, maximum air temperatures and average relative humidity during the season are shown in **Table 1**.

2.2. Plant Materials

Seventy-five tomato entries (WorldVeg Center: 41 nos., BARI varieties: 10 nos., local germplasm 17 nos., exotic germplasm 7 nos.) were included in the study (**Table 2**). The seeds were sown on the seedbed on 01 October 2020. Thirty-two days old seedlings were transplanted in the main field on 01 November, 2020.

2.3. Experimental Design and Layout

The experiment was laid out in an RCB design with three replications. The plot size was 5.0 × 1.0 m where 20 plants were planted with space of 60 × 50 cm in two rows.

2.4. Land Fertilization

The experimental area was enriched with organic fertilizer, Nitrogen, Phosphorus, Potassium, Sulphur, Zinc and Boron @ 3000, 250, 90, 125, 20, 3 and 2 kg/ha, correspondingly. One third of the organic fertilizer, 50% of Phosphorus and full of Sulphur, Zinc and Boron were incorporated for the period of last land-dwelling

Table 1. Average monthly minimum temperature (°C), maximum temperature (°C) and relative humidity (%) recorded during winter season.

Parameter	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Mean
Monthly minimum air temperature (°C)	24	19	14	16	15	20	18.0
Monthly maximum air temperature (°C)	31	29	26	28	28	32	29.0
Monthly mean relative humidity (%)	72	66	63	54	49	45	58.2

Table 2. Seventy-five tomato entries.

WorldVeg Center germplasm			BARI varieties	Local germplasm	Exotic germplasm
AVTO 0301	AVTO 1706	AVTO 1911	BARI Tomato-2	SLA 011	SLA 004
AVTO 1003	AVTO 1707	AVTO 1913	BARI Tomato-11	SLA 012	SLA 005
AVTO 1008	AVTO 1711	AVTO 1914	BARI Tomato-14	SLA 013	SLA 006
AVTO 1010	AVTO 1712	AVTO 1915	BARI Tomato-15	SLA 014	SLA 007
AVTO 1219	AVTO 1713	AVTO 1919	BARI Tomato-16	SLA 015-1	SLA 008
AVTO 1288	AVTO 1715	AVTO 1921	BARI Tomato-17	SLA 015-2	SLA 009
AVTO 1306	AVTO 1716	AVTO 1954	BARI Tomato-18	SLA 015-3	SLA 010
AVTO 1314	AVTO 1717		BARI Tomato-19	SLA 018	
AVTO 1315	AVTO 1718		BARI Tomato 20	SLA 025-1	
AVTO 1409	AVTO 1719		BARI Tomato 21	SLA 025-2	
AVTO 1424	AVTO 1720			SLA 025-3	
AVTO 1429	AVTO 1828			SLA 025-4	
AVTO 1464	AVTO 1829			SLA 025-5	
AVTO 1616	AVTO 1903			SLA 025-6	
AVTO 1619	AVTO 1907			SLA 025-7	
AVTO 1702	AVTO 1909			FOBHT8	
AVTO 1705	AVTO 1910			MOBHT8	
41			10	17	7

preparation. Rest of organic fertilizer and Phosphorus and 1/3 of Potassium were applied as basal in pit. Entire quantity of Nitrogen and rest of Potassium were applied in four equal portions beginning from 20 days after transplanting. Rest three portions were fertilized at 20, 40 and 60 days after transplanting.

2.5. Data Recorded

Data on yield and yield attributing parameters with qualitative traits were recorded from 20 inner plants of each plot escaping border plants following World Veg guideline. Tomato fruits were started harvesting at breaker stage from 20 inner plant of each treatment. Four to six harvesting was done according to the different germplasm characters and data on late blight infection (%), TYLCV infection (%), bacterial wilt infection (%), leaf miner infestation (%), fruit borer infestation (%), fruit size, fruit shape, plant growth nature, cluster nature of fruit, type of fruit.

3. Results and Discussion

The tomato entries differed significantly in all parameters studied and the results have been shown in **Table 3** and **Table 4**. In respect of pest and disease reaction,

Table 3. Late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation of 75 tomato entries.

Entries	Late blight infection (%)	TYLCV infection (%)	Bacterial wilt infection (%)	Leaf miner infestation (%)	Fruit borer infestation (%)
AVTO 0301	50	13	10	17	10
AVTO 1003	0	10	0	0	3
AVTO 1008	0	10	0	0	7
AVTO 1010	0	0	0	0	0
AVTO 1219	27	27	7	20	7
AVTO 1288	0	23	0	0	0
AVTO 1306	47	23	0	27	0
AVTO 1314	27	0	0	40	0
AVTO 1315	53	0	0	20	0
AVTO 1409	50	0	0	23	0
AVTO 1424	37	0	0	43	0
AVTO 1429	0	17	0	0	0
AVTO 1464	43	20	7	37	7
AVTO 1616	37	0	0	27	0
AVTO 1619	0	0	0	0	7
AVTO 1702	27	20	0	23	7
AVTO 1705	23	0	0	23	0
AVTO 1706	0	0	0	0	0
AVTO 1707	50	20	0	40	7
AVTO 1711	0	0	0	0	3
AVTO 1712	40	0	0	7	7
AVTO 1713	0	0	0	0	0
AVTO 1715	50	0	0	23	0
AVTO 1716	43	23	10	30	0
AVTO 1717	43	0	0	7	7
AVTO 1718	53	0	0	23	7
AVTO 1719	53	0	0	40	0
AVTO 1720	47	10	0	37	7
AVTO 1828	0	17	0	0	0
AVTO 1829	0	0	0	0	0
AVTO 1903	0	0	0	0	7

Continued

AVTO 1907	0	0	0	0	0
AVTO 1909	0	0	0	0	0
AVTO 1910	0	13	10	0	7
AVTO 1911	0	0	0	0	0
AVTO 1913	0	17	0	0	7
AVTO 1914	0	0	0	0	7
AVTO 1915	0	0	0	0	0
AVTO 1919	50	0	0	40	0
AVTO 1921	0	0	0	0	0
AVTO 1954	0	0	0	0	0
SLA 004	47	20	0	23	7
SLA 005	33	20	0	23	7
SLA 006	50	0	0	23	3
SLA 007	43	0	0	7	0
SLA 008	50	0	0	23	0
SLA 009	47	20	10	20	7
SLA 010	23	0	0	27	3
SLA 011	0	0	0	0	0
SLA 012	20	0	0	20	3
SLA 013	0	13	7	27	7
SLA 014	23	3	0	23	0
SLA 015-1	23	7	7	17	0
SLA 015-2	40	7	0	23	7
SLA 015-3	23	0	3	20	0
SLA 018	27	23	10	0	0
SLA 025-1	23	0	7	37	0
SLA 025-2	0	7	7	3	0
SLA 025-3	0	0	0	37	0
SLA 025-4	23	7	0	0	7
SLA 025-5	23	0	0	27	0
SLA 025-6	0	0	0	7	0
SLA 025-7	0	0	0	37	0
FOBHT8	0	0	0	20	10
MOBHT8	0	0	0	7	10

Continued

BARI Tomato-2	23	0	0	23	0
BARI Tomato-11	0	0	0	7	0
BARI Tomato-14	23	20	0	7	7
BARI Tomato-15	23	7	0	20	7
BARI Tomato-16	0	0	0	20	0
BARI Tomato-17	37	0	0	23	7
BARI Tomato-18	0	0	0	20	0
BARI Tomato-19	0	0	0	0	7
BARI Tomato 20	20	3	0	0	0
BARI Tomato 21	0	0	0	20	0
Range	0 - 53	0 - 27	0 - 10	0 - 43	0 - 10
Mean	20.0	5.6	1.3	15.2	2.8

Table 4. Fruit size, fruit shape, plant growth nature, cluster nature of fruit, type of fruit characters of 75 tomato entries.

Entries	Fruit size	Fruit shape	Plant growth nature	Cluster nature of fruit	Type of fruit
AVTO 0301	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1003	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1008	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1010	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1219	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1288	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1306	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1314	Medium	Flat round	Determinate	Cluster	Table purpose
AVTO 1315	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1409	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1424	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1429	Medium	Round	Indeterminate	Cluster	Cherry type
AVTO 1464	Small	Round	Indeterminate	Cluster	Cherry type
AVTO 1616	Medium	Round	Semi Determinate	Cluster	Table purpose
AVTO 1619	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1702	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1705	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1706	Medium	Round	Determinate	Cluster	Table purpose

Continued

AVTO 1707	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1711	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1712	Medium	Flat round	Determinate	Cluster	Table purpose
AVTO 1713	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1715	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1716	Medium	Flat round	Determinate	Cluster	Table purpose
AVTO 1717	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1718	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1719	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1720	Big	Flat round	Determinate	Cluster	Table purpose
AVTO 1828	Medium	Round	Indeterminate	Cluster	Cherry type
AVTO 1829	Medium	Oval	Indeterminate	Cluster (long)	Cherry type
AVTO 1903	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1907	Medium	Oval	Determinate	Cluster (long)	Table purpose
AVTO 1909	Medium	Oval	Semi Determinate	Cluster	Table purpose
AVTO 1910	Medium	Round	Semi Determinate	Cluster	Table purpose
AVTO 1911	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1913	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1914	Medium	Oval	Determinate	Cluster	Table purpose
AVTO 1915	Medium	Oval	Semi Determinate	Cluster	Table purpose
AVTO 1919	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1921	Medium	Round	Determinate	Cluster	Table purpose
AVTO 1954	Medium	Round	Determinate	Cluster	Table purpose
SLA 004	Small	Round	Determinate	Cluster	Cherry type
SLA 005	Small	Round	Indeterminate	Cluster	Cherry type
SLA 006	Small	Round	Indeterminate	Cluster	Cherry type
SLA 007	Medium	Flat round	Determinate	Cluster	Table purpose
SLA 008	Small	Round	Indeterminate	Cluster (long)	Cherry type
SLA 009	Medium	Round	Determinate	Cluster	Table purpose
SLA 010	Big	Flat round	Semi Determinate	Cluster	Table purpose
SLA 011	Small	Round	Indeterminate	Cluster	Cherry type
SLA 012	Small	Round	Indeterminate	Cluster (long)	Cherry type

Continued

SLA 013	Small	Round	Indeterminate	Cluster (long)	Cherry type
SLA 014	Medium	Round	Determinate	Cluster	Table purpose
SLA 015-1	Small	Round	Indeterminate	Cluster (long)	Cherry type
SLA 015-2	Small	Round	Indeterminate	Cluster (long)	Cherry type
SLA 015-3	Small	Round	Indeterminate	Cluster (long)	Cherry type
SLA 018	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-1	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-2	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-3	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-4	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-5	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-6	Medium	Round	Semi Determinate	Cluster	Table purpose
SLA 025-7	Medium	Round	Semi Determinate	Cluster	Table purpose
FOBHT8	Medium	Round	Determinate	Cluster	Table purpose
MOBHT8	Medium	Round	Determinate	Cluster	Table purpose
BARI Tomato-2	Medium	Round	Determinate	Cluster	Table purpose
BARI Tomato-11	Small	Oval	Indeterminate	Cluster	Cherry type
BARI Tomato-14	Medium	Round	Determinate	Cluster	Table purpose
BARI Tomato-15	Medium	Oval	Determinate	Cluster	Table purpose
BARI Tomato-16	Medium	Round	Determinate	Cluster	Table purpose
BARI Tomato-17	Big	Flat round	Determinate	Cluster	Table purpose
BARI Tomato-18	Medium	Round	Determinate	Cluster	Table purpose
BARI Tomato-19	Medium	Oval	Determinate	Cluster	Processing type
BARI Tomato 20	Medium	Round	Indeterminate	Cluster	Cherry type
BARI Tomato 21	Medium	Oval	Semi Determinate	Cluster	Table purpose

it was revealed that all the entries showed different level of resistance or susceptibility against late blight infection (%), TYLCV infection (%), bacterial wilt infection (%), leaf miner infestation (%), fruit borer infestation (%) (**Table 3**).

In case of late blight infection, the range of infection was 0% to 53% at later stage of growing condition. The zero percent infection was observed in 34 entries, while 50% - 53% infection was observed in 10 entries. The TYLCV infection is an important disease for the tomato cultivation and it was observed 0% to 27% infection, while 47 entries showed 0% and 11 entries showed 20% - 27% infection. Bacterial wilt infection was very negligible among the entries in

the study, where the range was 0% to 10% and zero percent infection was observed in 63 entries. Since the season was winter season, that is why the bacterial wilt infection was low.

In case of leaf miner, 0% to 43% infestation was observed among the entries. Zero percent infestation was observed in 26 entries, while more than 25% infestation was observed on 16 entries. The most devastating insect was fruit borer in this study, while the infestation range was 0% to 10%. The zero percent infestation was observed in 43 entries, while 10% infestation was observed in 3 entries.

In terms of fruit size, fruit shape, plant growth nature, cluster nature of fruit, type of fruit characters of the tomato entries, there was a wide variation was observed (**Table 4**). Three sizes of fruits were observed *viz.*, big (8 entries), medium (55 entries) and small (12 entries), while round type was observed in 47 entries, oval was in 16 entries and flat round was in 12 entries. Three types of plant were observed *viz.*, determinate (46 entries), semi-determinate (14 entries), indeterminate (15 entries). Though all the fruits were beard cluster orientation but medium cluster was in 67 entries, while long type cluster was in 8 entries. Maximum tomato fruits were table purpose (58 entries), while cherry type was produced in 16 entries and one was processing type.

4. Conclusion

The TYLCV infection was observed 0% to 27% infection, while 47 entries showed zero percent infection. The range of bacterial wilt infection was 0% to 10% and zero percent infection was observed in 62 entries. In case of leaf miner infestation and fruit borer infestation the range was 0% to 43% and 0% to 10%, respectively. Considering tolerance to late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation, fruit size, fruit shape, plant growth nature, cluster nature of fruit, type of fruit ten entries AVTO 1010, AVTO 1706, AVTO 1713, AVTO 1829, AVTO 1909, AVTO 1911, AVTO 1915, AVTO 1921, AVTO 1954 and SLA 011 were found zero percent late blight, TYLCV, bacterial wilt infection and leaf miner, fruit borer infestation. So, these ten entries can be selected for disease and insect tolerant tomato varieties development as well as developing disease and insect tolerant hybrid tomato varieties.

Acknowledgements

This study was completed with the financial support of AFACI under the project of “Development of vegetable varieties in Asia Region”.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Agarwal, S. and Rao, A.V. (1998) Tomato Lycopene and Low Density Lipoprotein Oxidation: A Human Dietary Intervention Study. *Lipids*, **33**, 981-984.

- <https://doi.org/10.1007/s11745-998-0295-6>
- [2] Erdman, J.W., Ford, N.A. and Lindshield, B.L. (2009) Are the Health Attributes of Lycopene Related to Its Antioxidant Function. *Archives of Biochemistry and Biophysics*, **483**, 229-235. <https://doi.org/10.1016/j.abb.2008.10.022>
- [3] Prakash, A. and Kumar, A. (2014) Implicating the Role of Lycopene in Restoration of Mitochondrial Enzymes and BDNF Levels in β -Amyloid Induced Alzheimer's Disease. *European Journal of Pharmacology*, **741**, 104-111. <https://doi.org/10.1016/j.ejphar.2014.07.036>
- [4] Giovannucci, E. (1999) Tomatoes, Tomato-Based Products, Lycopene, and Cancer: Review of the Epidemiologic Literature. *Journal of the National Cancer Institute*, **91**, 317-331. <https://doi.org/10.1093/jnci/91.4.317>
- [5] Balestrieri, M.L., De Prisco, R., Nicolaus, B., Pari, P., Moriello, V.S., Strazzullo, G., Iorio, E.L., Servillo, L. and Balestrieri, C. (2004) Lycopene in Association with R-Tocopherol or Tomato Lipophilic Extracts Enhances Acyl-Platelet-Activating Factor Biosynthesis in Endothelial Cells during Oxidative Stress. *Free Radical Biology and Medicine*, **36**, 1058-1067. <https://doi.org/10.1016/j.freeradbiomed.2004.01.014>
- [6] Di Mascio, P., Kaiser, S. and Sies, H. (1989) Lycopene as the Most Efficient Biological Carotenoid Singlet Oxygen Quencher. *Archives of Biochemistry and Biophysics*, **274**, 532-538. [https://doi.org/10.1016/0003-9861\(89\)90467-0](https://doi.org/10.1016/0003-9861(89)90467-0)
- [7] Stahl, W. and Sies, H. (1996) Lycopene: A Biologically Important Carotenoid for Humans. *Archives of Biochemistry and Biophysics*, **336**, 1-9. <https://doi.org/10.1006/abbi.1996.0525>
- [8] Clinton, S.K. (1998) Lycopene: Chemistry, Biology and Implications for Human Health and Disease. *Nutrition Reviews*, **56**, 35-51. <https://doi.org/10.1111/j.1753-4887.1998.tb01691.x>
- [9] Kotíková, Z., Lachman, J., Hejtmánková, A. and Hejtmánková, K. (2011) Determination of Antioxidant Activity and Antioxidant Content in Tomato Varieties and Evaluation of Mutual Interactions between Antioxidants. *LWT—Food Science and Technology*, **44**, 1703-1710. <https://doi.org/10.1016/j.lwt.2011.03.015>
- [10] Kennedy, G.G. (2003) Tomato, Pests, Parasitoids and Predators: Tritrophic Interactions Involving the Genus *Lycopersicon*. *Annual Review of Entomology*, **48**, 51-72. <https://doi.org/10.1146/annurev.ento.48.091801.112733>
- [11] Singh, D., Singh, S., Cheema, D.S. and Brar, K.S. (1994) Resistance to *Helicoverpa armigera* (Hubner) in Tomato Genotypes. *Journal of Insect Science*, **7**, 28-31.
- [12] Brar, K.S., Raman, H., Dhaliwal, H.S. and Cheema, D.S. (1995) Field Screening of Different Species of *Lycopersicon* against Tomato Fruit Borer, *Helicoverpa armigera* (Hubner). *Journal of Insect Science*, **8**, 196-197.
- [13] Kalloo, G. (1991) Genetic Improvement of Tomato. Monographs on Theoretical and Applied Genetics, No. 14. Springer-Verlag, Berlin. <https://doi.org/10.1007/978-3-642-84275-7>
- [14] Brewer, M.J., Trumble, J.T., Alvarado-Rodriguez, B. and Chaney, W.E. (1990) Beet Armyworm (Lepidoptera: Noctuidae) Adult and Larval Susceptibility Three Insecticides in Managed Habitats and Relationship to Laboratory Selection of Resistance. *Journal of Economic Entomology*, **83**, 2136-2146. <https://doi.org/10.1093/jee/83.6.2136>
- [15] Oatman, E.R. and Kennedy, G.G. (1976) Methomyl-Induced Outbreak of *Liriomyza sativa* on Tomato. *Journal of Economic Entomology*, **69**, 667-668. <https://doi.org/10.1093/jee/69.5.667>

- [16] Saberfar, F. and Sheikhi, G. (2009) Influence of Phenological and Physical Characters of Tomato on Fruit Borer, *Helicoverpa armigera* (Hubner) Infestation. *Resistant Pest Management Newsletter*, **19**, 46-47.
- [17] Yurk, B. and Powell, J. (2010) Modeling the Effects of Developmental Variation on Insect Phenology. *Bulletin of Mathematical Biology*, **72**, 1334-1360.
<https://doi.org/10.1007/s11538-009-9494-7>
- [18] Waluniba and Alemla Ao, A. (2014) Seasonal Incidence of Insect-Pests in Tomato (*Lycopersicon esculantum* M.) on Different Planting Dates and Its Correlation with Abiotic Factors. *International Journal of Bio-Resource and Stress Management*, **5**, 280-284. <https://doi.org/10.5958/0976-4038.2014.00568.5>