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Research Article

Distribution and Damage Potentials of Tomato Leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae) Sindh, Pakistan

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Abstract: Tomato leafminer (TLM), *Tuta absoluta* (Lepidoptera: Gelechiidae), is a serious oligophagous pest of tomatoes. Although originated in South America, it has now been introduced and spread in almost all the tomato-growing areas of the globe. Therefore, studies were undertaken to determine the infestation of *T. absoluta* on tomato parts at various locations of six main tomato growing areas of Sindh i.e., Badin, Thatta, Mirpur Khas, Hyderabad, Sanghar and Shaheed Benazirabad. Five tomato fields (locations) were randomly selected from each district to determine the infestation of TLM based on its characteristic mines on tomato leaves and fruits. *Tuta absoluta* infestation was recorded on tomato leaves and fruits observed at all the sampling locations of six districts with significant differences among plant parts, locations, and districts. The highest infestation on leaves (19.36±0.92 %) and fruits (1.36±0.28 %) was observed from location one of Mirpur Khas district. District-wise, overall, the highest infestation of *T. absoluta* on tomato leaves (17.04±0.38 %) and stems (1.10±0.11 %) was recorded at Mirpur Khas, whereas Shaheed Benazirabad and Hyderabad districts suffered the lowest infestation on leaves (4.18±0.22 %) and fruits (0.26±0.04 %), respectively. The highest infestation of *T. absoluta* at Badin (14.10±0.28 %), Thatta (11.10±0.27 %), Sanghar (8.22±0.34 %), Hyderabad (5.32±0.18 %) and Shaheed Benazirabad (4.18±0.22 %) was also recorded on leaves. Therefore, early monitoring and management should be taken by growers to restrict the losses of *T. absoluta* on tomatoes, whereas government should adopt strict quarantine measures on the movement of tomato nurseries to restrict its spread.

Keywords: Infestation, leafminer, Solanaceae, survey, tomato

1. INTRODUCTION

Globally among vegetables, tomato (*Solanum lycopersicum* L.) (Solanaceae) is cultivated and consumed on a large scale, mainly because of its nutrient contents (Vitamins A, C, K, and minerals) that are essential for human health [1-2]. In Pakistan, tomatoes are cultivated in all four provinces as total area and production during 2018-2019, were 54.5 thousand hectares and 560.6 thousand tons, respectively [3]. In Pakistan, Sindh province contributed a major share in the area and production of tomatoes. The area and total production during 2018-19 in the province stood at 21.0 thousand hectares and 153.3 thousand tons, respectively [3]. However, in Pakistan, yield potential of tomatoes is not fully exploited because of many constraints with insect pests being one of the key factors for significant yield reduction [4].

Tomato leafminer (TLM), *Tuta absoluta* (Lepidoptera: Gelechiidae), originated from South America, is a highly invasive pest of tomato and other solanaceous plants including potato [5, 6], along with other cultivated crops such as eggplant [7, 8]. Its larvae cause severe damage to tomatoes, after emergence from egg, it penetrates leaves, apicals buds, flowers, fruits and stems [9]. It forms extensive galleries in the feeding areas, which hinders the normal growth and development of the plants as the plants may bear a necrotic appearance [10]. The yield losses due to the attack TLM may

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be enormous as in severe cases it may cause 100 % loss to the produce in both green house and open field tomatoes [1, 5, 11].

Tuta absoluta was first reported outside South America in 2006 and then spread rapidly in almost all tomato-growing areas in Europe, Africa and Asia including China [1, 5, 12-15]. Thus, within ten years of its first invasion, it has attacked up to 60 % of the tomato-growing regions of the world including China, Spain, Italy, Iran, Egypt, Turkey and India, seven of the top ten tomato producers [16, 17]. Therefore, it is surprising that these countries including the European Union and USA did not take serious quarantine measures to restrict its invasion despite knowing its status as a key pest of tomatoes in its native region [5, 11]. Among the main reasons for its invasion includes the commercialization and importation of tomato seedlings and fruits from the infested areas [5, 18, 19] as well as its ability to survive on plants other than the Solanaceae family [20].

Tuta absoluta was first reported from Pakistan in tomato-growing areas of Southern Punjab during 2020 [21], whereas [4] also confirmed its presence in the Charsadda district of Khyber Pakhtunkhwa province. Although, no confirmed reports of TLM infestation have been reported from Sindh province, it has been mentioned that having information about the prediction, relative abundance, and geographical distribution potential of the invasive species is key for their restriction and proper management [22, 23]. Therefore, this study was undertaken from the main tomato-growing areas of Sindh to determine the presence and infestation level of TLM.

2. MATERIALS AND METHODS

Six districts i.e., Badin, Thatta, Mirpur Khas, Hyderabad, Sanghar, and Shaheed Benazirabad were selected for the survey because they are the main tomato-growing areas of Sindh. Survey was conducted at the time of fruit set to confirm the damage percentage of *T. absoluta* as its attacks on all the above-ground growing parts of the tomato. Five fields were randomly selected from each district (Table 1). Fifty plants were randomly selected from each field to determine the infestation percentage by observing the characteristic mines (Figure 1) in leaves and fruits [10], and also by counting the number of healthy and infested leaves, stems and

Table 1. Names and GPS co-ordinates of locations where samples were collected

District	Location	Address	Latitude	Longitude
Badin	One	Village Ibraheem Junejo	24.60222	68.78219
	Two	Village Mevo Jaskani, UC Kazia Wah, Taluka Badin	24.60622	8.78184
	Three	Village Mevo Jaskani, UC Kazia Wah, Taluka Badin	24.60367	68.7754
	Four	Village Mosa Junejo, UC Kazia Wah, Taluka Badin	24.58904	68.79211
	Five	Village Mosa Junejo, UC Kazia Wah, Taluka Badin	24.58974	68.79142
Mirpur Khas	One	Village Muhammad Yousif Rajar Taluka Shujabaad	25.42368	69.00844
	Two	Goth Haji Rajar Taluka Shujabaad	25.42508	69.04349
	Three	Goth Ismail Rajar Taluka Shujabaad	25.43213	69.0401
	Four	Village Allah Bachayo Rajar Taluka Shujabaad	25.417267	69.02167
	Five	Village Hamid Rajar Taluka Shujabaad.	25.420116	69.02388
Sanghar	One	Village Muhammad Saeed Araen, UC Kurkli, Taluka Sinjhoro	25.93791	68.81557
	Two	Village Khan Muhammad Brohi, UC Kurkli, Taluka Sinjhoro	25.93769	68.81793
	Three	Village Kurkli, Taluka Sinjhoro	25.93955	68.81306
	Four	Village Ali Gul Qambrani, Taluka Sinjhoro	25.93182	68.8228
	Five	Village BK Daas, Taluka Sinjhoro	25.96131	68.7912
Shaheed Benazirabad	One	Village M. Safar Dahari Deh 78 Nusrat Taluka Daur	26.43979	68.34136
	Two	Village M. Safar dahari Deh 78 Nusrat Taluka Daur	26.44101	68.3429
	Three	Village Haji Meeran Mari 60-Miles, Taluka Daur	26.41035	68.44041
	Four	Village Haji Meeran Mari 60-Miles, Taluka Daur	26.41373	68.4308
	Five	Village Syed Mithal shah deh 16 Dad, Taluka Nawab Shah	26.52263	68.33262

District	Location	Address	Latitude	Longitude
Thatta	One	Village Karam Khan Magsi, UC Faqueer Goth, Taluka Thatta	24.74726	67.95761
	Two	Village Karam Khan Magsi, UC Faqueer Goth, Taluka Thatta	24.74706	67.95755
	Three	Village Faqueer jo goth, UC Faqueer Goth, Taluka Thatta	24.74989	67.95202
	Four	Village Faqueer jo goth, UC Faqueer Goth, Taluka Thatta	24.75075	67.95215
	Five	Village Karam khan Magsi, UC Faqueer Goth, Taluka Thatta	24.74726	67.95761
Hyderabad	One	Village Haji Allahdad, near Channel Mori, Tando Jam Hyderabad	25.38768	68.40959
	Two	Village Haji Allahdad, near Channel Mori, Tando Jam Hyderabad	25.38691	68.412
	Three	Village Naseer Morio, near Channel Mori, Tando Jam Hyderabad	25.40691	68.40977
	Four	Village Naseer Morio, near Channel Mori, Tando Jam Hyderabad	25.41033	68.40599
	Five	Village CH Nizam Din, near Channel Mori, Tando Jam Hyderabad	25.41777	68.4599

fruits. The percentage infestation was calculated using the following formula:

The collected data were subjected to analysis of variance using Statistix 8.1 computer software and their means were compared for significant differences using Least Square Difference (LSD) at a 5 % probability level.

3. RESULTS

The survey results confirmed the presence of *T. absoluta* from all the sampling locations of six districts of Sindh, Pakistan. The infestation of *T. absoluta* was recorded from both leaves and fruits of tomatoes. A three-way ANOVA results (Table 2) confirmed a highly significant difference ($F = 6.97$, $P < 0.0001$, $n = 20$) in the infestation level of *T. absoluta* on leaves and fruits of tomato fields of five randomly selected locations of six districts of Sindh. Among the sampling districts, significantly the highest infestation of *T. absoluta* was observed at Mirpur Khas, whereas its attack was more on leaves than fruits. Accordingly, location one of Mirpur Khas district suffered the highest infestation of *T. absoluta* on leaves (19.36±0.92 %), followed by location five (17.36±0.95 %) of the same district, also observed on leaves. Among other districts i.e., Badin, Thatta, Sanghar, Hyderabad, and Shaheed Benazirabad, the highest infestation percentage of *T. absoluta* recorded was 14.80±0.64 % (location two), 13.84±0.83 % (location one), 13.68±0.63 % (location five), 6.36±0.50 % (location two), and 6.04±0.53 % (location two), respectively, all recorded on tomato leaves (Table 3).

Although the infestation of *T. absoluta* on tomato fruits was very low as compared to leaves, the highest infestation on fruits (1.36±0.28 %) was recorded at location one of Mirpur Khas district, followed by 1.32±0.29 % infestation observed at location two of the same district. Among sampling locations of other districts i.e., Badin, Thatta, Sanghar, Hyderabad, Shaheed Benazirabad, the maximum infestation of *T. absoluta* on tomato fruits were recorded as 1.24±0.29 % (location one), 0.72±0.21 % (location two), 0.40±0.14 % (location two), 0.36±0.13 % (location two), and 0.40±0.16 % (location two), respectively (Table 3).

Fig. 1. Damage symptoms of *Tuta absoluta* on tomato leaf and fruit observed during the study

Table 2. Analysis of Variance for mean percentage infestation of *Tuta absoluta* on tomato leaves and fruits at various sampling locations of six districts of Sindh, Pakistan.

Source	df	Sum of Squares	Mean sum of squares	F-value	P-value
Districts	5	9050.3	1810.1	422.05	0.0000
Plant Parts	1	33210.2	33210.2	7743.62	0.0000
Farmers	4	396.5	99.1	23.11	0.0000
District * Plant part	5	6858.5	1371.7	319.84	0.0000
District * Farmers	20	659.2	33.0	7.68	0.0000
Plant part * farmers	4	344.1	86.0	20.06	0.0000
District * Plant part * farmer	20	597.9	29.9	6.97	0.0000
Error	1440	6175.8	4.3		
Total	1499	57292.4			

Results regarding the overall mean infestation percentage of *T. absoluta* observed on leaves and fruits of tomatoes at various sampling districts illustrated a highly significant difference ($F = 319.84$, $P < 0.001$) (Figure 2). At all the sampling districts, as compared to fruits, tomato leaves suffered a significantly highest infestation of *T. absoluta* as the highest overall infestation (17.04±0.38 %) was recorded on tomato leaves from various sampling locations of Mirpur Khas district, whereas the lowest infestation on tomato leaves was recorded at Shaheed Benazirabad (4.18±0.22 %). The overall infestation on leaves recorded at Badin, Thatta, Sanghar, and Hyderabad districts was 14.10±0.28, 11.10±0.27, 8.22±0.34, and 5.32±0.18 %, respectively, which were all significantly different from each other. As compared to tomato leaves, very little infestation of

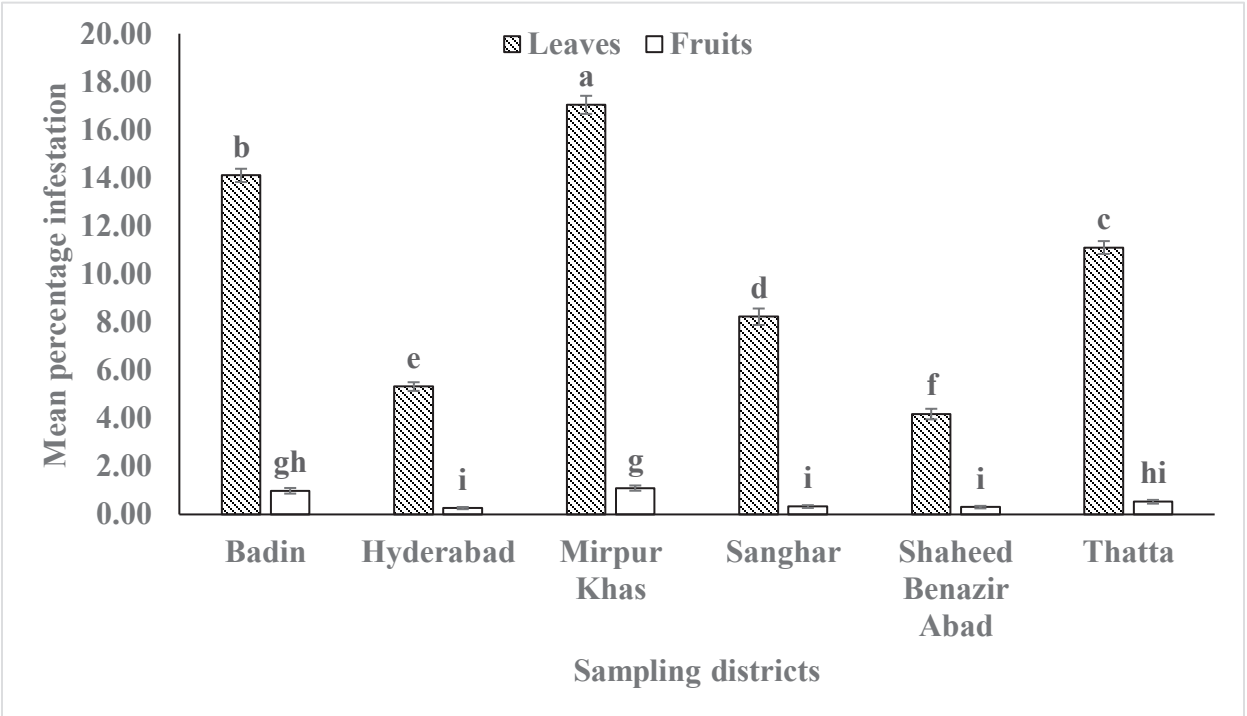

Fig. 2. Overall mean infestation of Tuta absoluta on tomatoes (leaves and fruits) at various sampling districts of Sindh, Pakistan (*Mean followed by the same letters are not significantly different from each other (LSD = 0.5139, $P < 0.05$)

Table 3. Mean percentage infestation of *Tuta absoluta* on tomato leaves and fruits at various sampling locations of six districts of Sindh, Pakistan.

District	Locations	Plant Part	Percentage Infestation
Badin	One	Leaves	14.56±0.77cde
		Fruits	1.24±0.29pqr
	Two	Leaves	14.80±0.64cd
		Fruits	1.16±0.29pqr
	Three	Leaves	13.52±0.62e
		Fruits	0.68±0.21pqr
	Four	Leaves	14.00±0.57cde
		Fruits	1.16±0.29pqr
	Five	Leaves	13.64±0.47e
		Fruits	0.68±0.21pqr
Hyderabad	One	Leaves	5.60±0.46jkl
		Fruits	0.28±0.09
	Two	Leaves	6.36±0.50ij
		Fruits	0.36±0.13pqr
	Three	Leaves	4.48±0.33lm
		Fruits	0.24±0.10pqr
	Four	Leaves	4.88±0.32klm
		Fruits	0.16±0.07r
	Five	Leaves	5.28±0.28jkl
		Fruits	0.28±0.11pqr
Mirpur Khas	One	Leaves	19.36±0.92a
		Fruits	1.36±0.28p
	Two	Leaves	17.28±0.73b
		Fruits	1.32±0.29pq
	Three	Leaves	14.84±0.54c
		Fruits	0.84±0.20pqr
	Four	Leaves	16.36±0.79b
		Fruits	1.16±0.22pqr
	Five	Leaves	17.36±0.95b
		Fruits	0.80±0.21pqr
Sanghar	One	Leaves	7.40±0.47i
		Fruits	0.32±0.11pqr
	Two	Leaves	8.72±0.62h
		Fruits	0.40±0.14pqr
	Three	Leaves	5.80±0.32jk
		Fruits	0.36±0.15pqr
	Four	Leaves	5.52±0.33jkl
		Fruits	0.20±0.10qr
	Five	Leaves	13.68±0.63de
		Fruits	0.36±0.14pqr

District	Locations	Plant Part	Percentage Infestation
Shaheed Benazirabad	One	Leaves	5.40±0.53jkl
		Fruits	0.24±0.09pqr
	Two	Leaves	6.04±0.53j
		Fruits	0.40±0.16pqr
	Three	Leaves	3.04±0.16no
		Fruits	0.28±0.11pqr
	Four	Leaves	2.60±0.33o
		Fruits	0.28±0.11pqr
	Five	Leaves	3.80±0.37mn
		Fruits	0.32±0.11pqr
Thatta	One	Leaves	13.84±0.83cde
		Fruits	0.52±0.17pqr
	Two	Leaves	9.92±0.40g
		Fruits	0.72±0.21pqr
	Three	Leaves	11.28±0.40f
		Fruits	0.56±0.19pqr
	Four	Leaves	9.28±0.41gh
		Fruits	0.48±0.17pqr
	Five	Leaves	11.20±0.37f
		Fruits	0.36±0.11pqr

*Means followed by the same letters are not significantly different from each other (LSD = 1.1490, P < 0.05)

T. absoluta was recorded on fruits with the highest overall percentage infestation observed at Mirpur Khas district (1.10±0.11 %), not significantly different from overall infestation recorded at Badin (0.98±0.12 %). The lowest overall infestation of *T. absoluta* fruits was recorded Hyderabad district (0.26±0.04 %) that was not significantly different from the infestation recorded at Shaheed Benazirabad (0.30±0.05 %), Sanghar (0.33±0.06 %) and Thatta (0.53±0.08 %) districts (Figure 2).

4. DISCUSSION

The comprehensive survey of *T. absoluta* presence and infestation in the main tomato-growing areas of Sindh, Pakistan confirmed its presence in all the sampling locations, however, there was a significant difference among various locations and districts regarding its infestation. Moreover, characteristic symptoms of *T. absoluta* mines were only observed on tomato leaves and fruits. The infestation of *T. absoluta* in Pakistan was first time reported in the tomato-growing areas of the Multan district of Punjab [21]. However, a recent comprehensive survey study confirmed its presence from Charsadda district of Khyber Pakhtunkhwa, besides Multan and Rawalpindi districts of Punjab with significantly more attacked samples (15.54 %) collected from Charsadda, followed by Rawalpindi (1.45 %) and Multan (0.52 %), whereas no infestation of *T. absoluta* was observed from Muzaffargarh, Lodhran and Rahim Yar Khan districts [4]. However, in our study, the infestation of *T. absoluta* was recorded from all the sampling locations of six major tomato-growing districts of Sindh showing significant differences among locations and districts. Such a rapid spread of *T. absoluta* in new locations including recent infestation observed in this study may be attributed to the free movement of the tomatoes or their nurseries from the infested areas to the new locations. Generally, no strict quarantine measures are observed in different areas of Pakistan when there is a growing demand for tomatoes, hence it facilitates the transportation of infested tomatoes from areas of infestation to the new locations [4].

It has been mentioned by McNitt *et al.* [24] that in the absence of proper quarantine measures and large-scale self-mediated, unmitigated spreading

potential of the pest among cities, *T. absoluta* can invade almost all the key vegetable-growing areas of Southeast Asia within a short period of 5 to 7 years. Similar kind of findings was reported by Tonnang *et al*. [25] and Kinyanjui *et al*. [26] who observed the trade of infested tomato fruits among the neighbouring cities of Kenya as its main source of spread in the country. Many other studies also identified that the main reason for the rapid spread of *T. absoluta* in new localities and regions was the commercialization and importation of tomato fruits and seedlings [5, 18-19, 27-28].

Moreover, Pakistan has a long border with China, which is the largest producer and exporter of tomatoes [29], where the presence of *T. absoluta* has been confirmed by Zhang *et al.* [6]. It has been also reported that *T. absoluta* has the potential to spread around 800 kilometers in a year [5, 30]. Therefore, having such an invasive characteristic along with a long border with China can easily facilitate the movement of *T. absoluta* into Pakistan, as the climatic conditions and long tomato growing seasons of tomatoes in Pakistan can facilitate its spread all over the country [4].

A significant difference in the level of *T. absoluta* infestation of various plant parts (leaves and fruits) at various locations surveyed of six districts may be attributed to various tomato cultivars grown or the cultural practices adopted by the respective growers, besides the geographical location and weather conditions of the survey areas. The recent study of Sadique *et al.* [4] also significant effect of rising temperatures on the mean capture of *T. absoluta* moths in pheromone traps in Pakistan. Another study also mentioned that *T. absoluta* showed a preference for some cultivars, whereas some showed relative resistance against it [31]. Kinyanjui *et al.* [26] also found similar results while evaluating the infestation of *T. absoluta* at various locations in Kenya as the number of mines and larvae differ significantly at the locations. Moreover, a relatively lower level of infestation on fruits has been reported by Kinyanjui *et al.* [26] as the same support the findings of our study. However, 80-100 % damage to open-field tomatoes has been reported by Mohamed *et al.* [32] in Sudan which may be due to the susceptibility of the cultivars grown or the free movement of the pest.

5. CONCLUSION

Tuta absoluta infestation was recorded from tomato leaves and fruits observed at all the surveyed locations of six districts i.e., Badin, Thatta, Mirpur Khas, Hyderabad, Sanghar and Shaheed Benazirabad. However, the level of infestation varies among various locations, districts, and plant parts. The highest infestation of tomato leaves and fruits was recorded in the Mirpur Khas district, whereas Shaheed Benazir Abad and Hyderabad tomato fields showed the lowest infestation of leaves and fruits. Tomato leaves were more attacked by *T. absoluta* than fruits. Therefore, appropriate monitoring and management measures should be taken by growers against *T. absoluta* to restrict its damage. Moreover, the government should strictly quarantine measures regarding the movement of transplanting tomato seedlings to restrict the spread of *T. absoluta* in new areas.

6. CONFLICT OF INTEREST

The authors declared no conflict of interest.

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