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(Original Article)

The Differential Impacts of *Tuta absoluta* Infestations on Some Nutrient and Pigments contents of Tomato Plant Leaves

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Abstract

Tomato is one of the most important vegetable crops cultivated in Egypt. *Tuta absoluta* is a devastating insect pest that causes tremendous damage to tomato's fields. An experiment was conducted at the Faculty of Agriculture Farm, Assiut University, Assiut, Egypt to study the effect of *Tuta absoluta* (Lepidoptera: Gelechiidae) infestation on tomato leaf contents of nutrients (Calcium, Magnesium, and Potassium) along with photosynthetic pigments (Carotene and Chlorophyll a + b). The results shows that plants with un-infested leaves had higher mean levels of calcium, potassium, and magnesium compared to infested plants. Regarding the effect of *T. absoluta* infestation on carotene and (A+B) in tomato leaves, the results indicate a significant difference for the average contents of carotene and Chlorophyll a + b between the un-infested and infested tomato leaves. This study highlights the differential risk of *T. absoluta* infestations in tomato production.

Keywords*: Carotene, Chlorophyll, Nutrient elements, Tomato, Tuta absoluta.*

Introduction

Lycopersicon esculentum (Tomato) is one of the most important vegetables used primarily in preparing many meals and highly utilised in food industries in several forms, i.e. juices, fresh, and dried fruits. Egypt ranks fifth in global tomato production (Faied *et al*., 2022). The tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) is a highly specialized insect pest that attacks solanaceous crops (Lietti *et al*., 2005). It is a typical example of a serious pest threatening tomato production worldwide (Biondi *et al*., 2018 and Santana *et al*., 2019). The caterpillars cause direct damage by forming tunnels in leaves, stems, and fruits, posing enormous challenges for control within these tunnels. Indirect damage occurs through the access provided to pathogens while forming the tunnels. Total losses could reach up to 100 % in tomato fields (Bayindir *et al*., 2015).

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The trend of avoiding insecticides has become the first-world demand to reduce human and environmental hazards. Resistant or tolerant varieties are characterized with high nutritive elements and pigment contents in leaves. It could be the best solution to avoid the excessive use of insecticides to penetrate tunnels and strike *T. absolua* (Campos *et al*., 2017). One of the main pigments in tomato leaves responsible for the process of photosynthesis is chlorophyll "a" and "b" (Solomon *et al*., 2011). Carotene is an important pigment in plants that is responsible for physiological processes within the plant, including photosynthesis (Nisar *et al*., 2015).

The nutritive elements and photosynthetic pigment contents in leaves play an important role in the defending system against insect attacks on various plants. Leaf elements are essential for the complex biochemistry related to plant growth and in many cases support plants in tolerating growth under severe damage (Chen *et al*., 2010 and Gahukar, 2012). Calcium (Ca) is an extremely important mineral and is considered the key element responsible for the development of cell wall and roots (Marschner, 2011). Magnesium (Mg) plays a vital role in photosynthesis, as it is the central atom in the chlorophyll molecule and is involved in many enzyme reactions and reacts with phosphorus in uptake and transport. Potassium (K) is important for many vital physiological processes and has a significant impact on tomato crop quality due to its vital role in photosynthesis. It plays a role in disease tolerance and increases the overall hardiness of grass plants. Feeding by sucking insects, such as aphids, leafhoppers, and scale insects on leaves leads to yellowing of the leaves and a decrease in the photosynthesis process (Zvereva *et al*., 2010). Hence this study aims to investigate the effect of infestation by *T. absoluta* on the contents of nutritive elements (Ca, Mg, and K) and photosynthetic pigments (Chlorophyll a + b and Carotene).

Materials and Methods

1. Experimental design and field trials

The experiment was conducted during 2022 and 2023 seasons in the Faculty of Agriculture Farm, Assiut University in Assiut, Egypt. Infested leaves were removed before planting the seedlings of the tomato hybrid (010). Tomato hybrid was planted in two rows each row consisting of ten replicates per row. The plot size was 4x4 m and contained four terraces each with six seedlings, with 25 cm spaces between terraces.

2. Collection protocol of infested and non-infested leaves

The protocol of Land Reclamation and the Ministry of Agriculture in Egypt (2013) was the standard used during the collection of leaves. The leaves were collected weekly four times per month in polyethylene bags and transferred into the Laboratory of Plant Protection Research. The leaves were carefully examined using a binocular microscope and then separated into infested and non-infested leaves. The numbers of *T. absoluta* larvae in the infested leaves were directly counted.

3. Determination of nutritive elements and photosynthetic pigments

The samples were taken from tomato leaves of tomato hybrid (010) to determine calcium, magnesium and potassium concentrations. The leaves were dried at 70°C, weighed and digested using a mixture of H_2SO_4 and H_2O_2 according to the method described by FAO (1989). Potassium concentration was determined using flame photometer as described by (Horneck and Hanson, 1998), while calcium and magnesium concentrations were determined according to Stefánsson *et al*. (2007). The results were obtained from ten randomly chosen plants to each of infested and un-infested plants with *T. absoluta* (ten leaves per plant) after 45 days from agriculture. Pure acetone was used to extract the pigments (carotenoids and chlorophyll a, b) from the leaves of the tomato plant according to Wellburn (1994). A spectrophotometer was used to measure the optical densities at 452.5 and 664.5, 647 nm, for carotenoids and chlorophyll a, b, respectively.

Statistical analysis

Analysis was performed using SPSS (Version 16.0). Additionally, the Independent-Sample T-test was used to analyse the results of photosynthetic pigments and nutritive elements in both - infested and un-infested tomato leaves.

Results and Discussion

1. The nutritive element's contents and infestation of *T. absoluta*

The feeding damage caused by *T. absoluta* significantly reduced the nutritive elements content produced by the leaves of tomato. Where the results indicate that there was a significant difference between the average content of nutritive elements in un-infested and infested tomato leaves (Table 1 and Figure 1). It was observed that the mean contents of calcium, magnesium, and potassium were 62.79±1.77, 4.212±0.456 and 51.58±0.912 mg/gFW in non-infested tomato leaves, respectively during 2022 season. However, the mean content of calcium, magnesium and potassium were 22.27±1.33, 1.543±0.260 and 40.31±5.30 mg/gFW in infested tomato leaves, respectively. Moreover, the mean content of calcium, magnesium and potassium was 63.60±1.26, 4.325±0.418 and 51.71±0.689 mg/gFW, respectively in un-infested tomato leaves during the 2023 season. The mean content of calcium, magnesium and potassium in infested tomato leaves was 22.45±1.02, 1.430±0.28 and 40.29±3.068 mg/g FW, respectively. Tomato crops require nutrients, such as calcium, nitrogen, sulfur and potassium (Fayad *et al*., 2002). Mineral elements play a crucial role in plant growth by influencing various physiological processes within the plant (Maathuis, 2009). Essential elements for plants are phosphorus (P), potassium (K), nitrogen (N), calcium (Ca), sulfur (S) and magnesium (Mg) (Kirkby, 2012). Plant growth, reproduction, development, survival, and defense depend on their nutritional status (Chen *et al*., 2004). (Gahukar, 2012) Balanced nutrition in plants leads to faster growth, increased green leaf mass, and higher nutrient content in leaves compared to unbalanced plants. Additionally, leaves with balanced nutrition contain high levels of secondary metabolites that contribute to

defense mechanisms against herbivores. Infestation by the *Tuta absoluta* insect can result in leaf damage, reduced-nitrogen levels, and decreased photosynthesis rates in tomato plants (Mahlangu *et al*., 2022). Pest infestation of plants can reduce photosynthesis by up to 50% (Welter, 1989). Nutritive elements such as calcium, nitrogen, manganese and magnesium are significantly reduced by beetle herbivory (Marler, 2018).

Table 1. Mean contents of nutritive elements Ca, Mg, and K in infested and un-infested tomato leaves by *T. absoluta* during the 2022 and 2023 seasons.

Nutritive Elements	Season	Infested tomato leaves	Un-infested tomato leaves	T test
Ca	2022	22.27±1.33	62.79±1.77	63.34**
	2023	22.45±1.02	63.60±1.26	87.80**
Mg	2022	1.543±0.260	4.212±0.456	17.62**
	2023	1.430±0.28	4.325±0.418	19.86**
K	2022	40.31±5.30	51.58±0.912	7.259**
	2023	40.29±3.068	51.71±0.689	12.58**

Ca= Calcium; Mg= Magnesium; K= Potassium ** Highly significant (P<0.01)

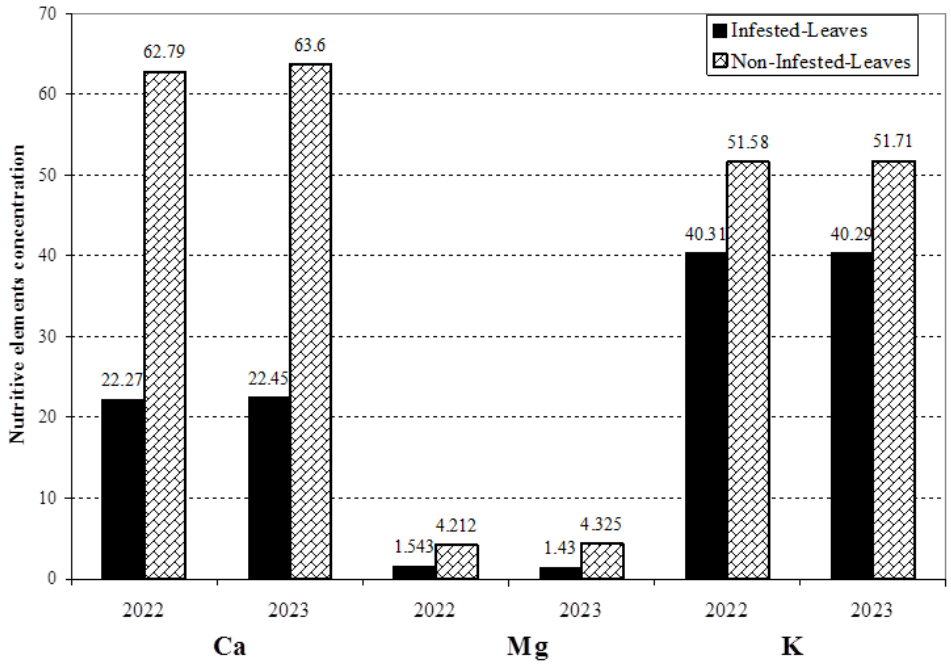

Fig. 1. Mean of nutritive elements in tomato leaves in relation to *T. absoluta* infestation during the 2022 and 2023 seasons.

2. Pigments

Data in Table 2 and Figure 2 indicate the presence of significant differences in the mean content of carotene and chlorophyll (A+B) between both un-infested and infested tomato leaves. The results show that the mean content of carotene and chlorophyll (A+B) were 5.913±0.451 and 17.13±0.311 mg/gFW in un-infested tomato leaves, respectively.

Table 2. Mean contents of photosynthetic pigments carotene and chlorophyll in infested and un-infested tomato leaves by *T. absoluta* during the 2022 and 2023 seasons

Photosynthetic pigments	Season	Infested tomato leaves	Un-infested tomato leaves	T test
Car.	2022	3.002±0.748	5.913±0.451	11.54**
	2023	3.035±0.393	6.102±0.264	22.43**
Chlo. (A+B)	2022	9.918±2.953	17.13±0.311	8.415**
	2023	10.76±1.539	17.17±0.403	13.96**

Car.= Carotene; Chlo.=Chlorophyll ** Highly significant (P<0.01)

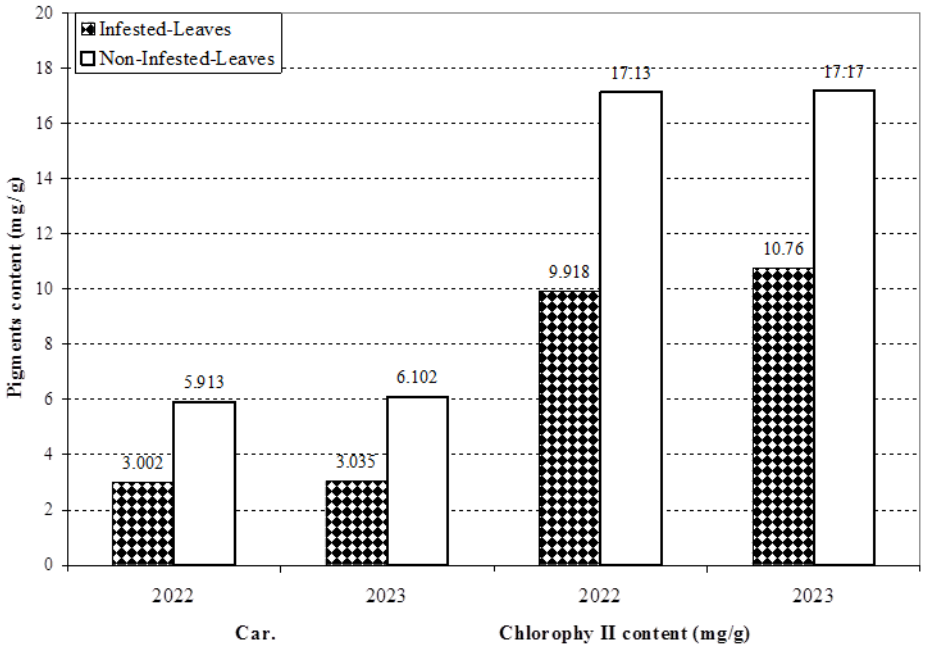

Fig. 2. Mean photosynthetic pigment content (mg/gFW) of tomato leaves in relation to *T. absoluta* infestation during the 2022 and 2023 seasons.

In infested tomato leaves during the 2022 season the mean content of carotene and chlorophyll (A+B) were 3.002±0.748 and 9.918±2.953 in infested tomato leaves, respectively in the 2023 season the mean content of carotene and chlorophyll (A+B) were 6.102±0.264 and 17.17±0.403 in non-infested tomato leaves, respectively, while, the mean content of Carotene and Chlorophyll (A+B) were 3.035±0.393 and 10.76±1.539 in infested tomato leaves, respectively. Insect pests that suck plant juices, such as aphids and scale insects, as well as larvae that feed on leaves cause cell damage and consequently reduce the photosynthetic rate (Mansour *et al*., 2017). The results of the study in both seasons showed that the feeding of *Tuta absoluta* on leaves reduced pigments due to the insect consumption of large portions of the leaves. The chlorophyll content of the plant is an indicator of plant health as it is directly related to physiological processes within the plant, such as the process of photosynthesis (Palta, 1990). Plants infested with *Tuta absoluta* exhibited yellowing and unhealthy appearance, leading to decreased photosynthesis and halted physiological processes in tomato plants. Infestation by *Tuta absoluta* resulted in a decrease in chlorophyll content due to chloroplast removal and alterations in the photosynthesis process (Hussain

et al., 2015). Bughdady *et al*. (2020) found that the whitefly, *B. tabaci*, feeding reduced plant pigment content (carotenoids and chlorophyll a, chlorophyll b), due to sap-sucking leading to a decline in plant pigments. Al Shareef (2011) studied the effect of whitefly infestation on carotene and chlorophyll, in zucchini and cucumber plants in a greenhouse showing a reduction in pigment content in the leaves due to whitefly infestation. Buntin *et al*. (1996) observed that brown soft scale feeding on pigments and chlorophyll content in leaves resulted in decreased pigment content with an increase in insect pest population. Ni *et al*. (2002) found that *Diuraphis noxia and Rhopalosiphum padi* caused a decrease in chlorophyll and carotenoid content in infested wheat leaves. Studying the relationship between plants and herbivores is crucial for determining integrated pest management programs.

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التأثيرات المختلفة للإصابة بحشرة توتا ابسولوتا على العناصر الغذائية والصبغات في أوراق نبات الطماطم

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الملخص

يعتبر نبات الطماطم من أهم محاصيل الخضر المزروعة في مصر. وتعتبر حشرة توتا ابسولوتا من الآفات الحشرية المدمرة لمحاصيل الطماطم وتسبب أضراراً جسيمة لمحاصيل الطماطم الحقلية .أجريت التجربة في مزرعة كلية الزراعة بجامعة أسيوط، أسيوط، مصر لدراسة تأثير الإصابة بحشرة توتا ابسولوتا (حرشفية الأجنحة: جيليكيداي) على محتوى أوراق الطماطم من العناصر الغذائية (الكالسيوم والمغنيسيوم والبوتاسيوم) والصبغات (الكاروتين والكلوروفيل أ + ب). أظهرت النتائج أن النباتات ذات الأوراق غير المصابة كان متوسط مستويات الكالسيوم والبوتاسيوم والمغنيسيوم بها أعلى من النباتات المصابة .وفيما يتعلق بتأثير الإصابة بحشرة توتا ابسولوتا على أصباغ الطماطم، أظهرت النتائج وجود فروق ذات دلالة إحصائية عالية في جميع متوسطات محتوى الصبغات (الكاروتين والكلوروفيل) في أوراق الطماطم السليمة مقارنة بأوراق الطماطم المصابة .تقدم هذه الدراسة المخاطر التفاضلية للإصابة بحشرة توتا ابسولوتا في إنتاج الطماطم

الكلمات المفتاحية: *توتا ابسولوتا، الطماطم، العناصر الغذائية، الكاروتين، الكلوروفيل*