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Using Silica Nanoparticles and Neemoil Extract as New Approaches to Control *Tuta absoluta* (Meyrick) in Tomato under Field Conditions

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study aimed to evaluate the efficacy of silica nanoparticles and neem oil extract at different concentrations compared with recommended chemical insecticide (imidacloprid) against *T. absoluta* under field conditions.
Study Design: Seven treatments plus control in randomized complete block design (RCB) at four replicates.
Place and Duration of Study: This experiment was carried out at El-Ryiad region, Kafr El-Sheikh Governorate under field conditions during two tomato growing seasons; 2012 and 2013.
Methodology: About 0.14 hectar (1400 m^2) was transplanted with Star variety seedlings as one of the most common variety cultivated at Kafr El-Sheikh region. Recommended agricultural practices were adopted normally. The nano silica size was 20 nm with a purity of 99.99% at three concentrations and neem oil at three concentrations also compared with chemical insecticide with recommended dose. To calculate the percentage of *T. absoluta* reduction, Henderson Tilton's formula was used. Also, the number and the weight of tomato fruits at harvest from 20 plants (5 plants/replicate) were recorded and estimating the Vitamin C (mg/100 g of sample) and Total Soluble Solids percentage (TSS %) as a quality parameters.
Results: Using silica nanoparticles reduced significantly the numbers of *T. absoluta*

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larvae followed by neem oil extract compared with check (without any treatments). There were not significant differences between using silica nanoparticles and imidacloprid ($p<0.05$) in control *T. absoluta*. There were not significant differences when analyzing the content of tomato fruits resulting from the different treatments compared to the check, however, must be taken into account the residual impact of the chemical pesticide. The results also showed a significant increase in the weight and size of tomato fruits as a result of the silica nanoparticles treatment.

Conclusion: Silica nanoparticles was effective in control *T. absoluta* under field condition with high yield in tomato. Also, we need more study to showed the side effects on natural enemies during using silica nanoparticles.

Keywords: Tomato; tuta; nano; plant extracts; control.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most widely grown vegetable in the world. It is grown on more than 5 million ha with a production of nearly 129 million ton. China is the world's top tomato grower, accounting for more one-quarter of the world's tomato acreage. Egypt and India together account for more than one-fifth of the world total; Turkey and Nigeria are the other major tomato producing countries. Asia and Africa account for about 79 percent of the global tomato area, with about 65 percent of world output [1,2,3,4].

The tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the most important lepidopterous pests associated with tomato crops in South America [1,5,6,7,8,9]. It is considered as a limiting factor for tomato production all over the world, accounting for about 70% of the losses [10,11,12,13].

This pest entered Europe through the Mediterranean coast, being first sighted late 2006 in the Iberian Peninsula [14]. In August 2007, the first affected tomato plantation was detected in the south of Catalonia (NE Spain) [15]. Recently the pest has been detected in France, Italy, United Kingdom and the Netherlands [10,16,5] and it has become a significant problem in greenhouses or in open crops in other Mediterranean countries. The newly introduced pest from South America to the shores of the Mediterranean found a perfect new environment where it can breed between 10–12 generations a year. Each female can lay 250–300 eggs in her lifetime. This pest is crossing borders and devastating tomato production in both protected and open fields and is considered a very challenging pest to control [5,17,18,19,20,21,22].

Owing to the increasing environmental hazards and enhanced resistance towards insecticides, has prompted active research in biological control (plant extracts) and in highly efficacious insecticides with novel modes of action. These are becoming increasingly important in agriculture as components of integrated pest management, resistance management strategies and to replace older classes of compounds which are perceived to carry higher safety and environmental risks [23,24].

Nanotechnology is emerging as a highly attractive tool for formulation and delivery of pesticide active ingredients as well as enhancing and offering new active ingredients. Silica nanoparticle using as a new approach to control some insect pests in Egypt, such as aphids and leaf miner in faba bean fields and *T. absoluta* under greenhouse conditions [13].

This hypothesis for the physical mode of action makes the case for the use of nanocides stronger, since the insect is unlikely to become genetically selected or physiologically resistant to such a mechanism. However, the insect may develop a behavioural response to these particles by avoiding contact [25].

This study aimed to 1- Evaluate the efficacy of silica nonoparticles and neem oil extract compared with chemical insecticide (imidacloprid) against *T. absoluta* under field conditions. 2-Estimating the number and the weight of tomato fruits at harvest at 20 plants (5 plants/replicate).3- Estimating the Vitamin C and Total Soluble Solids percentage (TSS %) in resulted tomato fruits as some quality parameters.

2. MATERIALS AND METHODS

This experiment was carried out at El-Ryiad region, Kafr El-Sheikh Governorate, Egypt under field conditions during two tomato growing seasons; 2012 and 2013. About 0.14 hectar (1400 m^2) was transplanted with Star variety seedlings as one of the most common variety cultivated at Kafr El-Sheikh region. Recommended agricultural practices were adopted normally. The plantation date of tomato seeds in the green house was on March 22^{nd} during two seasons (2012 and 2013) and transplanted to experimental field on April 25^{th} during two seasons. The field experiment was carried out in a complete randomized block design (RCB), with four replicates and each plot size was 42 m^2 (6×7 m) with six rows cultivated by about 60 tomato plants.

2.1 Examined Materials

The silica nanoparticles were obtained from Nanotech Egypt Company Limited, Cairo, Egypt. The nano silica size was 20 nm with a purity of 99.99%. The shape of the nanosilica is shown in Fig. 1. Three concentration of silica nano particles (100, 200 and 300 ppm/4200 m^2) were examined under field conditions as bioinsecticide.

The plant extract of Neem oil was obtained from Al-Badawia Company (commercial preparation) and used at three rates; 150, 300 and 450 cm^3/4200 m^2.

The tested insecticide used in this study was imidacloprid (Kanzacloprid 20% SC) produced by Shreeji Pesticides as field rate 100 cm^3/4200 m^2. This insecticide is recommended for control *T. absoluta* in vegetable crops.

2.2 Treatment Evaluation

Each treatment was applied during 45 days after transplanting when the numbers of *T. absoluta* larvae reached 5 larvae/10 plants at least under natural infestation (According to Agricultural Pesticides Committee Protocols, Egypt). Each sample was 10 leaflets from tomato plant/replicate (4 replicates).

The volume of spray per hectar was 700 liters of water. Control replicates were left without any chemicals treatments only water sprayed.

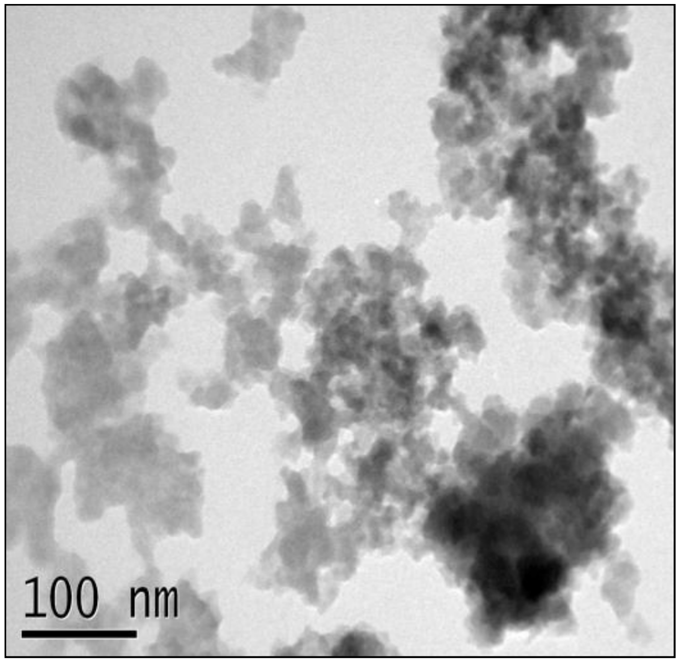

Fig. 1. The shape and size of silica nanoparticles

a. Number of *T. absoluta* larvae were recorded before treatments and after 24 hrs, 3, 5, 7, 10 and 15 days from treatments (According to Agricultural Pesticides Committee Protocols).

To calculate the percentage of *T. absoluta* reduction, Henderson Tilton's formula [26] was using as follow:

$$\text{Reduction \%} = 1 - \left[\left(\frac{TA \times CB}{TB \times CA}\right)\right] \times 100$$

Where

TA = No. of larvae after treatment, TB = No. of larvae before treatment, CB = No. of larvae before treatment, CA = No. of larvae after treatment

b. Record the number and the weight of tomato fruits at harvest at 20 plants (5 plants/replicate) at harvest.
c. Estimating the Vitamin C (mg/100 g of sample) and Total Soluble Solids percentage (TSS %) in resulted tomato fruits according to standard procedures described by [27].

2.3 Statistical Analysis

Analysis of variance was calculated, and the means of the treatments were compared using Duncan's Multiple Range Test [28].

3. RESULTS AND DISCUSSION

3.1 Efficacy of Different Applied Treatments against *T. absoluta* in Tomato under Field Conditions

Data in Tables (1 and 2) show the reduction percentage resulted from three treatments; nanosilica (three rates), neem oil extract (three rates also) and chemical insecticide, imidaclopride (recommended rate) during two seasons 2012 and 2013.

The efficacy of the applied treatments against *T. absoluta* in tomato plants under field conditions with respect to larval mortality are presented in Tables 1 and 2 during two seasons 2012 and 2013. Most of the tested treatments were effective against *T. absoluta* in tomato plants under field conditions relative to the control treatment (Tables 1 and 2). Nanosilica was the most effective treatment against *T. absoluta* with highly rate (300 ppm/4200 m^2) followed by imidacloprid with respect to reduction of larvae counts in treated plants.

Table 1. Efficacy of different applied treatments on *Tuta absoluta* in tomato with respect to reduction in larval counts during 2012 season

Treatment	Rate/4200 m^2	Reduction % of larvae after					
		24 hrs	3 days	5 days	7 days	10 days	15 days
Nanosilica (ppm)	100	52.53	55.41	56.93	61.42	97.43	84.88
	200	58.70	60.75	61.88	67.86	99.07	97.84
	300	67.62	68.69	72.79	74.81	100.00	100.00
Neem extract (cm^3)	150	36.74	37.58	42.46	44.69	57.60	36.13
	300	42.07	47.19	46.15	50.63	61.66	39.84
	450	52.00	52.83	56.69	59.29	70.47	42.27
Imidacloprid (g*a.i.*)	22.26	64.90	74.37	68.35	71.44	99.63	99.63

Table 2. Efficacy of different applied treatments on *Tuta absoluta* in tomato with respect to reduction in larval counts during 2013 season

Treatment	Rate/4200 m^2	Reduction % of larvae after					
		24 hrs	3 days	5 days	7 days	10 days	15 days
Nanosilica (ppm)	100	53.86	63.22	61.62	70.63	98.52	83.98
	200	61.85	67.10	69.48	76.24	99.64	87.50
	300	65.93	70.34	76.29	80.90	100.00	92.35
Neem extract (cm^3)	150	47.77	52.06	52.12	47.89	62.18	37.53
	300	50.51	53.60	53.33	54.40	64.61	46.43
	450	59.98	61.56	63.38	65.61	76.22	60.34
Imidacloprid (g*a.i.*)	22.26	71.99	76.85	77.01	81.29	99.23	90.66

The general mean reduction percentages of the *T. absoluta* larvae during 2012 and 2013 seasons showed in Fig. 2. Results during two seasons reported that nanosilica particles treatments followed by imidacloprid were the best treatments in reducing infestation with tomato leaf miner according statistical analysis. The statistical analysis showed significant differences between all treatments. The lowest reduce number of *T. absoluta* larvae resulted from neem oil extract during two seasons (Fig. 1).

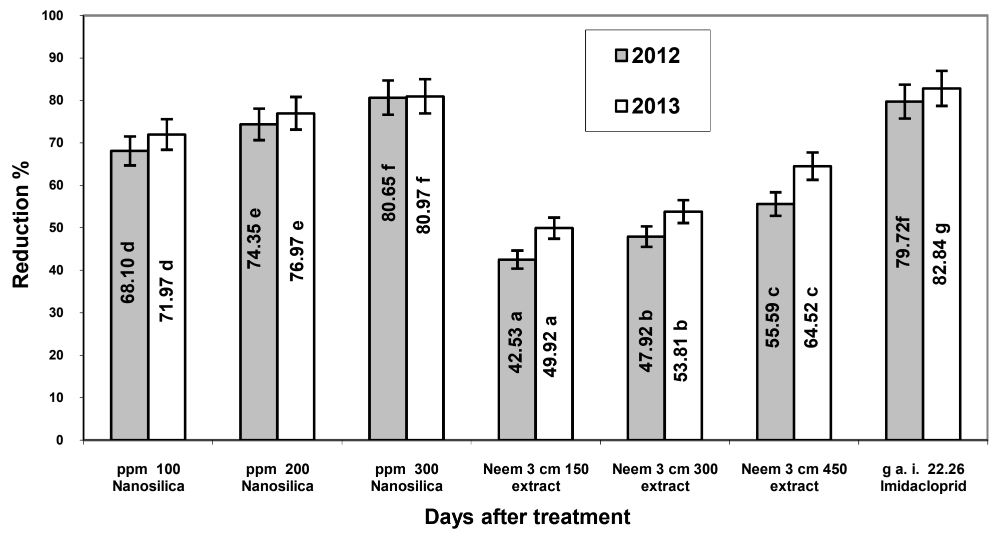

Fig. 2. General mean reduction percentages of the *Tuta absoluta* larva during 2012 and 2013 seasons

Means followed by a common letter are not significantly different at the 5% level by DMRT

The results showed that nanosilica was the most effective treatment against *T. absoluta*on treated tomato plants. This agrees with the finding of [16] who reported that nanosilica showed entomotoxic potential and has no negative effect on plant growth. In addition the silica enhances structural rigidity and strength of the plant cells [29].

The high efficacy of nanosilica against *T. absoluta* may be due to the absorbance of nanosilica into the cuticular lipids of the insect resulting in damage to the protective wax layer (made of various fatty acids and lipids that act as an effective barrier to water loss) and induces death by desiccation [25,30,31,13].

This indicates that the superior entomotoxicity is due to nanosized silica itself, not due to the surface groups attached to them.

The use of such nanomaterials is more acceptable as they are safe for plants and causes less environmental pollution compared to conventional chemicals [32,33,31,30]. Moreover, application of nanoparticles on the leaf and stem surface does not alter either photosynthesis or respiration in several groups of horticultural and crop plants. Therefore, nanosilica and other nanomaterials may offer an important role in improving the pest management techniques for tomato and other crops [13].

The tested insecticide (imidacloprid) in this study showed high efficacy against *T. absoluta* and this agrees with the findings of [34] as well as [35] who reported that these insecticides were effective against larval infestation of *T. absoluta* in tomato. Also, the obtained results agree with that obtained from [13] who showed that the infestation of *T. absoluta* reduced resulted from using silica nanoparticles under greenhouse conditions.

3.2 Estimating the Number and Weight of Tomato Fruits

The statistical analysis showed that, (Fig. 3) all treatments significantly differences compared with control at resulted tomato fruits. The silica nanoparticles (300 ppm/4200 m^2) and chemical insecticide imidacloprid (22.26 g *a.i.*/4200 m^2) were the highly treatments and not significantly at resulted tomato fruit numbers. Data showed also, there were not significant differences between the neem oil extract at the three examined rates.

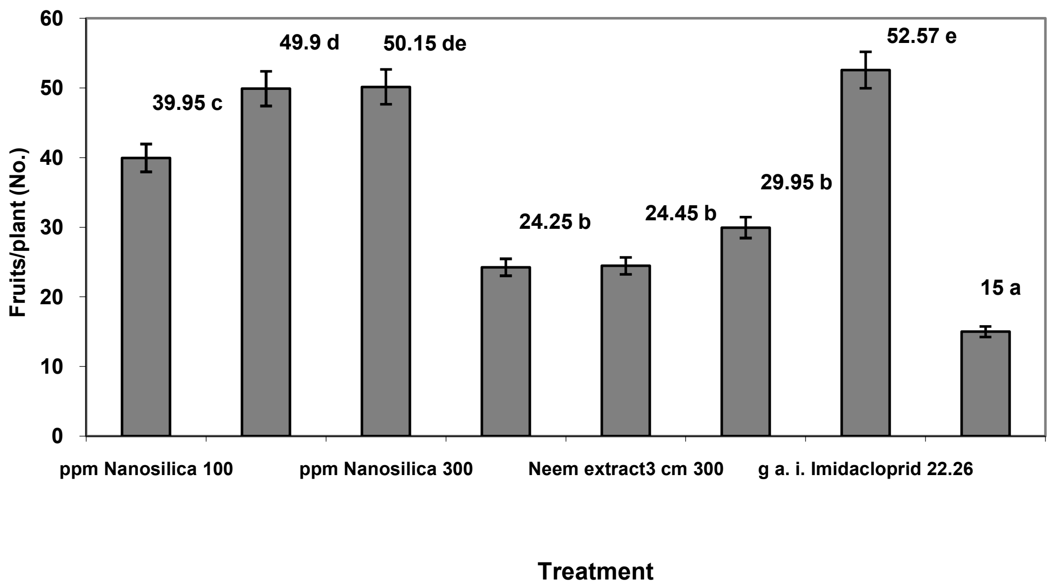

Fig. 3. Number of tomato fruits resulted from control *Tuta absoluta* with silica nanoparticles and neem oil extract

Means followed by a common letter are not significantly different at the 5% level by DMRT

Data in Fig. (4) showed the weight of tomato fruits (kg) resulted from examined treatments. Statistical analysis showed significant differences between all treatments compared with control. The highly tomato fruits obtained from silica nanoparticles (300 and 200 ppm) and imidacloprid compared with all treatments followed by the lowest rate of silica nanoparticles. There were not significant differences between all neem oil extract treatments. The highest rate of all treatments showed the highest weight of tomato fruits followed by another rates.

3.3 Estimating the Vitamin C (Mg/100 G of Sample)

Data in Fig. (5) showed the vitamin C value (mg/100 g of sample) in tomato resulted from all treatments. All examined treatments were significantly with control. Silica nanoparticles at its three rates showed significant differences compared with control at vitamin C content. The silica nanoparticles at 200 and 300 ppm and imidacloprid were the highest treatments in vitamin C content. On the other hand, neem oil extract showed moderate significantly compared with control in vitamin C tomato content.

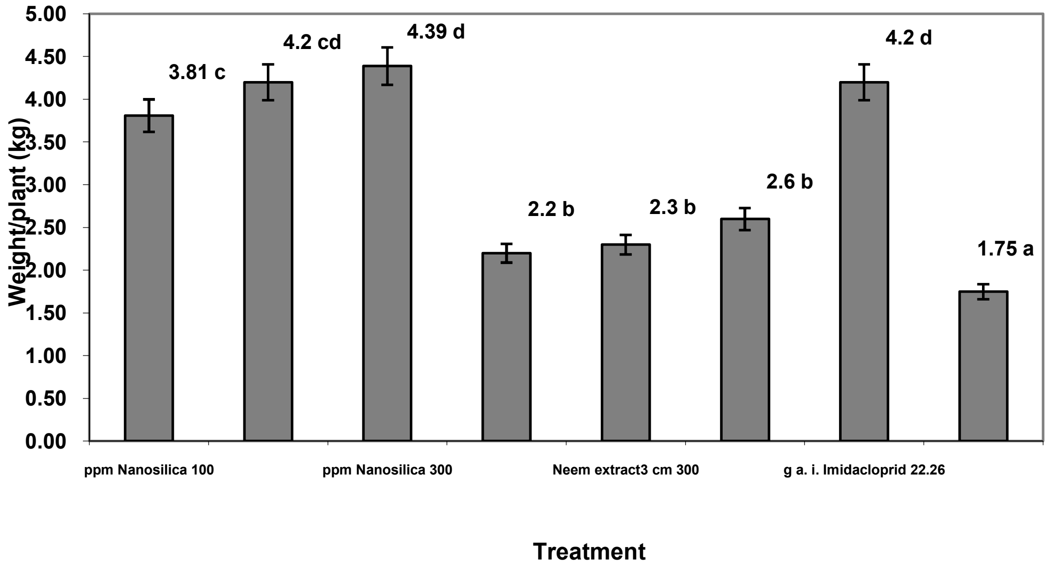

Fig. 4. Weight of tomato fruits resulted from control *Tuta absoluta* with silica nanoparticles and neem oil extract

Means followed by a common letter are not significantly different at the 5% level by DMRT

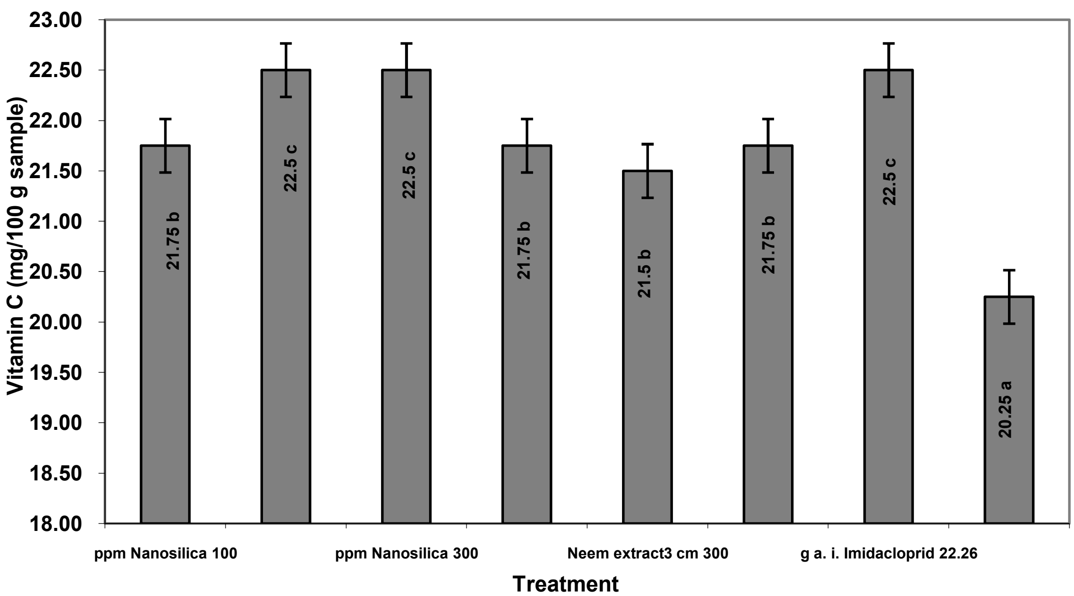

Fig. 5. Effect of silica nanoparticles, neem plant extract and imidaclopride on tomato vitamin C.

Means followed by a common letter are not significantly different at the 5% level by DMRT

3.4 Estimating Tomato Total Soluble Solids Percentage (TSS %)

Fig. (6) showed the differences in total soluble solids percentage (TSS %) on tomato resulted from silica nanoparticles, neem oil extract and imidacloprid compared with control. The highest TSS % recoded in 200 ppm silica nanoparticles and 160 cm3 neem oil extract/4200 m^2. Followed by the 100 ppm silica nanoparticles treatment. The chemical insecticide showed the lowest TSS %

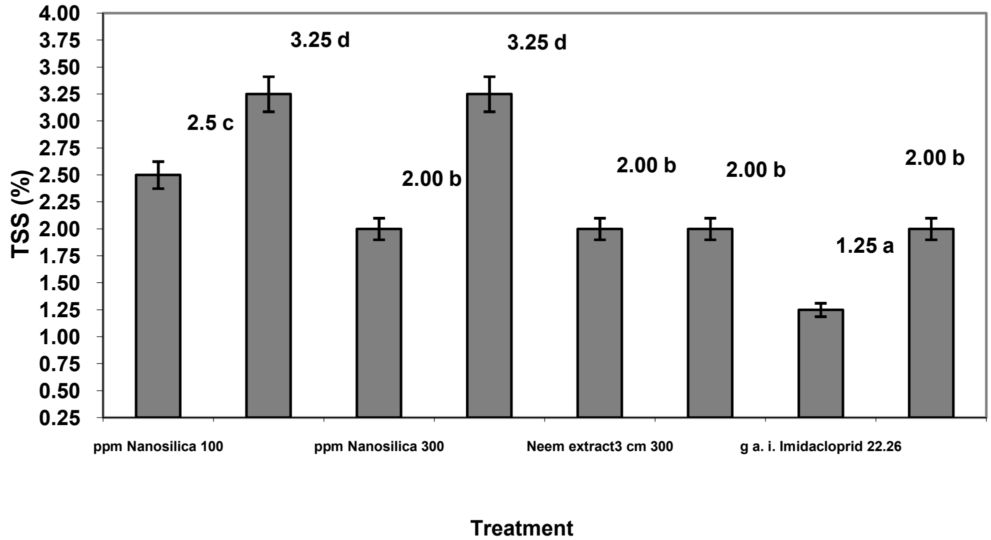

Fig. 6. Effect of silica nanoparticles, neem plant extract and imidaclopride on tomato Total Soluble Solids percentage (TSS %)

Means followed by a common letter are not significantly different at the 5% level by DMRT

4. CONCLUSION

Silica nanoparticles showed highly efficient in reduction the infestation of *T. absoluta* compared to check. Neem oil treatments showed moderate efficient in control this insect. In addition to we should do more studies to know the side effects of examined silica nanoparticles on natural enemies and environmental.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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