Applied Science Reports
www.pscipub.com/ASR
E-ISSN: 2310-9440 / P-ISSN: 2311-0139

App. Sci. Report.
4 (3), 2013: 241-246
© PSCI Publications

First record nanotechnology in agricultural: Silica nano-particles a potential new insecticide for pest control

H. M. El-bendary[1] and A. A. El-Helaly[2]

1. Department of Plant protection, Faculty of Agriculture, Fayoum University Egypt
2. Department of Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University Egypt.
Corresponding author Email: H. M. El-bendary

Key words

Nano-silica particles

Spodoptera littoralis

tomato plants

pest control

A B S T R A C T

The cotton leaf warm *Spodoptera littoralis* is considered the major important pest of plenty of vegetables, for causing severe injuries to the plants in all phonological crop stages, beside its rising resistance to several groups of pesticides. The overall objective of this investigation was to look for new control strategy through evaluate the effects of the application of hydrophobic nano-silica on the resistance of tomato plants to this pest. The experiments were carried out under semi field conditions; the experiment was conducted with two treatments, consisting of nano-silica application, and a negative control (distilled water) with five replications. Nano-silica LD_{50} found to be 212.045 ppm with slope 4.553, it was applied in six doses 100, 150, 200, 250, 300, and 350 ppm of 50 ml/plant, neonates of *Spodoptera littoralis* were exposed daily to tomato leaves mortality was detected after 15 days post application. The following evaluations were performed: a) Mortality%; b) reproduction and development of the *Spodoptera littoralis*. Results of treatment of hydrophobic nano-silica in larval test indicated high toxic action at all concentrations used parallel with concentrations. High resistance in tomato plants was found against this insect-pest especially at 300, 350 ppm, respectively. It can be concluded that this is probably the first report that demonstrated that nano-silica could be used in *Spodoptera littoralis* control.

Introduction

Spodoptera littoralis (Bosid) (Lepidoptera: Noctuidae) is an extremely serious pest, the larvae of which can defoliate many economically important crops cutting across over 40 families, such crop includes cotton and tomatoes EPPO, (2008) the insect is very prolific pest whose female layes hundreds of eggs in egg masses, and the larvae pass through six instars in 15 to 23 days Miyahara *et al*., (1971) many insecticides have been tested against this pest Haas-Stapleton *et al.,* (2003) the use of insecticides in agriculture field causes biological imbalance Yadav (2010) some new eco- friendly formulations pesticides became the target Bulmer *et al.*, (2009), zhang and Xiao-zhen, (2010) and Cloyd and Bethke (2011). Control of tomato insect pests can be achieved through optimizing the cultural practices, planting date, insect-resistant varieties, proper fertilization and biological control Ali *et al.*, (1993); (1998); Shalaby (2001); Helal (2004); Abou-Atti and Abd El-Aziz (2007). The application of silicon in crops provides a viable component of integrated management of insect pests and diseases because it leaves no pesticide residues in food or the environment and can be easily integrated with other pest management practices Laing *et al.*, (2006). The field application of silicon to susceptible wheat cultivars increased crop resistance and reduced pest infestation Basagli *et al*., (2003); Ecole and Sampaio, (2004). The induced resistance of plants to insects is a potential strategy in the integrated pest management aiming the reduction of deleterious effects of chemical compounds. Therefore, although not being considered an essential nutritional element to the plants, the addition of silicon has induced resistance in many plant species. Besides, this procedure jointly with the plant genotype has determined the potential of production as well as the tolerance to insect-pests and diseases. Whenever a new technology has emerged, it has opened many vistas to be explored. Nowadays, nanotechnology has being embraced in the world of pesticides and pest control Harper, (2010) and has a potential to revolutionize modern day agriculture pest control, different groups of nano pesticide overcome like insecticides, fungicides, herbicides Matsumoto *et al* ., (2009) and Peteu (2010). The new nanotechnology with materials having unique properties than their macroscopic or bulk counter parts, has promised applications in various fields. The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. The aim is to exploit these properties by gaining control of structures and devices at atomic, molecular, and supra molecular levels and to learn to efficiently manufacture and use these devices. Nanotechnology has provided new solutions to problems in plants and food science (post-harvest products) and offers new approaches to the rational selection of raw materials, or the processing of such materials to enhance the quality of plant products. 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. Such as nanocapsules based on polymers are being designed for controlled release of active ingredient as well as enhanced delivery through improved penetration through leaves. The objective of this study was to evaluate the effect of the application of nano-silica on the resistance of tomato plants to the *Spodoptera littoralis* aiming at providing relevant imputes to the management of cotton leaf warm on this crop. This is a first record of using such rational new nano pesticides as new method of control using new approach.

Materials and Methods

Experimental design

The experiments were installed within the period of April to July (2013) and were carried out in two steps, under semi-field and laboratory conditions at the Department of Economic Entomology and Pesticides, Faculty of Agriculture, Cairo University Egypt. Under semi field conditions, one types of nano-silica was tested, namely hydrophilic nano-silica, which applied in six doses 100, 150, 200, 250, 300, 350 ppm. This product was obtained from Nano Tech. Egypt.

Experimental parameter

The following evaluations were performed

(a) Mortality percentage under semi-field conditions

Six doses 100, 150, 200, 250, 300, 350 ppm were prepared in total volume 50 ml for each concentration. Tomato plants were covered completely with each concentration with five replicates for each, leaves were emerged daily into glass jar 350 cm^3, 50 neonates *Spodoptera littoralis* were release into each jar. Each replicate was represented into three jars. The jar was then covered with double muslin cloth. The evaluations were performed 15 days post *Spodoptera littoralis* release by counting the living ones.

(b) Reproduction and development of the *Spodoptera littoralis*

The larvae which survived from all treatments were taken and some biological aspects were counted in comparison with untreated larvae (control). These were placed into environmental condition at 25±1°C temperature, 70±10% RH and 12h photophase. The following observations were performed: larval duration, pupal period, and adult longevity, number of laid eggs per female and percent of hatchability.

Statistical analyses

For the first experiment, a completely randomized experimental design, with two treatments (silicon nanoparticles application and non-treated control) and ten replications was used. Data were submitted to ANOVA, and the means were compared by the means-grouping test of Scott and Knott (1974) at $P \leq 0.05$. And for concentration- mortality response curve for probit analysis Fenny, (1952) was used.

Results and Discussion

Mortality percentage under semi-field conditions

When the feeding preference test was carried out directly on the plants in the laboratory conditions 28±2 ºC and RH = 65%, statistically significant differences among treatment were observed in Table (1) and Fig. (1). *Spodoptera littoralis* release, a significant increase on development of larvae occurred on the control plants as opposed to a significant decrease occurring on the nanosilica-treated, ones concentrations 250, 300 and 350 caused more than 50% death percentage) it gave 64.18, 68.93 and 98.24%, respectively in comparison to control which gave zero death %.

Table 1. Mortality percentage among neonate larvae of *Spodoptera littoralis* tested with nano-silica after 15 days post emergence

Nanosilica/ ppm	Mortality % among neonate larvae of *Spodoptera littoralis* tested with nano-silica after 15 days post emergence					
	R1	R2	R3	R4	R5	Mean %
Control*	0.00 (0/148)	0.00 (0/148)	0.00 (0/150)	0.00 (0/146)	0.00 (0/149)	0.00
100 ppm	15.75 (23/146)	12.16 (18/148)	20.40 (30/147)	19.46 (29/149)	12.16 (18/148)	15.98
150 ppm	16.89 (25/148)	21.23 (31/146)	19.33 (29/150)	14.76 (22/149)	25.00 (37/148)	19.44
200 ppm	20.54 (30/146)	29.33 (44/150)	36.66 (55/150)	25.00 (37/148)	30.13 (44/146)	28.33
250 ppm	66.43 (97/146)	54.73 (81/148)	64.86 (96/148)	67.78 (101/149)	67.11 (100/149)	64.18
300 ppm	60.00 (90/150)	50.00 (74/148)	80.00 (120/150)	87.33 (131/150)	67.33 (101/150)	68.93
350 ppm	97.88 (139/142)**	98.00 (147/150)	100.00 (150/150)	97.33 (146/150)	97.98 (146/149)	98.24

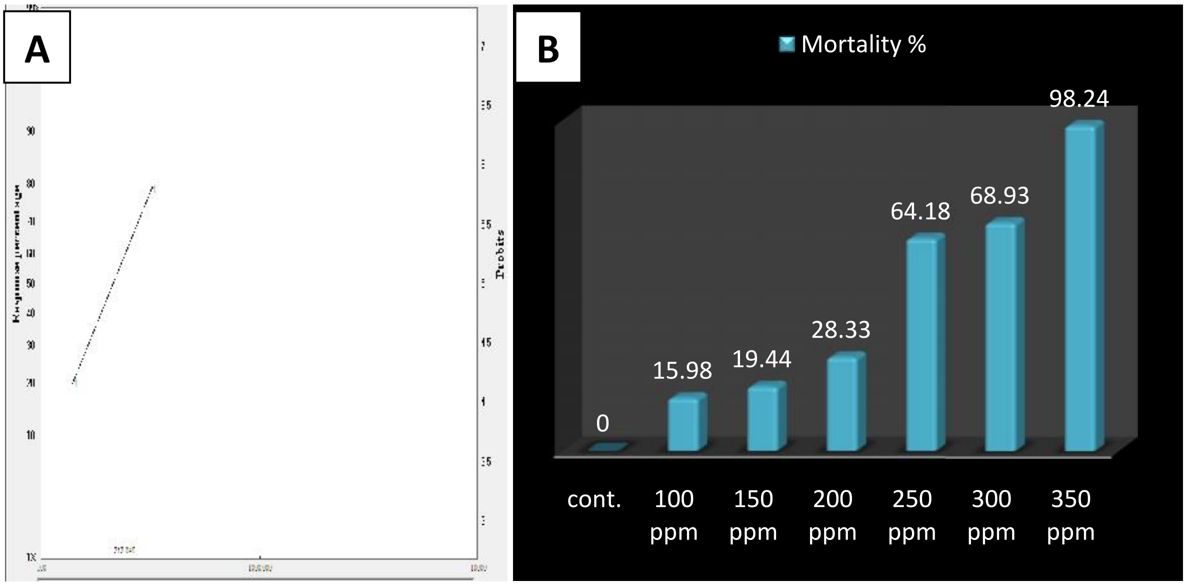

Figure 1. A- The collected LC50 using probit program, B- The mean of mortality percentage among neonate larvae of Spodoptera littoralis tested with nano-silica after 15 days post emergence.

Reproduction and Development of the *Spodoptera littoralis*

Statistically significant differences (P > 0.05) were detected neither for the biological characteristics related to pre-reproductive and reproductive periods nor for survival of the larvae phase Table (2). For the biological aspects related to longevity, however, statistically significant differences (P $\leq$ 0.05) did occur. On the other hand, the total number of eggs laid per female was affected in all treatments compared with control, the percentage of hatchability was reduced in nano-silica treatments compared with control, therefore the larval duration, pupal period and adult longevity were not affected in all treatment compared with control. In order to that, the total number of larvae produced within the reproductive period was affected by nano-silica application Fig. (2-7). However, females that developed on leaf sections of nano-silica free plants (control) produced 80% more larvae than those reared on leaf sections of nano-silica treated tomato plants Fig. (2-7).

Table 2. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. Temperature 25±1°C., RH: 70±10%, Photophase 12h.

Biological test Treatments		Larval duration/D.	Pupal stage/D.	Adult longevity/D.	No. of Laid egg/female	Hatchability (%)
Nanosilica-free (cont.)	---	15.3±0.20	9.1±0.50	13.3±0.80	280.5±6.20	86.1±0.30
Nanosilica-trated	100 ppm	15.9±0.90	10.9±0.40	12.9±0.30	260.9±0.30	78.3±0.90
	150 ppm	17.3±0.60	12.5±0.10	13.7±0.50	250.3±0.70	71.5±0.40
	200 ppm	17.8±0.50	13.3±0.80	13.5±0.40	220.8±0.50	67.8±0.70
	250 ppm	19.1±0.10	15.9±0.60	14.1±0.20	190.4±0.50	63.1±0.20
	300 ppm	19.2±0.30	17.2±0.40	12.8±0.70	160.2±0.60	55.3±0.30
	350 ppm	19.9±0.70	17.9±0.02	13.7±0.30	130.8±3.10	53.2±0.70

Results indicate that nano-silica seems to enhance tomato plants in controlling the cotton leaf worm, *Spodoptera littoralis*; this control tactic increased the obtained yield. Similar results were recorded when used potassium silicate for both the second and third larval instars, as the percentage reductions ranged 41.61-51.50 and 22.07- 36.68 %, respectively, and reduction in feeding consumption of the fourth instars ranged 15.56 - 31.50 %. Goussain *et al.* (2002) registered increased mortality and cannibalism in groups of fall armyworm, *Spodoptera frugiperda* for the larvae of the second and sixth instars with silicon application. Results of Goussain *et al.* (2002) proved that *Spodoptera frugiperda* larvae displayed increased mortality, cannibalism and mandibular wear after feeding on corn plants fertilized with silica. Similar results were obtained by Massey *et al.* (2006) who indicated that increasing silica content of grasses deterred feeding and reduced the growth rates and feeding efficiency of *Spodoptera exempta*.

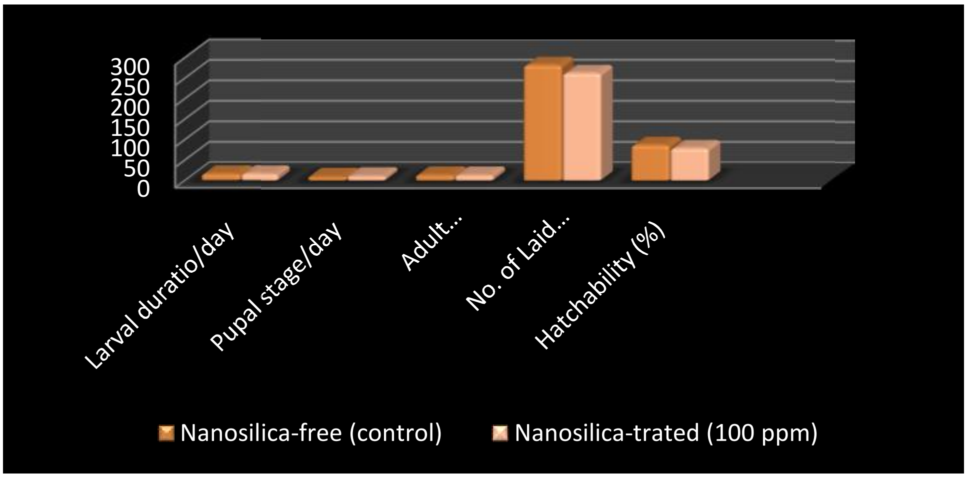

Figure 2. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. (Nano-silica treated 100 ppm).

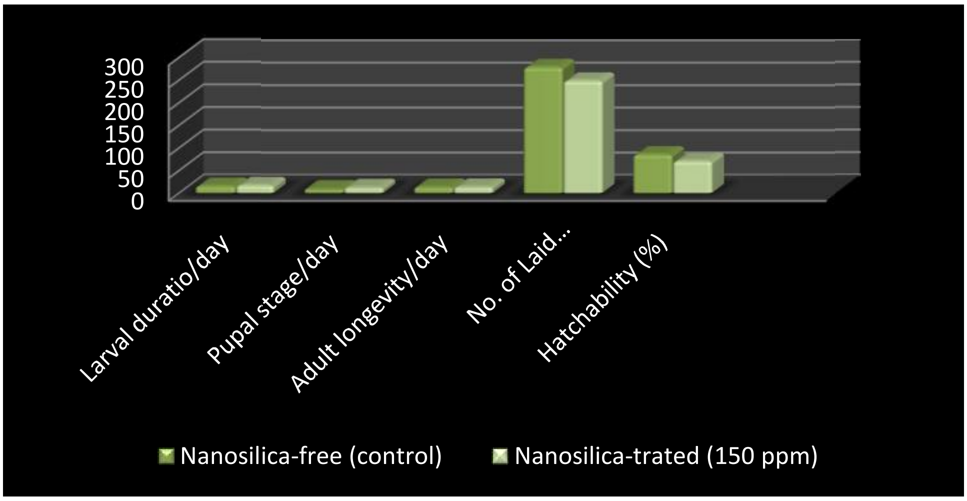

Figure 3. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. (Nano-silica treated 150 ppm).

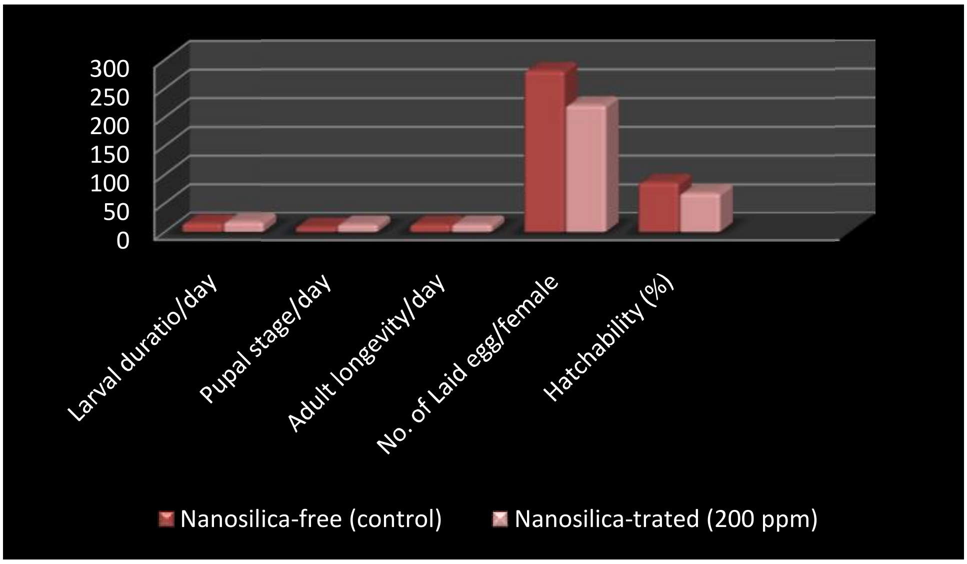

Figure 4. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. (Nano-silica treated 200 ppm).

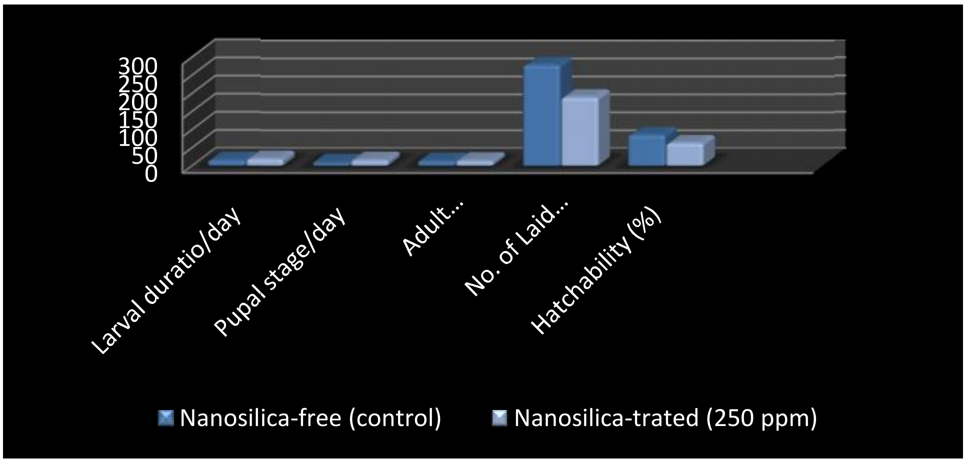

Figure 5. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. (Nano-silica treated 250 ppm).

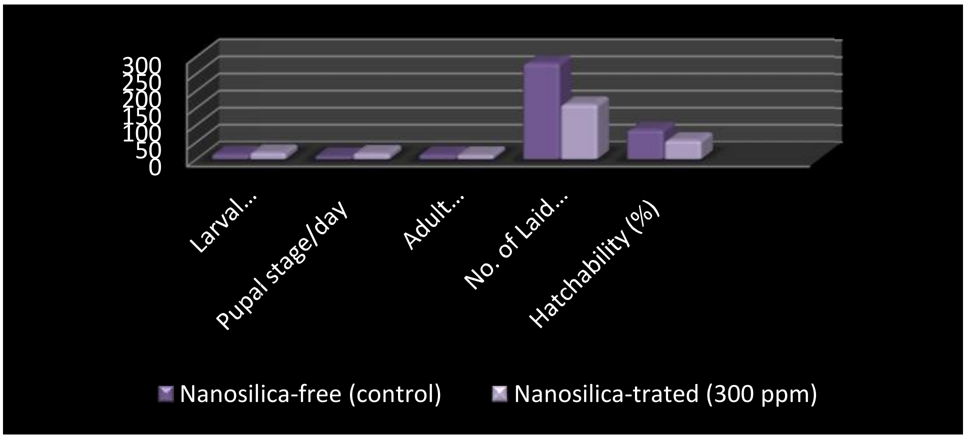

Figure 6. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants. (Nano-silica treated 300 ppm).

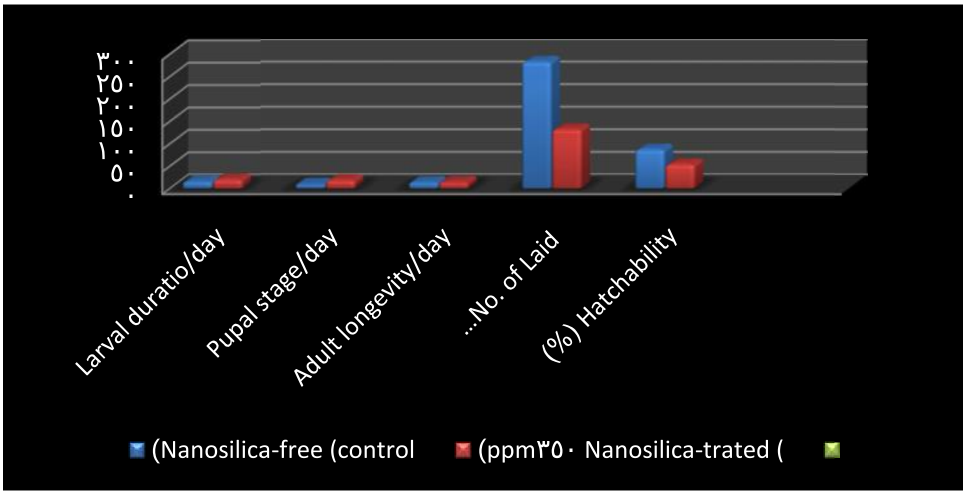

Figure 7. Duration of the larval, pupal, adult longevity (days), number of laid eggs and hatchability (%) of treated and non-treated tomato plants.(Nano-silica treated 350 ppm).

Similar observations had already been reported by other authors for different species of insects and/or host plants. In feeding preference tests conducted with the green-aphid *S. graminum* on silicon-treated and non-treated sorghum plants, Carvalho *et al.* (1999) observed almost twice the number of aphids on leaf sections, which did not receive silicon treatment. These researchers concluded that the non-preference of aphids for silicon-treated leaves was due to a mechanical barrier provided by the deposition of this element on the cell wall. Analogous conclusions have also been drawn from other crops and for other insects Djamin and Pathak (1967), Tayabi and Azizi (1984), Salim and Saxena (1992), Sawant *et al.* (1994), Goussain *et al.* (2002). Tomato leaves that received silicon sprays were more turgid than those silicon-free ones (control). Research results have indicated that the silicon, once absorbed by the xylem veins, is deposited on the wall of the plant tissues, forming a mechanical barrier Blum (1968). Several authors (e.g. Richmond and Sussman, (2003) and Ma, (2004) indicated that silicon also alleviates many a biotic stresses including chemical stress (salt, metal toxicity, nutrient deficiency).

Conclusion

We concluded that the application of nano-silica to the tomato plants may minimize the problems caused by *Spodoptera littoralis*. It provides a moderate degree of resistance, but presents the advantage of being feasibly integrated to other management tactics in controlling this pest. Nano-silica sprays affect the feeding preference of the *Spodoptera littoralis*, thus increasing the resistance of tomato plants. Concomitantly it affects biological parameters of the insect such as longevity and nymph production, thus reducing the reproductive potential of females on tomato plants and therefore reducing the insect population density, damages and yield losses to the crop. In conclusion, this study demonstrates that nano-silica is effective against *Spodoptera littoralis* and would therefore be a useful component of an integrated pest management strategy.

References

Abou-Attia FAM, Abd El-Aziz KhA. 2007. Effect of bio and mineral fertilization on the main insect pests and some characters of sugar beet plants. J. Agric. Sci. Mansoura Univ. 2007; 32 (2): 1471-1485.

Ali FA, Samy MA, El-Adl FE, Ibrahim SM. 1993. Effect of planting dates on the infestation ratio of the main insect in sugar beet field. J. Agric. Sci., Mansoura Univ. 1993; 18 (6): 1805-1812.

Basagli MAB, Moraes JC, Carvalho GA, Ecole CC, deC.R R. 2003. Goncalves-Gervasio. Effect of sodiumsilicate application on the resistance of wheat plants to the green aphid Schizaphis graminum (Rond.)(Hemiptera: Aphididae). Neootropical Entomology. 2003; 32 (4): 659-663.

Blum A. 1993. Anatomical phenomena in seedlings of sorghum varieties resistant to the sorghum shoot fly *Atherigona varia soccata*. Crop Sci.1993; 8: 388-391.

Bulmer MS Bacheletb I, Ramanb R, Rosengaus B, Sasisekharan R. 2009. Targeting an antimicrobial effector function in insect immunity as a pest control strategy. PNAS, 106(31):12652-12657.

Carvalho SP, Moraes JC, Carvalho JG.1999. Efeito do silício na resistência de plantas de sorgo (*Sorghum bicolor*) ao pulgão-verde *Schizaphis graminum* (Rond.) (Homoptera: Aphididae). An. Soc. Entomol. Bras. 1999; 28: 505-510.

Cloyd RA, Bethke JA. 2011. Impact of neonicotinoid insecticides on natural enemies in greenhouse and interiorscape environments. Pest Manage. Sci. 67(1): 3-9.

Cruz I, Vendramin JD, Oliveira AC. 1998. Determinação do período de avaliação de não preferência de sorgo ao pulgão-verde, *Schizaphis graminum* (Rond.) (Homoptera: Aphididae). An. Soc. Entomol. Bras. 1998; 27: 299-302.

Djamin A, Pathak MD. 1967. Role of silica in resistance to Asiatic rice borer, *Chilo suppressalis* (Walker), in rice varieties. J. Econ. Entomol. 1967; 60: 347-351.

Ecole CC, Sampaio M. 2004. Silicon influence on the tritophic interaction: wheat pests, the greenbug Schizaphis graminum (Rondani) (Hemiptera: Aphididae), and its natural enemies, Chrysoperla externa (Hagen) (Neuroptera: Chrysopidae) and Aphidius colemani Viereck (Hymenoptera: Aphididae). Neotrop. Entomol. 2004; 33: 619-624.

EPPO. 2008. European and Mediterranean Plant Protection Organization. Spodoptera litura Fabricious EPPO Bull. 9:142-146.

Finney DJ. 1952. Probit analysis. IIndEdition. Cambridge University Press.pp 318

Goussain MM, Moraes JC, Carvalho JG, Nogueira NL, Rossi ML. 2002. Efeito da aplicação do silício em plantas de milho no desenvolvimento biológico da lagarta-do-cartucho *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae). Neotrop. Entomol. 2002; 31: 305-310.

Goussain MM, Moraes JC, Cravalho JG, Nogueira NL, Rossi ML. 2002. Effect of silicon application on corn plants upon the biological development of the fall armyworm Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae). Neotropical Entomology. 2002; 31(2): 305-310.

Haas-Stapleton EJ, Washburn JO, Volkmann LE. 2003. Pathogenesis of Autographa californica M nucleopolyhedrovirus in fifth instar Spodoptera frugiperda. J. Gen. Virol. 84: 2033-2040.

Harper S. 2010. New Approaches Needed to Gauge Safety of Nanotech-Based Pesticides, Researchers Urge. Published In Physics & Chemistry. 4(33): 2010-2012 .

Helal RMY. 2004. Ecological studies on the main insect pests of sugar beet plants and most common predators at Kafr El-Sheikh region. J. Agric. Sci., Mansoura Univ. 2004; 29 (2): 911-923.

Laing MD, Gatarayiha MC, Adandonon A. 2004. Silicon use for pest control in agriculture: A review Proc. S Agr. Sug. Technol. 2006; Ass., 80, page 278.

Ma JF. 2004. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. Soil Sci. Plant Nutr. 2004; 50: 11-18.

Massey JH, Gracen VE, Everett HL, Keeping MG. 2006. Impact of silicon in alleviating biotic stress in sugarcane in South Africa. Sugarcane International. 2006; 23: 14-18.

Matsumoto S, Christie RJ, Nishiyama N, Miyata K, Ishii A. 2009. Environment- responsive block copolymer micelles with a disulfide cross-linked core for enhanced siRNA delivery, Biomacromology, 10: 119-127.

Miyahara Y, Wakikado T, Tanaka A. 1971. Seasonal changes in the number and size of the egg masses of Prodenia litura . Jpn. J. Appl. Entomol. Zool. 15: 139-143.

Peteu SF. 2010. Micro- to nano-biosensors and actuators integrated for responsive delivery of countermeasures. IEEE CAS. Proc. in print.

Richmond KE, Sussman M. 2003. The nonessential beneficial plant nutrient. Curr. Opin. Plant Biol. 2003; 6: 268-272.

Salim M, Saxena RC. 1992. Iron, silica and aluminium stresses and varietal resistance in rice: effects on whitebacked planthopper. Crop Sci. 1992; 32: 212-219.

Sawant AS, Patil VH, NK. 1994. Savant. Rice hull ash applied to seedbed reduces deadhearts in transplanted rice. Int. Rice Res. Notes. 1994; 19: 20-21.

Scott AJ, Knott MA. 1974. A cluster analysis method for grouping means in the analysis of variance. Biometrics. 1974; 30: 507-512.

Shalaby GAM. 2001. Ecological studies on some important sugar beet pests and natural enemies and their control. Ph.D. Thesis, Fac. Agric., Tanta Univ. 2001; 141 pp.

Tayabi K, Azizi P. 1984. Influence of silica on rice yield and stem-borer (*Chilo supremain*) in Rasht/Iran 1979-1980. Pesticides. 1984; 18: 20-22.

Yadav SK. 2010. Pesticide Applications-Threat to Ecosystems. J. Hum. Ecol. 32(1): 37-45.

Zhang S, Xiao-zhen YE. 2010. Impacts of chemical insecticides on extracellular protease and chitinase activities of Metarhizium anisopliae. J. Fujian College Forest. 4: 289-292.