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Impact of nanoparticle materials on the control of seedling pests in the Egyptian cotton.

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Abstract:

Nanotechnology opens a large scope of novel application in the fields of biotechnology and agricultural industries, because nanoparticles often have unique physical and chemical properties, i.e. high surface area, high reactivity, tunable pore size, and particle morphology. So, this study aims to assess the effects of nanoparticles on cotton seedling pests under field conditions. Cotton seeds were treated with five nanoparticles (NPs) ; titanium dioxide (TiO_2), zinc oxide (ZnO), iron oxide (FeO), silicon dioxide (SiO_2) and Copper oxide (CuO) at three concentrations; high 1000 ppm, middle 500 ppm and low 250 ppm in a field experiment during 2017 and 2018. Our results demonstrated that cotton plants cultivated among 25cm distance treated with five nanoparticles affect the seedling pest infestation. Both CuO and TiO_2 nanoparticles were the most effective treatments against the Jassid pest *Empoasca lybica* (De Berg.) (Hemiptera:Cicadellidae) at high concentration during the two tested years. While, the ZnO had the most potent effect in decreasing the whiteflies populations *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) at the three tested concentrations during both 2017 and 2018 years. Also, TiO_2, SiO_2 and CuO induced the most potent effect against thrips pest *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) at high concentrations during the two tested years, also ZnO and FeO reduced thrips pest populations to zero at 1000 ppm during 2017 year. On the other hand, Tio_2 nanoparticles caused the highest powerful effect against the red spider pest *Tetranychus telarius* (L.) (Acari: Tetranychidae) in during the two years. TiO_2 and ZnO nanoparticles treatments caused the most competent action against aphids *Aphis gossypii* Glover (Hemiptera: Aphididae) during 2017 and 2018 respectively. Thus, treatment of cotton plants with these nanoparticles extremely contributed in lessening insect populations and so improving cotton crop production.

Introduction

Cotton plants from the genus Gossypium are one of the major sources of fiber (Trapero *et al*., 2016). Besides its fibers, cotton plants also produce a large amount of seeds (1.65 kg seeds per kg lint) (Cai *et al*., 2010). The seeds are rich in protein and are a valuable source of oil and fodder (Watkins and Waldroup, 1995 and Bertrand *et al*., 2005). Cotton crop is infested by a wide range of insect pests at various growth stages (Uthamasamy, 1994). The insect pest's spectrum of cotton is quite complex and about 1326 species of insect pests have been listed on this crop throughout the world (Shivanna *et al*., 2011). Among these insects, Jassid *Amrasca devastans* (Distant) (Hemiptera: Cicadellidae) , thrips *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) and whitefly *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) are very serious affecting the yield and quality of this cultivar (Ali, 1992). Thrips are minute plant feeding insects that produce scars on leaves, flowers and fruit surface (Mahesh *et al*., 2010). Cotton aphids *Aphis gossypii* Glover (Hemiptera: Aphididae) injure cotton plants by continually feeding on fluids in plant phloem tubes. This feeding can stimulate foliar alterations, delay of the plant growth, fewer fruit setting, lower fruit retention and reduced cotton lint weight (Raboudi *et al*., 2002). Cotton jassids are known as standard sucking pest of cotton crop. Cotton yield becomes lesser, as low due to the increasing population of jassid which contrasted with different cotton yields (Ahmad, 1999 and Sahito *et al*., 2011). Cotton whitefly has very old history of infestation on cotton even before the introduction of modern insecticides (Hussain and Trehan, 1933). It is a polyphagous insect pest of many agricultural crops and cosmopolitan in distribution. In addition to direct damage to cotton crop, it inhibits photosynthetic activity and impairs fiber quality of the cotton. It is also well known vector of various viral diseases on many economic crops (Henneberry *et al*., 1999). Two spotted spider mite (TSSM) *Tetranychus urticae* (Koch.) (Acari: Tetranychidae) is a polyphagous and cosmopolitan pest of many field and horticultural plants (Hoy, 2011). TSSM is the 5th most damaging pest of cotton (Williams, 2016).

In the agricultural systems, nanotechnology has a great potential in providing a novel and improved solutions for many challenges. Nanotechnology improves safety of products, increases the efficiency of the production and decreased the pollution through the using of controlled delivery of pesticides, herbicides and fertilizers (Mehrazar *et al*., 2015). The Application of nanotechnology in crop protection have promising the future in management of the insects and pathogens, through controlled and targeted delivery of agrochemicals and as a tool for early detection (Pavitra *et al*., 2018). The toxic effects of nanoparticles (NPs) can be attributed to the small size and large surface area, thereby increasing chemical reactivity and penetration in the living cells (Gojova *et al.,* 2007; Medina *et al.,* 2007 and Pan *et al.,* 2009). Shaker *et al*. (2017a) demonstrated that TiO_2 NPS are effective against the survival of the 2nd and 4th instar larvae of *Spodoptera littoralis*. Also, Shaker *et al*. (2018) indicated the efficacy of titanium dioxide (TiO_2) (NPs)+ copper oxide (CuO) (NPs) mixture against the same insect. Seed treatment is one of the highly progressive and demandable technologies in integrated pest management (IPM) for controlling various crop pests (Taylor *et al*., 2001 and Magalhaes *et al*., 2009). Thus, this study was designed to evaluate the beneficial effects of titanium dioxide (TiO_2), zinc oxide (ZnO), iron oxide (FeO), silicon dioxide (SiO_2) and Copper oxide (CuO) NPs on decreasing the populations of cotton jassids, aphids, thrips, white fly and two-spotted spider mite under field conditions during two seasons (2017 and 2018).

Materials and methods

Experiments were conducted in 2017 and 2018 at the Sids research station farm in Beni suef. Prior to planting, seeds were treated with the five nanomaterials, TiO_2, ZnO_2, FeO_2, SiO_2 and CuO NPs tested at three concentrations, High 1000ppm, Middle 500ppm and low 250ppm.Trials in 2017 year were planted on 15 Mars and on 10April at 2018 year. The cultivated area divided into several plots, each plot exceed 13.6 meter, in addition to that of control. Five replicates was utilized for each treatment of the five treatment in addition to three replicates or plots used as control to estimate the five NPs treatments impact on the seedling pests populations

Analytical grade titanium tetrachloride, sodium hydroxide Precursor zinc nitrate (Zn (NO3)2. 6H2O), precipitating agent KOH, Copper (II) chloride dehydrates and sodium hydroxide pellets were covered. Explanatory reagent graded chemicals were utilized within the analysis without further purification. Deionized water was utilized for washing purposes. All Nanoparticles were synthesized and characterized according to our previous work Shaker *et al*. (2017a and b)

Results and discussion

1. Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and Copper oxide nanaoparticles treatments on jassid count on cotton plants during 2017 and 2018:

Data shown in Table (1) illustrated the effect of treatments of cotton seeds cultivated among 25cm distance with TiO_2, ZnO, FeO, SiO_2 and CuO NPs at three tested concentrations (1000, 500, 250 ppm) on jassid pest infestation on cotton crop during 2017 and 2018. Treatments with the five tested NPs in all concentrations showed highly significant ($P<0.01$) effect on diminishing the jassid count on cotton plants during 2017 and 2018. Treatments with the high concentration of TiO_2 and CuO NPs seemed to have the highest significant ($P<0.01$) effect on decreasing jassid infestation during 2017 and 2018 years. Also, treatment FeO NPs in the three concentrations highly significantly ($P<0.01$) decreased the mean numbers of the Jassid/25 leaflets in 2017 and 2018 to average 39.9, 49.7, 62.9 and 35.1, 39.9, 55.8, respectively, as compared to controls.

Table 1: Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on jassid count on cotton plants during 2017 and 2018.

Treatments	Concentrations	Insect count (Mean±SE)	
		2017	2018
TiO_2	H.Conc.	10.8±0.7**	7.9±0.3**
	M. Conc.	56.8±0.7**	49.9±4.1**
	L. Conc.	69.7±5.8**	65±2.1**
ZnO	H.Conc.	53.3±0.9**	49.8±4.1**
	M. Conc.	62.2±0.4**	54.9±2.1**
	L. Conc.	76.6±0.9**	69.9±4.1**
FeO	H.Conc.	39.9±5.9**	35.1±2**
	M. Conc.	49.7±5.8**	39.9±4.1**
	L. Conc.	62.9±0.7**	55.8±1.9**
SiO_2	H.Conc.	53.2±0.7**	49.9±4.1**
	M. Conc.	61.2±0.7**	64.5±1.8**
	L. Conc.	77.3±0.9**	69.9±4.1**
CuO	H.Conc.	11±0.6**	8.9±0.4**
	M. Conc.	23.2±1**	27.9±0.4**
	L. Conc.	28.2±0.4**	36.7±0.5**
Untreated (Control)		140.2±1	130.1±0.7
P-value		0.000155	0.00155
F-value		60643.57	21912.93
at 0.05		9.546667	7.46
at 0.01		20.31333	13.68667

Data are expressed as Mean±Standard error (SE) ****= Highly significant (P<0.01)**

2. Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and Copper oxide nanaoparticles treatments on the whitefly on cotton plants during 2017 and 2018:

Data illustrated in Table (2) showed illustrated the effect of treatments of cotton seeds with TiO_2, ZnO, FeO, SiO_2 and CuO NPs at three tested concentrations (1000, 500, 250 ppm) on White fly count on cotton plants during 2017 and 2018. Treatments with the five tested NPs in all concentrations showed highly significant (P<0.01) effect on lessening the white fly count on cotton plants during 2017 and 2018. ZnO NPs treatment was the most potent in lowering the white fly count on cotton crop followed by TiO_2 and SiO_2 NPs treatments during the two tested years. Whereas, the plants treated with the FeO NPs had the least significant effect in the mean numbers decrease of the white fly/ 25 leaflets with the three concentrations. It averaged during the two tested years; 3.2, 4.8, 6.2 and 3.98, 4.8, 7, respectively as compared to 12.8 and 9.6 of the untreated plants.

Table (2): Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanoparticles treatments on the whitefly on cotton plants during 2017 and 2018.

Treatments	Concentrations	Insect count (Mean±SE)	
		2017	2018
TiO_2	H.Conc.	1.8±0.1**	1.5±0.2**
	M. Conc.	2±0.09**	1.8±0.2**
	L. Conc.	2.95±0.4**	2.98±0.3**
ZnO	H.Conc.	1.6±0.2**	1.4±0.2**
	M. Conc.	1.8±0.2**	1.8±0.1**
	L. Conc.	2.2±0.3**	2.3±0.4**
FeO	H.Conc.	3.2±0.3**	3.98±0.7**
	M. Conc.	4.8±0.1**	4.8±0.9**
	L. Conc.	6.2±0.1**	7±1.1**
SiO_2	H.Conc.	1.8±0.2**	1.9±0.2**
	M. Conc.	3±0.3**	3.1±0.3**
	L. Conc.	3.4±0.3**	4±0.7**
CuO	H.Conc.	2.6±0.2**	2.8±0.3**
	M. Conc.	3.6±0.5**	4±0.3**
	L. Conc.	4.2±0.7**	5±0.4**
Untreated (Control)		12.8±0.7	9.6±0.6
P-value		0.00176	0.00718
F-value		161.0667	1.35
at 0.05		2.706667	2.31
at 0.01		4.86	4.19

Data are expressed as Mean±Standard error (SE) **** = Highly Significant (P<0.01)**

3. Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on thrips during 2017 and 2018:

The effect of treatments of cotton seeds with TiO_2, ZnO, FeO, SiO_2 and CuO NPs at three tested concentrations (1000, 500, 250 ppm) on thrips count on cotton plants during 2017 and 2018 is demonstrated in Table (3). All treatments induced highly significant (P<0.01) effect on diminishing the thrips count on cotton plants during 2017 and 2018. TiO_2, SiO_2 and CuO treatments in high concentration recorded the most potent effect by decreasing the thrips count to zero in both years. Also, treatment with ZnO and FeO caused marked effect causing thrips count to be zero in 2017 compared with 8.9 of controls.

Table (3): Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on thrips during 2017 and 2018.

Treatments	Concentrations	Insect count (Mean±SE)	
		2017	2018
TiO_2	H.Conc.	0±0**	0±0**
	M. Conc.	0±0**	0.1±0.03**
	L. Conc.	0±0**	0.3±0.06**
ZnO	H.Conc.	0±0**	0.4±0.07**
	M. Conc.	0.8±0.1**	0.8±0.2**
	L. Conc.	1.1±0.3**	1±0.2**
FeO	H.Conc.	0±0	0.8±0.1**
	M. Conc.	0.5±0.04**	0.7±0.1**
	L. Conc.	0.8±0.1**	0.8±0.1**
SiO_2	H.Conc.	0±0**	0±0**
	M. Conc.	0.8±0.1**	1.1±0.3**
	L. Conc.	1±0.3**	1.2±0.2**
CuO	H.Conc.	0±0**	0±0**
	M. Conc.	0±0**	0.4±0.07**
	L. Conc.	0.6±0.1**	0.5±0.2**
Untreated (Control)		8.9+0.4	10.9+0.4
P-value		0.000013	0.000151
F-value		1010	1149.94
at 0.05		1.111111	1.34
at 0.01		2.027778	2.466667

Data are expressed as Mean±Standard error (SE) **** = Highly Significant (p<0.01)**

4.Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanoparticles treatments on the red spider during 2017 and 2018:

As depicted in Table (4) treatments of cotton seeds with TiO_2, ZnO, FeO, SiO_2 and CuO NPs at three tested concentrations (1000, 500, 250 ppm) caused a remarkable highly significant (P<0.01) effect on spider count on cotton plants during 2017 and 2018. Spider count in cotton plants decreased from 4.9 and 9.9 in controls of the two tested years to be 0.8 and 1.1 in high concentrated TiO2 treated plants. TiO_2 treatment induced the most potent effect followed by ZnO in 2017 and 2018.

Table (4): Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on the red spider during 2017 and 2018.

Treatments	Concentrations	Insect count	
		2017	2018
TiO_2	H.Conc.	0.8±0.04**	1.1±0.2**
	M. Conc.	1.1±0.3**	1.3±0.2**
	L. Conc.	1.2±0.3**	1.5±0.3**
ZnO	H.Conc.	1±0.4**	1.2±0.2**
	M. Conc.	1.6±0.3**	1.6±0.3**
	L. Conc.	1.8±0.4**	1.7±0.2**
FeO	H.Conc.	2±0.2**	3±0.4**
	M. Conc.	2.6±0.4**	3.6±0.2**
	L. Conc.	3±0.6**	3.9±0.4**
SiO_2	H.Conc.	1.8±0.4**	2.2±0.4**
	M. Conc.	2.2±0.4**	2.6±0.2**
	L. Conc.	2.8±0.5**	2.95±0.2**
CuO	H.Conc.	1.6±0.2**	2±0.4**
	M. Conc.	1.95±0.5**	2.7±0.4**
	L. Conc.	2.4±0.4**	3±0.4**
Untreated (Control)		4.9+1	9.9+0.4
P-value		0.021	0.00095
F-value		15.5	251.4067
at 0.05		2.84	1.72
at 0.01		5.21	3.193333

Data are expressed as Mean±Standard error (SE) **** = Highly Significant (p<0.01)**

5. Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on the aphid during 2017 and 2018:

Data showing the effect of treatments of cotton seeds with TiO_2, ZnO, FeO, SiO_2 and CuO NPs at three tested concentrations (1000, 500, 250 ppm) on aphids count on cotton plants during 2017 and 2018 are presented in Table (5). Treatments with these tested NPs in all concentrations showed highly significant ($P<0.01$) effect on reducing the aphid count on cotton plants during 2017 and 2018. TiO_2 and CuO Nps treatments induced the most potent against aphids in 2017 while ZnO NPs treatment was the most remarkable one in 2018.

Table (5) : Effect of titanium dioxide, zinc oxide, iron oxide, silicon dioxide and copper oxide nanaoparticles treatments on the aphid during 2017 and 2018.

Treatments	Concentrations	Insect count	
		2017	**2018**
TiO_2	H.Conc.	10.9±0.3**	1.1±0.2**
	M. Conc.	56.9±0.3**	1.9±0.6**
	L. Conc.	70±4.2**	3±0.3**
ZnO	H.Conc.	53±1.6**	0.9±0.1**
	M. Conc.	62±2.7**	0.8±0.2**
	L. Conc.	77.8±3**	1.1±0.3**
FeO	H.Conc.	40±3.2**	1.2±0.2**
	M. Conc.	50±3.2**	1.8±0.5**
	L. Conc.	63±0.9**	1.4±0.2**
SiO_2	H.Conc.	53.3±2.3**	2.9±0.5**
	M. Conc.	61±0.5**	3.1±0.3**
	L. Conc.	77±2.4**	5±0.9**
CuO	H.Conc.	11±0.3**	3.3±0.3**
	M. Conc.	22.6±0.8**	5.8±0.9**
	L. Conc.	27.5±0.5**	9.5±0.7**
Untreated (Control)		139.8	13±1.6
P-value		0.0000092	0.0102
F-value		81407.83	51.9
at 0.05		5.744667	4.95
at 0.01		10.54667	9.11

Data are expressed as Mean±Standard error (SE) **** = Highly Significant (p<0.01)**

Thiamethoxam and Imidacloprid pesticides were examined against *B. tabaci* on cotton seeds. The data revealed that the used pesticides have a great effect on the control of *B. tabaci* up to 45 days under laboratory and greenhouse conditions, and up to 2 months under field conditions (Zhang *et al*., 2011). Also maize seeds treated with imidacloprid show resistance against soil pests, aphids, leafhoppers and the first generation of corn borers (Pons and Albajes, 2002). Treatments of cotton seeds with TiO_2, ZnO, FeO_2, SiO_2 and CuO at 1000, 500, 250 ppm in the current study reduced the cotton seedling pests; *T. tabaci*, *E. lybic*a, *B. tabac*i, *A. gosspiila*, *T. telarius*, as respect of that of control. Rouhani *et al*. (2012a) indicated that Ag and Ag-Zn NPs synthesized through a solvothermal method at different concentrations induce insecticidal activities aganist *Aphis nerii*. They recorded that LC_{50} value for imidacloprid, Ag and Ag-Zn NPs were 0.13 µL mL-1, 424.67 mg mL-1, and 539.46 mg mL-1, respectively. They showed that Ag NPs can be used as a valuable tool in the pest management programs of *A. nerii*. However; Rouhani *et al*. (2012b) estimated the efficacy of silica NPs against the larvae and adults of *Callosobruchus maculatus*. They showed that the silica nanoparticles were very effective against both larvae and adults.

Vinutha *et al.* (2013) reported that nanotechnology played a very important role in the pest control of *Helicoverpa armigera* through biological control of its life cycle. Osman *et al*. (2015) mentioned that the nano-silica was the most effective compound followed by nano-Zinc oxide, then effective microorganisms (EMs), in causing high toxicity against *S. littorals*. They reported that all tested materials exhibited latent effect via producing high reduction in pupation and adult emergence rates, decreasing both larval and pupal weight of this pest and reducing estimated enzymes activity, except phenol oxidase. Also, these NPs decrease both total carbohydrates and proteins suggesing that using silica, ZnO NPs as well as EMs would be useful eco-friendly components for controlling *S. littoralis*. Moreover, Araj *et al.* (2015) used five sources of silver NPs and sulfur NPs in different concentrations on the larval, pupal, and adults of the fruit fly *Drosophila melanogaster* under laboratory conditions. They found that Ag NPs were most effective against the larvae, pupae, and adults' mortality and egg suppression. In addition, Routray *et al*. (2016) proved that Application of nanotechnology in the crop protection holds a significant promise in management of insects and pathogens, by controlled and targeted delivery of agrochemicals. They found that the nanoparticles had insecticidal properties well studied on the stored grain insects (*Tribolium castaneum, Martianus dermestoides*, *Callosobruchus maculatus*, *Sitophilus oryzae*, *Corcyra cephalonica*, *Rhyzopertha dominica*), crop pests (*Spodoptera litura*, *Aphis nerii*, *Bactrocera dorsalis*) and other pests. They supposed that nanotechnology will revolutionize agriculture including pest management in the near future.

Khooshe-Bast *et al*. (2016) demonstrated high mortality rates of *Trialeurodes vaporariorum* after treatment with with ZnO NPs. Also, Shaker *et al*. (2017a and b) recorded that treatments with TiO_2 NP tested against the larvae of *Spodoptera littoralis* at all concentrations used 1000, 500, 250, 125, 62.5 and 31.25 ppm indicated higher toxic action for the 2nd instar parallel with concentrations than of the 4thone. Athanassiou *et al. (*2018) mentioned that NPs can be used successfully as insecticides alone and several types of NPs are produced by natural resource-based substances used them promising green alternatives to the use of traditional pest control.

It is concluded that cotton seed treatments withTiO2, ZnO, FeO, SiO_2 and CuO NPs induced potential effects against seedling insect population which were evidenced by decreasing jassid, aphids, thrips, whitefly and red spider counts in cotton plants.

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