

Impact of Foliar Spray by Zinc Oxide Nanoparticles on Peanut Production Under New Valley Conditions

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Abstract

Increasing seed and oil yields production of oil crops in reclaimed soils is an important goal of vision Egypt 2030. Therefore, a field experiment was conducted in newly reclaimed sandy soil in Farafra, New valley Governorate, Egypt during the two summer seasons of 2017 and 2018 to examine the impact of Zn nano-fertilizer foliar spray on peanut production. The field experiment was laid out in a randomized complete block design (RCBD) using a strip plot arrangement with three replications. Zinc oxide nanoparticles concentrations (0 as control, 200, 400 and 600 ppm) were allotted horizontally while, the cultivars NC9, Gregory and Ismailia were a signed vertically. Highly significant differences were observed among zinc oxide nanoparticles (ZnO NPs) concentrations for most studied traits in both seasons. Furthermore, peanut cultivars had a significant effect on most studied traits in both seasons. All peanut cultivars showed remarkable positive responses to the spray of zinc nanoparticles. In most cases, an enhancement was observed in most studied traits by increasing the concentration from 200 ppm to 600 ppm. Also, NC9 cultivar gave the highest seed yield (kg/fed) in both seasons, while there were non-significant differences among peanut cultivars for oil yield (kg/fed) but as an average over both seasons, NC9 gave the highest oil yield (kg/fed). Therefore, the findings of this study suggest that NC9 cultivar with spraying by zinc nanoparticles might be a good choice for planting and production under newly reclaimed soils in the Farafra region with other important recommended agronomical practices for such region.

Keywords: Peanut, Zn Fertilization, reclaimed sandy soils.

Introduction

Peanut (*Arachis hypogaea* L.) is the fourth major oilseeds crop of the world. In 2015, peanut contributed 8.7% of the total oil seeds production (45 million ton) in the world (Anonymous, 2015). Peanut is an important oilseed crop for vegetable oil production. About two-thirds of total peanut production is crushed for oil and the remaining one-third is used in confectionery products in the world (Arioglu, 2014). In Egypt, peanut

production was about 237129 tonnes, which was produced from 65000 hectares with an average yield of 36481kg/ha (FAO, 2018).

Nutrients deficiency is the third most important stress limiting plant productivity worldwide. Peanuts are a sensitive crop of micro-elements deficiency, especially in alkaline and poor sandy soils (Zuo and Zhang 2011). Moreover, Zn is most deficient in soils and it does not throw away the deficiency symptoms, unlike iron,

that is why it is called as “Hidden hunger”. It is reported that Zn deficiency will be increased from 49% to 63% by (Singh.,2010). Increasing production of peanuts and improve seed quality using Fe, Mn and Zn considered an important factor especially in poorly nutritive sandy soil (El-Metwally *et al.* 2018; Abd El-Moneem and Said, 2018 and Hagab *et al.*, 2018).

Nanotechnology has affected all aspects of human life through different productions (Soleimanpouret *al.*2011). One of the nanotechnology application in agriculture is the use of essential elements in nanoparticulate-form (nanoparticles) as nanofertilizers that can be more effective than bulk fertilizers, so that the amount used is very much lower (Jha *et al.* 2011). In some new fertilizers, different plant nutrients have been coated with various metal nanoparticles, as an important ingredient in new commercial fertilizers (Dastjerdi *et al.* 2015; Hagab *et al.*, 2018 and Deb, 2019).

Nanoparticles (NPs) interact with plants causing many morphological and physiological changes, depending on the properties of NPs. Efficacy of NPs is determined by their chemical composition, size, surface covering, reactivity, and most importantly the dose at which they are effective. Researchers from their findings suggested both positive, negative effects on plant growth, development, the impact of NPs on plants depends on the composition, concentration, size, physical and chemical properties of NPs as well as plant species (Hagab *et al.*, 2018).

In many studies, increasing evidence suggests that zinc oxide nanoparticles (ZnO NPs) increase plant growth and development. Prasad *et al.* (2012) studied the effect of nanoscale zinc oxide on the germination, growth and yield of peanut and observed significantly more growth and yield. There are many peanut cultivars grown around the world and several investigations in Egypt have reported that the local and introduced cultivars are genetically and morphologically differed in seed and oil yields (Abd-Alla, 2004; Ali *et al.*, 2004; Ahmed and Rahim, 2007 and Osama and Abdel-Motagally, 2009).

The objective of this study was to elucidate the effect of zinc oxide nanoparticles concentrations as foliar application on peanut seed and oil yields of three peanut cultivars under reclaimed sandy soils conditions in the New Valley.

Materials and Methods

The present investigation was conducted in the newly reclaimed soils in Farafra of New valley Governorate, Egypt; during 2017 and 2018 seasons to study the impact of foliar spray by zinc oxide nanoparticles on production of peanut cultivars.

Plant materials and experiment layout

A field experiment was carried out in a randomized complete block design (RCBD) using a strip plot arrangement with three replications. Zinc oxide nanoparticles concentrations (0 as control, 200, 400 and 600 ppm) were allotted horizontally while, the cultivars (NC9, Gregory and Ismailia1) were a signed vertically. Sub plot included six rows, a

single row was 3 m long and spaced 0.50 cm apart with 0.25 cm (plot size 10.5 m²). Seed were sown on June 14th in both seasons. All other cultural practices recommended for peanut crop under reclaimed soils were done in both seasons. The soil of the experiments was sandy loam, the physical and chemical analysis of the soil were carried out before sowing and presented in Table 1.

Measured traits

At harvesting, five guarded plants were taken randomly from each subplot for measuring the following data: Number of pods /plant, pods weight (g) /plant, seed weight (g) /plant, 100-seed weight (g), biological yield (kg/fed.) and seed yield (kg/fed.). Seed oil content was determined by Soxhlet apparatus according to A.O.A.C. (1995). Multiplication of oil percentage by seed yield in kg fed⁻¹ to obtain oil yield in kg fed⁻¹.

Statistical analysis

All collected data were analyzed with analysis of variance (ANOVA) Procedures, using the SAS Statistical Software Package v.9.2 (SAS, 2008). Differences between means were compared by revised least significant difference (R LSD) at 5% level of significant (Gomez and Gomez, 1984).

Results and Discussion

The results of the experiment in both seasons are presented and discussed in detailed for each trait separately as follow:

Number of pods / Plant

There were significant differences among studied peanut cultivars only in the second season (Table 2). Ismailia and NC9 peanut cultivars recorded the highest number of

Pods/plant (55.26 and 60.16) in 2017 and 2018 seasons, respectively. While the lowest number of pods/plant (51.81 and 54.90) were obtained by Gregory and Ismailia cultivars in the first and second seasons, respectively. This is may be due to the genetic behavior in combination with the environmental conditions which was suitable for Ismailia and NC9 cultivar than Gregory one. The previous results are in accordance with those obtained by Ahmed & zeidan (2001), Ahmed *et al.* (2007b) and Atayese (2007).

Furthermore, highly significant differences were observed among tested zinc oxide nanoparticles (ZnO NPs) concentrations for number of pods/plant in both seasons (Table 2). Since the highest mean values of pods number/plant (71.62 and 83.40 in the first and second seasons, respectively) were obtained when plants sprayed with 600 ppm of ZnO NPs concentrations, while the lowest values (38.11 and 34.04) were observed under control treatment in both seasons, respectively. This is to be logic since the same trend was observed with regard to number of branches/plant trait (data not shown). These results are in the same trend with that reported by Majumdar *et al.* (2001).

Also, the exhibited data in Table (2) denote that the interaction between ZnO NPs concentrations and peanut cultivars were significant ($P \leq 0.05$) in the second season only. The highest mean value of pods number/plant in the second season (85.53) was registered from Gregory cultivar which was sprayed by ZnO NPs at 400 ppm.

Pods weight / Plant:

The illustrated data in Table (3) show that the tested peanut cultivars failed to reach a significant effect in both seasons. NC9 and Ismailia peanut cultivars were surpassed Gregory cultivar in pods weight/plant and registered the heaviest pod weight/plant (87.50 and 79.25 g) in 2017 and 2018 seasons, respectively. While the lowest ones (82.16 and 71.91 g) were achieved with Ismailia cultivar in the first season and NC9 cultivar in the second season. This is may be due to the genetic behavior in combination with the environmental conditions which was suitable for NC9 and Ismailia cultivars than Gregory one. The previous results are in accordance with those obtained by Ahmed & zeidan (2001), Ali *et al.* (2004), Ahmed *et al.* (2007b).

In addition, the analysis of variance revealed highly significant differences among zinc oxide nanoparticles concentrations for pods weight/plant in both seasons (Table 3). Furthermore, the heaviest values of pod weight / plant (117.22 and 104.88 g in the two respective seasons) were obtained from 600 ppm of ZnO NPs concentration, while the thinnest ones (55.62 and 51.00 g) were found at the control in the first and second seasons, respectively. This is to be logic since the same trend was observed with regard to number of pods / plant trait as mentioned before (Tables 2). These findings are in a good line with those obtained by Majumdar *et al.* (2001).

Also, it is clear from recorded data in Table (3) that the interaction between ZnO NPs concentrations and peanut cultivars was a highly signifi-

cant regarding pods weight/plant in both seasons. The heaviest pod weight/ plant (130.66 g) was noted from NC9 cultivar which was sprayed by ZnO NPs at 600 ppm in the first season, while in the second season the heaviest pod weigh/ plant (116.66 g) was recorded from Ismailia cultivar which was sprayed by ZnO NPs at 600 ppm, as well as the NC9 cultivar under the control (without ZnO NPs) gave the 200ppm lightest ones (44.33 and 49.00 g in the two growing seasons).

Weight of 100 seeds (g):

Non-significant differences were observed among peanut cultivars in both seasons (Table 4) for 100-seed weight. NC9 and Gregory cultivars were surpassed Ismailia cultivar in this respect and registered the maximum values of 82.50 and 94.16 g for the weight of 100 seeds in the first and second seasons, respectively. While the minimum values of weight of 100-seed were 78.75 and 86.25 g which achieved with Ismailia cultivar in the two respective seasons, respectively. These results are in agreement with those reported by Ahmed *et al.* (2007b), Annadurai *et al.* (2009), Mohamed (2009).

Here too, weight of 100 seeds trait was affected highly significantly by the (ZnO NPs) concentrations in both seasons (Table 4). The maximum values in this trait were 88.88 and 100.55 g in the first and second seasons, respectively were obtained from peanut plants which were sprayed by ZnO NPs concentration at 600 ppm. While the minimum values were 71.66 and 81.66 g in the first and second seasons were found at 200 ppm. This may be due to the zinc

oxide nanoparticles increase the zinc absorption via peanut plants and consequently increased photosynthesis process which led to an increment in metabolic translocation from sources to seeds. These findings are in a good line with those obtained by Babaeian *et al.* (2011), Al-Doori (2013) and Laware and Shilpa (2014).

Moreover, the interaction between ZnO NPs concentrations and peanut cultivars failed to reach a significant effect at 5% level of probability in the first and second seasons, respectively (Table 4). These findings are in a good line with those obtained by Al-Doori (2013).

Seed weight/plant (g):

Data in Table (5) reveal that zinc oxide (ZnO NPs) concentrations had a highly significant ($P \leq 0.01$) effect on seed weight/plant (g) in the two growing seasons. Thus, the heaviest seed weight/plant were 52.33 and 47.36 g in the first and second seasons, respectively were obtained from 600 ppm of ZnO NPs concentration. While the lightest seed weight/plant were 41.67 and 34.33 g which were found at the control (without ZnO NPs) in the first and second seasons, respectively. This is due to the same trend was observed with regard to number of pod and weight of 100 seeds traits as mentioned before. These results are in agreement with those reported by Laware and Shilpa (2014).

Moreover, the exhibited data in Table (5) focus that the tested peanut cultivars had a significant influence on seed weight/plant trait in the first season only while, to failed to reach a significant effect in the second season. In addition, NC9 and Gregory

peanut cultivars were superior Ismailia in this trait and gave the highest mean values of seeds weight/plant (49.00 and 40.21g), while the lightest ones (45.67 and 38.90g) were achieved with Ismailia and Nc9 cultivar in the two respective seasons, respectively. This is may be due to the increase in number of pod and weight of 100 seeds. These results are in accordance with those reported by Ali *et al.* (2004), Mohamed (2009).

Also, the obtained data in Table (5) reveal that the interaction between ZnO NPs concentrations and peanut cultivars had a highest significant influence on seed weight / plant trait in the second season only but, it failed to reach a significant effect in the first season. The heaviest seed weight / plant (55.67 and 48.17 g in the two respective seasons) were obtained from NC9 and Gregory cultivars which was sprayed by ZnO NPs at 600 ppm, while the Gregory and Ismailia cultivars under the control (without ZnO NPs) gave the lightest ones (39.67 and 33.67) in the two growing seasons.

Biological yield/ fed.

Biological yield (kg/fed) trait reacted highly significantly ($P \leq 0.01$) to the tested concentrations (ZnO NPs) in the second growing season only (Table 6). Thus, the maximum values of biological yield trait (1.62 and 1.70 in the first and second seasons, respectively) were obtained from 600 ppm of ZnO NPs concentration, while the minimum one (1.15 and 1.11) was found at the control in the first and second seasons, respectively. The previous results are in accordance with those obtained by Babaeian *et al.* (2011) and Ghasemi *et*

al. (2017). Also, the recorded data in Table (6) denote that the tested Peanut cultivars had a significant influence on biological yield trait in second season only. Moreover, NC9 and Gregory cultivars were superior Ismailia one in this trait and gave the maximum values of biological yield trait (1.42 and 1.44 kg in the two respective seasons), while the minimum ones (1.31 and 1.30 kg) were achieved with Ismailia and Gregory cultivars in the two respective seasons. These results are in accordance with those reported by Abd-Alla (2004) and Mohamed (2009).

Concerning the interaction effect on biological yield, the exhibited data in (Table 6) reveal that the interaction between ZnO NPs concentrations and peanut cultivars had a highly significant effect in the second season. The maximum values of biological yield were 1.70 and 1.78 kg in the first and second seasons, respectively, which were obtained from Gregory and NC9 cultivars which was sprayed by ZnO NPs at 600 ppm, as well as the Ismailia and Gregory cultivars under the control (without ZnO NPs) gave the minimum ones (1.11 and 1.02 kg) in the two growing seasons.

Seed yield (kg/ fed.)

Seed yield (kg/fed) trait reacted highly significantly ($P \leq 0.01$) to the tested ZnO NPs concentrations (ZnO NPs) in the two growing seasons (Table 7). Since the highest mean values of seed yield trait were 588.09 and 659.64 kg/fed. in the first and second seasons, respectively which were obtained from 400 ppm and 600 ppm of ZnO NPs concentration. This is to be expected since the same trend

was observed regarding seed weight (Table 5). While the minimum ones were 533.33 and 497.87 kg/fed. were found at the control and 200 ppm in the first and second seasons. The previous results are in accordance with those obtained by Gitte *et al.* (2005) and Patel (2016).

Also, the recorded data in Table 7 denote that the tested peanut cultivars had a significant influence on seed yield trait in the first season only while, peanut cultivars failed to reach a significant effect in the second season. Furthermore, NC9 cultivar was superior Gregory and Ismailia in this respect and gave the highest mean values of seed yield (574.40 and 587.13 kg/fed. in the two respective seasons). This is to be expected since the same trend was observed with regard to seed weight/plant. while the minimum ones (555.73 and 564.60 kg/fed.) were achieved with Ismailia and Gregory cultivars in the two respective seasons. These results are in agreement with those reported by Osama and Abdel-Motagally (2009).

Concerning the interaction effect on seed yield trait, the exhibited data in Table 10 reveal that the interaction between ZnO NPs concentrations and peanut cultivars failed to reach a significant effect at 5% level of probability in the two successive seasons. The highest mean values of seed yield trait (611.73 and 590.13 kg/fed. in the first and second seasons, respectively) were obtained from NC9 cultivar which was sprayed by ZnO NPs at 600 ppm. as well as the Gregory cultivar under the control (without ZnO NPs) gave the minimum ones were 522.13 and 488.53 kg/fed. In the first and second sea-

sons, respectively. Similar trend was observed by Al-Doori (2013).

Oil yield (kg/ fed.):

It is clear from the data in Table 8 that the zinc oxide nanoparticles concentrations had a highly significant ($P \leq 0.01$) effect on oil yield. Where, the heaviest mean of values of oil yield (295.23 and 321.73 kg/fed. in the first and second seasons, respectively) were obtained from 400 and 600 ppm ZnO NPs concentration. This is to be logic, since the same trend was observed with regard to seed yield traits as mentioned before. while the minimum one (259.55 and 230.51 kg/fed.) were found at control (without ZnO NPs) in the first and second seasons. These results are in agreement with those reported by Sankaran *et al.* (2001) and Al-Doori (2013).

Data in the same table exhibited that the studied peanut cultivars failed to reach a significant effect at 5% level of probability in the two growing seasons. Hence, Gregory and Ismailia cultivars in this respect gave the highest mean values of oil yield (278.14 and 279.63 kg/fed in the two respective seasons). This is to be expected since the same trend was observed with regard to seed yield trait as mentioned before (Table 7). While the minimum ones (274.63 and 273.90 kg/ fed.) were achieved with NC9 cultivar in the two respective seasons. These results are in agreement with those reported by Howlader *et al.* (2009).

Also, the obtained data in Table 14 reveal that the interaction between ZnO NPs concentrations and sunflower cultivars had a highly significant effect on oil yield. The highest

mean values of oil yield (723.61 and 701.37 kg/fed. in the two respective seasons) were obtained from Giza 102 cultivar which was sprayed by ZnO NPs at 200 ppm than Sakha 53 one. as well as the Gregory and NC9 cultivars under the control (without ZnO NPs) and 200 ppm gave the minimum ones (46.57 and 45.36%) in the two growing seasons. These results are in agreement with that reported by Al-Doori (2013).

Conclusions

From the previous results, it could be concluded that the analysis of variance revealed highly significant variation among peanut cultivars and zinc nanoparticles concentrations for the most studied traits in the two tested seasons under Farfra conditions. Furthermore, the interaction between peanut cultivars and the concentrations of zinc nanoparticles was significant in most cases in both seasons. This result indicates the variability of the genetic response of the peanut cultivars to the spray by zinc nanoparticles on the growth and productivity of peanut cultivars compared to the non-sprayed plants (control). Since all peanut cultivars showed remarkable positive responses to the spray of zinc nanoparticles. In most cases, an enhancement was observed in most studied traits by increasing the concentration from 200 ppm to 600 ppm. Also, NC9 cultivar gave the highest seed yield (kg/fed) in both seasons, while there were non-significant differences among peanut cultivars for oil yield (kg/fed) but as an average over both seasons, NC9 gave the highest oil yield (kg/fed). Therefore, it could be recommended that NC9 cultivar with

spraying by zinc nanoparticles is a good choice for planting and production under newly reclaimed soils in the Farafra region with other important recommended agronomical practices for such region.

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تأثير الرش الورقي بأكسيد الزنك النانوميتري على إنتاج الفول السوداني تحت ظروف الوادي الجديد

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الملخص

تعد زيادة إنتاج البذور والزيوت من المحاصيل الزيتية في التربة المستصلحة هدفاً مهماً من أهداف رؤية مصر ٢٠٣٠. لذلك تم إجراء تجربة حقلية في التربة الرملية المستصلحة حديثاً في الفراغة، محافظة الوادي الجديد، جمهورية مصر العربية خلال موسمي صيف ٢٠١٧ و ٢٠١٨ لدراسة تأثير رش سماد الزنك النانوميتري الورقي على إنتاج الفول السوداني من البذور والزيت. لوحظت فروق ذات دلالة إحصائية عالية بين تراكيز الرش بأكسيد الزنك النانوميتري (ZnO NPs) لمعظم الصفات المدروسة في كلا الموسمين. علاوة على ذلك، كان لأصناف الفول السوداني تأثير معنوي على معظم الصفات المدروسة في كلا الموسمين. بحيث أظهرت جميع أصناف الفول السوداني استجابات إيجابية ملحوظة لرش جزيئات الزنك النانوميتري. حيث لوحظ تحسن في معظم الصفات المدروسة عن طريق زيادة التركيز من ٢٠٠ جزء في المليون إلى ٦٠٠ جزء في المليون، كما أعطى الصنف NC9 أعلى محصول بذور (كجم / فدان) في كلا الموسمين، بينما كانت هناك فروق غير معنوية بين أصناف الفول السوداني في محصول الزيت (كجم / فدان) خلال الموسمين، ولكن أعطى NC9 أعلى إنتاج للزيت (كجم / فدان). لذلك، يمكن التوصية بأن يكون الصنف NC9 الذي يتم رشه ورقياً بأسمدة الزنك النانوميتري خياراً جيداً للزراعة والإنتاج تحت تربة مستصلحة حديثاً في منطقة الفراغة مع إجراء باقي المعاملات الزراعية الهامة الأخرى الموصى بها لهذه المنطقة.

Table 1. Soil physical and chemicals analysis of the experimental site.

Characteristic	Values
Particle size distribution	
Sand, %	75.10
Silt, %	10.90
Clay, %	14.00
Soil texture	Sandy loam
Field capacity, %	13.20
Wilting point %	6.10
Saturation water, %	21.00
Bulk density, gm/cm ³	1.70
Ph	7.70
Total soluble salt, EC1:1 dSm ⁻¹	0.31
CaCO ₃	12.10
Soluble Cations in soil (1:1)	meq/kg
Ca ²⁺	1.50
Mg ²⁺	0.50
Na ⁺	1.10
K ⁺	0.30
Soluble Anions	
Cl ⁻	2.30
HCO ₃ ⁻ + CO ₃ ²⁻	0.50
SO ₄ ²⁻	0.80
Total nitrogen %	0.01
A available phosphorus ppm	9.10
Analysis of the zinc in soil and water	
Soil	0.84* (mg/kg)
Water	0.00

*Zn was determined using the Inductively Coupled Plasma Emission Spectrometer) (ICAP6200)

Table 2. Means of pods number/plant as affected by zinc oxide nanoparticles concentrations, peanut cultivars, and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	35.13	40.86	38.33	38.11	35.86	33.93	32.33	34.04
200	38.40	37.80	40.20	38.80	36.93	35.60	34.60	35.71
400	65.86	60.66	69.26	65.26	82.86	85.53	72.80	80.40
600	73.66	67.93	73.26	71.62	85.00	85.33	79.86	83.40
Mean	53.26	51.81	55.26	-----	60.16	60.10	54.90	-----
F test and R. LSD	F test			R. LSD 0.05	F test			R. LSD 0.05
ZnO NPs	**			10.37	**			2.68
Cultivars	Ns			--	*			3.56
Interaction	Ns			--	*			5.05

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 3. Means of pods weight/plant as affected by zinc oxide nanoparticles concentrations, peanut cultivars and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	44.33	69.53	53.00	55.62	50.00	50.00	53.00	51.00
200	53.33	65.53	62.33	60.40	49.00	50.33	50.66	51.00
400	121.66	94.33	108.33	108.11	88.66	97.66	96.66	94.33
600	130.66	116.00	105.00	117.22	100.00	98.00	116.66	104.88
Mean	87.50	86.35	82.16	-----	71.91	74.00	79.25	-----
F test and	F test			R. LSD 0.05	F test			R. LSD 0.05
ZnO NPs	**			10.83	**			5.14
Cultivars	Ns			---	Ns			---
Interaction	**			7.26	**			6.46

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 4. Means of 100-seed weight/plant (g) as affected by zinc oxide nanoparticles concentrations, peanut cultivars and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	71.66	78.33	73.33	74.44	86.66	81.66	78.33	82.22
200	73.33	75.00	71.66	73.33	83.33	80.00	81.66	81.66
400	85.00	90.00	83.33	86.11	103.33	98.33	90.00	97.22
600	93.33	86.66	86.66	88.88	103.33	103.33	95.00	100.55
Mean	80.83	82.50	78.75	-----	94.16	90.83	86.25	-----
F test and R. LSD	F test		R. LSD 0.05		F test		R. LSD 0.05	
ZnO NPs	**		3.95		**		4.67	
Cultivars	Ns		---		Ns		---	
Interaction	Ns		--		Ns		---	

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 5. Means of seed weight/plant (g) as affected by zinc oxide nanoparticles concentrations, peanut cultivars, and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	43.67	39.67	41.67	41.67	35.67	33.67	33.67	34.33
200	43.33	42.67	43.33	43.11	36.93	36.33	34.33	35.87
400	53.33	51.6	49.33	51.42	35.33	42.67	45.33	41.11
600	55.67	53.00	48.33	52.33	47.67	48.17	46.25	47.36
Mean	49.00	46.75	45.67	-----	38.90	40.21	39.89	-----
F test and R. LSD 0.05	F test		R. LSD 0.05		F test		R. LSD 0.05	
ZnO NPs	**		5.52		**		4.76	
Cultivars	*		2.14		Ns		---	
Interaction	Ns		---		**		2.56	

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 6. Means of pods biological yield/fed. (ton/fed.) as affected by zinc oxide nanoparticles concentrations, peanut cultivars, and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	1.15	1.18	1.11	1.15	1.27	1.02	1.05	1.11
200	1.29	1.21	1.18	1.22	1.29	1.17	1.16	1.20
400	1.62	1.58	1.37	1.52	1.41	1.37	1.45	1.41
600	1.59	1.70	1.58	1.62	1.78	1.66	1.66	1.70
Mean	1.42	1.42	1.31	----	1.44	1.30	1.33	----
F test and R. LSD	F test		R. LSD 0.05		F test		R. LSD 0.05	
ZnO NPs	Ns		--		**		0.13	
Cultivars	Ns		--		*		0.07	
Interaction	Ns		--		**		0.10	

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 7. Means of seed yield/fed. (kg /fed') as affected by zinc oxide nanoparticles concentrations, peanut cultivars, and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	544.53	522.13	533.33	533.33	515.20	488.53	506.83	503.52
200	542.67	538.93	542.66	541.42	503.47	492.27	497.87	497.87
400	598.67	589.33	576.26	588.09	639.73	632.26	621.07	631.02
600	611.73	596.80	570.67	588.08	690.13	645.33	643.47	659.64
Mean	574.40	561.80	555.73	----	587.13	564.60	567.30	----
F test and R. LSD	F test		R. LSD 0.05		F test		R. LSD 0.05	
ZnO NPs	**		30.91		**		26.20	
Cultivars	*		11.99		Ns		--	
Interaction	Ns		---		Ns		---	

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.

Table 8. Means of oil yield/fed. (kg/fed) as affected by zinc oxide nanoparticles concentrations, peanut cultivars and their interaction in 2017 and 2018 seasons.

Season	2017				2018			
Zinc oxide nanoparticles (ppm)	Cultivars			Mean	Cultivars			Mean
	NC9	Gregory	Ismailia		NC9	Gregory	Ismailia	
Control	258.05	254.07	266.54	259.55	233.71	225.69	232.14	230.51
200	258.17	250.95	270.91	260.01	234.44	248.75	241.97	241.72
400	289.84	308.77	287.09	295.23	322.92	298.79	306.31	309.34
600	291.90	298.77	284.85	291.84	327.46	322.54	315.19	321.73
Mean	274.49	278.14	277.35	----	279.63	273.94	273.90	----
F test and R. LSD	F test		R. LSD 0.05		F test		R. LSD 0.05	
ZnO NPs	**		15.67		**		12.96	
Cultivars	Ns		--		Ns		--	
Interaction	**		4.24		Ns		---	

Where Ns, * and ** mean non-significant, significant at 5 and 1% level of probability, respectively.