APPLICATION OF NANO-SILICA TO MITIGATE THE EFFECTS OF DROUGHT ON SOME EGYPTIAN BARLEY VARIETIES

Amer, Kh. A[1], Kadria, M. EL Azab[1]. and F. A. Hellal, [2] and A. H. A. Hassanein

[1]Soils, Water and Environ. Res. Institute, Agric. Res. Center (ARC), Giza, Egypt.

[2]Plant Nutrition Dept., National Research Centre, Dokki, El-Behoos St., 12622, Cairo, Egypt.

ABSTRACT

With limited water resources in semi-arid regions, which receive precipitation below potential evapotranspiration and are characterized by excessive heat and drought stress, drought is one of the most severe abiotic stress which adversely affects crop growth and productivity. This study was carried out to investigate the negative effects of drought stresses on some Egyptian varieties of barley and its alluviation by using Nano silica particle application. To this end, a pot experiment was laid out in a completely randomized design with three replications, this experiment includes three varieties of Egyptian barley (Giza 129, Giza 133 and Giza 136) three levels of drought (80%, 60% and 40% of field capacity) and Nano silica were applied as foliar in concentration of (0.0 , 25.0, 50.0 and 100.0 mg l^{-1}.

The results showed that by water deficit both No of tiller/ plant and plant height (cm), photosynthesis, straw and grains yield and thousand grains weight was significantly reduced in all studied barley varieties, for example, at (40% FC) the reduction in straw and grain yield reached to 39.4, 21.3% for Giza 136 and 31.8, 33.0% for Giza 133 and 11.4, 12.3% in Giza 129 compared to the normal condition (80% FC) respectively. Data revealed the better performance of 'Giza 129' variety above 'Giza 133', followed by 'Giza 136' in the reduction rate of straw and grain yield and photosynthetic features against soil water deficit. On the other hand, Data showed increases have exceeded by 16.9% and 20.6 % in straw and grains respectively at using the highest concentration (100 mg/l) of Nano silica application compared to untreated plant, therefore it could be stated that this concentration of Nano-silica had the ability to mitigate some the adverse effect of drought.

KEYWORDS:*(Nano silica, Water stress, Morphological, chemical composition, yield, barley)*

INTRODUCTION

Recent trends show reductions in crop productivity worldwide due to severe climatic change. Different abiotic stresses significantly affect the growth and development of plants. Salinity and drought stresses are the most common abiotic stresses and important limiting factors to agricultural productivity, especially in arid and semi–arid regions, and are major constraints for barley production (**EL Sabagh et al., 2019).**

Drought is a meteorological term and is commonly defined as a period without significant rainfall or period low precipitation. Generally, drought stress occurs when the soil available water is reduced and atmospheric conditions cause continuous loss of water by evapotranspiration, **(Cheruth et al., 2009)**. Drought affects the morphological (induced senescence), physiological (stomata or osmotic adjustments and translocation of nutrients from older leaves to developing tissues and seeds), and biochemical processes (changes in the ratio of chlorophyll (chl) content, beta carotenoids, and reduced photosynthesis) in plants, resulting in growth inhibition of different barley genotypes (**EL-Shawy et al., 2017 and Temel et al., 2017)**. The decrease in photosynthesis at drought stressed plants can be attributed both to a decrease in stomatal conductance (stomatal closure) and/or to non-stomatal limitations (impairments of metabolic processes) factors, **(Mafakheri et al., 2010)**. At present, most researchers agree that the stomatal closure and the resulting CO_2 deficit in the chloroplasts is the main cause of disrupts photosynthetic pigments and reduces the gas exchange leading to a reduction in plant growth and productivity under mild and moderate stresses (**Flexas and Medrano, 2002; Shakeel et al., 2011).**

These adverse effects can be mitigated by include soil management practices, as well as crop, foliar applications of anti-oxidants and growth regulators that maintain an appropriate level of water in the leaves to facilitate adjustment of osmotic and stomatal performance. Also, numerous nutrients have been identified to act as drought stress ameliorants such as Nitrogen (**Gevrek and Atasoy, 2012**), Potassium (**Raza et al., 2012**), Selenium (**Nawaz et al., 2013**), and Salicylic acid (**Waseem et al., 2006**). On the other hand, plants can partly protect themselves against drought stress by accumulating osmolytes. Proline is one of the most common compatible osmolytes in drought-stressed plants. For example, (**Alexieva et al., 2001 and Mafakheri, et al., 2010**) reported that the proline content increased under drought stress in pea and chickpea cultivars.

Nanoparticles have unique physicochemical properties compared with their bulk counterparts.: their tiny size (at least two dimensions between 1-100 nm), and ability to traverse barriers (cell walls and plasma membranes) facilitate effective absorption, which is able to enter into plant cells and leaves, and can also transport DNA and chemicals into plant cells, their very large specific surface area can result in a good level of interaction with intracellular structures (**Galbraith, 2007; Torney et al., 2007; Monica & Cremonini, 2009**). Because of those numerous benefits of nanoparticles; use of nanotechnology in the field of biotechnology and agriculture has increased considerably in recent years to boost the yield, **(Siddiqui et al., 2015). Ajey Singha, et al., (2015)** showed that Nanoparticles accumulated in the plant cells may be transported by apoplast or symplast through plasmodesmata, however, the exact mechanisms by which plants take up nanoparticles and plant-specific accumulation of nanoparticles is are still unknown and remain to be explored.

The recent available in literatures indicate that some engineered nanomaterials can enhance plant-growth in certain concentration ranges and could be used as nano fertilizers to increase yields and/or minimize environmental pollution, **Liu, and**

Lal, (2015). So, Nanotechnology has the potential to act as an alternative for the conventional agriculture system and thus can be a cure for the major problems faced by agriculture in present times. **(Kalteh et al., 2014; Haghighi et al., 2012; Li et al., 2012; Siddiqui et al., 2014)** reported that application of nano-SiO_2, enhance improving the tolerance of plants to abiotic stress caused due to increase in the accumulation of proline, free amino acids, content of nutrients, antioxidant enzymes activity. **Suriyaprabha et al., (2012)** indicated that seed germination increased by nano SiO_2 which provided better nutrients availability to maize seeds. Also, Changbai larch (Larix olgensis) seedlings when exposed to nano SiO_2, improved seedling growth and quality, including mean height, root length and diameter, number of lateral roots of seedlings and also induced chlorophyll biosynthesis, (**Bao-shan et al., 2004**). Application of silica nanoparticles has shown to increase plant growth and development by increasing photosynthetic rate, transpiration rate, stomatal conductance for gas exchange, electron transport rate and other physiological parameters, (**Al-Whaibi, 2014**). SiO_2 NPs increase photosynthetic rate by changing the activity of carbonic anhydrase and synthesis of photosynthetic pigments (**Siddiqui et al., 2014 and Xie et al., 2012**).

Barley (*Hordeum vulgare* L.) is ranked fourth for world cereal crops in both quantities produced and in acres of cultivation, after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and maize (*Zea mays* L.). It is well grown in the Mediterranean region due to high tolerance against heat, drought, and salinity compared to other small grains (**Zhou, 2009 and El-Wahid et al., 2015**). It has been given the least importance in Egypt among the cereal crops and cultivation confined to marginal lands associated with drought and saline conditions. Barley strains and cultivars (Hordeum vulgare L.) differ considerably in their response and adaptation to drought stress (**Zare et al., 2011**). Among all the factors limiting barley productivity, drought remains the single most important factor affecting the world food security and sustainability in agricultural production. Drought is undoubtedly one of the most important environmental stresses limiting the productivity of crop plants around the world (**Bohnert et al., 1995; Farooq et al., 2009**). The present study was therefore carried out with the hypothesis that Nano silica particle as a foliar application could play a significant role in attenuates the damaging effects of water stress to some barley varieties production under drought stress.

MATERIALS AND METHODS

Pots experiment was conducted during the growth winter season of 2017 at El Gharbia governorate, Egypt, in the open filed under natural weather conditions (climate of middle delta). Three varieties of Egyptian barley were obtained from Agricultural Research Center (ARC, Giza, Egypt), e.g. Giza 129, Giza 133 and Giza 136, they selected according to its sensitivity for drought which recorded through our previous experiments and were cultivated in pots experiment to test the ability of different concentrations of Nano silica (0, 25, 50, 100 mg l^{-1}) as foliar application to increase the resistance of barley to drought. The field capacity of clay soil used in pots experiment was determined by saturating the soil with water, the pots were covered with plastic sheets and left to drain for 3 days. Pot weights were recorded after 3 days of drainage. The weight of soil moisture at field capacity was calculated as the difference between the soil weight after drainage and soil weight after oven drying for 105 °C for 24 h.

In clean plastic pots (29 × 25 cm in diameter and depth, respectively) containing 10 kg of clayey soil, 15 Grains of barley were sown in each pot on 17th November, 2017 and irrigated to 100% of field capacity, The experimental soil has FC, 31ml /100g soil; pH, 7.2; EC, 1.1 ds m^{-1} and 42 mg /kg soil of available N. The pots were placed under natural filed conditions. The pots experiment was arranged a completely randomized design with three replicates. Total pots = [3 varieties of barley (Giza 129, Giza 133 and Giza 136) × 3 levels of drought (80%, 60% and 40% FC %) × 4 different concentration of Nano silica (0, 25, 50 and 100 mg l^{-1}) × 3 rep.] = 108 pots.

After 15 days from sowing, plants were thinned to 10 plants / pot and all pots were watered till the field capacity was full. The water stress treatment was started after the appearance of the fourth leaf on day 21. While water was totally withheld from the stressed plants until the soil moisture content reached 60% and 40% of field capacity. The stressed plants were still at this moisture content until ripening by weighing the pots weekly and watering as required (irrigated once a week). The control pots were irrigated weekly (to reach 80% of field capacity) until ripening. Different concentrations of Nano silica (0, 25, 50 and 100 mg L^{-1}) were added *via* a foliar application on plant growth after 30, 45, 60 and 75 days from sowing, the control plants were sprayed with tap water. In addition, for improving and accelerating the growth of plants, each pot was received NPK macronutrient (20: 20: 20) Crystalline at the recommended rates, (20 g /pot) through life cycle of plant devised par two time at 25 and 45 days from sowing.

Biochemical parameters

Chlorophyll content: Leaf greenness present in a plant was measured on day 90 after planting and determined using the Minolta-SPAD Chlorophyll Meter (Minolta Camera Co., Osaka, Japan). The SPAD-502 chlorophyll meter measures the chlorophyll absorbance in the red and near-infrared regions and calculates a numeric SPAD value which is proportional to the amount of chlorophyll in the leaf (**Minolta, 1989**).

Proline content: First, 0.4 g of fresh plant material was homogenized in 1.5 ml of distilled water and then incubated in water bath at 100 °C for 30 min. Then, the samples were cooled to room temperature (22 °C) and centrifuged for 10 min at 4 000 rpm. Next, 1 ml of a 1% solution of Ninhydrin in 60% acetic acid was added to 0.5 ml of the supernatant and incubated at 100 °C for 20 min. After cooling to 22

°C, 3 ml of toluene was added and the samples were shaken and left in the dark for 24 h for phase separation. One ml of proline extract was introduced to a cuvette and the absorbance was measured by spectrophotometer at a wavelength of λ = 520 nm according to (**Bates et al., 1973, and Maria et al., 2014**).

At harvest maturity (in 30th April, 2018), all plants in each experimental unit (pot) were hand-harvested to measure yield and yield components. Number of tillers /plant, plant height, 1000-grain weight, and total grain, straw weight were recorded for the harvested plants. Data were expressed as a value per different variety of barley. The harvested barley varieties were oven dried for 48h at 70°C, dry weights recorded, grinded and digested for Nitrogen determinations. **Crud protein content (%)** in seeds was determined by multiplying the nitrogen percentage by 5.75 according the method described by **A.O.A.C., (1984)**.

Statistical analysis: The collected data were subjected to a convenient statistical analysis as a split split plot design by using MINITAB Statistical software Program for Windows Release 16, according to Barbara and Brain (1994). The ANOVA test was used to determine significance of ($p \leq 0.05$) treatment effect and the least significant difference (L.S.D.) test was used to determine significance of the difference between individual means.

RESULTS AND DISCUSSION

This study is devoted to investigate the effect of Nano-silica application under different drought stress levels (80, 60 and 40% of FC) on the morphological, chemical, and yield components of some Egyptian varieties of barley (Giza 129, Giza 133 and Giza 136).

Morphological and growth properties:

Some morphological and growth properties are important parameters in the estimation of productivity potential of the plant. Data presented in Table (1) clearly showed that the Nano-silica treatment as an individual factor **(C)** increased significantly the mean values of No of tiller/ plant for all the studied varieties. In the same time the mean values of plant height (cm) decreased significantly compared with non-addition of Nano silica (the control). Regardless the varieties of barley, the interaction between levels of humidity (FC%) and Nano silica concentration **(B*C)** on the mean values of both No of tiller/ plant and plants height (cm) were decreased significantly, these results may be due to, the relative increase caused by the addition of silica nanoparticles versus the negative effect of drought on the varieties of cultivated barley. Abiotic stress generally affect morphological parameters in most varieties of barley, numerous of researchers noticed theses negative effects on enlargement of barley cells **(James et al., 2002)**, reduces the number of tillers, spike length, number of spikelet's spike^{-1}, biomass plant^{-1}, and finally grain yield plant^{-1} **(Ahmad et al., 2013; 2015).** The results were agreement with this trend, which is clear in the individual effect (B) of the different drought stress levels (60 and 40% of FC) on the mean values of both No of tiller/ plant and plant height (cm). These morphological properties were significantly decreased compared to the control (80% FC), by 26.25% and 5.26% at the level 60% FC and reached 43.63%, 18.62 % at 40% FC respectively in the same order. This reduction may be happened because of the reduction in photosynthetic ability of barley under water stress conditions. Reversely, positive effect of Nano silica application on No. of tiller/ plant does not exceed 10.43% at the maximum Nano silica concentration used as individual factor **(C).** Although the use of drought-sensitive varieties in the experiment, the varieties can be arranged in descending order : Giza 136 > Giza 133 > Giza 129 according to their sensitivity to drought, that the decreasing percentage calculated in growth properties (ex No. of tiller/ plant) from the interaction data between (A*B) in Table (1) by (30.80, 50.40%), (30.87, 46.21%) and (17.49, 34.60%) at the drought stress levels (60 and 40% FC) respectively compared to the normal condition (80% FC) for the previous same order of barley varieties. On the other hand, the morphological data in Table (1) clearly showed that the mean values interaction (A*B) of both No. of tiller/ plant, and plants height are similar for the varieties of Giza 136 and Giza 133 at the natural condition (80% FC). But their response to drought levels are significantly different particularly at the drought stress level (40% FC), as the decreasing percentage calculated to No. of tiller/ plant for Giza 136 was more than Giza 133 (50.40 and 46.21%, respectively). On the contrary, the decreasing percentage calculated to plant height for Giza 136 was little than Giza 133 (18.77 and 24.90 %, respectively).

As a general, the decreasing percentage in all studied morphological properties for the variety of Giza 136 is more than Giza 133 and more than Giza 129, these results indicate that the barley variety Giza 136 is more sensitive to drought than Giza 133 follows by Giza 129. These varieties showed contrary trend with Nano silica addition as, Giza 136 is less response than Giza 133 and then follows by Giza 129, this may be due to the used Nano silica concentrations are non-sufficient to causes higher increases which resist the deleterious effects of drought on the morphological and growth properties. In addition, the statistical analyses for the varieties as the individual factor (A) showed that the barley variety Giza 136 is the least branching (No. of tiller/ plant) and tallest plant (plant height) compared to Giza 129 which is the most branching and the shortest plant, while Giza 133 is moderately.

Table 1: Effect of Nano silica application on some morphological characters of some barely varieties under different field capacity (FC%) during the winter season 2017

Item study		Plant height (cm)				No of tiller/ plant			
Treatments		Varieties (A)			mean (B*C)	Varieties (A)			mean (B*C)
Field capacity (FC %) (B)	Nano-Silica mg/l (C)	Giza 129	Giza 133	Giza 136		Giza 129	Giza 133	Giza 136	
80%	0	60.75	75.17	70.47	*68.79*	4.60	4.17	4.87	*4.54*
	25	61.13	72.80	71.85	*68.59*	4.90	5.35	5.00	*5.08*
	50	56.25	65.35	65.48	*62.36*	5.20	6.00	5.25	*5.48*
	100	57.60	69.93	72.25	*66.59*	6.35	5.60	4.90	*5.62*
60%	0	61.85	69.17	70.47	*67.16*	4.27	3.30	3.60	*3.72*
	25	53.63	64.25	71.85	*63.24*	4.55	3.95	3.75	*4.08*
	50	51.20	61.50	65.48	*59.39*	4.50	3.27	3.20	*3.66*
	100	53.50	61.78	72.25	*62.51*	4.05	4.10	3.30	*3.82*
40%	0	57.17	52.08	59.57	*56.27*	3.47	2.97	2.43	*2.96*
	25	49.85	53.33	54.90	*52.69*	3.50	2.80	2.30	*2.87*
	50	48.55	50.50	56.38	*51.81*	3.45	2.90	2.35	*2.90*
	100	54.38	56.80	56.63	*55.93*	3.35	2.70	2.85	*2.97*
mean (A)		55.49 c	62.72 b	65.63 a		4.35 a	3.93 b	3.65 c	
mean (B)		66.58 a	63.08 b	54.18 c		5.18 a	3.82 b	2.92 c	
mean (C)		64.08 a	61.51 b	57.85 c	*61.68 b*	3.74 b	4.01 a	4.01 a	*4.13 a*
*mean (A*B)*		58.93	70.81	70.01		5.26	5.28	5.00	
		55.04	64.17	70.01		4.34	3.65	3.46	
		52.49	53.18	56.87		3.44	2.84	2.48	
*mean (A *C)*		59.92	65.47	66.83		4.11	3.48	3.63	
		54.87	63.46	66.20		4.32	4.03	3.68	
		52.00	59.12	62.44		4.38	4.06	3.60	
		55.16	62.83	67.04		4.58	4.13	3.68	
LSD at 0.05 level		*(A : 1.02) (B : 1.02) (C : 1.18) (A*B :1.77) (A* C : n) (B* C : 2.04) (A*B* C :3.54)*				*(A : 0.18) (B : 0.18) (C : 0.21) (A*B : 32) (A* C : n) (B* C : 0.36) (A*B* C : 0.63)*			

Plant chemical composition:

Photosynthetic pigments:

Photosynthesis is one of the main responsible process for biomass accumulation in plants. Its rate depends on the content of chemical change pigments in foliar tissues, their composition, and ratio. Data in Table (2) clearly showed that total chlorophyll contents (SPDA) significantly decreased with increasing the drought stress condition as an individual effect (B) . the observed minimum values in total chlorophylls were 42.3, and 41.2% at 60% and 40% FC respectively compared to the control condition (43.5% at 80% FC). This decrease in chlorophyll could be rendered to the inhibition in biosynthesis of Chlorophyll precursors under water stress conditions according to **Makhmudov, (1983)**. Recently, **Anjum, et al., (2011)** reported that the reduction of photosynthesis under drought stress could be attributed to the formation of proteolytic enzymes such as chlorophyllase, destruction of chlorophyll molecules by reactive oxygen species (ROS), decline in membrane permeability, reducing water availability and nutrients particularly magnesium.

Concerning the interaction between the effect of drought stress levels and Nano-silica application (**B*C**), the chlorophyll contents (SPDA) in the treated plants with Nano-silica was gradually increased up to the maximum of mean values at the highest concentration of Nano silica (100 mg/l) compared to untreated plant (control) under the same level of water stress. This trend supported with the findings of **Suriyaprabha, et al., (2012).** These increments in total chlorophylls contents decreased with increasing the drought stress. They were 47.45, 45.76 and 44.61% at the levels of water stress; 80, 60, and 40% FC, respectively. It was noticed also, that highest values for SPAD Chlorophyll in the leaves of varieties barley **(factor A)** registered at Giza 133 followed by Giza 136 and Giza 129 under all treatments. On the other hand, statistical data presented in Table (2) appeared the positive role of Nano Silica application as individual factor **(C)** as it showed significant increase in the content of total chlorophyll as a resulting of concentration. This will be promoted photosynthetic activity and rate in plants grown under water deficit conditions, then followed by increasing plant growth. Although we did not directly measure the photosynthetic rate, transpiration rate, stomatal conductance for gas exchange, electron transport rate and other physiological parameters, in leaf tissues, but increasing chlorophyll and plant growth were positively related to these previous physiological parameters as a result of Nano-silica application. This result is in line with many reported results (Al-Whaibi, 2014 and Siddiqui, et al., 2014).

Table 2: Effect of Nano silica application on chemical composition of some barely varieties under different field capacity (FC%) during the winter season 2017.

Item study		Total chlorophylls (SPDA units)				Proline content (mg/g F.W)				Protein content (%)			
Treatments		Varieties (A)			mean (B*C)	Varieties (A)			mean (B*C)	varieties (A)			mean (B*C)
Field capacity (FC)% (B)	Nano-Silica mg/l (C)	Giza 129	Giza 133	Giza 136		Giza 129	Giza 133	Giza 136		Giza 129	Giza 133	Giza 136	
80%	0	34.46	44.13	42.01	*40.20*	0.547	0.453	0.451	*0.484*	8.1	8.3	5.4	*7.2*
	25	37.13	46.13	43.07	*42.11*	0.567	0.470	0.447	*0.494*	9.1	9.7	6.1	*8.3*
	50	38.75	48.84	45.11	*44.23*	0.577	0.460	0.450	*0.496*	10.0	11.0	7.7	*9.6*
	100	41.07	52.07	49.22	*47.45*	0.557	0.447	0.447	*0.483*	11.3	12.3	9.4	*11.0*
60%	0	33.60	42.23	40.85	*38.89*	0.660	0.597	0.603	*0.620*	7.7	7.6	5.1	*6.8*
	25	35.79	45.66	43.22	*41.55*	0.673	0.600	0.590	*0.621*	8.6	9.4	5.6	*7.9*
	50	37.63	47.44	44.12	*43.06*	0.637	0.580	0.600	*0.606*	9.9	11.3	7.1	*9.4*
	100	40.86	49.73	46.70	*45.76*	0.623	0.560	0.540	*0.574*	10.7	12.0	8.0	*10.2*
40%	0	31.83	38.82	38.88	*36.51*	0.800	0.840	0.907	*0.849*	7.1	8.1	4.4	*6.5*
	25	35.74	44.96	41.88	*40.86*	0.807	0.830	0.907	*0.848*	8.3	8.5	5.6	*7.5*
	50	37.99	47.19	43.25	*42.81*	0.783	0.820	0.903	*0.836*	9.3	10.8	6.8	*9.0*
	100	39.38	49.17	45.28	*44.61*	0.653	0.623	0.757	*0.678*	10.4	11.4	8.1	*10.0*
mean (A)		37.02 c	46.36 a	43.63 b		0.657 a	0.607 c	0.633 b		9.2 b	10.0 a	6.6 c	
mean (B)		43.50 a	42.32 b	41.2 c		0.489 c	0.605 b	0.803 a		9.0 a	8.6 b	8.2 c	
mean (C)		38.53 d	41.51 c	43.37 b	45.94 a	0.651 a	0.654 a	0.646 a	0.579 b	6.8 d	7.9 c	9.3 b	10.4 a
*mean (A*B)*		37.85	47.79	44.85		0.562	0.457	0.448		9.6	10.3	7.2	
		36.97	46.27	43.72		0.648	0.584	0.583		9.2	10.1	6.4	
		36.24	45.03	42.32		0.761	0.778	0.868		8.8	9.7	6.2	
*mean (A *C)*		33.30	41.73	40.58		0.669	0.630	0.654		7.6	8.0	4.9	
		36.22	45.58	42.72		0.682	0.633	0.648		8.7	9.2	5.8	
		38.12	47.82	44.16		0.666	0.620	0.651		9.7	11.0	7.2	
		40.44	50.33	47.06		0.611	0.543	0.581		10.8	11.9	8.5	
LSD at 0.05 level		*(A : 0.273) (B : 0.273) (C :0.315) (A*B :0.473) (A* C : 0.473) (B* C : 0.546) (A*B* C :0.945)*				*(A : 0.015) (B : 0.015) (C :.018) (A*B :0.027) (A* C :n) (B* C : 0.031) (A*B* C :n)*				*(A : 0.026) (B : 0.026) (C :0.030) (A*B :0.044) (A* C :0.044) (B* C : 0.051) (A*B* C :0.089)*			

Proline content (mg/g FW):

It is worthy to mention that Proline is one of the important compatible solutes that accumulates under abiotic stress conditions and has been considered to play an actual role in osmotic adjustment (Nayyar and Walia 2003). In addition, these physiological trait (proline accumulation, and osmotic adjustment) are considered to be associated with plant adaptability to drought-prone environments (Farooq et al., 2009). However, other investigators consider increased proline levels as a symptom of injury rather than a cause for stress tolerance. Data presented in Table (2) showed that the mean values of Proline content increased up to 0.61 and 0.80 mg/g with increasing the drought stress (**B**) to 60 and 40% FC respectively, compared to 0.49 mg/g at the control (80 % FC) either in the treated or untreated plants with Nano silica application for all varieties of barley. These results fit with reports in the literatures **(Alexieva et al., 2001; Mafakheri et al., 2010; Mauad et al., 2016 and Nermeen et al., 2017),** which reported that the proline content in higher plants increases under different drought stresses. This result supports the view that proline accumulation is a symptom of stress-related injury. The highest content of proline in the untreated plants (0.91-0.84 mg/g) were recorded with 40% FC, in both Giza 136 and Giza 133 respectively, then reached to 0.80 mg/g for Giza 129. Although the proline content in the treated plants significantly decreased with increasing the Nano silica concentration particularly their highest concentration (100 mg/l) at the same level of drought, the proline content in plant treated and grown under drought stress (40 % FC) were still higher than those with the other FC levels. It reached 0.76, 0.62 and 0.65 mg/g for Giza 136, Giza 133 and Giza 129 respectively. These results may be due to the deleterious effect of drought stress at 40 % FC, which was higher than the positive role of Nano silica to improve the plants tolerance. So, the regulative role of Nano silica on the accumulations of proline and their roles in drought tolerance needs further investigation.

Protein content (%):

Data presented in Table (2) show highly increases in grain protein percentage as a result to use Nano-silica concentrations **(C)** on the selected varieties of Egyptian barley and was grown under water stress. These percentages reached 7.9, 9.3 and 10.4 % in plants treated with 25, 50 and 100 ppm respectively compared to untreated plants that contained 6.8%. It is clear to mention that increasing the water-deficient **(B)** up to 60 and 40% FC declined the protein content to 8.6 and 8.2% respectively compared to 9.0% at the normal condition (80% FC). This result may be attributed to decreasing availability of nutrients in soil and reducing its translocation to grains particularly Nitrogen element with increasing the drought stress. Generally, the highest percentage of protein content was observed at Giza 133 followed by Giza 129 then Giza 136 at the same conditions of water levels. This percent was decreased with increasing the drought stress and was increased with increasing the Nano silica concentration may be due to nano-$SiO2$ mediates the synthesis of protein, amino acids, nutrient uptake and stimulates antioxidant enzyme activity as indicated by Li**, et al., (2012).**

Yield component (g/pot):

Straw and grains yield:

Concerning the effects of drought stress **(B)**, data presented in Table (3) clearly indicate that the mean values of both straw and grains yield were markedly declined with increasing the drought stress level (60 and 40% FC) compared to the control condition (80% FC). This decline in straw and grains yield reached 17.1, 10.6% and 30.2, 21.8% at the level of 60 and 40% FC respectively. These results were confirmed by several previous studies showing that water deficit stress significantly affects straw and grains yield in barley**. (Vaezi el al., 2010, Azhand, et al., 2015, EL-Shawy et al., 2017)** observed that a reduction in growth and grain yield of different barley genotypes is significantly influenced by limitation and variation of soil moisture regimes. They discussed this reduction and attributed it to different reasons such as; closure of stomata and decrease in CO_2 concentration as an initial response to water stress, which inhibit biomass production due to limitation of photosynthesis and so that decreased of grain yield. It may be also, due to the negative role of water-deficiency on the availability of nutrients uptake and their translocation to new developing tillers and this might cause the death of the new tillers and depressed the number of spikes primordial, and also reduced available assimilates for grain filling and finally decreased grain yield.

Although previous results, the selected varieties of barley **(A)** showed different response at the same drought stress level, it is clear that the reductions in straw and grains yield were higher in Giza 136 and Giza 133 than Giza 129 at the same level of drought stress according to their sensitivity. The percentage of maximum reductions recorded with the highest level of drought stress (40% FC) compared to the other levels of drought were 39.4, 21.3% and 31.8, 33.0% for Giza 136 and Giza 133 compared to 11.4, 12.3% in Giza 129 in straw and grains yield respectively. This reduction may be attributed to the different responses of barley varieties cultivated to drought stress, which was affected by decreasing the number of fertile florets and the number of grains per spike, as well as the number of tillers bearing sterile spikes according to **(Samarah, 2005).** On the contrary, the mean statistical values of Nano silica application as an individual factor **(C)** showed highly significant increases in straw and grains yield of treated plant compared to the untreated ones (control) particularly with its highest concentration (100 mg/l). This value was exceeded the control by 16.9% and 20.6 % in straw and grains respectively. Thus, it could be stated that Nano-silica had beneficial effects and overcome the harmful injury that occurred by drought stress. Findings are in line with (Siddiqui et al., 2014 and Al-Whaibi, 2014), who reported that Nano silica promotes the growth and develops various higher plant species by increasing the different physiological parameters, and also it enhances the improvement of plants tolerance to drought stress.

Concerning the interaction effects between the factors **(B*C)** on the yield of barley, data showed a significant increase in straw yield and non-significant increase in grains yield with increasing the Nano silica concentration compared to the control (untreated plant). These increment in the straw has varied with different FC levels, it reached to 23.6, 15.0 and 10% by using the highest concentration of Nano silica (100 mg/l) with the levels 80, 60 and 40% of FC respectively. This meaning that the positive role of Nano silica decreased with increasing the drought which may be attributed to the large competition between their different effects. Thus, it could be stated that the Nano-silica concentration used had not sufficient to overcome the deleterious effects that occurred by the highest levels of drought (40% FC). On the other hand, it was noticed that the statistical analyses of **(B*C)** interaction showed similar results or non-significantly effects between the flowing treatments on straw yield, for example, the treatments (50 or 100 mg/l Nano silica with 60% FC and other 80% FC without treated plant). Also, the treatments (50 or 100 mg/l Nano silica with 40% FC and other 60% FC without treated plant)

Table 3: Effect of Nano silica application on yield components of some barely varieties under different field capacity (FC%) during the winter season 2017.

Item study		Straw weight (g/pot)				Grain weight (g/pot)				1000 grain weight (g)			
Treatments		varity (A)			mean (B*C)	varity (A)			mean (B*C)	varity (A)			mean (B*C)
Field capacity (FC)% (B)	Nano Silika mg/l (C)	Giza 129	Giza 133	Giza 136		Giza 129	Giza 133	Giza 136		Giza 129	Giza 133	Giza 136	
80%	0	60.33	79.07	108.62	*82.7*	26.33	22.60	23.05	*24.0*	30.09	44.29	39.93	*38.1*
	25	63.43	113.57	113.72	*96.9*	28.90	27.27	26.28	*27.5*	32.48	45.62	40.01	*39.4*
	50	65.78	116.64	112.17	*98.2*	29.22	27.80	27.00	*28.0*	29.02	44.48	41.30	*38.3*
	100	66.40	127.43	112.65	*102.2*	30.27	25.08	27.35	*27.6*	31.03	44.32	43.99	*39.8*
60%	0	57.50	72.63	87.47	*72.5*	24.17	19.03	20.87	*21.4*	32.61	37.51	38.20	*36.1*
	25	61.00	86.60	88.98	*78.9*	24.83	20.90	22.68	*22.8*	31.62	38.90	41.45	*37.3*
	50	63.63	87.07	90.00	*80.2*	25.53	26.27	23.00	*24.9*	29.70	35.95	40.33	*35.3*
	100	65.07	94.17	91.00	*83.4*	28.27	25.83	25.67	*26.6*	29.10	41.14	40.44	*36.9*
40%	0	52.33	71.67	64.44	*62.8*	21.00	16.67	18.90	*18.9*	23.92	33.14	34.68	*30.6*
	25	56.43	74.67	66.42	*65.8*	24.40	15.33	18.58	*19.4*	25.89	33.63	35.63	*31.7*
	50	57.45	75.73	68.93	*67.4*	27.55	17.60	21.07	*22.1*	28.34	34.22	35.29	*32.6*
	100	60.68	75.80	71.13	*69.2*	27.65	19.20	23.03	*23.3*	25.98	37.89	37.89	*33.9*
mean (A)		60.84 b	89.59 a	89.63 a		26.51 a	21.96 b	23.12 b		29.15 b	39.26 a	39.09 a	
mean (B)		94.98 a	78.76 b	66.31 c		26.76 a	23.92 b	20.92 c		38.88 a	36.41 b	32.21 c	
mean (C)		72.67 c	80.54 b	81.93 ab	84.93 a	21.40 c	23.24 bc	25.00 ab	25.81 a	34.93 b	36.14 b	35.41 ab	36.86 a
*mean (A*B)*		64.0	109.2	111.8		28.7	25.7	25.9		30.7	44.7	41.3	
		61.8	85.1	89.4		25.7	23.0	23.1		30.8	38.4	40.1	
		56.7	74.5	67.7		25.2	17.2	20.4		26.0	34.7	35.9	
*mean (A *C)*		56.7	74.5	86.8		23.8	19.4	20.9		28.9	38.3	37.6	
		60.3	91.6	89.7		26.0	21.2	22.5		30.0	39.4	39.0	
		62.3	93.1	90.4		27.4	23.9	23.7		29.0	38.2	39.0	
		64.1	99.1	91.6		28.7	23.4	25.4		28.7	41.1	40.8	
LSD at 0.05 level		*(A : 3.11) (B : 3.11) (C : 3.59) (A*B :5.38) (A* C : 6.21) (B* C :6.21) (A*B* C :10.76)*				*(A : 1.4) (B : 1.4) (C : 1.62) (A*B : 2.42) (A* C : n) (B* C : n) (A*B* C : n)*				*(A : 1.49) (B : 1.49) (C :1.72) (A*B :2.58) (A* C : n) (B* C : n) (A*B* C :n)*			

Thousand grain weight (g):

Data in Table (3) showed that water stress **(B)** induces a significantly reduction in thousand grain weight by 6.3 and 17.2 % at 60 and 40 % FC compared to the normal condition (80% FC) respectively. The decrease in thousand grain weight under water stress could be attributed to water deficiency during the growth, flowering and grain filling stages, which reduce available assimilate for grain filling and re-translocation of stored assimilates to grains which in turn cause a reduction in grain size. Also, water stress conditions decrease the weight of 1000-grain by lower level of carbohydrates stored in vegetative organs in growth and to the decrease in leaf area duration which resulted in the shortened grain-filling period. On the other hand, treated plants by one of the different Nano-silica concentrations **(C)** showed significantly increases in thousand grain weight compared to untreated plants (control), although, the different concentrations of Nano silica did not show different significantly effects among them, the highest rate used (100 mg/l) showed significant increases in thousand grain weight by 5.5% compared to the control (untreated plants). These results indicated that the concentration used of nano-silica in the experiment has promoted the parameters of barley yield but it was not sufficient to curb the damaging effect of drought stress. Concerning the varieties of barely **(A)**, the means value of thousand-grain weight was similarly in Giza 133 and Giza 136 (39.3 and 39.1g) respectively, while it was higher than Giza 129 (29.15g).

CONCLUSION

Water deficit throughout growing season affects the growth, and yield of Barley crop. The occurrence of drought in the region became an inevitable matter, which is important for screening the barley varieties tolerance and their response to this stress. In this present work, application of Nano silica concentrations improved the morphological, chemical composition and yield components of barley, but are insufficient to curb the deleterious effects of drought, so we recommend to increase the concentration of Nano silica application above 100 mg/l.

Acknowledgement

The authors warmly thank the Agricultural Research in the Mediterranean Area 2 (ARIMNet2) and Academy of scientific research and technology (ASRT) and National Research Centre (NRC), Egypt who have funded this research work.

REFERENCES

Ahmed, IM., Cao F., Zhang, M., Chen, X., Zhang, G., and F. Wu, (2013) Difference in yield and physiological features in response to drought and salinity combined stress during anthesis in Tibetan wild and cultivated barleys. PloS One 8(10): e77869.

Ahmed, IM., Nadira, UA., Bibi, N., Zhang, G., F. Wu, (2015) Tolerance to combined stress of drought and salinity in barley. In: Combined Stresses in Plants Physiological, Molecular, and Biochemical Aspects; Mahalingam, R., Ed.; Springer: Basel, Switzerland, 2015; pp. 93–121.

Ajey Singha, N. B. Singha, Imtiyaz Hussaina, Himani Singha, and S.C. Singhb, (2015). Plant-nanoparticle interaction: An approach to improve agricultural practices and plant productivity, *International* Journal of Pharmaceutical Science, Invention ISSN (Online): 2319 – 6718, ISSN (Print): 2319 – 670X www.ijpsi.org Volume 4 Issue 8 ǁ August 2015 ǁ PP.25-40, www.ijpsi.org 25 | P a g e

Alexieva, V., Sergiev, I., Mapelli, S., and E. Karanov, (2001). The effect of drought and ultraviolet radiation on growth and stress markers in pea and wheat. Plant Cell Environ 24: 1337–1344.

Al-Whaibi MH., (2014). Role of nano-SiO2 in germination of tomato (Lycopersicum esculentum seeds Mill.) Saudi Biol Sci, 2113–17.

Anjum, S.A., Xie Xiao-yu, Wang L. chang, Saleem M.F., Man Chen and Lei Wang, (2011). Morphological, physiological and biochemical responses of plants to drought stress. Afric. J. of Agric. Res., 6 (9): 2026-2032.

A.O.A.C., (1984). Official Methods of Analysis of the association of Official Analytical Chemists.14 ed. Association of Official Chemists, the Washington D.C., U.S.A.

Azhand, M., Saeidi, M., and M. Abdoli, (2115) Evaluation of the relationship between gas exchange variables with grain yield in barley genotypes under terminal drought stress. International Journal of Biosciences.Vol.6,No.2,p.366-374, http://dx.doi.org/10.12692/ijb/6.2.366-374

Barbara, F.R. and L.J. Brain, (1994). Minitab Hand book. Duxbury press. An Imprint of Wad Sworth Publish. Comp. Belonont California, USA

Bates LS, Waldren R.P and I.D. Teare, (1973). Rapid determination of free proline for water stress studies. Plant Soil, 39: 205-207.

Bohnert HJ, Nelson DE, and RG. Jensen, (1995). Adaptations to environmental stress. Plant Cell **7,** 1099 - 1111. http://dx.doi.org/10.1105/tpc.7.7.1099

Cheruth abdul Jaleel, Paramasivam manivannan, Abdul wahid, Muhammad Farooq, Hameed jasim al-juburi, Ramamurthy Somasundaram and Rajaram panneerselvam (2009). Drought Stress in Plants: A Review on Morphological Characteristics and Pigments Composition. Int. J. Agric. Biol., 11: 100–105 ISSN Print: 1560–8530; ISSN Online: 1814–9596.08–305/IGC-DYT/2009/11–1–100–105. http://www.fspublishers.org.

EL Sabagh Ayman, Akbar Hossain, Md. Shohidul Islam, Celaleddin Barutcular, Saddam Hussain, Mirza Hasanuzzaman, Tauseef Akram, Muhammad Mubeen, Wajid Nasim, Shah Fahad, Narendra Kumar, Ram Swaroop Meena, Ferhat Kızılgeçi, Mehmet Yıldırım, Disna Ratnasekera, Hirofumi Saneoka (2019). Drought and salinity stresses in barley: Consequences and mitigation strategies. Australian Journal of Crop Science, Vol. 13, No. 6, 810-820, ISSN:1835-2707.

EL-Shawy, EE., EL Sabagh A., Mansour, M., and C. Barutcular, (2017). A comparative study for drought tolerance and yield stability in different genotypes of barley (*Hordeum vulgare* L.). J Exp Biol Agric Sci. 5(2): 151.162.

El-Wahed, MA., Sabagh, AE., Saneoka, H., Abdelkhalek, A., and C. Barutçular, (2015). Sprinkler irrigation uniformity and crop water productivity of barley in arid region. Emirates J Food.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., and SMA. Basra, (2009). Plant drought stress: effects, mechanisms and management. Agronomy for Sustainable Development 29, 185-212. http://dx.doi.org/10.1051/agro:2008021

Flexas J, and H. Medrano, (2002). Drought-inhibition of photosynthesis in C-3 plants: Stomatal and nonstomatal limitation revisited. Ann. Bot. 89: 183-1890.

Galbraith, DW., (2007). Nanobiotechnology: silica breaks through in plants. *Nat Nanotechnol*, 2(5) 272–273.

Gevrek, M.N. and G.D. Atasoy, (2012). Effect of post anthesis drought on certain agronomical characteristics of wheat under two different nitrogen application conditions. *Turk. J. Field Crops*, 17: 19-23.

Haghighi M, Afifipour Z, and M. Mozafarian, (2012) The effect of N-Si on tomato seed germination under salinity levels. J Biol Environ Sci 6:87–90

James RA., Rivelli AR., Munns R., and S. von Caemmerer, (2002). Factors affecting CO2 assimilation, leaf injury and growth in salt-stressed durum wheat. Funct Plant Biol. 29: 1393-1403.

Kalteh M., Alipour ZT., Ashraf S., Aliabadi MM., and AF. Nosratabadi, (2014). Effect of silica nanoparticles on basil (Ocimum basilicum) under salinity stress. J Chem Health Risks 4:49–55

Li B., Tao G., Xie Y., and X. Cai, (2012). Physiological effects under the condition of spraying nanoSiO2 onto the Indocalamus barbatus McClure leaves. J Nanjing For Univ (Natural Science Edition) 36:161–164

Liu, R., and R. Lal, (2015). Potentials of Engineered Nanoparticles as Fertilizers for Increasing Agronomic Productions. A Review. Science of the Total Environment, 514, 131-139. https://doi.org/10.1016/j.scitotenv.2015.01.104

Mafakheri, A. Siosemardeh, A., Bahramnejad, B., Struik, P.C., and E. Sohrabi, (2010). Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars AJCS 4(8):580-585 ISSN:1835-2707.

Makhmudov SA., (1983). A study on chlorophyll formation in wheat leaves under moisture stress. Baku, Azerbiajan SSR P. 40-44. Wheat, Barley and Triticale Abstract 3(2), 1987.

Maria Filek, Jolanta Biesaga-Kościelniak and Michał Dziurka (2014). Determination of proline, carbohydrates and ethylene content and their role in drought stress in plant.M. Surma, P. Krajewski (ed.), Methodology of system approach to study drought tolerance in barley, Institute of Plant Genetics PAS, Poznań: 95-104.

Mauad, M., Carlos, A.C.C., Adriano, S.N., Hélio G.F., and P.P L. Giuseppina, (2016). Effects of silicon and drought stress on biochemical characteristics of leaves of upland rice cultivars. Revista Ciência Agronômica, 47 (3): 532-539.

Minolta, (1989). Chlorophyll meter SPAD-502. Instruction manual. Minolta Co., Ltd., Radiometric Instruments Operations, Osaka, Japan.

Monica RC and R. Cremonini, (2009). Nanoparticles and higher plants. *Caryologia* 62(2): 161-165.

Nawaz, F., M.Y. Ashraf, R. Ahmad and E.A. Waraich, (2013). Selenium (Se) seed priming induced growth and biochemical changes in wheat under water deficit conditions. Biol. Trace Elem. Res., 151: 284-293.

Nayyar H, and DP. Walia, (2003). Water stress induced proline accumulation in contrasting wheat genotypes as affected by calcium and abscisic acid. Biol Plant 46:275–279. doi:10.1023/a:1022867030790

Nermeen T. Shanan and Zeinab H. El Sadek, (2017). Influence of Silicon on Tuberose Plants under Drought Conditions Middle East Journal of Agriculture Research ISSN 2077-4605 Volume: 06 | Issue: 02 | April. June | 2017 Pages:348-360

Raza, A.M.S., Saleem, M.F., Anjum, S.A., Khaliq T., and A.M. Wahid, (2012). Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticum aestivum* L.). The J. Anim. Plant Sci., 22: 431-437.

Samarah, N.H., (2005). Effects of drought stress on growth and yield of barley. Agron. Sustain. Dev., 25: 145–149

Shakeel Ahmad Anjum, Xiao-yu Xie, Long-chang Wang, Muhammad Farrukh Saleem, Chen Man and Wang Lei, (2011). Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research Vol. 6(9), pp. 2026-2032, Available online at http://www.academicjournals.org/AJAR DOI: 10.5897/AJAR10.027 ISSN 1991-637X ©2011 Academic Journals

Siddiqui MH., Al-Whaibi MH., Faisal M and AA. Al Sahli, (2014). Nano-silicon dioxide mitigates the adverse effects of salt stress on *Cucurbita pepo* L. *Environ Toxicol Chem* 33(11), 2429–2437. doi:10.1002/etc.2697

Siddiqui MH., Al-Whaibi MH., Firoz M. and MY. Al-Khaishany, (2015). Role of nanoparticles in plants. In: Siddiqui MH, Al-Whaibi MH, Mohamad F (eds.), Nanotechnology and plant sciences: nanoparticles and their impact on plants, pp. 19-35, Springer International Publishing.

Suriyaprabha R., Karunakaran G., Yuvakkumar R., Rajendran V. and N. Kannan, (2012). Silica nanoparticles for increased silica availability in maize (*Zea mays* L.) seeds under hydroponic conditions. Current Nanoscience, 8:902–908.

Temel A., Janack, B., and K. Humbeck, (2017). Drought Stress-Related Physiological Changes and Histone Modifications in Barley Primary Leaves at HSP17 Gene. Agron 7(2): 43.doi:10.3390/agronomy7020043

Torney F., Trewyn BG., Lin VS., and K. Wang, (2007). Mesoporous silica nanoparticles deliver DNA and chemicals into plants. Nat Nanotechnol, 2(5) 295–300.

Vaezi B., Bavei V., and B. Shiran, (2010). Screening of barley genotypes for drought tolerance by agro-physiological traits in field condition. African Journal of Agricultural Research 5: 881-892.

Waseem, M., Atharand H.U.R., and M. Ashraf, (2006). Effect of salicylic acid applied through rooting medium on drought tolerance of wheat. Pak. J. Bot., 38: 1127-1136.

Xie, Y., Li, B., Zhang, Q., and C. Zhang, (2012). Effects of nano-silicon dioxide on photosynthetic fluorescence characteristics of Indocalamus barbatus McClure. J Nanjing Forest Univ (Natural Science Edition) 2: 59–63

Zare M., Azizi M.H., and F. Bazrafshan (2011). Effect of drought stress on some agronomic traits in ten barley (Hordeum vulgare) cultivars. Tech. J. Engin. & App. Sci. 1 (3): 57-62.

Zhou MX. (2009) Barley production and consumption. In: Genetics and Improvement of Barley Malt Quality (pp. 1-17 Zhang G, Li C (eds),). Springer, Berlin, Heidelberg.

تطبيق النانو سيليكا للتخفيف من آثار الجفاف على بعض أصناف الشعير المصرية

١ احمد خليل عامر – ١ قدريه مصطفى العزب و ٢ فريد عبد العزيز هلال و احمد حسنين احمد حسنين

١ معهد بحوث الاراضى والمياه والبيئه – مركز البحوث لزراعيه٢ قسم تغذيه النبات– المركز القومى للبحوث

مع محدودية موارد المياه في المناطق شبه القاحلة، والتي تتلقى أمطارًا أقل من التبخر المحتمل وتتميز بالحرارة المفرطة والإجهاد الناتج عن الجفاف، يعد الجفاف أحد أشد انواع الإجهاد اللاحيوي الذي يؤثر سلبًا على نمو المحاصيل وإنتاجيتها. أجريت هذه الدراسة لاستقصاء الآثار السلبية لجهد الجفاف على بعض أصناف الشعير المصرية والتخفيف منها باستخدام جزيئات النانوسلكا التي يمكن أن تلعب دوراً هاماً في تحسين أداء النبات واستدامته. تحقيقا لهذه الغاية ، تم وضع تجربة اصص في تصميم كامل العشوائيه مع ثلاثة مكررات. أوضحت النتائج أنه نتيجة للعجز المائي ، فقد انخفض كل من عدد الاشطاء / النبات وارتفاع النبات (سم) ، والبناء الضوئي ، ومحصول القش والحبوب و وزن الألف حبه بشكل ملحوظ في جميع أصناف الشعير المدروسة ، على سبيل المثال ، عند (٤٠٪ FC) فان الانخفاض فى محصول القش والحبوب وصل إلى ٣٩.٤ ، ٢١.٣٪ في الجيزة ١٣٦ و ٣١.٨ ، ٣٣.٠٪ في الجيزة ١٣٣ و ١١.٤ ، ١٢.٣٪ في الجيزة ١٢٩ مقارنة بالحالة الطبيعية (٨٠٪ FC) على التوالي. وكشفت البيانات عن الأداء الأفضل لصنف "الجيزة ١٢٩" من "الجيزة ١٣٣" و "الجيزة ١٣٦" في معدل انخفاض محصول القش والحبوب وخصائص التمثيل الضوئي ضد ظروف عجز مياه التربة. من ناحية أخرى ، أظهرت البيانات أن الزيادات تجاوزت بنسبة ١٦.٩٪ و ٢٠.٦٪ في القش والحبوب على التوالي باستخدام أعلى تركيز (١٠٠ مجم / لتر) من تطبيق نانو سيليكا مقارنة بالنبات غير المعالج ، لذلك يمكن القول أن هذا التركيز للنانو سيليكا لديه القدرة على تخفيف بعض الآثار السلبية للجفاف ، ولكنها غير كافية للحد من الآثار السلبية للإجهاد الجفاف بشكل ملحوظ.