Irrigation Intervals and Nano-Silicon Applications Effect on Maize Growth, Yield, Yield Attributes and Chemical Composition of Grains

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ABSTRACT

A field trial was carried out on maize (*Zea mays* L.) single cross (Pioneer 3080) variety in the Experimental Farm, Faculty of Agriculture, Omar Al-Mukhtar University, Al-Bayda, Libya during 2023 summer season to evaluate the effect of foliar application of five nano-silicon particles (NSP) concentrations, i.e., 1.5, 3, 4, 6 and 9 mg/ l besides the control treatment on maize growth, yield, yield attributes and chemical components of grains under three irrigation intervals (10, 17 and 24 days between irrigations) at the beginning of the second irrigation till harvest. Randomized complete block design in split plot arrangement was used in three replications, where irrigation intervals were randomly assigned to main plots and (NSP) concentrations were randomly distributed in sub-plots. Obtained results demonstrated that increasing interval between irrigations up to 24 days significantly decreased all the studied traits, except shelling percent and harvest index. Conversely, all the studied characters increased with increasing (NSP) concentrations, where (NSP) applications with 6 or 9 mg/ l produced the highest LAI (4.45 and 4.42) tallest plants (218.33 and 221.90 cm), highest shelling percent (80.73 and 81.83 %), high harvest index (41.57 and 43.32 %) and grain nitrogen content (1.52 and 1.60 %), respectively. However, spraying maize plants with 9 mg/ l (NSP) in resulted the heaviest ears (409.63 g), heaviest grain weight/ ear (335.25 g), 100-kernel weight (37.94 g), maximum grain and biological yields (9.09 and 20.98 t/ ha), respectively. On the other hand, irrigation intervals × (NSP) concentrations interaction had significant effects on all studied traits, where spraying maize plants with 6 or 9 mg/ l, generally alleviate the bad effects of increasing irrigation intervals up to 24 days.

Keywords: Maize, Nano-silicon particles, Water deficit, Growth, Yield, Chemical components.

INTRODUCTION

Maize (*Zea mays* L.) is the most important cereal crops all over the world after wheat and rice (FAO, 2018). It is known as queen of cereals, because of its quick growth, short duration and high yield (Begam *et al*., 2018). Endosperm protein of maize has high essential amino acids as lysine and treptophan (Bhatia and Rabson, 1987). Maize is used for extensive industrial application in South Africa (Macauley and Ramadjita, 2015) and it is one of the most important food crops in Sub-Saharan Africa (Adejuwon, 2018). Also, this crop is the most important source of green fodder during summer season and silage industry. For these reasons, there is an essential need to increase maize grain yield through breeding programs and application of the recommended cultural practices as irrigation and nutrition.

Previous studies indicated that maize needs high irrigation requirements (Stone *et al.*, 2001), where its evapotranspiration in arid and semi-arid regions reach to 10 mm/ day (Howell *et al*., 1997). Furthermore, this crop is very sensitive to water stress during its life cycle, especially at pollination and grain filling periods, where water stress during these periods significantly decreased maize grain yield by at least 90 %, leaf area and internode length (Nesmith and Ritchie, 1992) and harvest index (Pandey *et al*., 2000). Frederick *et al.* (1989) indicated that drought stress decreased grain yield, number of kernels/ ear, grain filling period and increased number of barren plants. El-Ganayni *et al.* (2000) also reported that water stress during flowering stage of maize reduced grain yield by (67 %), number of ears/ plant by (53 %) and number of rows/ ear (4 %) compared to the control treatment. Similarly, Doorenbos and Kassam (1979) reported that severe water stress significantly decreased maize leaf area and shoot dry weight. Silicon (Si) ranks the second common element in the crust of earth (≈ 28 %). It is available to plants as uncharged H_2SiO_4 molecules (Monzerrat *et al*., 2019). Liu *et al.* (2014) reported that (Si) has favorable effects on cereals plants as maize, where it improves plant water relations, photosynthetic pigments, increasing LAI and enhances plant resistance to abiotic stress. Treated maize plants with Silicon had higher water content than untreated. That could be due to silicon effect on epidermis wall and vascular tissues. Suriyaprabha *et al.* (2012) reported that nano particles can change physico-chemical properties of the element, increase surface area and its activity and solubility and consequently, tiny size of the element will be of faster and better absorption. Nano silicon particles (NSP) increased water use efficiency by (53 %), total chlorophyll content in maize by (13- 17 %), stem length, diameter and number of leaves (Yuvakkumar *et al.*, 2011). Amer and El-Emary (2018) reported that (NSP), combined with fertilizers, improved nutrition use efficiency and protection against abiotic stress. Also, Lanne (2018) pointed out that spraying maize plants with (NSP) increased growth and yield, and decreased both biotic and abiotic stresses effects. Also, Aqaci *et*

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al. (2020) stated that maize treated with (NSP) significantly increased number of grains per ear and biological yield.

Based on that, this study aimed to increase maize growth and yield, save irrigation water by management of irrigation and nano silicon application.

MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2023 at the Research Station, Faculty of Agriculture, Omar Al-Mukhtar University, Al-Bayda, Libya, to evaluate nano-silicon particles (NSP) spraying on growth, yield, yield components and chemical composition of maize under water-deficit stress. Single cross yellow seeds (Pioneer 3080 variety) was sown on May fifth. The experimental design was randomized complete blocks in split plot arrangement in three replicates. Three irrigation intervals, i.e., every 10 days (control), 17 days (moderate stress) and 24 days (severe stress) from the second irrigation till maturity were randomly distributed in main plots, however, five nano-silicon particles (NSP) concentrations (1.5, 3, 4.5, 6 and 9 mg/ l) besides the control treatment were randomly allocated to sub-plots. Sub-plot area was 10.5 m^2 (5 ridges of 3 m long and 0.7 m width). Nano-silicon was provided by National Research Center (NRC), Giza, Egypt. Specific surface area of particles ranged from (300- 330 m^2/ g) with mean diameter (10 mm/ g) and pH 4- 4.5. Two seeds were hand sown per hill spaced at 25 cm. At 21 days after sowing (DAS), plants were thinned to one plant/ hill. Phosphorus fertilizer at the rate of 53 kg K_2O/ ha was applied during seed bed preparation, however 58 kg P_2O_5/ ha was applied after thinning. Nitrogen fertilizer at the rate of 288 kg N/ ha was applied in two equal doses before the first and second irrigations. At six leaf growth stage, NSP levels were applied as foliar application.

Just before tasseling, leaf area index (LAI) was measured, while plant height (cm), number of kernels/ ear, ear weight (g), kernel weight/ ear (g), shelling percent, 100-kernel weight (g), grain (t/ ha) and biological yields and harvest index (%) were recorded at harvest. Grain protein content (%) was calculated by multiplication total nitrogen in milled grains by 6.25 according to AOAC (1990), however N, P and K content were determined according to the methods described by Jackson (1973).

Obtained data were subjected and analyzed according to Gomez and Gomez (1984). Comparison between treatment means was carried out using least significant difference values at 0.05 level of probability ($L.S.D_{0.05}$).

RESULTS AND DISCUSSION

Effect of irrigation intervals and nano-silicon particles (NSP) on growth:

Results presented in Tables (1 and 3) revealed that maize leaf area index (LAI) and final height of plants were significantly affected by both irrigation intervals and (NSP) concentrations beside their interaction. Concerning leaf area index (LAI), increasing interval between irrigations up to 24 days produced the lowest LAI value (3.60) and gave the significantly shortest maize plants (186.47 cm) compared with irrigation every ten days (3.95 and 195.83 cm, respectively). However, irrigated maize plants every 17 days produced intermediate LAI (3.82) and plant height (192.75 cm). These results are in agreement with those obtained by Hsiao (1973) who reported that maize leaf elongation is most sensitive to water stress. Also, Istanbulluoglu *et al.* (2002) showed that there was a positive linear relation between number of irrigations and LAI. On the other hand, increasing intervals between irrigations led to decrease in internode length by inhibition of the developing cells and consequently decreased plant height (Atta Allah, 1996). On the contrast increasing (NSP) concentrations up to 6 or 9 mg/ l produced the highest LAI values (4.45 and 4.42) and tallest plants (218.33 and 221.90 cm), respectively, without significant differences between the two (NSP) concentrations. Similar results were reported by Yuvakkumar *et al.* (2011), who showed that spraying maize plants with nano-silicon increased number of leaves/ plant, stem length and diameter. Also, Laane (2018) indicated that treated maize plants with silicates significantly increased vegetative growth. As for interactions between irrigation intervals and (NSP) concentrations effect on LAI and maize plant height, results in Table (3) showed that irrigated of maize plants every ten days combined with foliar application of (NSP), produced the highest LAI, however increasing intervals up to 17 days needed higher (NSP) concentrations (4.5, 6.0 and 9 mg/ l), while increasing intervals to 24 days needed the higher (NSP) concentrations (6.0 and 9.0 mg/ l) to achieve the highest leaf area index (LAI). The same trend was found for plant height, where maize plant height significantly increased with increasing (NSP) combined with any irrigation interval study. The tallest maize plants (230.1 and 225.2 cm) resulted from (NAP) with (9.0 and 6.0 mg/ l) application to maize plants irrigated every ten days, respectively. That could be due to water abundance and the alleviation effect of (NSP) and their effects on growth acceleration.

Effect of irrigation intervals and nano-silicon particles (NSP) on maize yield and its attributes:

Regarding intervals between irrigations and (NSP) concentrations effect on maize grain yield and yield components, data in Table (1) revealed that increasing interval between irrigations up to 24 days, generally, significantly decreased all studied maize yield and yield attributes, except shelling percent and harvest index, where reduction in those traits did not reach the significance level. The tallest interval between irrigations (24 days) reduced number of kernels/ ear, ear weight, kernel weight/ ear, shelling percent, 100-kernel weight, grain and biological yields and harvest index by 4.58 %, 13.94 %, 17.20 %, 4.55 %, 6.91 %, 9.02 %, 5.0 % and 4.37 %, respectively, compared with ten days interval. Water deficit had harmful effects on photosynthesis, physiological processes and increased osmotic pressure of cell sap and decreased the rate of metabolic process and metabolites translocation from leaves to other plant organs. Those harmful effects led to decrease in maize grain yield and its attributes (Atta Allah, 1996). Obtained results were in agreement with those obtained by El-Noemani *et al.* (1990); Ibrahim *et al.* (1992) and Gomaa *et al.* (2017). On the other hand, Cakir (2004) showed that soil water deficit significantly decreased leaf area, elongation of maize internode, delayed ear formation and development of pollen grains and ovules and consequently number of kernels/ ear and carbohydrates accumulation in kernel which led to decrease kernel weight.

On the contrary, nano-silicon particles (NSP) applications significantly increased yield and yield components maize grain yield and its components compared with untreated treatment and those increases were gradual. The highest (NSP) concentration (9 mg/ l), generally, produced the highest number of kernels/ ear (714.93), heaviest ear weight (409.63 g), kernel weight/ ear (335.25 g), 100-kernel weight (37.94 g), highest grain and biological yields (9.09 and 20.98 t/ ha), respectively, compared with other treatments. However, both (6.0 and 9.0 mg/ l) of (NSP) produced the highest values of shelling (80.37 and 81.83 %) and harvest index (41.57 % and 43.32 %), respectively, without significant differences. These results could be due to (NSP) effect on increasing solar radiation absorption, improving structure of chloroplast and increasing chlorophyll content in plant leaves (Monzerrat *et al*., 2019). Rizwan *et al.* (2019) added that (NSP) application decreased transpiration rate. Obtained results were in accordance with those reported by Lanne (2018) for maize growth and yield, and Aqaci *et al.* (2020) for biological yield and number of kernels/ ear. Regarding irrigation intervals × (NSP) concentrations interaction effect on maize yield and yield components, results presented in Table (3) indicated that grain yield and all its attributes were statistically affected by interactions between the two studied factors.

Results presented in that table revealed that (NSP) foliar application with the highest concentration (9 mg/ l) produced the highest number of kernels/ ear (720.2, 712.7 and 711.9) at irrigation intervals (10, 17 and 24 days), respectively. Moreover, the same concentration produced the heaviest ears and kernels weight/ ear (436.70 and 358.97 g), respectively, at ten days interval between irrigations. With regard to shelling percent, spraying maize plants with 3, 4.5, 6.0 or 9 mg/ l of nano-silicon particles at ten or seventeen days intervals, and spraying with 6 or 9 mg/ l (NSP) at 24 days interval produced the highest percentages of shelling. Nano-silicon particles application with (4.5, 6.0 or 90 mg/ l) produced the heavies 100-kernel weights at any of the three irrigation intervals studied.

The highest grain yield at ten days irrigation interval (8.71 and 9.63 t/ ha) resulted from spraying with (6.0 and 9.0 mg/ l) nano-silicon particles, respectively, and (9.08 and 8.57 t/ ha) from spraying (NSP) with 9 mg/ l at seventeen and 24 days between irrigations, respectively. However, the highest biological yield at ten days interval (20.60 and 21.82 t/ ha), and at seventeen days (20.10 and 20.67 t/ ha) resulted from 6.0 and 9.0 mg/ l (NSP), respectively, while spraying maize plants with 9.0 mg/ l of (NSP) at 24 days between irrigations showed the highest biological yield (20.45 t/ ha). Treated maize plants with 6.0 or 90 mg/ l nano-silicon particles showed the highest harvest index values (42.27 % and 44.13 %) at ten days irrigations intervals, (41.76 % and 43.92 %) at seventeen days interval and (40.67 % and 41.92 %) at 24 days interval, respectively. The aforementioned results clearly showed the positive effects of nano-silicon application under water deficit, where the highest concentrations (6 and 9 mg/ l) of (NSP) can significantly ameliorate the negative effects of water deficit on growth and dry matter of maize plants. That might be due to the positive effect of (NSP) in improving fertilizers and water use efficiency besides increasing gas exchange and photosynthetic processes efficiency (Xie *at al*., 2012 and Kalteh *et al*., 2014). These increasing in dry matter production as a source could be due to increasing in maize plant growth and biological yield as a sink.

Effect of irrigation intervals and nano-silicon particles (NSP) on maize grain chemical composition:

Regarding the effect of both irrigation intervals and nano-silicon particles (NSP) concentrations on chemical composition of maize grain, data presented in Table (2) indicated that increasing interval between irrigations up to 24 days, generally, showed the lowest N, P, K and

Table 1. Effect of irrigation intervals and (NSP) on maize growth, yield and yield components

Irrigation intervals	LAI	Plant height (cm)	No. of kernels/ ear	Ear weight (g)	Kernel weight/ ear (g)	Shelling (%)	100-kernel weight (g)	Grain yield (t/ ha)	Biological yield (t/ ha)	Harvest index (%)
10 days	3.95	195.83	273.55	325.30	245.92	73.72	33.86	7.20	19.01	37.50
17 days	3.82	192.75	563.85	300.83	224.21	72.68	32.28	7.03	18.62	37.35
24 days	3.60	186.47	547.27	279.94	203.60	70.36	31.52	6.55	18.06	35.86
$L.S.D_{0.05}$	0.22	8.72	21.47	14.52	11.17	--	1.82	0.62	0.78	--
NSP (mg/ l)										
0	2.96	161.40	414.07	20494	114.29	55.53	26.86	4.92	16.28	30.20
1.5	3.34	171.86	449.93	230.93	149.78	64.86	28.49	5.60	17.05	32.84
3.0	3.66	180.53	529.57	273.08	206.15	75.30	30.76	6.20	17.65	35.10
4.5	3.89	196.07	577.60	327.09	147.78	75.63	34.95	7.40	19.27	38.38
6.0	4.45	218.33	683.23	366.07	294.22	80.37	35.98	8.37	20.14	41.57
9.0	4.42	221.90	714.93	409.63	335.25	81.83	37.94	9.09	20.98	43.32
$L.S.D_{0.05}$	0.34	3.94	14.13	6.44	5.41	4.39	1.16	0.40	0.56	2.09
Interaction	*	**	*	**	**	**	**	**	*	**

* and ** significant effect at 0.05 and 0.01 levels of probability, respectively.

Table 2. Effect of irrigation intervals and (NSP) on the chemical composition of maize grains

Irrigation intervals	N (%)	P (%)	K (%)	Protein (%)
10 days	1.40	1.08	1.01	9.71
17 days	1.45	0.88	0.85	9.39
24 days	1.23	0.80	0.84	7.97
$L.S.D_{0.05}$	0.20	0.23	0.12	0.66
NSP (mg/ l)				
0	1.12	0.72	0.75	8.06
1.5	1.20	0.80	0.81	8.42
3.0	1.33	0.93	0.89	8.85
4.5	1.41	0.99	0.94	9.0
6.0	1.52	1.0	0.99	9.64
9.0	1.60	1.06	1.02	10.18
$L.S.D_{0.05}$	0.15	0.08	0.14	0.52
Interaction	*	*	*	*

* and ** significant effect at 0.05 and 0.01 levels of probability, respectively.

Table 3. Means of maize growth, yield and yield components as affected by irrigation intervals × (NSP) interaction

Irrigation intervals	NSP	LAI	Plant height (cm)	No. of kernels/ ear	Ear weight (g)	Kernel weight/ ear (g)	Shelling (%)	100-kernel weight (g)	Grain yield (t/ ha)	Biological yield (t/ ha)	Harvest index (%)	N (%)	P (%)	K (%)	Protein (%)
10 days	**0**	3.20	168.2	433.4	218.68	131.42	60.1	29.13	5.11	16.97	30.12	1.11	0.80	0.89	9.11
	1.5	3.93	172.5	458.7	245.39	157.78	64.3	30.52	5.88	17.54	33.54	1.24	0.89	0.97	9.24
	3.0	3.93	180.6	546.4	300.23	231.47	77.1	31.98	6.58	18.11	36.37	1.44	1.08	1.0	9.52
	4.5	4.09	198.4	582.1	352.17	275.40	78.2	35.22	7.33	19.02	38.55	1.40	1.10	1.06	9.86
	6.0	4.45	225.2	700.5	398.62	320.49	80.4	37.13	8.71	20.60	42.27	1.48	1.24	1.05	10.20
	9.0	4.62	230.1	720.2	436.70	358.97	82.2	38.14	9.63	21.82	44.13	1.70	1.31	1.10	10.33
17 days	**0**	3.00	160.7	412.6	206.27	116.13	56.3	26.66	5.00	16.10	31.06	1.23	0.69	0.70	8.66
	1.5	3.34	173.7	459.0	236.44	154.86	65.5	28.17	5.65	17.07	33.10	1.34	0.70	0.73	8.74
	3.0	3.66	184.4	531.3	278.49	213.32	76.6	29.67	6.21	17.66	35.19	1.35	1.0	0.79	8.86
	4.5	3.90	199.0	578.7	321.43	243.64	75.8	35.07	7.86	20.11	39.09	1.52	0.92	0.84	9.97
	6.0	4.47	218.3	688.8	359.84	290.03	80.6	36.45	8.39	20.10	41.76	1.54	0.95	1.02	10.0
	9.0	4.54	220.4	712.7	402.53	327.25	81.3	37.67	9.08	20.67	43.92	1.74	1.02	1.0	10.12
24 days	**0**	2.67	155.3	396.2	189.87	95.31	50.2	24.80	4.64	15.77	29.42	1.02	0.67	0.66	6.41
	1.5	3.28	169.4	432.1	210.96	136.70	64.8	26.79	5.27	16.54	31.88	1.02	0.81	0.73	7.28
	3.0	3.42	176.6	511.0	240.53	173.66	72.2	30.64	5.80	17.20	33.76	1.20	0.71	0.88	8.17
	4.5	3.68	190.8	572.0	307.68	224.29	72.9	34.55	7.00	18.67	37.52	131	0.95	0.92	7.17
	6.0	4.44	211.5	660.4	339.76	272.14	80.1	34.37	8.02	19.72	40.67	1.49	0.81	0.90	8.72
	9.0	4.11	215.2	711.9	389.67	319.52	82.0	38.01	8.57	20.45	41.92	1.36	0.85	0.96	10.09
L.S.D$_{0.05}$		0.70	5.4	17.90	8.86	8.22	6.86	3.87	1.12	1.73	3.48	0.19	0.14	0.22	0.72

protein contents in maize grain (1.23, 0.80, 0.84 and 7.97 %), respectively. That could be due to the harmful effect of severe drought on maize root and shoot dry weight, and consequently decreased macro and micronutrients content in maize plant (Mahdy *et al*., 2012). On the other hand, treated maize plants with 6.0 or 9.0 mg/l (NSP), achieved the highest N, P, K and protein contents in grains (1.60, 1.06, 1.02 and 10.18 %), respectively, as shown in Table (2). That effect might be due to the alleviation of water deficit and consequently increasing maize plant growth and photosynthesis processes as a result of (NSP) foliar application which decrease both biotic and abiotic stresses (Yuvakkumar *et al.*, 2011 and Laane, 2018).

Considering the interaction between irrigation interval and (NSP) concentrations effect on chemical composition of maize grains, data in Table (2) indicated that (NSP) foliar application with 9 mg/ l at ten and 17 days between irrigations produced the highest maize grain nitrogen content (1.70 and 1.74 %), respectively. However, 6 and 9 mg/ l of (NSP) application to irrigated maize every ten days produced the highest phosphorus grain content (1.24 and 1.31 %), respectively.

Considering grain potassium content, data presented in that table showed, that under adequate water irrigation (every ten days), (NSP) application, generally, produced the highest potassium content, while under moderate and severe- water stress, foliar application with 6 and 9 ml/ l of (NSP) showed high potassium content in maize grains. On the other hand, to achieve the highest grain protein content in maize irrigated every ten or seventeen days it must sprayed with 4.5, 6.0 or 9.0 mg/ l of (NSP), while these concentrations increased up to 9.0 mg/ l (NSP) to obtain the highest grain content (10.09 %) in maize plants irrigated every 24 days (severe-water deficit). These results clearly showed the essential role of nano-silicon particles (NSP) application in improving maize growth, yield and yield components and macro nutrients content in maize grains.

CONCLUSION

Conclusion:

From the field study, obtained results indicated that nano-silicon particles (NSP) application significantly enhanced the water relations and photosynthesis and consequently improved maize plant growth, yield and yield attributes and grain chemical composition under water deficit conditions.

REFERENCE

A.O.A.C. 1990. Official Methods of Analysis, 15th Ed., Association of Official Analytical Chemists, Washington, USA.

Adejuwon, J.O. 2018. Assessment of the changing pattern in maize cultivation in Sokoto-Rima River Basin, Nigeria. J. Appl. Sci. Environ. Manag., 22: 1433- 1437.

Amer, M.M. and F.A. El-Emary.2018. Impact of foliar with nano-silica in mitigation of salt stress on some soil properties, crop-water productivity and anatomical structure of maize and faba bean. Environ. Biodiv. Soil Security, 2: 25-38.

Aqaci, P., W.Weisany, M. Diyanat, J. Razmi and P.C. Struik.2020. Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. J. Plant Nutri. https://doi.org/10.1080/01904167.2020.1727508.

Atta Allah, S.A.A. 1996. Effect of irrigation intervals and plant densities on growth, yield and its components of some maize varieties. Proc. 7th Conf. Agron., 9-10 Sept. pp. 59-70.

Begam, A., M. Ray, D.C. Roy and A. Sujit .2018.Performance of hybrid maize (*Zea mays* L.) in different levels and time of nitrogen application in Indo-Gangetic plains of eastern India. J. Exp. Biol. Agric. Sci., 6 (6): 929-935.

Bhatia, C.R. and R. Rabson.1987. Relationship of grain yield and nutrition quality. In Nutritional Quality of Cereal Grains. Genetic and Agronomic Improvement, Olson, R.A. Frey, K.J. Eds., Agron. Monograph No. 28; ASA, CSSA and SSSA: Madison, WI, USA, pp. 11-43.

Cakir, R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crop Res., 89: 1-16.

Doorenbos, J. and A.K. Kassam. 1979. Yield response to water irrigation and drainage. Paper 33, FAO, U.N, Rome, p. 176.

El-Ganayni, A.A., A.M. Al-Naggar, H.Y. El-Sherbieny and M.Y. El-Sayed.2000. Genotypic differences among 18 maize populations in drought tolerance at different growth stages. J. Agric. Sci. Mansoura Univ., 25: 713-727.

El-Noemani, A.A., A.K. Abd El-Halem and H.A. El-Zeiny.1990. Response of maize (*Zea mays*, L.) to irrigation intervals under different levels of nitrogen fertilization. Egypt. J. Agron., 15 (1-2): 147-158.

FAO. 2018. Part-3: Feeding the World, Statistical Year Book of FAO of U.N., Retrived on Dec. 21, 2019 from http://www.fao.or/3/%2013107e/i31070e03.pdf.

Fredrick, J.R., J.D. Hesketh, D.B. Peters and F.E. Below.1989.Yield and reproductive trait responses of maize hybrids to drought stress. Maydica, 34 (3): 319-328.

Gomaa, M.A., I.F. Rehab, F.A. Salama and A.S.M. Al-Deeb.2017.Water-stress in relation to maize (*Zea mays*, L.) grain yield, plant height and proline content. Alex. J. Agric. Sci., 62 (3): 311-317.

Gomez, K.A. and A.A. Gomez.1984. Statistical Procedures of Agricultural Research. 4th Ed. John Wiley and Sons, Inc. New York, USA.

Howell, T.A., A.D. Schneiter and S.R. Evett.1997. Surface and subsurface micro irrigation of corn-Southern Plains. Trans. ASAE, 40: 635-641.

Hsiao, T.C.1973.Plant responses to water stress. Ann. Rev. Plant Physiol., 24: 519-570.

Ibrahim, M.E., H.M.M. El-Naggar and A.A. El-Hosary.1992.Effect of irrigation intervals and plant densities on some varieties of corn. Menofiya J. Agric. Res., 17 (3): 1083- 1098.

Istanbulluoglu, A., I. Kocaman and F. Konukcu.2002. Water use production relationship of maize under Tekirdag conditions in Turkey. Pakist. J. Biol. Sci., 5: 287-291.

Jackson, M.L. 1973. Soil chemical Analysis. Prentice-Hall of Englewood Clifs, New Jersy.

Kalteh, M., Z.T. Alipour, S. Ashraf, M.M. Aliabadi and A.F. Nosratabadi. 2014. Effects of silica nano particles on basil (*Ocimum basilicum*) under salinity stress. J. Chem. Health Risks, 4 (3): 49-55.

Laane, H.M. 2018. The effects of foliar sprays with different silicon compounds. Plants, 7(2):45. http://doi.org//10.3390.plants7020045.

Liu, P., L. Yin, X. Deng, S. Wang, K. Tanaka and S. Zhang.2014. Aquaporin mediated increase in root hydraulic conductance is involved in silicon-induced improved root water uptake under osmatic stress in *Sorghum bicolor* L., J. Exp. Bot., 65: 4747- 4756.

Macauley, M. and T. Ramadjita. 2015. Cereals Crop: Rice, Maize, Millet Sorghum, Wheat. In. Proceedings of the Feeding Africa, Dakar, Sengal: 21-23.

Mahdy, A.M., Nieven O. Fathi, M.M. Kandil and A.E. Elnamas.2012. Synergistic effect of biofertilizers and antioxidants on growth and nutrients content of corn under salinity and water-deficit stresses. Alex. Sci. Exch. J., 33 (4): 292-304.

Monzerrat, R.S., L.I. Treio-Tellez, J.A. Perezsate and F.C. Gomez-Merino. 2019.Silicon stimulates initial growth and chlorophyll a/ b ratio in rice seedlings and alters the concentrations of Ca, B and Zn in plant tissues. J. Plant Nutri. 42 (16): 1928- 1940. http://doi.org/10.1080/01904167.2019.1648678.

Nesmith, D.S. and J.T. Ritchie .1992. Short and long-term responses of maize to a pre-anthises soil water stress. Agron. J., 84: 107-113.

Pandey, R.K., J.W. Maranville and M.M. Chetima.2000. Deficit irrigation and nitrogen effects on maize in a Sahelian environment. II-Shoot growth. Agric. Water Manage., 46: 15-27.

Rizwan, M., S. Ali, M.Z. Adrees, M. Arshad, M.F. Qayyum, H.A. Shahid and S.A. Chatha.2019. Allevation of cadmium accumulation in maize (*Zea mays* L.) in foliar spray of zinc oxide nano particles and biochar to contaminated soil. Environ. Pollut., 248: 358-367.

Stone, P.J. D.R. Wilson, J.B. Reid and G.N. Gillespie.2001. Water deficit effects on sweet maize: 1. Water use, radiation use efficiency, growth and yield. Aust. Res., 52: 103-113.

Suriyaprabha, R., G. Karunakaran, R. Yuvakkumar, P. Prabu, V. Rajendran and N. Kannan.2012. Growth and physiological response of maize (*Zea mays* L.) to porous silica nano particles in soil. J. Nanopart. Res., 14: 1294.

Xie, Y., B. Li, Q. Zhang and C. Zhang.2012. Effects of nano-silicon dioxide on photosynthetic fluorescence characteristics of *Indocalamus barbatus*, Mc Clure. J. Nanjing For Univ., 2: 49-53.

Yuvakkumar, R., V. Elango, V. Rajendran, N.S. Kannan and P. Prabu. 2011.Influence of Nano-silica powder on the growth of maize crop (*Zea mays* L.). Int. J. Green Nanotechn., 3 (3): 180-190.

Economic Entomology. 83(1): 97-100.

الملخص العربي

تأثير فترات الرى وإضافة النانو سليكا على النمو والمحصول ومكوناته والمحتوى الكيماوى للحبوب فى الذرة الشامية

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أجريت تجربة حقلية على الذرة الشامية هجين فردى (بيونير ٣٠٨٠) بالمزرعة البحثية بكلية الزراعة– جامعة عمر المختار– البيضاء– ليبيا خلال الموسم الصيفى ٢٠٢٣ وذلك لدراسة تأثير الرش الورقى لخمسة تركيزات من النانو سليكا هى ١,٥، ٣، ٤,٥، ٦، ٩ ملليجرام/ لتر بالإضافة إلى المعاملة القياسية (control) على النمو والمحصول ومكوناته والمحتوى الكيماوى لحبوب الذرة الشامية تحت ثلاث فترات للرى وهى ١٠ أيام، ١٧ يوماً، ٢٤ يوماً بين كل ريتين وقد طبقت هذه الفترات بعد رية المحاياه وحتى الحصاد. وقد نفذت التجربة فى تصميم قطاعات عشوائية كاملة بترتيب قطع منشقة مرة واحدة فى ثلاث مكررات حيث وزعت فترات الرى عشوائياً على القطع الرئيسية فى حين وزعت تركيزات النانو سليكا عشوائياً على القطع الفرعية، وقد أوضحت النتائج أن زيادة عدد الأيام بين الريات إلى ٢٤ يوماً أدى بوجه عام إلى نقص معنوى فى جميع الصفات تحت الدراسة عدا كل من نسبة التفريط ودليل والحصاد حيث لم يصل الانخفاض فى كليهما إلى مستوى المعنوية. وعلى العكس من ذلك فقد أدى الرش بالنانو سليكا إلى زيادة فى جميع الصفات وقد أدى رش النانو سليكا بتركيز ٦ أو ٩ ملليجرام/ لتر إلى الحصول على أقصى قيم لدليل المساحة الورقية (٤,٤٥، ٤,٤٢)، أطول النباتات (٢١٨,٣٣، ٢٢١,٩٠ سم)، أعلى نسبة تفريط (٨٠,٧٣، ٨١,٨٣ %)، وأعلى قيم لدليل الحصاد (٤١,٥٧، ٤٣,٣٢ %) ومحتوى الحبة من النيتروجين (١,٥٢، ١,٦٠ %) على الترتيب– بينما أدى الرش الورقى بتركيز ٩ ملليجرام/ لتر من النانو سليكا إلى الحصول على أثقل الكيزان وزناً (٤٠٩,٦٣ جم)، أثقل وزن الحبوب/ الكوز (٣٣٥,٢٥ جم)، أثقل وزن للمائة حبة (٣٧,٩٤ جم)، أقصى محصول للحبوب ومحصول بيولوجى (٩,٠٩ و٢٠,٩٨ طن/ هكتار) على الترتيب. من ناحية أخرى فقد أظهر التفاعل بين فترات الرى والرش بالنانو سليكا تأثيرات إيجابية معنوية على جميع الصفات التى تم دراستها وقد أظهرت النتائج بوجه عام أن الرش بالتركيزات المرتفعة (٦، ٩ ملليجرام/ لتر) من النانو سليكا أدى إلى تخفيف الآثار السلبية الناتجة عن زيادة الفترة بين الريات خاصة عند ٢٤ يوماُ والتى تمثل النقص الشديد للماء بالنسبة لمحصول الذرة الشامية.