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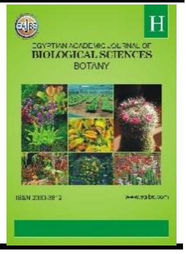

Relationship of Irrigation Intervals, Silicon, and Nano-Silver to Maize Productivity Under Soil Affected by Salinity

Gomaa[1], M. A., M. A. A. Nassar[1] and Omer T. S. Al-Qaltaqge[2]

1-Plant Production Department, Faculty of Agriculture (Saba Basha) Alexandria University, Egypt.

2- Department of Plant Genetic Resources, Directorate of Seed Testing and Certification, Baghdad, Iraq

*E-mail: omer_tahseen@yahoo.com

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ABSTRACT

Two field experiments were conducted at the Experimental Farm, Faculty of Agriculture, (Saba Basha), Alexandria University, Alexandria Governorate, Egypt, during two the summer seasons of 2020 and 2021 to investigate the effect of foliar application treatments on maize yield and quality under the three irrigation intervals. In both seasons, this factorial experiment was set up in a split-plot design with three replications. Irrigation intervals (every 15, 20, and 25 days) were the main plot, whereas foliar application treatments (water=control, Si, Ag NPs, and Si + Ag NPs) were distributed at random within the subplot in both seasons. The results showed that irrigation intervals, foliar application and their interaction significantly affected yield and its components in both seasons, whereas irrigation interval (20 days) recorded the highest values, foliar application of Si + Ag NPs to maize reduced the effect of irrigation intervals and increased yield and its component, whereas foliar application of Si + Ag NPs to maize with irrigation intervals every 20 days increased yield and yield component characters in the two seasons under study conditions. Finally, the results could be concluded that to increase the grain yield and its component of yellow hybrid of maize (SC 2066), it can be irrigated every 20 days with foliar application of Si + AgNps under soil salt-affected in Alexandria conditions and similar Regions.

INTRODUCTION

Maize is one of the world's most significant cereal crops, regardless of how much emphasis has been placed on increasing overall output. Where agronomic procedures like fertilisation and irrigation for new hybrids are employed in the recently recovered desert land. After wheat and rice, maize is Egypt's and the world's third most significant staple food crop (Gerpacio and Pingali, 2007). It is used to make bread. Egypt has a maize-growing area of around 994818 ha, with an average production of about 7.5 t/ha, whereas Iraq has a cultivated area of 100594 ha, with an average output of about 4.7 t/ha, and the globe has a cultivated area of 197.2 million ha, with an average yield of roughly 5.8 t/ha (FAO, 2019).
Water stress is one of the most important environmental stress that can impact plant development, physiological features, yield, and quality. In general, agricultural plants grow

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slower and yield less when there is less water available (Du *et al*., 2010). Under water stress, the vegetative development stage of maize plants was slowed, resulting in lower growth, leaf area, and yield (Cakir *et al*., 2004). When the soil water content is low throughout the vegetative development and grain-filling stages, substantial irrigation during the blooming stage may be necessary to get a high maize yield (Igbadun *et al*., 2007). Due to the low water requirement of maize throughout these phases, maize with minor water stress during the early development and late grain-filling stages exhibited a particular water stress tolerance threshold (Tariq and Usman, 2009). Maximizing agricultural output from available irrigation water, particularly in dry and semi-arid locations, is a long-term objective for the entire globe and numerous studies, especially because agriculture is the primary consumer of freshwater (Singh *et al*., 2014; Al-Mansor *et al*., 2015). Irrigation every 15 days resulted in the highest maize growth rates. The maximum values of growth characteristics were obtained by applying K- silicate three times to the leaves. The greatest values of the most yield features of maize were reported with irrigation every 15 days and foliar application of K- silicate three times (Gomaa *et al.*, 2021a). Plant height at harvest, ear length (cm), number of rows/ear, number of grains/row, number of grains/ear, 100-grain weight (g), biological yield, grain yield (t/ha), straw yield (t/ha), and harvest index (%) when Si rates were increased from 0 to 200 mg/l in both seasons (Gomaa *et al.*, 2021b).

Silicon (Si) is essential for plant growth and development, including richer pollination, increased dry biomass, and increased yield (Korndörfer and Lepsch, 2001). Increasing the rates of Si from 100 to 250 mg/l significantly improved grains yield and its components (Hanafy *et al*., 2008).In addition, silicon treatment is critical for increasing plant growth and output under heat and water stress, as well as protecting plants from abiotic and biotic challenges. Abiotic stress, including salt, dryness, and temperature, can all be mitigated by Si (Liang *et al*., 2008). Si may enhance plant tolerance to water and salinity stress in a variety of plants by a distinct method that involves reduced Na uptake, transportation, and increased water status (Ali *et al*., 2012; Toledo *et al*., 2012). Furthermore, Salar and Torabian (2018) found that 0.5 and 1 mM of nano-silicon oxide (Si NPs) boosted soybean growth and increased K^+ concentration under salt and water stress between treatments. Plant height, leaf area, fresh and dry weight of leaves, and stem of maize were all significantly affected by the administration of K- silicate as a foliar spray (from 5 to 10 cm^3/L).In addition, when compared to the control, the same treatment helped plants improve some photosynthetic pigments, macro and micronutrients, resulting in an increase in maize production (Shedeed, 2018). Through its regulatory impact on osmoprotectants and anti-oxidant enzymes, silicon helps maize overcome adverse stressors by fostering greater growth and dry weight (Sriramachandrasekharan *et al*., 2021). Silicon application might be a major tool for enhancing plant-soil N control, particularly in Si accumulator crops, resulting in more sustainable grain production in tropical climates (Galindo *et al*., 2021).

Because of their proven bacteriostatic and fungistatic activity, silver nanoparticles (AgNPs) are currently used primarily for disinfection and functionalization in a wide range of materials, as well as in technical applications (Sotiriou and Pratsinis 2011). Many plants grew and yielded more when they were given nanoparticles of Ag (NPs Ag) (Yasur and Rani, 2013). AgNPs may be utilised as an environmentally benign nano fertiliser with a suggested dose of 20 ppm, which is regarded as a safe dose for the environment and human health when compared to the insane levels of commercially available fertilisers (Fouda *et al.,* 2020). Using NPs boosted maize growth and yield, according to (Fouda *et al*., 2020, Kandil *et al*., 2020 and Gomaa *et al*., 2020 a, b). Increasing agricultural productivity under adverse environmental circumstances with nanoparticles. However, the harmful effects of nanoparticles on the environment and vegetation should not be overlooked in this process (Iqbal *et al*., 2020). Silver nanoparticles (Ag Nps) were shown to be effective in enhancing salinity tolerance in S. hortensis seedlings, and their use may trigger plant defence systems against salt toxicity (Nejatzadeh, 2021).

The aims of this study were to study the effect of irrigation intervals (water stress) and Ag NPs and Si and their interaction on yield and yield components of maize.

MATERIALS AND METHODS

During the two summer seasons of 2020 and 2021, two field experiments were conducted at the Experimental Farm of the Faculty of Agriculture, (Saba Basha) Alexandria University, Alexandria Governorate, Egypt, to investigate the effect of irrigation intervals and foliar application of nano-silver (Ag NPs), silicon (Si), and their interaction on maize single cross (SC.2066) productivity under the soil affected by salinity.Table (1) shows the physical and chemical parameters of the experimental soil, which were determined using the method outlined by Page *et al*. (1982).In the first and second seasons of this study, Egyptian clover (*Trifoluim alexandrinum* L.) was the previous crop.

The design of the experiment was a split-plot design was used. Where, the main plots were occupied by three irrigation intervals (15, 20, and 25 days), while the subplots were occupied by four foliar application treatments (spray water, Si (200 mg/l, Ag NPs (10 mg/l) and Si (200 mg/l) + AgNPs (10 mg/l).

Each plot size was 10.5 m^2 including 5 ridges each 3.00 m in length and 0.70 m in width. Sowing takes place on the 26^{th} and May 24^{th} in 2020 and 2021 seasons, respectively. The field was sprayed with herbicide after sowing then irrigated on the same day .

The seeds were planted at the rate of 2 seeds/hill. The space between hills was 30 cm. Hills were made on the north side of each ridge and thinned to one plant/hill before the first irrigation. Maize hybrids grains were gained from Misr High Tech International Seed Co.

Table 1. Soil Physical and chemical properties of experimental sites in both seasons.

Soil properties	Seasons	
	2020	**2021**
A- Mechanical analysis		
Sand	14.50	14.70
Silt	42.10	42.10
Clay	43.40	43.20
Soil texture	Clay loam	Clay loam
B- Chemical properties		
pH (1:1)	8.20	8.30
EC (1:1) dS/m	4.30	4.25
1- Soluble cations (1:2)		
K^+	1.40	1.35
Ca^{++}	14.20	14.4
Mg^{++}	11.30	11.00
Na^+	13.60	13.5
2- Soluble anions (1:2)		
CO^-_3+ HCO^-_3	2.85	2.90
CL^-	22.5	22.6
SO^-_4	14.7	14.8
Calcium carbonate (%)	6.70	6.90
Total nitrogen (%)	1.10	1.20
Available P (mg/kg)	3.70	3.60
Organic matter (%)	1.50	1.60

Phosphorus fertilizer was added at a rate of 480 kg/ha calcium superphosphate of (12.5 % P_2O_5) just before sowing. Mineral nitrogen fertilizer at the rate of (288 kg N/ha) in the form of urea (46 % N) and applied at two equal doses the first one after thinning before the first irrigation and the second dose was before the second irrigation according to irrigation treatments. Potassium sulphate (48 % K_2O) as a source of K at the rate of 50 kg K_2O/fed). Other agricultural practices were done as recommended by the Ministry of Agriculture and Land Reclaimed.

At harvest time, 120 days from sowing, ten plants were taken randomly from each subplot to ear length (cm), number of grains/rows, number of grains/ears, 100- grain weight (g), biological yield, grain yield (t/ha), straw yield (t/ha) and harvest index (%) were measured from the inner three ridges of each subplot in both seasons.

Data obtained was exposed to the proper method of statistical analysis of variance as described by Gomez and Gomez (1984). The treatments means were compared using the least significant differences test (LSD) at a 5% level of probability. All the statistical analysis using CoStat 6.311 (2005) computer software package.

RESULTS AND DISCUSSION

The results presented in Tables (2 and 3) showed the effect of irrigation intervals, foliar application of Si and Ag NPs and their interaction on grain yield (t/ha), straw yield(t/ha), biological yield (t/ha), harvest index (HI %), ear length, number of grains/rows, number of grains/ear, and 100- kernel weight (g) during 2020 and 2021 seasons.

Concern to the effect of irrigation intervals on yield and its components characters, the results in Tables (2 and 3) revealed that irrigation every 20 days achieved the highest values of grain yield (7.74 and 7.99 t/ha), straw yield (9.28 and 9.68 t/ha), biological yield (17.02 and 17.67 t/ha) in both season, and the highest values of ear length (23.56 and 24.95 cm), number of grains/row (44.75 and 46.73 grains), number of grains/ear (650.00 and 700.87 grains), and 100- kernel weight (43.69 and 44.77 g) in the two seasons, respectively. Meanwhile, irrigation every 25 days recorded the lowest ones for grain yield, straw yield, biological yield, ear length and 100- grain weight during 2020 and 2021 seasons. These results are in the same line with those reported by Dioudis *et al*. (2009); Shariot-Ullah *et al*. (2013); El-Sherpiny *et al.* (2020); Gomaa *et al*. (2021 a, b) they stated that irrigation treatments significantly affected yield and its components.

In terms of the effect of foliar application of silicon (Si), nanosilver (Ag NPs) and Si + nano-silver (AgNPs) on yield and its components characters, the results in Tables (2 and 3) showed that foliar application of the combination of Si + Ag NPs recorded the highest values of grain yield (7.99 and 8.17 t/ha), straw yield (9.45 and 9.85 t/ha), biological yield (17.44 and 18.03 t/ha), respectively in the two seasons, while in the first season HI was (45.81 %), also the highest mean values of ear length (24.00 and 25.33 cm), number of grains/row (45.11 and 46.53 grains), number of grains/ear (642.67 and 672.71 grains), and 100- kernel weight (44.28 and 45.55 g), while irrigation every 25 days recorded the lowest ones in both seasons and harvest index in the first season, only. These results may be due to the role of Si and Ag NPs in the growth of maize. The positive effect of silicon and Ag NPs could be due to improved cell division, cell elongation and also deposition of silicon in plant tissue causing erectness of leaf and stem under stress. In this way, Sriramachandrasekharan *et al*. (2021) cleared that silicon helps maize overcome adverse stressors by fostering greater growth and dry weight throughout its regulatory impact on osmoprotectants and anti-oxidant enzymes. Ag nanoparticle is also important to encounter oxidative and osmotic stresses (Khan and Bano, 2016). These results are in harmony with those reported by El-Sherpiny *et* *al*. (2020); Gomaa *et al*. (2021 a, b); Tefera (2021) who indicated that using Si or AgNPs or its combination increased yield and yield components.

Belong to the interaction effect between irrigation intervals and foliar application treatments on yield and its components, Tables (2 and 3) showed that the highest values of grain yield were 8.72 t/ha with 20 days irrigation intervals + Ag NPs + Si and 8.77 t/ha with 15 days irrigation intervals + Ag Nps + Si, straw yield (10.20 and 10.70 t/ha), biological yield (18.92 and 19.23 t/ha), ear length (26.67 and 28.33 cm), number of grains/row (47.33 and 48.27), and number of grains/ear (726.67 and 739.47) were recorded with the combination when irrigated maize plants every 20 days with foliar application of Si + Ag NPs, while 20 days with foliar application of Si gave the highest 100- kernel weight (46.17 and 47.67 g) with no significant difference between AgNps and Si + AgNPs, respectively in 2020 and 2021 seasons. On the other hand, the highest harvest index % (47.00 and 47.58 %) was given with irrigated maize plants every 20 days + water spray. These showed that irrigation intervals every (15, 20 and 25 days) and foliar application of (water, Si, AgNPs, and Si + AgNPs) act dependently on the previous studied charters under this study.

Table 2: Effect of irrigation intervals, foliar application treatments and their interactions on yield of maize in both seasons.

Attributes	A). Irrigation intervals (Irrigation every)	Season 2020								Season 2021							
		B). Foliar application treatment (mg/l)				Average (A)	L.S.D. at 0.05			B). Foliar application treatment (mg/l)				Average (A)	L.S.D. at 0.05		
		water	Si	Ag NPs	Si + Ag NPs		A	B	AB	water	Si	Ag NPs	Si + Ag NPs		A	B	AB
Grain yield (t/ha)	15 days	5.80	6.16	7.07	8.44	6.87				6.20	6.56	7.47	8.77	7.25			
	20 days	6.89	7.53	7.82	8.72	7.74	0.16	0.28	0.49	7.29	7.93	8.22	8.53	7.99	0.27	0.24	0.41
	25 days	4.99	5.39	6.13	6.82	5.83				5.39	5.79	6.53	7.22	6.23			
Average (B)		5.89	6.36	7.01	7.99					6.29	6.76	7.41	8.17				
Straw yield (t/ha)	15 days	7.29	7.99	8.69	10.00	8.49				7.70	8.30	8.97	10.33	8.83			
	20 days	7.77	9.31	9.83	10.20	9.28	0.54	0.63	1.09	8.03	9.43	10.56	10.70	9.68	0.25	0.41	0.70
	25 days	6.07	7.09	7.53	8.15	7.21				7.07	7.53	8.04	8.53	7.79			
Average (B)		7.04	8.13	8.68	9.45					7.60	8.42	9.19	9.85				
Biological yield (t/ha)	15 days	13.09	14.15	15.76	18.44	15.36				13.90	14.86	16.44	19.10	16.08			
	20 days	14.66	16.84	17.65	18.92	17.02	0.55	0.77	1.33	15.32	17.36	18.78	19.23	17.67	0.40	0.54	0.94
	25 days	11.06	12.48	13.66	14.97	13.04				12.46	13.32	14.57	15.75	14.03			
Average (B)		12.94	14.49	15.69	17.44					13.89	15.18	16.60	18.03				
Harvest index (HI %)	15 days	44.31	43.53	44.86	45.77	44.62				44.60	44.15	45.44	45.92	45.03			
	20 days	47.00	44.71	44.31	46.09	45.53	ns	1.61	2.80	47.58	45.68	43.77	44.36	45.35	ns	ns	1.99
	25 days	45.12	43.19	44.88	45.56	44.68				43.26	43.47	44.82	45.84	44.35			
Average (B)		45.47	43.81	44.68	45.81					45.15	44.43	44.68	45.37				
ns: no significant difference.																	

Table 3: Effect of irrigation intervals, foliar application treatments and their interactions on yield traits of maize in both seasons.

Attributes	A). Irrigation intervals (Irrigation every)	Season 2020								Season 2021							
		B). Foliar application treatment (mg/l)				Average (A)	L.S.D. at 0.05			B). Foliar application treatment (mg/l)				Average (A)	L.S.D. at 0.05		
		water	Si	Ag NPs	Si + Ag NPs		A	B	AB	water	Si	Ag NPs	Si + Ag NPs		A	B	AB
Ear length (cm)	15 days	18.83	19.20	20.33	23.33	20.42				20.03	20.27	21.83	24.17	21.58			
	20 days	19.57	23.00	25.00	26.67	23.56	1.19	0.94	1.63	19.97	24.50	27.00	28.33	24.95	1.20	1.01	1.74
	25 days	17.83	19.48	19.67	22.00	19.75				18.43	19.67	20.83	23.50	20.61			
Average (B)		18.74	20.56	21.67	24.00					19.48	21.48	23.22	25.33				
Number of grains/row	15 days	34.33	41.00	42.00	45.00	40.58				37.33	43.33	45.00	47.33	43.25			
	20 days	43.00	44.33	44.33	47.33	44.75	2.65	1.46	2.52	44.00	47.33	47.33	48.27	46.73	1.59	1.22	2.11
	25 days	38.00	43.00	44.67	43.00	42.17				37.67	44.00	47.67	44.00	43.34			
Average (B)		38.44	42.78	43.67	45.11					39.67	44.89	46.67	46.53				
Number of grains/ear	15 days	412.00	574.00	560.00	599.33	536.33				448.00	606.67	540.00	662.67	564.34			
	20 days	602.00	620.67	650.67	726.67	650.00	58.16	65.19	112.92	676.00	693.33	694.67	739.47	700.87	71.78	51.36	88.96
	25 days	456.00	575.33	597.33	602.00	557.67				452.00	616.00	637.33	616.00	580.33			
Average (B)		490.00	590.00	602.67	642.67					525.33	638.67	624.00	672.71				
100- kernel weight (g)	15 days	36.50	37.33	42.92	45.83	40.65				38.25	38.58	45.08	47.33	42.31			
	20 days	38.00	44.58	46.17	46.00	43.69	1.93	1.80	3.12	39.25	45.17	47.67	47.00	44.77	2.16	2.39	4.15
	25 days	35.58	37.00	37.33	41.00	37.73				36.67	40.58	38.33	42.33	39.48			
Average (B)		36.69	39.64	42.14	44.28					38.06	41.44	43.69	45.55				

CONCLUSION:

From the result of these two growing seasons field's study, it was concluded that yield and its components of maize crop increased with irrigation yellow SC 2066 hybrid every 20 days with combination between foliar application of Si at the rate of 200 mg/l + Ag NPs at the rate of 10 mg/l under study conditions at Alexandria Governorate, Egypt.

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ARABIC SUMMARY

علاقة فترات الري والسيليكون والفضة النانوية بإنتاجية الذرة الشامية تحت التربة المتأثرة بالملوحة

محمود عبد العزيز جمعة[1]، محمد أحمد عبد الجواد نصار[1] ، عمر تحسين صلاح الدين القالطقجي[2]

[1] قسم الأنتاج النباتي – كلية الزراعة – سابا باشا – جامعة الأسكندرية
[2] قسم المصادر الوراثية النباتية- دائرة فحص وتصديق البذور –وزارة الزراعة -العراق

أجريت تجارب حقلية خلال موسمى 2020 و2021 لدراسة التأثير العام وتأثير التداخل بين فترات الري والرش الورقي للسليكون والفضة النانوية على محصول الذرة الشامية ومكوناته فى تصميم تجريبى وهو القطع المنشقة مرة واحدة Split plot design فى ثلاث مكررات مع التوزيع العشوائى للمعاملات لتقليل الفجوة بين الاستهلاك والانتاج لمصر والعراق. وتم زراعة هجين فردي 2066 حيث تم الحصول عليه من شركة هاي تك الدولية.
كان المحصول السابق البرسيم المصري خلال موسمي الزراعة. ووزعت المعاملات عشوائياً كما يلي:
أ- القطع الرئيسية: ثلاث فترات للري: بحيث يكون الري كل (15 ، 20 ، 25) يوم.
ب- القطع الشقية:أربعة معاملات للرش الورقي : (ماء =كنترول ، سليكون 200ملجم/لتر- نانو فضة 10 ملجم/لتر وسليكون 200 ملجم/لتر + نانو فضة 10 ملجم/لتر) على أن يتم الرش أربعة مرات في عمر 30 ، 50 ، 70 ، 90 يوم من الزراعة.
وكانت مساحة القطعة التجريبية 10.5 م2 تضم 5 خطوط بطول 3 م وعرض الخط 70سم. وكان موعد الزراعة في الموسم الأول 26 مايو/2020 وفي الموسم الثاني 24 مايو/ 2021 وزراعة الحبوب على مسافة 30 سم بين الجور وتم الخف على نبات واحد بالجوره قبل رية المحاياة في عمر 21 يوم.
ولخصت أهم النتائج فيما يلي:
- أثرت معاملات الري تأثير معنوياً على الصفات المحصولية المدروسة وهي محصول الحبوب ومحصول القش والمحصول البيولوجي ووزن 100 حبة وعدد الحبوب بالصف وعدد الحبوب بالكوز في موسمي الزراعة حيث اعطى الري كل 20 يوم أعلى القيم بينما اعطى الري كل 25 يوم أقل القيم لهذه الصفات تحت ظروف التجربة في موسمي الدراسة اما بالنسبة لدليل الحصاد لم يكن هناك فروق معنوية بين معاملات الري على دليل الحصاد خلال موسمي الدراسة.
- كما أثرت معاملات الرش الورقي تأثيراً معنوياً على صفات المحصول ومكوناته خلال موسمي الزراعة حيث وجد أن التوليفة بين الرش الورقي للسليكون والنانو فضة حققت أعلى القيم لهذه الصفات في حين أن معاملة الكنترول (الرش بالماء) حققت اقل القيم، أما بالنسبة لدليل الحصاد % فالرش الورقي للسليكون سجل أقل دليل حصاد خلال موسمي الدراسة للجميع الصفات ماعدا دليل الحصاد خلال الموسم الأول فقط.
- كما كان التداخل بين عاملي الدراسة (الري x الرش الورقي) تأثيراً معنوياً على صفات المحصول ومكوناته حيث وجد أن ري نباتات الذرة الشامية كل 20 يوم مع الرش الورقي بالسليكون والنانو فضة سجل أعلى القيم في حين أن الري كل 25 يوم ومعاملة الرش بالماء (الكنترول) أعطت أقل القيم خلال موسمي الزراعة وتحت ظروف منطقة البحث. أما بالنسبة لدليل الحصاد % وجد أن الري كل 15 يوم مع الرش بالماء سجل أعلى القيم وفي حين أن أقل القيم سجلت مع الري كل 25 يوم مع الرش الماء أو السليكون خلال موسمي الدراسي على التوالي.

التوصية:يوصي البحث بزراعة الذرة الشامية هجين أصفر فردي 2066 والري كل 20 يوم والرش الورقي بمعدل 200 ملجم / لتر سيليكون + 10ملجم/ لتر نانو فضة للحصول على محصول مرتفع من الذرة الشامية الصفراء عند الزراعة في الأراضي المتأثرة بالاملاح مثل منطقة ابيس محافظة الأسكندرية جمهورية مصر العربية والمناطق المماثلة .