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EFFECT OF IRRIGATION APPLICATION RATE AND SPRAYING OF SELECTED COMPOUNDS ON DROUGHT AND SALINITY TOLERANCE OF WHEAT PLANT GROWN IN CLAY SOIL

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ABSTRACT: A field experiment was conducted in the research farm of Al-Hussainiya Plain. The wheat plant was cultivated in clay saline soil that received four irrigation application rates. The experiment repeated two successive winter seasons to evaluate the effect of five mitigators of the environmental stresses (i.e., drought and salinity) on wheat productivity and water use efficiency (WUE). The physical and chemical properties of the soil were determined and some parameters of wheat yield for both straw and grains were measured, as well as the WUE. The obtained results showed a positive significant effect of both irrigation rates and sprayed compounds on wheat productivity and WUE in clay salt affected soil. Generally, the results indicate that the highest productivity for both straw and grain was associated with 100% and 110% of the field capacity (FC), followed by 90%, and then 80%, with all sprayed compounds. The plant height and basal numbers increased significantly with sprayed compounds compared to the control treatment. The positive effect of the sprayed regulators taken the order of K-silicate, Mg-silicate, salicylic acid, proline, and ascorbic acid. This investigation revealed that the application of K and Mg silicate with 110% FC could be recommended to mitigate the harmful impact of salts on wheat grown in clay soil.

Key words: Irrigation application rate; Drought and salinity stress regulators; Clay soil; Wheat Crop.

INTRODUCTION

Drought and salinity lead to decline of plants productivity and soil desertification. Wheat is considered one of the most strategic crops around the world and especially for Egypt. It is also sensitive to both salinity and drought. Very low wheat production is expected in saline soils, especially in hot-arid regions. Therefore, employing stress regulators to improve and enhance plant tolerance against drought and salinity is fundamentally important. The most famous chemical compounds that improve plants tolerance against environmental stresses are potassium silicate, magnesium silicate, salicylic acid, ascorbic acid and proline. Such chemical compounds reduce the large water losses through evaporation from epidermis and transpiration through stomata (Ma and Yamaji, 2006; Abdalla, 2011; and Sandhya *et al.*, 2018). Furthermore, reducing the rate of water loss, which is considered excessive consumption and not beneficial to the plant, is a very important goal, especially in hot regions, where evapotranspiration rates (which reach more than 90% of the total water obtained) may exceed the rates of water withdrawal from the soil by the roots. The plant's consumption of water in this way eventually leads to an increase in the bad effect of drought stress, as well as an increase in water consumption.

The present study aims to test the effect of foliar applications of potassium silicate, magnesium silicate, salicylic acid, ascorbic acid, and proline on the water use efficiency, growth and productivity of wheat plants, affected by the amount of applied irrigation water in saline clay soil.

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MATERIALS AND METHODS

A field experiment was carried out in the Experimental Station at Al-Hussainiya Agricultural Research Station, Agricultural Research Center (31° 2' 50.86" N and 32° 0' 22.07" E), Sharkia Governorate, Egypt, which is an arid zone. The main purpose of this trial is to evaluate the effects of spraying some stresses mitigators on wheat yield (*Triticum aestivum* L, vc Misr1) that grown in saline soil at different irrigation application rates (80%, 90%, 100%, 110% of soil field capacity, FC) and sprayed with five regulators compounds. Twenty-four treatments with three replicates were used in this experiment. Experimental design was split plot. The experimental area was divided into four main plots representing the four irrigation treatments (80%, 90%, 100%, 110% of soil FC). Each main plot was divided into six sub-plots representing foliar treatments of the stress regulators compounds. The control treatment was spraying with distilled water. The concentrations of the five sprayed compounds were 0.5% ascorbic acid, 2% proline, 200 ppm salicylic acid, 150 ppm Mg-silicate, and 200 ppm K-silicate. The five compounds plus distilled water sprayed three times at 30, 45 and 75 days of planting. Thus, the area of each plot was 16 m^2 (4 m × 4 m), therefore the total experimental area was 1152 m^2.

Furthermore, farmyard manure was added to the soil at the rate of 10 tons per hectare. The farming practices of wheat plants under saline soil conditions were carried out as recommended by Agriculture Ministry of Egypt Moreover, mineral fertilizers were applied in the same amount to each treatment. Gypsum (86% $CaSO_4 .2H_2O$) at rate of 12 ton per hectare, (19.2 kg/ plot) and superphosphate fertilizer (15.5% P_2O_5) with the rate of 476 kg per hectare (0.76 kg/ plot) were applied to the whole experimental area. Ammonium sulphate (20.5%N) was used as source of N fertilizer where it's added at rate of 31 kg per hectare (0.050 kg /plot). Also, potassium sulphate (48 % K_2O) was applied at rate of 238 kg per hectare (0.38 kg/plot). Both N and K fertilizers were divided into two equal doses added after 20 and 40 days of planting. The experiment was conducted for two winter seasons from 17th of November 2018 to 28th of April 2019 and repeated at the same time of the year after.

Before and after harvesting, disturbed and undisturbed surface soil samples were taken to determine some chemical and physical soil properties. The disturbed soil samples were air–dried, crushed and passed through a 2 mm sieve. Selected physical and chemical properties of the experimental soil, determined according to Page *et al.*, (1982) and Klute (1986) are presented in Table (1). The resource of irrigation water was EL Salam Canal. Surface basin irrigation was followed. The chemical analysis of the irrigation water was carried out according to (Cottenie *et al.*, 1982) and presented in Table (2).

In addition, at harvesting stage, the plants of all plots were harvested above the soil surface. Some yield parameters (i.e., number of plants per meter square, basal branching, plant height, weight of 1000 grains, grain yield, straw yield, and biological yield) were measured. Water use efficiency (WUE, kg/m^3) was calculated for grain yield as follows:

WUE = Grain yield (kg/hectare) / Amount of total water received (m^3/hectare).

All obtained results were statistically examined (i.e., ANOVA and LSD at 0.05 probability level) to evaluate the significance effect of the tested variables (irrigation and sprayed compounds) and their interaction. costat software version 6.311 was used in calculation.

Table (1): Some physical and chemical properties of the studied soil at three depths.

Characteristics	**Depths (cm)**		
	0-20	**20-40**	**40-60**
Particle density	2.69	2.69	2.69
Bulk density	1.21	1.17	1.20
pH (1: 2.5 soil: water susp.)	8.20	8.60	8.20
EC (Soil paste extraction) $dS.m^{-1}$	13.0	14.5	14.3
Soluble cations ($meq.L^{-1}$)			
Calcium	15.7	16.3	20.6
Magnesium	10.3	12.2	14.2
Potassium	1.6	1.8	0.9
Sodium	102.4	104.3	111.3
Soluble anions ($meq.L^{-1}$)			
Bicarbonate	2.5	3.6	2.6
Chloride	121.9	127.4	140.2
Sulphate	5.6	3.6	4.2
Exchangeable sodium percentage (ESP, %)	21.5	19.9	18.5
Physical properties			
Organic matter (%)	0.54	0.46	0.21
Coarse sand (%)	4.4	3.5	5.1
Fine sand (%)	9.2	9.2	11.3
Silt (%)	33.6	34.2	34.7
Clay (%)	52.8	53.1	48.9
Texture class	Clay	Clay	clay
Field capacity (%)	29.6	30.5	27.4
Permanent wilting point (%)	18.9	18.4	15.2
Saturation percent (%)	74.1	78.1	75.2

Table (2): Some chemical properties of the used irrigation water

EC ($dS.m^{-1}$)	**pH**	**K^+**	**Na^+**	**Ca^{2+}**	**Mg^{2+}**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**	**SAR**
1.1	7.59	**Soluble ions ($meq.L^{-1}$)**							
		0.3	6.1	3.2	1.4	0.7	7.6	2.7	4.02

RESULT AND DISCUSSION

The presented results were average values of the two years. The statistical analysis (ANOVA) and estimated LSD values, for the significant results, are presented in Figures 1:5 and Table 3. A significant effect of both irrigation and sprayed compounds and their interaction on plant height and number of basal branches were illustrated in Fig 1 and 2. The presented data in Fig 1, shows that all sprayed chemical compounds, under the four irrigation applied rates, resulted in a significant increase in plant height, compared to the control treatment. Its effect followed the order: K silicate > Mg silicate > salicylic acid > proline > ascorbic acid. This may be related to the effect of added compounds on the activity of many enzymes and biochemical processes within different plant tissues reduced the harmful effect of soil salinity on plant growth (Murphy *et al.*, 2003; Cameron *et al.*, 2017; Flores *et al.*, 2018). Moreover, Hayat *et al.* (2007) found a beneficial effect of silicon and salicylic acid on plant hormones and growth. Furthermore, potassium has an important effect in the process of water balance within the plant and the opening and closing of stomata. Fig. 1, also, reveals that the plant height was increased with increasing irrigation water up to both 100% and 110% of field capacity. This indicates that the sprayed compounds improved wheat tolerance against salinity and drought as it appeared with the plant height and basal branches.

Fig. 2 shows a wide range of basal branches in relation to the sprayed compounds and irrigation levels, where their number per square meter ranged between 170.2 for the control treatment with 80% FC of irrigation water to 301.2 for the plants sprayed by K- silicate with irrigation levels of 110 % FC. Based on the mean values of basal branches per square meter, the sprayed compounds, according to their increase effect on basal branches, followed same order of plant height. While these numbers were 213.3, 220.3, 236.5 and 255.6 with irrigation levels of 80, 90,100 and 110 %FC, respectively. Tawfik (2022) stated that the significant increase in the basal branches of wheat plants resulted from the increase in the soil available water.

In this regard, Hayat *et al.* (2007) and Hayat *et al.*, (2010) found that these compounds affect plant growth, flower initiation, nutrient uptake, ethylene biosynthesis, stomata resistance photosynthesis and enzyme activities.

The presented data in Fig. 3 reveals positive effect of both sprayed compounds and irrigation water level on straw and grain yields. This yield was ranged between1190 g.m^{-2} for the unsprayed plant (control) irrigated with 80% FC and 3320 g.m^{-2} for the plants sprayed by K-silicate and irrigated by irrigation level of 110% FC.

K and Mg silicates are found to enhance plant growth, particularly when exposed to salt stress, according to several research (Fernandez and Eichert, 2009; Fernandez *et al.*, 2013; Liang *et al.*, 2005; Tahir *et al.*, 2006). According to Omran (2005), Romero-Aranda *et al.*, (2006), Omran *et al.*, (2014) and Tawfiq (2022), the effect of irrigation application rate can be explained by increasing the amount of water that is available in the soil, which lowers salt concentration and promotes nutrient uptake.

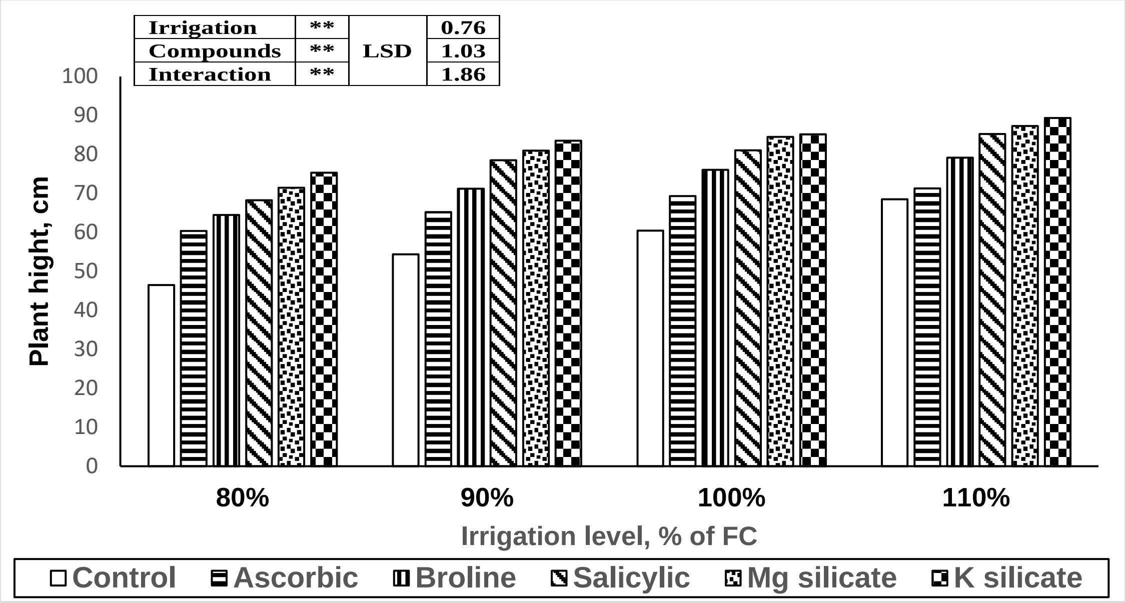

Fig (1): Effect of the selected chemical compounds on wheat plant height with different levels of irrigation

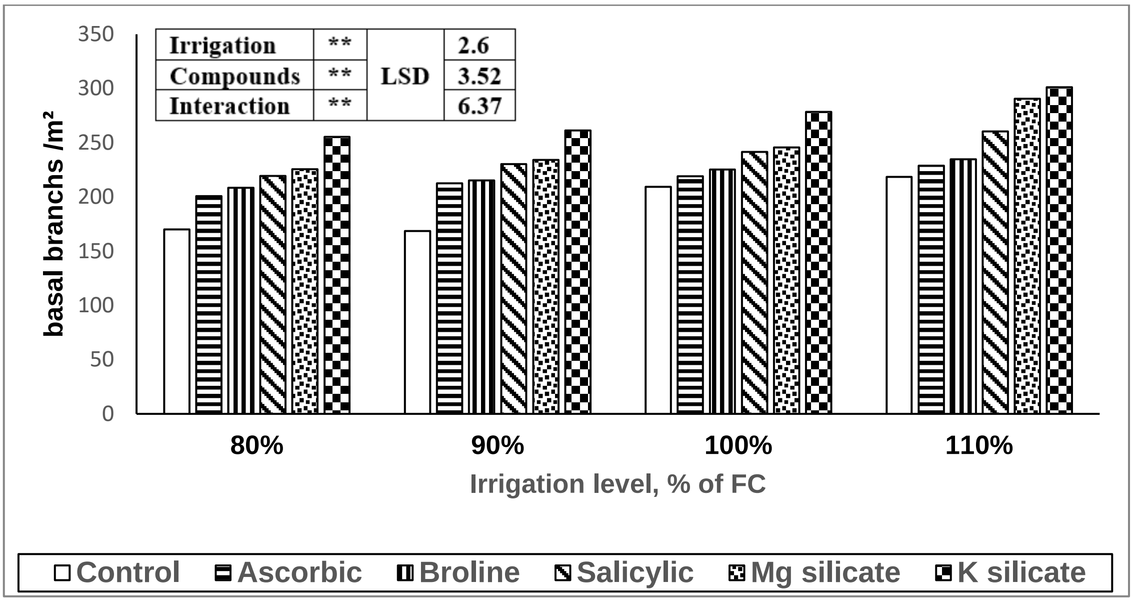

Fig. (2): Effect of the selected chemical compounds on the basal branching of wheat in m² soil area under different levels of irrigation.

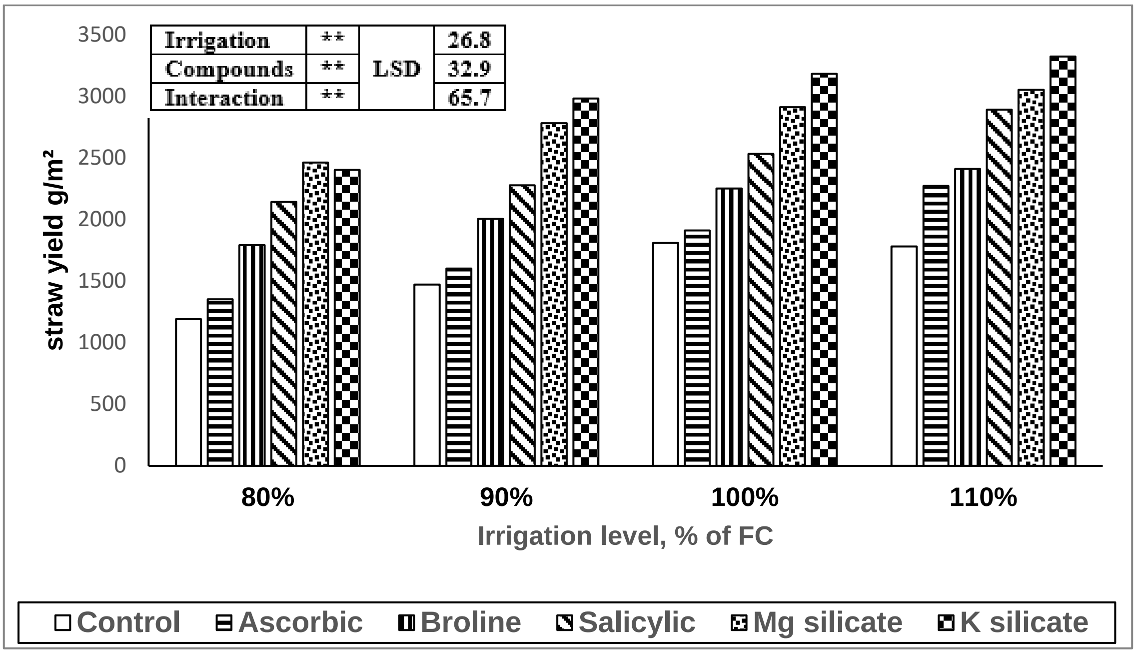

Fig (3): Effect of the selected chemical compounds on the straw yield of wheat in g/m² soil area with irrigation on at different levels.

The illustrated data in Fig 4 noted that application of K-silicate at 110% FC irrigation level raised the weight of 1000 grains from 36.5 g for control (non-sprayed) to 43.1 g for treated plants at the irrigation rate of 110% FC.

The beneficial effect of silicon on yield might be due to its role in ethylene inhibition, which slows the aging and degeneration of harvested plant parts and its positive effect on chlorophyll content (Balakhnina and Borkowska, 2013). Therefore, the use of silicon can help in minimizing the harmful effect of salts and enhance some necessary physiological processes and increase yield through the accumulation and polymerization of silicate in the epidermal cells (Giongo and Bohnen, 2011). This forms a double-layer silicon cuticle that reduces transpiration, which lower water consumption and, therefore, increased tolerance against the osmotic effect caused by salinity.

Potassium foliar application has many benefits in improving leaf erectness and photosynthesis efficiency (Ahmad *et al.*, 2013), also improves the nutrient balance of crops, which in turn leads to increase yield and greater resistance to diseases and improve drought tolerance (Zhu *et al.*, 2004).

Data of grains yield of wheat plants grown on saline soil as shown in Fig. 5 revealed that application of K-silicate at 110% FC enhanced the grains yield by more than 70% in comparison with the control at 80% FC. The result agrees with these obtained in the same soil and same location by Tawfik (2022) who relate the increase of wheat production in salt affected clay soil due to the increase in soil water content as well as the nutrients availability.

Table 3 shows the water use efficiency (WUE), calculated based on the straw and grain portions, as affected by the different sprayed compounds and different irrigation rates. This may be due to the sensitivity of the wheat plant to water deficit which produces straw and grain yield proportional to the amount of applied water. In other words, the percentage of water stress is more than the resulting yield drop. Therefore, the final value of the WUE is not preferred in such kind of saline soil.

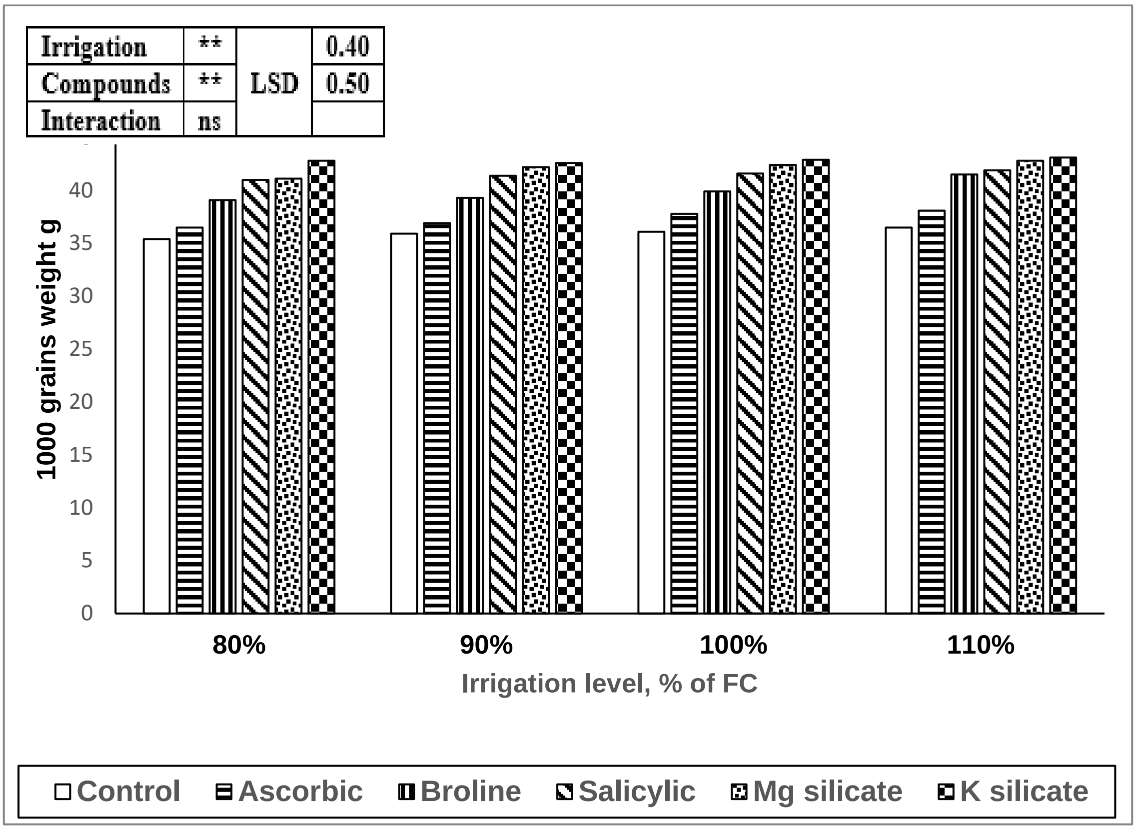

Fig (4): Effect of the selected chemical compounds on the weight of 1000 grains (g) of wheat plant with different levels of irrigation (FC %) in saline soil

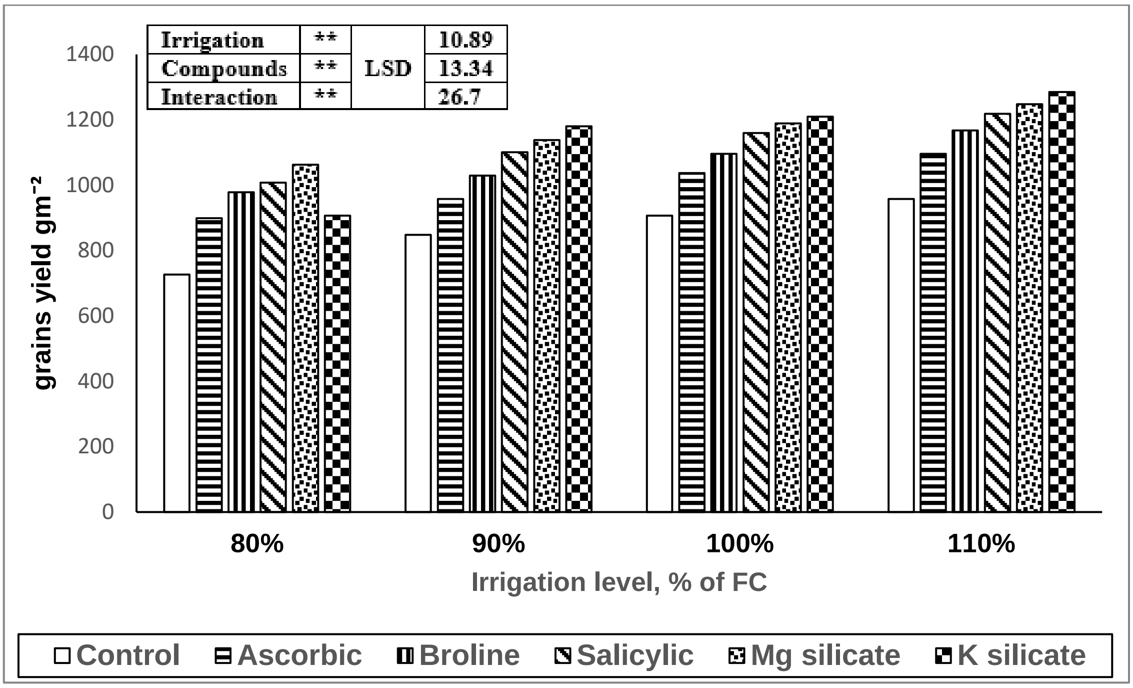

Fig. (5): Effect of selected chemical compounds on the weight of wheat grains (g/m²) in soil area with different levels of irrigation in saline soil

Table (3): Effect of chemical compounds and irrigation levels on water use efficiency (WUE) of wheat straw and grains (kg/m³).

Added chemical compounds	**Straw-WUE**				**Grains-WUE**			
	Irrigation Level (%FC)							
	80%	**90%**	**100%**	**110%**	**80%**	**90%**	**100%**	**110%**
Control	3.03	3.32	3.68	2.74	1.86	1.92	1.85	1.78
Ascorbic acid	3.43	3.62	3.89	4.20	2.29	2.17	2.12	2.04
Proline	4.55	4.53	4.58	4.46	2.49	2.33	2.24	2.17
Salicylic acid	5.44	5.15	5.15	5.35	2.57	2.49	2.36	2.26
Magnesium silicate	6.26	6.29	5.92	5.64	2.71	2.58	2.42	2.31
Potassium silicate	7.58	5.43	6.47	6.14	2.80	2.67	2.46	2.38
a **	**LSD at 0.05**		0.024	**a**	**	**LSD at 0.05**		0.089
b **			0.032	**b**	**			0.12
ab **			0.059	**ab**	**			0.22

The notable point here is that foliar application of all applied compounds improved productivity under drought conditions and water consumption as well. Also, same general positive order effect, i.e., Potassium silicate > Magnesium silicate > Salicylic acid > Proline > Ascorbic acid, was found with all studied parameters. Also, 110% FC > 100% FC > 90% FC > 80% FC was the order of the beneficial effect, except the WUE, followed the reverse trend in same sequence. In this regard, (Zhang *et al.*, 1998) conducted a field experiment studying WUE and harvesting index of wheat grown in clay soil. The study revealed that WUE, based on grains, was greatly improved with irrigation treatments compared to non-irrigated soil (rain-fed). Consequently, Omran (2005) conducted a field experiment to quantify the effect of deficit irrigation on maize grown in clay soil. It was found that a direct linear proportional relation between water application and resulting yield. Moreover, Omran (2013) scheduled deficit irrigation for Medicago sativa in pot experiment and obtain similar trend, as maize. Moreover, Abd El-Mageed *et al.* (2022) found that deficit irrigation could be applied to sorghum grown in salt affected soil to save 10% of irrigation water without any significant drop in grain yield.

CONCLUSION

In conclusion, better to over irrigate wheat grown in saline clay soil to obtain higher biological yield. On the other hand, in case of drought circumstances it is advised to spray wheat plants with K-silicate in order to conserve water and maintain yield in such saline soil.

REFERENCES

Abdalla, M. M. (2011). Beneficial effects of diatomite on the growth, the biochemical contents and polymorphic DNA in Lupinus albus plants grown under water stress. Agriculture Biology J. North America, 2(2): 207-220.

Abd El-Mageed, T. A.; Rady, M. O. A.; Abd El-Wahed, M. H.; Abd El-Mageed, S. A.; Omran, W. M.; Aljuaid, B.S.; El-Shehawi, A.M. and El-Tahan, A. M. (2022). Consecutive seasonal effect on yield and water productivity of drip deficit irrigated sorghum in saline soils. Saudi J. Biological Sci. 29 (4): 2683-2690.

Ahmad, A.; Afzal, M.; Ahmad, A. U. H. and Tahir, M. (2013). Effect of foliar application of silicon on yield and quality of rice (Oryza sativa L.). Cercetări Agronomiceîn Moldova. 3: 21-28.

Balakhnina, T. and Borkowska, A. (2013). Effects of silicon on plant resistance to environmental stresses. International Agrophysics. 27(2): 225-232.

Cameron, D. L.; Schröder, J.; Penington, J. S.; Do, H.; Molania, R.; Dobrovic, A. and Papenfuss, A. T. (2017). GRIDSS: sensitive and specific genomic rearrangement detection using positional de Bruijn graph assembly. Genome research. 27(12): 2050-2060.

Cottenie, A.; Verlo, M.; Kjekens, L. and Camerlynch, R. (1982). Chemical Analysis of Plant and Soil. Laboratory of Analytical Agrochemistry. State University, Gent, Belgium. 42: 80-284.

Fernandez, V. and Eichert, T. (2009). Uptake of hydrophilic solutes through plant leaves: current state of knowledge and perspectives of foliar fertilization. Critical Reviews in Plant Sciences, 28(1-2): 36-68.

Fernandez, V.; Sotiropoulos, T. and Brown, P. (2013). Foliar fertilization: scientific principles and field practices. Paris, France. Int. Fert. Ind. Assoc. (IFA): 12-70.

Flores, R. A.; Arruda, E. M.; Damin, V.; Junior, J. P. S.; Maranhao, D. D. C.; Correia, M. A. R. and de Mello Prado, R. (2018). Physiological quality and dry mass production of Sorghum bicolor following silicon (Si) foliar application. Australian J. Crop Sci. 12(4): 631-638.

Giongo, V. and Bohnen, H. (2011). Relation between aluminum and silicon in maize genotypes resistant and sensitive at aluminum toxicity. Bioscience J., Uberlândia. 27(3): 348-356.

Hayat, S.; Ali, B. and Ahmad, A. (2007). Salicylic acid: biosynthesis, metabolism and physiological role in plants. Salicylic acid: A plant hormone. 1-14.

Hayat, Q.; Hayat, S.; Irfan, M. and Ahmad, A. (2010). Effect of exogenous salicylic acid under changing environment: a review. Environ. Experim. Botany. 68(1): 14-25.

Klute, A. (1986) Methods of soil analysis. Part 1: Physical and mineralogical methods. 2nd Edition, American Society of Agronomy and

Soil Science Society of America, Madison, USA.

Liang, Y.; Wenhua, Z.; Chen, Q. and Ding, R. (2005). Effects of silicon on HP+P-pase activity, fatty acid composition and fluidity of tonoplast vesicles from roots of salt stressed barley. Environmental Experimental Botany. 53: 29-37.

Ma J. F. and Yamaji, N. (2006). Silicon uptake and accumulation in higher plants. Trends plant Sci. 11(8): 392-397.

Murphy, L. R.; Kinsey, S. T. and Durako, M. J. (2003). Physiological effects of short-term salinity changes on Ruppia maritima. Aquatic Botany. 75(4): 293-309.

Omran, W. M. (2005). Maize yield response to available soil moisture. Menoufia J. Agric. Res. 30 (4): 1257–1268

Omran, W. M. (2013). Quantifying Medicago sativa Yield under Deficit Irrigation Technique in Sandy Soil. International J. Plant Soil Sci. 2 (2): 202-211.

Omran, W. M.; Mansour, M. F. and Fayez, K. A. (2014). Magnetized water improved germination, growth and tolerance to salinity of cereal crops. International J. Advanced Research 2 (5): 301-308.

Page, A. L.; Miller, R. H. and Keeney, D. R. (1982). Methods of soil analysis part 2: chemical and microbiological properties second edition. Agronomy 920 Am. Soc. Agron. Inc. Soil Sci. Soc. Am. Inc. Pub. Madison, Wisconsin, USA.

Romero-Aranda, M. R.; Jurado, O. and Cuartero, J. (2006). Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. J. plant physiology. 163(8): 847-855.

Sandhya, S.; Maulik, A.; Giri, M. and Singh, M. (2018). Domain architecture of BAF250a reveals the ARID and ARM-repeat domains with implication in function and assembly of the BAF remodeling complex. PLOS One.13(10): e0205267.

Tahir, M. A.; Rahmatullah, T.; Aziz, M.; Ashraf, S.; Kanwal, S. and Maqsood, M. A. (2006). Beneficial effects of silicon in wheat (Triticum aestivum L.) under salinity stress. Pakistan J. Botany.38(5): 1715-1722.

Tawfik, S. A. I. (2022). Effect tillage and irrigation treatment on the properties and productivity of saline soil. M. Sc Thesis fac. of agric. Menoufia univ, Egypt.

Zhang, H.; Oweis, T. Y.; Garabet, S. and Pala, M. (1998). Water-use efficiency and transpiration efficiency of wheat under rain-fed conditions and supplemental irrigation in a Mediterranean-type environment. Plant and Soil, 201: 295-305.

Zhu, Z.; Wei, G.; Li, J.; Qian, Q. and Yu, J. (2004). Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (Cucumis sativus L.). Plant Sci. 167(3): 527-533.

تأثير معدلات الري والرش بمركبات مختارة على مقاومة إجهادات الجفاف والملوحة للقمح النامي في التربة الطينية

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الملخص العربي

أجريت تجربة حقلية في مزرعة أبحاث سهل الحسينية. حيث تم زراعة محصول القمح في تربة طينية ملحية وتم تطبيق أربعة معدلات للري. كررت التجربة موسمين شتويين متتاليين لتقييم تأثير خمسة منظمات للإجهادات البيئية (أي الجفاف والملوحة) على إنتاجية القمح وكفاءة استخدام المياه. تم تحديد الخواص الفيزيائية والكيميائية للتربة وقياس بعض معاملات محصول القمح لكل من القش والحبوب وكذلك كفاءة استخدام المياه. أظهرت النتائج المتحصل عليها تأثيراً معنوياً إيجابياً لكل من معدل رش الري ومركبات الرش على إنتاجية القمح وكفاءة استخدام المياه في التربة الطينية المتأثرة بالأملاح. تشير النتائج إلى أن أعلى إنتاجية لكل من القش والحبوب ارتبطت بـ ١٠٠٪ و ١١٠٪ من السعة الحقلية، تليها ٩٠٪ ، ثم ٨٠٪ كمتوسط عام، بغض النظر عن نوع المعاملة التي تم رشها. . كما أوضحت النتائج أن ارتفاع النبات وعدد الأشطاء القاعدية قد ازدادا بالمركبات التي تم رشها مقارنة بمعاملة المقارنة. كان ترتيب التأثير الإيجابي للرش مع منظمات الاجهادات البيئية بشكل عام على النحو التالي: بوتاسيوم سيليكات ، ثم مغنيسيوم سيليكات ، ثم حمض الساليسيليك ، ثم البرولين، ثم حمض الأسكوربيك. ولذلك توصي هذه الدراسة باستخدام سيليكات البوتاسيوم والمغنيسيوم ومعدل ري ١١٠٪ من السعة الحقلية لتخفيف الأثر الضار للملوحة على نبات القمح النامى في التربة الطينية.

الكلمات المفتاحية: معدلات الري – منظمات اجهادات الجفاف والملوحة – الأرض الطينية – محصول القمح.