EFFECT OF K-SOURCES IN COMBINATION WITH GIBBERELLIC ACID ON MAIZE PRODUCTION UNDER WATER STRESS IN SANDY SOIL

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ABSTRACT: A field experiment was conducted along the two successive summer seasons of 2019 and 2020 under sandy soil conditions at Ismailia Agricultural Research Station. This study aim to evaluate the effect of K sources i.e. K-silicate and K- humate, combined with gibberellic acid application under different irrigation levels on yield characters and NPK uptake by maize plant (Zea maize *L.*). The experimental treatments were arranged in a split –split plot design as follows: (1) three irrigation levels were assigned as main plots i.e. 100% (I_1) 80 %(I_2) and 60 %(I_3) of maize evapotranspiration (ET_c), (2) three treatments of K-source as foliar application were arranged as sub plot i.e. 0, K-humate at rate of 4 g L^{-1} and K-silicate at rate of 150 mg L^{-1} Si (3) three application rates of gibberellic acid 0 (G_0), 100 (G_1) and 150 (G_2) mg L^{-1}were arranged as sub-sub plots. The obtained results indicated that the heist values of grain yield, straw yield and NPK- uptake by plant were recorded at treatment of $I_2*K_{humate}*GA_1$. Soil content of available N was significantly increased with the foliar spraying of the K-silicate, K-humate and the different levels of gibberellic acid, but not significantly affected by irrigation levels. Soil available P was not significantly affected by different treatments while, soil available K was significantly affected by irrigation level, K-silicate and K-humate but not significantly affected by the different levels of Gibberellic acid.

Key words: Maize; Irrigation level; K-humate; K-silicate; and Gibrillic acid

INTRODUCTION

Foliar spraying for maize with potassium silicate and potassium humate are one of the major popular replacements in chemical and nature compound for plant development. It' can improve plant tolerance against many stress factors, assists plants to stay alive in water shortage conditions, and decrease transpiration. In sandy soil water deficit is one of the major factors that affects critical growth stages and crop production. In tropical countries where yield decline or stagnation is a problem, the silicon management increase yield, sustain crop productivity which is necessary in high temperatures. It can also develop integrated nutrients and help overcome low leaching process and soil erosion (Meena *et al.,* 2014). In sandy soils where Irrigation water applied at 5955, 4762 and 3572 m^3 ha^{-1}, IWUE, maize yield, yield components significantly increased with increasing irrigation rates and decreasing population densities (El-Hendawy *et al.,* 2008).Atta (2014)reported that the highest of plant height, ear diameter, ear height, ear length, ear weight, number of ears/plant, 100-kernel weight and grain yield for maize cultivars were achieved at irrigation treatment of 5676.0 m^3ha^{-1} irrigation as compared with 8143.0 and 3810.0 m^3 ha^{-1}. (Ewis *et al.,* 2016) noted that full irrigated maize plants with 3525 and 3590 m^3 fed^{-1} with 150 kg N fed^{-1} inducing the highest effect on plant height, 100- grain weight, weight of grains ear^{-1}, ear diameter, and grain yield while, treatment as 2723 and 2773 m^3 fed^{-1} were the lowest recorded .In Egypt, water requirements recommended for

maize under current climate range between 772 to 1090 mm and water requirements under climate change range between 859 to 1290 mm (Ouda *et al.,* 2018). Irrigation water required yearly ranged between 390 to 575 mm water for maize growth stages as non-stressed production, and caused positive effect on maize grain yield (Recep, 2004). Stage of the falling rate began after 5 days of evaporation and during the falling rate stage; moisture content of the sandy soil increased exponentially, in the tropics. The best control of soil water loss would be the constant rate stage(Mensah,1997).

Foliar spraying with potassium silicate and potassium humate at 1,2,and 4 cm L^{-1} reduce the negative effects of soil salinity stress and showed significant increase on growth, yield, and yield Attributes, chemical contents in the leaves and seeds and quality of pea while potassium humate at different rates significantly increased all parameters (Ismail *et al.,* 2017).Also, water irrigation could be necessary to sandy soil and new management such as K-humate and K-silicate can increase maize yield in these conditions. Sandy soil has low Si soluble concentrations which are prone to water deficit. Si content (0.9 mg kg^{-1} sandy soil) can lead to positive effect of Si application at 600 kg ha^{-1}(Camargo *et al.,* 2014). In maize, addition of silicon can affect some physiological activities, increase amounts of nutrients, increase osmo-regulators and improve tolerance against water stress and plant growth under deficit water. Silicon has an important role in the mineral balance and it can increase the Kcontent (Asgharipour and Mosapour, 2016). Silicon with foliar application can be used with stressful conditions for cereals crops such as salinity, excess or deficiency of water. It also showed to increase the yield of crops in the last 15 years (Arkadiusz, 2018). Silicon fertilization significantly showed superior

effect on carbohydrate, stalk yield, dry biomass and water deficit compared to its absence. Si at planting reduced the damage caused by water deficit (Camargo *et al.,* 2017). Foliar application of silica-nano increase in plant growth, yield, quality and biotic stress (Henk-Maarten 2018). Potassium silicate at 200 ml L^{-1} with 40 mm water increased leaf water potential, growth, total dry biomass, net photosynthetic rate and decreased shoot to root ratio, decreased leaf water potential and transpiration in sorghum cultivars (Mukhtar *et al.,* 2011).

Application of Salicylic acid sprays to maize plants at concentrations of 1 to 3 mL L^{-1} (7 to 22 ppm Si) in sandy loam soil increase the growth, yield and yield component (Jawahar *et al.,* 2017). Foliar sprays with 2 mL L^{-1} (15 ppm Si) Salicylic acid increased N, P, K and Si content in the leaves of white, shoot dry matter, NO. of panicles, NO. of grains per panicle and increased significantly grain yield (Soratto *et al.,* 2012). Liquid potassium silicate at rate 100, 200, 300 mg Si kg^{-1} added to plant showed positive effect and 200 or 300 mg Si kg^{-1} resulted in highly significant growth parameters and yield (Ratnayake *et al.,* 2016). In the USA, with applying silicon at 59, 118 and 236 mg kg^{-1}, beneficial rates effect was observed in the winter wheat irrigated (Walsh *et al.,* 2017). Foliar application of both potassium silicate at rate 8.5 mM and salicylic acid at 2 mM can be considered as an optimal treatment to vegetative growth, good quality and can also produce high yield (Abd-Elaziz *et al.,* 2019). Potassium silicate (6.0 cm^3 L^{-1}) as foliar application gave the highest increases of NPK in leaves, growth, plant dry weight, quality of garlic, yield and yield component (Zyada and Bardisi, 2018).

In sandy soil, K-humate has improved soil physical, chemical, biological properties, crop yield and nutrients

(Hussein and Hassan, 2011). A small concentration of humic substances has shown positive effect on shoot length, plant growth parameters, root length, moisture and nutrient contents (Ylmaz, 2007). K-humate improves soil physical, chemical properties and nutrient movements (Abd-All *et al.,* 2017).

Humic substances have increased nutrients efficiency, plant biomass and plant growth. Humic substances can improve the root growth and contents of N, P and K, under stress such as salinity (Rose *et al.,* 2014). Humic substances showed improvement of the soils physical properties and moisture contents, CEC, yield quality and soil productivity (Zhang and He, 2004). HA or K-humate fractions increased availability P, hydrolysable P and crop uptake (Zhongqi *et al.,* 2011). Humic acid increased yield components, soil pH, organic carbon, NPK contents, available NPK (Dongfeng *et al.,* 2016). Humic acid can increase plant growth, nitrogen uptake, and transport of potassium, phosphorus and calcium for plants. Humic acid, improved exchangeable calcium, total phosphorus, cation exchange capacity and total nitrogen (Jamala and Oke, 2013). The spray solution of K-humate added at rate 0.5 to 10% (w/v) showed positive effect on seed germination and root, gave highest yield and NPK under the soil salinity stress(Abdel-Rahman, 2017). The foliar application of liquid humic acids at 0, 0.1 and 0.2% under salt stress increased the maize uptake of N, P and K (Hussein and Hassan, 2011). K-humate at 0.5% and 1.0% solution increased yield, yield components and plant growth parameters (Harshad *et al.,*2018).

Application of gibberellic acid (GA) is the main controlling, readily available, sustainable, low costs, measures that is less expensive with minimal environmental hazards (Cumagun and Moosavi, 2015). Application spray of GA in sandy soil under salt stress through 60 days after sowing improved all the growth parameters, physio-biochemical characters, electrolyte leakage, proline, thiobarbituric acid reactive, activities of superoxide, glycine betaine, content activities of superoxide dismutase, catalase and leaf nutrients content (Nasir Khan *et al.,* 2012). Application of GA to the cereal roots improve growth root, tall, exogenous, leaf elongation and reduced number of tillers (Mauricio *et al.,* 2013). Moreover, involvement in the roots growth is highly sensitive to added GA and rapidly increase root growth rates than for shoots (Tanimoto, 2012). Foliar spray at 25 and 35 days after sowing GA at 50 and 100 ppm caused significant increase in 1000 seeds of pea, length of pod, NO of pods / plant, NO of seeds / pod, pods fresh, dry weights, increase in total soluble carbohydrates, total chlorophylls, total proteins, phenol, sugars in seeds, endogenous phytohormones in seeds and GA concentration in plants (El-Shraiy and Hegazi, 2009). Foliar application of GA at 20 ppm was the promising treatment under sandy soil condition for increasing productivity, yield, fruit retention, increased fruit set, decreased fruit drop and improved the physical and chemical fruit characteristics (Abd El-Moneim *et al.,* 2007).GA at rate 0.25, 0.82, 2.03, 5.38 and 5.76 ppm showed positive effect on plant growth-promoting ability and fungi (Sumera *et al.,* 2009).

This study aim to evaluate the effect of K source i.e. K-silicate and K- humate, combined with gibberellic acid application under different irrigation levels on yield characters and NPK uptake of maize plant (Zea maize *L.*) and water use efficiency.

MATERIALS AND METHODS

Site description

These field experiments were conducted two successive during summer grown seasons of 2019 and 2020 under sandy soil conditions; Entisol [Arenosol AR] of the Farm Ismailia Agricultural Research Station, Agricultural Research Center (ARC) - Egypt (30° 35' 42.9"N 32°16'51"Eelevation 14m). Main properties of physical and chemical soil were carried out according to Page *et al.* (1982) and obtained data are shown in Table 1.

Climatic condition:

The meteorological data at Ismailia Station, Egypt were obtained from the agro meteorological unit at SWERI, ARC had been daily recorded and their monthly mean values were calculated during the last ten years period and presented in Table 2.

Experimental design and treatments

The experimental treatments were arranged in a split –split plot design including 27 treatments with three replicates. The experiment included 3 factors as follows: (1) three irrigation levels were assigned to main plots i.e. 100% (I_1) 80 % (I_2) and 60 % (I_3) of maize evapotranspiration (ET_c)(2) three treatments of K-source as sub plot K_0 without application, K-humate at rate of 4 g l^{-1} and K-silicate at rate of 150 mg l^{-1} Si (3) three application rates of gibberellic acid 0 (G_0), 100 (G_1) and 150 (G_2) mg l^{-1} as sub-sub plots. Each source of K and gibberellic acid was applied at 3000 l ha^{-1}

Table 1. Main characteristic of the studied soil.

Particle size distribution (%)				Texture class	Bulk density (Mgm⁻³)	Organic matter g kg-1	Available nutrients (mg kg⁻¹)			*pH	*EC (dSm⁻¹)	CEC (cmolc/kg soil)	CaCO₃ g kg⁻¹
Coarse sand	Fine sand	Silt	Clay				N	P	K				
71.14	23.86	3.36	1.64	Sandy	1.84	1.28	11.22	3.25	60	8.01	1.10	1.10	7.15

*pHsoil: water suspension at 1: 2.5,EC in soil saturation extract

Table 2. The meteorological data of Ismailia Station during the last ten years (2010 -2020) period.

Month	T_{max}. °C	T_{min}. °C	T_{mean}°C	RH_{max} %	RH_{min} %	RH_{mean}%	W.S m sec^{-1}	N $hour_{min}$	N $hour_{max}$	Rs MJm⁻²day⁻¹	Ra MJm⁻²day⁻¹
May	31.9	17.7	24.5	61.2	20.8	41	3.15	10.3	13.6	26.99	40
June	35	21.2	27.5	67.6	22.8	45.2	3	13.1	13.97	29.7	41.27
July	35.9	23.2	29	72.8	28	50.4	3	12.6	13.83	28.67	40.63
August	36.25	23	29.1	75.4	28.4	51.9	2.8	12.2	13.13	27.13	37.97

T_{max}: maximum air temperature, T_{min}: minimum air temperature, T_{mean}: mean air temperature, RH_{max}: maximum relative humidity, RH_{min}: minimum relative humidity, RH_{mean}: mean relative humidity, W.S:wind speed, N $hour_{min}$: minimum daylight hours, N $hour_{max}$: maximum daylight hours, Rs: solar radiation and Ra: extraterrestrial radiation.

Potassium silicate fertilizer (K_2SiO_3) contained 114g Si kg^{-1} and 500 g K kg^{-1} imported by Technogene Company, China and prepared through mixed 1.32 L (150 g Si l^{-1}) K- silicate with 998.68 l ha^{-1} irrigation water. Liquid fertilizer of K-humate (5% humic acid) prepared by mixed 4 kg K-humate with 1000.0 l ha^{-1} irrigation water. Main properties of K-humate are shown in Table 3. Gibberellic acid solution prepared through mixed 50 and 100 cm^{-3} from gibberellic acid with irrigation water and kept it solution spray at 1000 liter total.

Irrigation system

Three irrigation levels i.e. 100%, 80% and 60% of maize evapotranspiration (ET_C) were assigned. Levels of ETc at the maize growth season are presented in Table 4.

Crop evapotranspiration (ETc) under varying irrigation levels was calculated as follows:

$$ET_c = K_c \times ET_O$$

Where: Kc is the crop coefficient Kc was calculated by Doorenbos and Kassam (1979) are 0.4, 0.775 for the initial, development, respectively. While, the adjust maize crop coefficient K_c calculated by the next equation are 1.22 and 0.479 for mid-season and late-season corroding Allen *et al.* (1998), respectively.

$$K_{c\ mid} = K_{c\ mid(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)] (h/3)^{0.3}$$

$$K_{c\ end} = K_{c\ end(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)](h/3)^{0.3}$$

ET_O was calculated by Penman-Monteith formula (Allen *et al.* 1998):

$$ET_o = \frac{0.408\Delta (R_n - G) + \gamma \dfrac{900 U_2 (e_s - e_a)}{T+273}}{\Delta + \gamma (1+0.34u_2)}$$

Where: ET0 is the referenced crop evapotranspiration (mm day^{-1}), Rn is the surface net radiation [$MJm^{-2}\ day^{-1}$], G soil heat flux density [$M\ J\ m^{-2}\ day^{-1}$], T mean daily air temperature at 2 m height [^0C], U_2 wind speed at 2 m height [ms^{-1}], e_s saturation vapor pressure [KP_a], e_a actual vapor pressure [KP_a], $e_s - e_a$ saturation vapor pressure deficit [KP_a], Δ slope vapor pressure curve [$K\ P_a{}^oC^{-1}$], γ psychometric constant [$K\ P_a{}^oC^{-1}$].

Table 3. Main characteristics of the applied K-humate.

*EC (dSm^{-1})	*pH	Total C (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total K (g kg^{-1})	Total Mg (g kg^{-1})	Total Ca (g kg^{-1})
8.34	7.29	486.0	38.9	3.42	96.1	10.50	5.70

EC at (solution 1: 5), pH at (solution 1: 5)

Table 4. Maize evapotranspiration (ET$_c$)

Treatments	May*		June		July		August**		Total mm	Total m3 /ha
	Daily mm	Monthly mm	Daily mm	Monthly mm	Daily mm	Monthly mm	Daily mm	Monthly mm		
100% ET$_C$	4.03	125	6.67	200.2	10.06	312	4.84	150.1	787	7870
80% ET$_C$	3.22	99.82	5.34	160.2	8.05	249.5	3.87	120.03	629.6	6296
60% ET$_C$	2.42	75.02	4	120	6.04	187.12	2.9	90	472.2	4722

* Sowing date at first of May   ** Harvest date at 31 of August

Irrigation formed 15 mm at initial stage as recommended maize soil water depletion. Then, irrigation formed 22 mm at next stages. This range of soil water depletion represents between 50 % of total available soil water in the root depth.

Crop managements

Zea maize (Zea mays *L.* hybrids single cross 310) grain were sown in the first day of May 2019 and 2020 under sprinkler irrigation system. One grain/hill were manual sowing with 25 cm apart between hills. Four foliar spraying times of K-humate, K-silicate and gibberellic acid were applied at 30, 45, 60 and 75 days from sowing. Nitrogen fertilizer was added as ammonium sulfate (200 g N kg^{-1}) at rate of 285.6 Kg N ha^{-1}.Phosphorus was applied in the form of super phosphate (0.068 kg P kg^{-1}) at rate of 16.09 P ha^{-1}during the final stage of land preparation for planting and potassium was added in the form of potassium sulphate (0.398 kg K kg^{-1})at rate of 95 kg K ha^{-1} in two equal doses after sowing and flowering.

The experimental unit area was 10.5 m^2 with dimensions 3 x 3.5 m, each plot included 4 ridges (3.5 m in length and 30 cm in width).

Soil and plant analyses

After harvesting disturbed and undisturbed soil samples were collected from surface layer (0-30 cm) to determine physical and chemical soil properties according to Klute (1986). Total carbonate content (%) was determined volumetrically using Collin's calcimeter (Page *et al.,* 1982). Organic matter was determined by the chromic acid method of Walkely and Black (Jackson 1973). Available N, total N were estimated by distillation using Kjeldahl apparatus and K indicator by the flame photometer

apparatus. Available phosphorus extracted by (0.5 N) NaHCO$_3$ solution as described by Olsen *et al.* (1954) by using of molybdate and stannous chloride according Page *et al.* (1982).

Harvesting was carried out after about 140 days after planting. The plants were air dried. Samples of plants at harvesting as well as grain and straw were oven dried at 72^{0}C for 48 h and digested by using sulfuric(H$_2$SO$_4$) and per chloric acid (HClO$_4$) - mixed (1:1) Page *et al.,* 1982.

RESULTS AND DISCUSSIONS
Yield of maize plant

Data presented in Tables 5 and 6 showed that the main effect of water deficit, K-sources and gibberellic acid application and their interactions on yield characters of maize plant. Results clear that all yield characters of maize plant were affected significantly by the different levels of irrigation. The results indicated the superiority of the yield characters at 100 % from ETc of maize plant, this treatment gave higher average of grain and straw yields as compared with treatments of 80 % and 60 % of ETc these results are in agreement with those obtained by Al-Shaheen and Ismael, (2016) and Al-Shaheen and Awany, (2018).

Regarding to the individual effect of K-source as a foliar application, data in the same Tables (5 and 6) indicated that the treatments of K$_{silicate}$ and K$_{humate}$ had a significant effect on grain and straw yields, harvest index, crop index and shelling yield of maize plant compare with the unfertilized treatment (K$_0$). The highest mean value of all yield character were obtained when the plants were sprayed with K-humate at a rate of 4000 mg L^{-1} compared with k-silicate at a rate of 150 mg L^{-1} and also there was a significant effect between them. This

trend attributed to that the K-humate contains many elements which improve the plant growth and yield. These results are in accordance with this obtained by (El-Bassiony *et al.,* 2010; Ahmed *et al.,* 2017; and El-Edfawy 2017).

With respect to the effect of gibberellic acid on yield character of maize plant, the results of statistical analysis showed superiority of the treatmentGA$_1$ with a significant difference from the other levels of gibberellic acid spraying. The lowest values in all yield characters were recorded when did not spray by gibberellic acid (control treatment). Also there were a significant difference between the two levels of gibberellic acid (GA$_1$ and GA$_2$). These results are consistent with Al-Shaheen and Awany (2018) and Qasim *et al.* (2018).

Table 5. Effect of water deficit, K source and foliar application of gibberellic acid on grain and straw yield of maize plant (average of two seasons).

Irrigation	K source	Gibberelic acid							
		GA$_0$	GA$_1$	GA$_2$	Means	GA$_0$	GA$_1$	GA$_2$	Means
		Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
I$_1$	K$_0$	2061.00	3120.00	3019.42	2733.47	2147.67	2437.67	2732.67	2439.34
	K$_{silicate}$	2277.33	6543.33	5558.00	4792.89	2652.50	7994.67	5836.67	5494.61
	K$_{humate}$	2374.00	7341.67	7396.33	5704.00	2673.33	8991.90	7390.00	6351.74
Means		2237.44	5668.33	5324.58	4410.12	2491.17	6474.74	5319.78	4761.90
I$_2$	K$_0$	2014.00	2620.67	2081.33	2238.67	2703.00	2880.00	2857.33	2813.44
	K$_{silicate}$	2345.33	6550.33	5569.00	4821.56	2705.67	5546.67	5974.33	4742.22
	K$_{humate}$	2391.00	7334.67	7350.67	5692.11	2696.67	7097.33	7410.33	5734.78
Means		2250.11	5501.89	5000.33	4250.78	2701.78	5174.67	5414.00	4430.15
I$_3$	K$_0$	1404.33	2516.67	2520.00	2147.00	1310.00	2892.00	2838.33	2346.78
	K$_{silicate}$	1375.67	4043.33	4107.00	3175.33	1663.67	6565.67	4200.67	4143.34
	K$_{humate}$	1483.33	4055.00	4020.00	3186.11	1703.33	8165.00	4093.00	4653.78
Means		1421.11	3538.33	3549.00	2836.15	1559.00	5874.22	3710.67	3714.63
Grand mean		1969.55	4902.85	4624.64	3065.86	2250.65	5841.21	4814.81	4170.58
Means of Ksource									
	K$_0$	1826.44	2752.45	2540.25	2373.05	2053.56	2736.56	2809.44	2533.19
	K$_{silicate}$	1999.44	5712.33	5078.00	4263.26	2340.61	6702.33	5337.22	4793.39
	K$_{humate}$	2082.78	6243.78	6255.67	4860.74	2357.78	8084.74	6297.78	5580.10
LSD0.05		I=312.34 Ks=184.11 GA=157.16 IxKs=272.21 IxGA=296.83 GAxKs=283.52 IxKsXGA=856.47				I=ns Ks=329.21 GA=292.24 IxKs=506.17 IxGA=530.76 GaxKs=506.17 IxKsXGA=872.76			

I$_1$, I$_2$ and I$_3$:irrigation at 1.0, 0.8 and 0.6 of (ET$_c$), K$_0$:without application, K-humate at rate of 4 g L^{-1}, K-silicate at rate of 150 ppm Si, G$_0$, G$_1$andG$_2$: gibberellic acid at 0,100 and 150 ppm. ns: non-significant at the 5% levels of probability at L.S.D test.

Table 6. Effect of water deficit, K source and foliar application of gibberellic acid on harvest index, crop index and shelling yieldof maize plant (average of two seasons).

Irrigation	K source	Gibberelic acid											
		GA0	GA1	GA2	Means	GA0	GA1	GA2	Means	GA0	GA1	GA2	Means
		Harvest index (%)				Crop index (%)				Sheling yield			
I1	K0	34.04	24.13	19.58	25.92	84.69	90.03	87.51	87.41	75.67	75.33	77.33	76.11
	Ksilicate	20.77	79.18	37.75	45.90	90.04	92.86	93.01	91.97	79.67	85.33	76.33	80.44
	Khumate	23.98	88.88	85.64	66.17	90.94	94.74	95.17	93.62	73.00	86.33	81.33	80.22
Means		26.26	64.06	47.66	45.99	88.56	92.54	91.90	91.00	76.11	82.33	78.33	78.93
I2	K0	25.49	28.81	20.34	24.88	74.07	87.71	87.33	83.04	73.67	73.33	72.00	73.00
	Ksilicate	26.03	71.04	38.38	45.15	85.60	95.16	93.05	91.27	77.33	85.00	76.33	79.56
	Khumate	24.74	80.16	53.91	52.94	88.16	96.57	83.33	89.35	74.67	86.67	81.33	80.89
Means		25.42	60.00	37.54	40.99	82.61	93.15	87.90	87.89	75.22	81.67	76.56	77.81
I3	K0	18.11	28.93	18.39	21.81	77.34	86.98	80.17	81.50	74.67	72.73	74.00	73.80
	Ksilicate	16.65	65.67	36.56	39.62	83.28	93.57	89.62	88.82	75.33	83.23	75.67	78.08
	Khumate	21.24	81.66	47.94	50.28	83.92	94.98	92.00	90.30	75.33	86.15	79.67	80.38
Means		18.67	58.75	34.30	37.24	81.51	91.84	87.26	86.87	75.11	80.70	76.44	77.42
Grand mean		23.45	60.94	39.83	42.38	84.23	92.51	89.02	88.66	75.48	81.57	77.11	78.63
Means of Ksource													
	K0	25.88	27.29	19.44	24.20	78.70	88.24	85.00	83.98	74.67	73.80	74.44	74.30
	Ksilicate	21.15	71.96	37.56	43.56	86.31	93.86	91.89	90.69	77.44	84.52	76.11	79.36
	Khumate	23.32	83.57	62.50	56.46	87.68	95.43	90.17	91.09	74.33	86.38	80.78	80.50
LSD0.05		I=ns Ks=3.29 GA=2.92 IxKs=5.06 IxGA=5.31 GaxKs=8.99 IxKsXGA=8.77				I=ns Ks=2.84 GA=3.45 IxKs=ns IxGA=ns GaxKs=ns IxKsXGA=ns				I=ns Ks=2.84 GA=3.45 IxKs=ns IxGA=ns GaxKs=ns IxKsXGA=ns			

I_1, I_2 and I_3:irrigation at 1.0, 0.8 and 0.6 of (ET_c), K_0:without application, K-humate at rate of 4 g L^{-1}, K-silicate at rate of 150 ppm Si, G_0, G_1andG_2: gibberellic acid at 0,100 and 150 ppm. ns: non-significant at the 5% levels of probability at L.S.D test.

Concerning to double interaction effect between the irrigation levels and foliar spraying of gibberellic acid levels, data indicated that the treatment of I_1*GA_1 gave the highest mean values in all yield characters. These increase were 60.53, 61.52, 59.00, 4.30 and 7.55 % for grain, straw, harvest index, crop index and shelling yield, respectively compared with treatment of I_1*GA_0. Results clarified that gibberellic acid encourage the vegetative growth and increase the efficiency of the plant, increased leaf area and seed weight thereby increasing the yield. These results are in the same line with those obtained by Al-Shaheen and Awany (2018) and (Mohamed and Ghada 2018).

Also the positive trend was recorded in the interaction effect between irrigation levels and K-sources (K-silicate and K-humate) in all yield characters of maize plant. In addition, the treatment of (I_1* K_{humate}) gave significant increase in all cases followed by (I_2* K_{humate}) and there were significant difference between (I_2* K_{humate}) and (I_2* $K_{silicate}$). It may be due to humic acid play an important role in reduction of transpiration and resistance to drought stress by plant. These results are in harmony with those obtained by Ahmed *et al.* (2017), Al-Shaheen and Awany, (2018) and Qasem *et al.* (2018)

who concluded that humic acid and potassium silicate as a foliar application was good practice to increase crop production under sandy soil condition.

As regard to interaction effect between different levels of irrigation, K-sources and gibberellic acid, data in Tables 5 and 6 showed that the highest mean values of yield characters were recorded at treatment of (I_1xK_{humate} x GA_1) when compared with the other treatments. It worthy to noted that the treatment of (I_2xK_{humate} x GA_1) in most cases gave a positive increase with non-significant difference as compared with treatment of (I_1xK_{humate} x GA_1). These results are consistent with Qasem *et al.* (2018) and Al-Shaheen and Ismael (2016) who reported that gibberellic acid and K-

sources is an innovative and promising way to reduce the impact of water deficit on pant growth and crop production.

Nutrient uptake

Results in Tables 7 and 8 showed the main effect of irrigation levels from ETc of maize plant on NPK uptake by both grain and straw. The obtained results clearly indicated a significant influence to full irrigation (100 % ETc). It was recorded the highest values in NPK uptake by both grain and straw followed by the treatment of 80% ETc while, the lower one has appeared at I_3 (60 % ETc) with a significant decrease from other irrigation treatments.

Table 7. Effect of water deficit, K source and foliar application of gibberellic acid on NPK uptake (kg /ha) by grain of maize plant (average of two seasons).

Irrigation	K source	GA_0	GA_1	GA_2	Means	GA_0	GA_1	GA_2	Means	GA_0	GA_1	GA_2	Means
		Gibberelic acid
		\multicolumn{4}{} N	\multicolumn{4}{} P	\multicolumn{4}{} K
I_1	K_0	16.34	20.99	15.90	17.75	6.56	10.60	6.69	7.95	11.80	15.36	9.98	12.38
	$K_{silicate}$	23.36	36.24	33.52	31.04	8.64	10.72	9.20	9.52	15.68	24.96	23.04	21.23
	K_{humate}	27.60	51.92	38.32	39.28	10.10	19.36	12.24	13.90	19.20	36.00	24.56	26.59
\multicolumn{2}{} Means	22.43	36.38	29.25	29.36	8.43	13.56	9.38	10.46	15.56	25.44	19.19	20.06
I_2	K_0	34.40	42.08	36.96	37.81	9.57	14.18	31.72	18.49	22.56	29.60	24.64	25.60
	$K_{silicate}$	42.24	73.04	47.92	54.40	15.36	26.08	20.64	20.69	27.20	54.16	27.44	36.27
	K_{humate}	45.36	83.92	74.80	68.03	20.51	29.12	33.52	27.72	24.48	59.04	52.80	45.44
\multicolumn{2}{} Means	40.67	66.35	53.23	53.41	15.15	23.13	28.63	22.30	24.75	47.60	34.96	35.77
I_3	K_0	40.48	37.12	50.80	58.61	15.68	13.28	24.24	23.57	22.64	22.80	27.84	24.43
	$K_{silicate}$	44.24	70.08	43.52	52.61	19.44	32.48	18.88	24.53	24.16	46.16	22.08	30.80
	K_{humate}	38.56	78.88	60.88	59.44	13.36	33.36	28.64	23.47	21.92	55.92	46.88	41.57
\multicolumn{2}{} Means	41.09	62.03	51.73	56.89	16.16	26.37	23.92	23.86	22.91	41.63	32.27	32.27
\multicolumn{2}{} Grand mean	34.73	54.92	44.74	56.31	13.25	21.02	20.64	23.95	21.07	38.22	28.81	34.88
Means of Ksource
	K_0	30.41	33.40	34.55	32.79	10.60	12.69	20.88	14.72	19.00	22.59	20.82	20.80
	$K_{silicate}$	36.61	59.79	41.65	46.02	14.48	23.09	16.24	17.94	22.35	41.76	24.19	29.43
	K_{humate}	37.17	71.57	58.00	55.58	14.66	27.28	24.80	22.25	21.87	50.32	41.41	37.87
\multicolumn{2}{} LSD0.05	\multicolumn{4}{} I=1.73 Ks=1.24 GA=0.95 IxKs=1.65 IxGA=1.99 GaxKs=2.18 IxKsXGA=2.86	\multicolumn{4}{} I= 2.43 Ks=0.98 GA=1.49 IxKs=2.59 IxGA=1.58 GaxKs=3.07 IxKsXGA=4.48	\multicolumn{4}{} I=2.04 Ks=1.07 GA=1.11 IxKs=1.92 IxGA=1.73 GaxKs=2.58 IxKsXGA=3.33

I_1, I_2 and I_3: irrigation at 1.0, 0.8 and 0.6 of (ETc), K_0: without application, K-humate at rate of 4 g L^{-1}, K-silicate at rate of 150 ppm Si, G_0, G_1 and G_2: gibberellic acid at 0,100 and 150 ppm. ns: non-significant at the 5% levels of probability at L.S.D test.

Table 8. Effect of water deficit, K source and foliar application of gibberellic acid on NPK Uptake (kg/ha) by straw of maize plant (average of two seasons).

Irrigation	K source	Gibberellic acid											
		GA$_0$	GA$_1$	GA$_2$	Means	GA$_0$	GA$_1$	GA$_2$	Means	GA$_0$	GA$_1$	GA$_2$	Means
		N				P				K			
I$_1$	K$_0$	22.88	27.44	20.18	23.50	18.94	22.57	15.62	19.05	18.94	22.57	15.62	19.05
	S$_{ilicate}$	22.88	35.76	26.00	28.21	18.14	29.04	20.83	22.67	18.14	29.04	20.83	22.67
	K$_{humate}$	26.72	43.04	41.20	36.99	21.14	32.64	30.64	28.14	21.14	32.64	30.64	28.14
Means		24.16	35.41	29.13	29.57	19.41	28.08	22.37	23.28	19.41	28.08	22.37	23.28
I$_2$	K$_0$	25.52	22.24	25.92	24.56	11.68	9.82	13.46	11.66	20.58	16.50	20.37	19.15
	S$_{ilicate}$	23.36	35.36	24.16	27.63	11.04	17.25	10.28	12.86	19.34	27.46	18.29	21.69
	K$_{humate}$	21.92	43.28	36.16	33.79	7.74	18.98	14.38	13.70	14.88	29.47	26.64	23.66
Means		23.60	33.63	28.75	28.66	10.15	15.35	12.71	12.74	18.26	24.48	21.77	21.50
I$_3$	K$_0$	8.96	10.88	9.12	9.65	1.19	3.92	3.44	2.85	5.50	8.18	7.28	6.98
	S$_{ilicate}$	12.98	20.69	17.80	17.16	5.96	8.87	7.59	7.47	9.84	16.98	15.12	13.98
	K$_{humate}$	12.69	32.68	25.92	23.76	5.74	15.98	12.28	11.33	10.18	26.64	21.29	19.37
Means		11.54	21.42	17.61	16.86	4.30	9.59	7.77	7.22	8.50	17.27	14.56	13.44
Grand mean		19.77	30.15	25.16	19.26	11.29	17.68	14.28	14.41	15.39	23.28	19.56	19.41
Means of K-source													
	K$_0$	19.12	20.19	18.41	19.24	10.61	12.10	10.84	11.18	15.01	15.75	14.42	15.06
	S$_{ilicate}$	19.74	30.60	22.65	24.33	11.71	18.39	12.90	14.33	15.77	24.49	18.08	19.45
	K$_{humate}$	20.44	39.67	34.43	31.51	11.54	22.54	19.10	17.73	15.40	29.58	26.19	23.72
LSD0.05		I= 2.20 Ks= 1.72 GA= 1.186 IxKs=ns IxGA=ns GAxKs= 2.78 IxKsXGA= 3.56				I= 1.39 Ks= 1.13 GA= 0.82 IxKs= 1.42 IxGA=ns GAxKs= 1.75 IxKsXGA= 2.47				I= 1.96 Ks= 1.20 GA= 1.011 IxKs= 1.75 IxGA= 1.94 GAxKs= 2.48 IxKsXGA= 3.03			

I$_1$, I$_2$ and I$_3$: irrigation at 1.0, 0.8 and 0.6 of (ET$_c$), K$_0$: without application, K-humate at rate of 4 g L^{-1}, K-silicate at rate of 150 ppm Si, G$_0$, G$_1$ and G$_2$: gibberellic acid at 0,100 and 150 ppm. ns: non-significant at the 5% levels of probability at L.S.D test.

Also data in the Tables (7 and 8) showed that the foliar spraying of the different levels of gibberellic acid gave significant effect on NPK uptake in both grain and straw of maize plant particularly at rate of 100 mg L^{-1} (GA$_1$) compared with other treatments.

Regarding to the effect of K-source application on NPK uptake (kg/ha) by grain and straw for maize plant, data indicate that NPK uptake were affected in increasing trend by spraying K-silicate and K-humate compared with the control. Moreover, using treatment of K-humate in all cases gave higher values than K-silicate with a significant difference

between them. These results in harmony with those obtained by Ahmed *et al.* (2017) and El-Edfawy (2017).

Concerning to the interaction effect between different levels of irrigation and gibberellic acid on NPK uptake, the obtained results showed that application of foliar gibberellic acid at any rate with different level of irrigation gave higher NPK uptake in both grain and straw of maize plant compared with GA$_0$. The highest values of NPK uptake were obtained by treatment of I$_1$* GA$_1$ and there were a significant difference as compared with other treatments.

As regard to interaction effect between irrigation level and K-source, results in the same tables clearly showed a positive and significant effect on NPK uptake by grain and straw of maize plant. It worthy to noted that, the treatments of $I_2 *K_{silicate}$ and I_2*K_{humate} gave the higher mean values in NPK uptake in both grain and straw and there were a significant difference between them. In addition spraying by K-humate gave values better than spraying by K-silicate at any level of irrigation.

Regarding to the interaction effect between irrigation rates, K-source and gibberellic acid on NPK uptake (kg/ha) the results indicated that, the treatment of $I_1*K_{humate} * GA_1$ gave the highest values of NPK uptake by both grain and straw of maize plant. Similar results were obtained by Al-Shaheen and Ismael (2016); Ahmed *et al.* (2017); El-Edfawy (2017) and Qasem *et al.* (2018).

Water use efficiency:

Water use efficiency (WUE) in kg/m³ was calculated for the deferent treatments, using the following form formulae of Vites (1965):

$$W.U.E = \frac{Seed\ yield\ (kg\ /\ fed)}{Actual\ evapotranspiration\ (m^3/fed)}$$

Fig.1. represent the obtained results of water use efficiency (W.U.E.) for maize crop expressed as kg grain yield per one cubic meter of water consumed irrigation water, which was affected by irrigation regime and K-silicate or K- humate companied 9as well as applying various rates of gibberellic acid during 2019 and 2020 summer seasons. The results go hand in hand with those obtained for maize grain yield. Similar results were found by El-Hendawy *et al.* (2008). However, it should be stated that the

highest W.U.E. value, 1.38 was obtained for 80% ET_c and K- humate at 50 mg L^{-1} concentration of gibberellic acid. This W.U.E. value is agreement with that reported by Goring *et al.* (1998) and Miceli *et al.* (2019) who stated that the increase of stomatal conductance due to gibberellic acid has been related to the higher accumulation of carbohydrates and potassium in guard cells of treated plants, that may influence speed and degree of stomata opening Even if the higher stomatal conductance of treated plants determines an increase of transpiration rates and water consumption, it also promotes gas exchange and photosynthetic CO_2 assimilation, thus increasing dry matter accumulation and WUE.

Soil content of available NPK

Results in Table 9 showed that the main effect of irrigation levels, K-silicate, K-humate and gibberellic acid on soil available N, P and K. The obtained results showed that the soil available N was significantly increased with the foliar spraying of the K-silicate, K-humate and the different levels of gibberellic acid, but not significantly affected by irrigation levels. The increasing percentages in soil available N due to K-silicate and K-humate application were 4.24 and 7.70 % respectively as compared with K_0 whereas, treatments of G_1 and G_2 recorded 6.71 and 3.80, respectively as compared with G_0. This irrigation requirement with K-humate and K-silicate caused positive effect on nitrogen movement and it's has been positive effect on moisture, nutrient contents and as results available nitrogen. These results are in the same line with those obtained by Recep (2004) and Yalmz (2007).
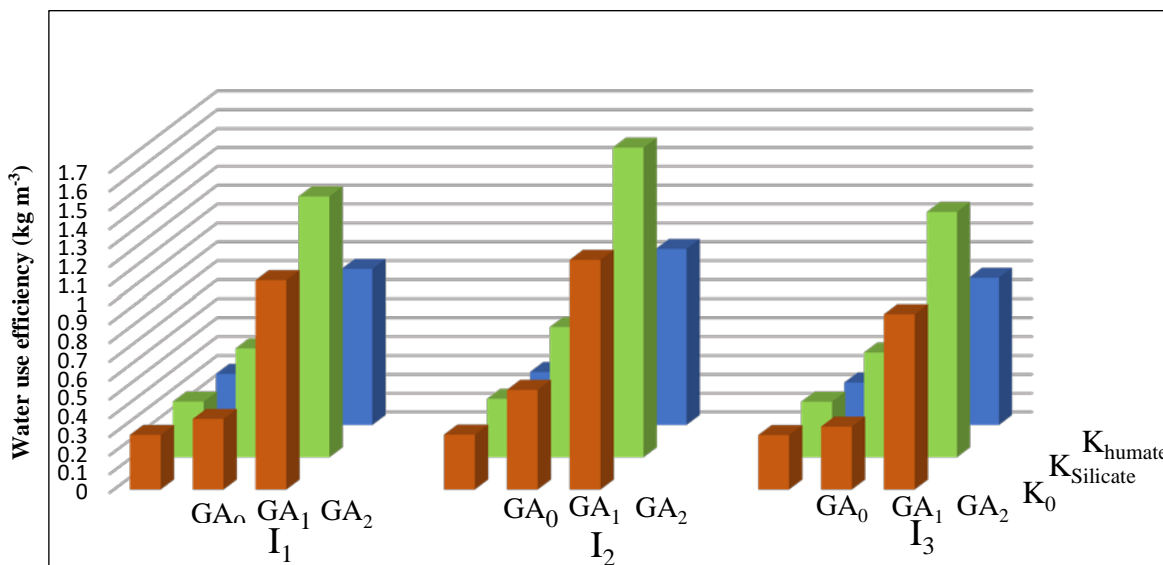
Fig. 1. Water use efficiency as affected by K sources, foliar application of gibberellic acid andirrigation levels.

Table 9. Effect of water deficit, K source and foliar application of gibberellic acid on available NPK (mg kg^{-1}) in soil (average of two seasons).

Irrigation	K source	Gibberelic acid											
		GA$_0$	GA$_1$	GA$_2$	Means	GA$_0$	GA$_1$	GA$_2$	Means	GA$_0$	GA$_1$	GA$_2$	Means
		N				P				K			
I$_1$	K$_0$	26.70	30.03	23.10	26.61	5.30	8.41	5.32	6.34	54.00	57.00	50.07	53.69
	K$_{silicate}$	30.47	26.40	28.97	28.61	8.89	6.13	8.20	7.74	54.00	56.00	50.07	53.36
	K$_{humate}$	24.63	27.70	32.10	28.14	5.49	6.83	9.84	7.39	54.50	57.67	49.97	54.04
Means		27.27	28.04	28.06	27.79	6.56	7.13	7.79	7.16	54.17	56.89	50.03	53.70
I$_2$	K$_0$	28.07	27.70	26.30	27.36	7.70	5.36	5.41	6.16	48.07	50.93	46.10	48.37
	K$_{silicate}$	24.47	31.13	23.97	26.52	5.25	8.96	6.40	6.87	53.10	50.13	56.13	53.12
	K$_{humate}$	25.67	31.33	27.17	28.06	6.07	8.21	5.52	6.60	53.40	50.10	61.77	55.09
Means		26.07	30.06	25.81	27.31	6.34	7.51	5.78	6.54	51.52	50.39	54.67	52.19
I$_3$	K$_0$	22.57	23.07	26.13	23.92	3.23	4.52	5.10	4.28	43.17	44.03	46.07	44.42
	K$_{silicate}$	22.00	29.07	27.07	26.04	5.53	6.47	5.30	5.77	49.07	44.00	53.03	48.70
	K$_{humate}$	30.17	24.07	28.80	27.68	8.21	5.43	6.57	6.74	51.53	51.00	48.10	50.21
Means		24.91	25.40	27.33	25.88	5.66	5.47	5.66	5.60	47.92	46.34	49.07	47.78
Grand mean		26.08	27.83	27.07	26.99	6.19	6.70	6.41	6.43	51.20	51.21	51.26	51.22
Means of Ksource													
	K$_0$	25.78	26.93	25.18	25.96	5.41	6.10	5.28	5.60	48.41	50.66	47.41	48.83
	K$_{silicate}$	25.64	28.87	26.67	27.06	6.56	7.19	6.63	6.79	52.06	50.04	53.08	51.73
	K$_{humate}$	26.82	27.70	29.36	27.96	6.59	6.83	7.31	6.91	53.14	52.92	53.28	53.11
LSD0.05		I=ns Ks=1.18 GA=0.85 IxKs=ns IxGA=1.04 GAxKs=2.01 IxKsXGA=1.52				I=ns Ks=ns GA=ns IxKs=ns IxGA=ns GaxKs= ns IxKsXGA=ns				I=1.24 Ks=1.47 GA=ns IxKs=2.42 IxGA=2.37 GaxKs= ns IxKsXGA=ns			

I$_1$, I$_2$ and I$_3$: irrigation at 1.0, 0.8 and 0.6 of (ET$_c$), K$_0$: without application, K-humate at rate of 4 g L^{-1}, K-silicate at rate of 150 ppm Si, G$_0$, G$_1$ and G$_2$: gibberellic acid at 0,100 and 150 ppm. ns: non-significant at the 5% levels of probability at L.S.D test.

Data in the same table also indicated that soil available P was not significantly affected by different treatments while, soil available K was significantly affected by irrigation level, K-silicate and K-humate but not significantly affected by the different levels of gibberellic acid. K-humate and K-silicate increased availability of P, but increased soil pH which negative effect on increased P availability may be caused the soil available P was not significant. These results are in the same line with those obtained by Zhongqi *et al.* (2011) and Dongfeng *et al.* (2016). Potassium affected by K-silicate and K-humate which reduce the negative effects of water deficit and increased K movements but K not response by gibberellic acid. These results are agreement with with that reported by Camargo *et al.* (2014) and Ismail *et al.* (2017).

As regard to interaction effect the data clearly showed a positive effect of the treatments of I_2*K_{humate} * GA_1 compared with the other treatments. These results are in harmony with those obtained by Camargo *et al.* (2014), Al-Shaheen and Ismael (2016), Ismail *et al.* (2017), El-Edfawy (2017) and Qasem *et al.* (2018).

From these results it could be concluded that using foliar application of gibberellic acid at 100 mg L^{-1} and K-humate at rate of 400 mg L^{-1} can reduce 15 % from total amount of water irrigation required to maize plant in sandy soil.

Conclusion

From the previous discussion it can be concluded that application of K-humate at rate of 4 g L^{-1} in combination with gibberellic acid at 100 mg L^{-1} under 80 % from ETc significantly increased grain yield, yield parameter and NPK uptake by maize plant which increased plant resistant to drought stress. It can reduce 20 % from total amount of water irrigation required to maize plant in sandy soil. Soil available P was not significantly affected by different treatments while, soil available K was significantly affected by irrigation level, K-silicate and K-humate but not significantly affected by the different levels of gibberellic acid.

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تأثير مصادر البوتاسيوم مع حمض الجبريلين على انتاجية نبات الذرة الشامية تحت الإجهاد المائى فى الأراضى الرملية

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الملخص العربى

أقيمت تجربة حقلية فى موسمين متعاقبين للموسم الصيفى ٢٠١٩ / ٢٠٢٠ تحت ظروف الأراضى الرملية بمحطة بحوث الإسماعيلية – مركز البحوث الزراعية . يهدف البحث لدراسة تأثير إضافة مصادر البوتاسيوم وهى سليكات البوتاسيوم وهيومات البوتاسيوم مع حمض الجيبيرللك تحت معدلات رى مختلفة على المحصول وخواص المحصول و NPK الممتص لنبات الذرة الشامية. صممت التجربة بنظام القطع المنشقة مرتين وكانت معاملات التجربة كالأتى: ١– ثلاثة معدلات رى مختلفة ١ (I_1)و٨ ،٠ (I_2) و ٠،٦(I_3) % من معدل البخر – نتح لنبات الذرة الشاميةفى القطع الرئيسية ٢– ثلاثة مصادر للبوتاسيوم وهى بدون إضافة و هيومات البوتاسيوم بتركيز ٤ جم / لتر وسليكات البوتاسوم بتركيز ١٥٠ جزء فى المليون فى القطع التحت رئيسية ٣– ثلاثة معدلات لحمض الحيبريلك وهى بدون إضافة و١٠٠ و ١٥٠ جزء فى المليون فى القطع التحت تحت رئيسية. وكانت النتائج المتحصل عليها كالأتى: اعلى قيم لمحصول الحبوب ومحصول القش و NPK الممتص لنبات الذرة الشامية كانت فى المعاملة هيومات البوتاسيوم مع حمض الجبريلك عند ١٠٠ جزء فى المليون تحت الرى عند ٠،٨ من معدل البخر نتح لنبات الذرة الشامية . وكان هناك تأثيرا معنويا للرش بواسطة هيومات البوتاسيوم وسليكات البوتاسيوم و المعدلات المختلفة لحمض الجبريلك على زيادة النيتروجين الميسر بالتربة ولم يتأثر بمختلف معدلات الرى. لم يتأثر الفوسفور الميسر فى التربة بمعاملات التجربة المختلفة بينما كان هناك تأثيرا معنويا بالرش بواسطة هيومات البوتاسيوم وسليكات البوتاسيوم ومعدلات الرى المختلفة على البوتاسيوم الميسر بالتربة بينما لم يتأثر بإضافة المعدلات المختلفة لحمض الجبريلين.