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(Original Article)

Impacts of Successive Accumulation of Salinity, Drought and Potassium on Maize (*Zea Mays* L.) Germination and Growth

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Abstract

A greenhouse experiment of maize (Pioneer P444) was conducted in Bader region, Behera governorate, Egypt to investigate the successive salinity application, irrigation level and potassium salt effects on maize germination and growth. Three levels of irrigation were included (80, 60 and 40 % of the potential evapotranspiration (ET)) as a main factor and four potassium salts (Control, K_2SO_4, KNO_3 and Salwax) as a sub factor with three replications. Moderately salinity water (≈4 dS/m) was used. Germination of seeds and growth parameters of maize were monitored. A second-degree polynomial was implemented to describe some growth parameters. The results showed that the potassium salts did not affect the seed germination in comparison to the control. The polynomial well described the plant height and leaf number as a function of growth time with an approximated R^2 of 0.99. The plant height and leaf number increased as the irrigation level increased but the stem diameter behaved differently. The stem height and leaf growth rates decreased with time for all investigated treatments. The irrigation levels at 80 and 60 % ET quickly increased the soil salinity compared to that irrigated at 40 % ET. So, the plants that received irrigation water at 60 or 80 % ET levels were hampered after 56 days of growth. However, the plants irrigated at the 40 % ET level continued in growing till 108 days (harvesting time). The KNO_3 was the best salt among other potassium salts types in boosting the maize growth in most of studied growth characters. Accordingly, the total water potential (matrtic and osmotic) is considered as a good criterion for defining drought maize tolerance.

Keywords: *Drought, Salinity, Irrigation, Maize, Potassium.*

Introduction

Drought and salinity are among the most important environmental factors that hamper the agricultural productivity worldwide. Abiotic stresses (e.g., drought, salinity, flood, storm, and extreme temperatures) cause enormous losses in the agricultural production (Ma *et al*., 2020; Jain *et al*., 2019). Cakir (2004) reported a growth rates reduction, a prolonged the vegetative growth stage, a roots

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redirection, and carbohydrate distribution alteration in maize because of the drought stress. Short-duration water deficits induced a 28–32% reduction in the dry weight during the rapid vegetative growth stage and 66–93% losses in the dry weight during the teaseling and ear formation stages, respectively. Similarly, Li *et al.* (2018) reported that the kernel weight was reduced by 12 and 11% when there were water deficits during V_{9-12} and V_{13-T}, respectively. Jain *et al.* (2019) reported that the plants such as maize display a range of mechanisms to withstand drought stress, such as deep root systems for enhanced water uptake, and smaller and succulent leaves to reduce the transpiration loss.

Abd El-Wahed and Ali (2013) reported that the highest values of grain yield were obtained from full irrigation requirement treatment while the lowest ones were observed in 70 % of full irrigation requirement. Likewise, Dutta *et al.* (2015) showed that a cob yield of baby maize (1310 kg/ha) was obtained with irrigation at water/cumulative pan evaporation of 1.0 and the maximum water use efficiency (WUE) of 3.91 kg ha/mm was recorded with net depth of irrigation water (IW) to cumulative pan evaporation of 0.6. Karyoti *et al.* (2018) reported that for plots receiving moderate or full irrigation, biomass, and seed yield and leaf area index (LAI) were much higher in comparison to stressed plants (33% ET_m). Rudnick and Irmak (2013) found that the grain yield was linearly related to ETa. Dong-liang *et al.* (2020) showed that the irrigation at 60–65% and 75–80% of field capacity significantly increased all growth parameters compared to that at 45–50% field capacity.

Farooq *et al.* (2015) stated that maize is moderately sensitive to salt stress; therefore, soil salinity is a serious threat to its production worldwide. Besides all their negative effects on plant performance to some extent, drought or salinity may result in some positive effects on plants (Raza *et al.*, 2019). For instance, Hatzig *et al.* (2018) found that the drought stress showed a positive transgenerational impact on seedling vigor of *Brassica napus*. Salinity at certain concentrations may also cause an increase in clonal/sexual reproduction, and thus improving plant fecundity (Van Zandt *et al.*, 2003). This effect strongly depends on the genotypes/cultivar and plant developmental stage.

Rasul (2010)'s results indicated that increasing the application of KCl fertilizer caused an increase in the dry matter yield of corn plants by an amount of 71.17% for Kanypanka location. Adnan (2020) concluded that potassium (K) is considered as one of the most ambient macronutrients required for proper growth, development, and sustainable crop yield. Most of the scientists reported that the application of 60 kg K/ha is the best dose to obtain a higher yield of maize. Pettigrew (2008) reported that potassium deficiency can lead to a reduction in both the number of leaves produced and the size of individual leaves. The production of less photosynthetic assimilates and reduced assimilate transport out of the leaves to the developing fruit greatly contributes to the negative consequences that deficiencies of potassium have on yield and quality production. Potassium helps crops to use water more effectively. Jain *et al.* (2019) found that potassium ions help in osmotic adjustment; silicon increases root endodermal silicification and improves the cell water balance. Adnan (2020) observed that application of potassium under the drought stress significantly enhanced all the studied characters of maize in comparison with control treatment. They observed that increasing potassium application rate, the nutrient uptake, plant growth, and concentration in roots and shoots, respiration rate, net photosynthesis, stomatal conductance, and sub stomatal CO_2 concentration were considerably improved. Potassium also improved the water use efficiency (WUE) of maize and decreased the root: shoot dry weight ratio.

Scheduling of irrigation is used to determine the quantity and time of irrigation that leads to optimize such a crop yield with the higher water use efficiency. The irrigation scheduling depends on several variables such as: type of crop and its growth stage, soil texture, and the weather parameters. Timing of irrigation can be defined using several criteria such the evapotranspiration rate, the soil water depletion, as a percentage of soil available water, as a percentage of water evaporation from free water surface, monitoring plant moisture stress levels, among others. Xu and Singh (1998) evaluated comparatively four equations for calculating evaporation. Of these four equations, the Penman equation, representing the mass transfer method, resulted in monthly evaporation values that agreed most closely with pan evaporation values. The Romanenko equation, representing the humidity method, also compared reasonably well with pan evaporation. The Penman and Romanenko equations reproduced the evaporation rate well among other equations.

The objective of the present work is to investigate the combined effects of cumulative salinity, irrigation levels and potassium salt type on germination and growth of maize (*Zea mays* L.) (Pioneer P4444).

Materials and Methods

A greenhouse experiment was conducted at Badr, territory, Behera province, Egypt in 2021seasons to determine the effect of consecutive salinity, irrigation levels and potassium salt type on growth characteristics and yield components of maize (Pioneer P4444) (*Zea mays* L.). The experiment was laid out as a randomized complete block design in split-plot arrangement with three replications. Irrigation levels were the main treatments (80% potential evapotranspiration (ET), 60% ET and 40% ET). The Romanenko's equation (1998) (it is stated later) was used for determining the ET. Potassium salt types were the sub-treatment (0.0 potassium (control), potassium sulfate (0.05 g/kg soil), potassium nitrate (0.05 g/kg soil) and Salwax (0.02 g/kg of soil). The Salwax includes N, K_2O, CaO, carboxylic acids with 4, 15, 14 and 51.74 %, respectively. These treatments of potassium were applied before sowing maize seed. 25 kg of the air-dry soil (2% gravimetric water content) was packed in a plastic pot (28 ID and 25- cm depth). The average bulk density of a pot soil is 1.59 g/cm^3. Fertilizers (NPK) were mixed in each pot at rates of 0.2, 0.05, and 0.1088 g/kg from mono superphosphate, potassium sulfate, and urea, respectively. The pots were buried to the soil surface in an open.

Experimental Soils

Loamy sandy soil (8, 13 and 79 % for clay, silt and sand, respectively) was selected for the present study. The soil samples were collected from the region of Badr region, Behera Governorate, Egypt (approximately latitude is 30° 42' N and 30° 42' E). The climate of Beheira is typically Mediterranean with dry and hot summers, and cool and wet winters. The mean annual temperature is 20.4° C. Annual precipitation is 102 mm, mainly falling in the months of November through February (Climate-Data.org, 2021). The soil samples were collected at a depth of 0–30 cm, air-dried and sieved through a 2-mm sieve prior to analysis. Sub-samples of the air-dried soil were used for determination of some chemical and physical parameters. The soil used in the present has filed capacity of 6.33% and wilting point of 3.16% gravimetrically. All the chemical properties mentioned later are measured in soil–water extract 1:1. The soil pH and Electrical conductivity (EC) was measured as (Jackson, 1958). Soil organic matter was determined by the modified Walkley-Black method as described by (Nelson and Sommers, 1983). Available K was estimated by 1 N ammonium acetate solution and measured by the flame photometer (Jackson, 1958). Available phosphorus was extracted with 0.5 N $NaHCO_3$ solutions and measured by spectrophotometer (Olsen and Sommers, 1982). Soluble Ca^{+2}, Mg^{+2}, CO_3^{-2}, HCO^{-3}, Cl^- was determined in the soil water extract by titration methods (Jackson, 1958). Soluble Na^+ and K^+ were measured by the flame photometer (Jackson, 1958). Total nitrogen in soil was determined using the micro Kjeldahl method according to Peack and Tracey (1956). Particle-size distribution was determined by hydrometer as described by Gee and Bauder (1986). In plant, Nitrogen content of samples was determined by wet digestion according to Ginsburg method and Kjeldahl distillation and Phosphorus was determined calorimetrically by molybdenum blue, and potassium using flame photometer (Peterburgskii, 1986).The main properties of the soil are shown in Table 1.

Table 1. Initial characterization for the studied soils

Organic matter (%)	Macronutrients (ppm)		Anions (ppm)			Cations (ppm)					EC	EC	pH
	N	P	SO_4^{--}	HCO_3^-	CO_3^{--}	Cl	Ca	Mg	K	Na	ppm	dS/m	
0.70	133	0.9	18	61	0	71	40	24	26	39.9	209.2	0.327	7.46

Seed germination

Germination experiment was conducted to study effect of potassium fertilizes types on maize seeds (pioneer p4444) germination. The seeds were soaked for 24 hrs in water prior to sowing. Farooq *et al.* (2015) reported that seed priming is an effective approach for improving maize germination under salt stress. Five soaked seeds were sown in each pot at 3-cm depth on 17 of July 2021. The soil water content was around the field capacity of soil during germination stage. Shoot emergence was monitored daily for 8 days. The germinated seeds were counted and converted to Final germination percentage (FGB) that was calculated as described by the Association of Official Seed Analysts (AOSA, 1983) as follows:

$$FGB\ \% = \frac{Number\ \text{of germinated seeds}}{\text{number of sown seeds}}\ x100 \qquad (1)$$

Growth parameters

Nine days after treatments initiation and germination of seeds, plants were thinned to two plants per pot for monitoring the maize growth on 26 of July 2021. Growth of the maize was lasted till the middle of November 2021 or wilted in some cases. Various growth traits like stem height, leaf numbers, and diameter of stem and chlorophyll percentage were recorded till 105-day growth. At the end of experiment, the shoot, root, and ears weights were recorded. Due to the combined stresses of water and salinity, the plants received 80 and 60 ET were wilted after 56 days of growing. While the plants irrigated at 40 % ET were grown till the harvesting time (108 days).

Data were analyzed based upon the nonlinear regression analysis. For describing relationship between such maize growth parameters (shoot height or leaf number) and time, the following polynomial was used (Burden and Faris, 1985):

$$y= ax^2+bx+c \qquad (2)$$

Where y(x) is the polynomial value at x (time) and a b, and c are polynomial coefficients. The equation was fitted to the average values of any shoot height or leaf numbers to determine the polynomial coefficients. Differentiating of the equation with respect to x (i.e. time) gives response of such a growth parameter to time.

Irrigation water levels

The three irrigation levels selected based upon the potential evapotranspiration using Romanenko's equation (Xu and Singh, 1998). The irrigation levels took place on the second of August 2021. The available irrigation water used in the present study possessed 2809 ppm (4.38 dS/m), 920 ppm of sodium and 1620 of chloride. The fraction of Na^+ is 0.327 of the total cations. This water is considered as moderately saline water (Water science school, 2018 and Li *et al.*, 2019). Because of the irrigation water is moderately saline; the plant must work hard to absorb water from the soil without leaching requirements.

The Romanenko's equation is presented as:

$$ET=0.0018\ (25+Ta)^2(100\text{-}hr) \qquad (3)$$

Where: ET = potential evaporation (mm/month), Ta =air temperature in °C, and hr = relative humidity in %.

The Romanenko's equation was modified by Xu and Singh (1998) and classified as humidity type because the ET depends mainly on the relative humidity of the surrounding enlivenment for evaporation. The temperature and relative humidity that required for the ET calculation were provided by climatologically station close by the experiment site. For accurate calculation of ET, the forecasted values of air temperature and relative humidity were used (Weather.com, 2021).

The forecasted values were very close to the actual measured temperature and relative humidity.

Statistical Analysis

To test for statistical differences, an analysis of variance was calculated using PROC GLM followed by Fisher's protected least significant difference for mean comparisons using SAS 13.1 statistical software (SAS Institute, 2013). A significance level of $\alpha = 0.05$ was chosen to reduce the likelihood of a Type II error during the analysis of germination data and growth parameters.

Results and Discussion

In this section, data of soil salt, germination, and growth of maize parameters are presented.

Salinity analysis

Since the irrigation water levels do not include leaching requirement, the salt loaded in the irrigation water must be precipitated and accumulated in soil. These amounts of salt depend on the amount of irrigation water used for each level. The irrigation with 80 % ET level consumed the greatest amount of water in a short growth time (56 days). These amounts of water were 9.27, 10.21 and 13.62 L/pot for 40, 60, and 80 % ET irrigation levels, respectively. Figure (1) shows the accumulated amount of water with the growth period for each irrigation level as a function of time. The accumulated water increased nonlinearly with time. This nonlinearity is attributed to the weather parameters that affect evapotranspiration. The total accumulated irrigation water for 40 % ET irrigation level is 27.164 L/pot within 92 days of growth at which irrigation was ceased. Since the growth period differed among the three levels, the total accumulated water differed too. The growth period was 108 days for the 40 % ET irrigation level. The maize plants had been wilted under the first two levels of irrigation, but they continued in the growth under 40 % ET irrigation till a complete harvesting season. The wilting phenomena occurred because of salt accumulation (Figure 2) in a short period of growth.

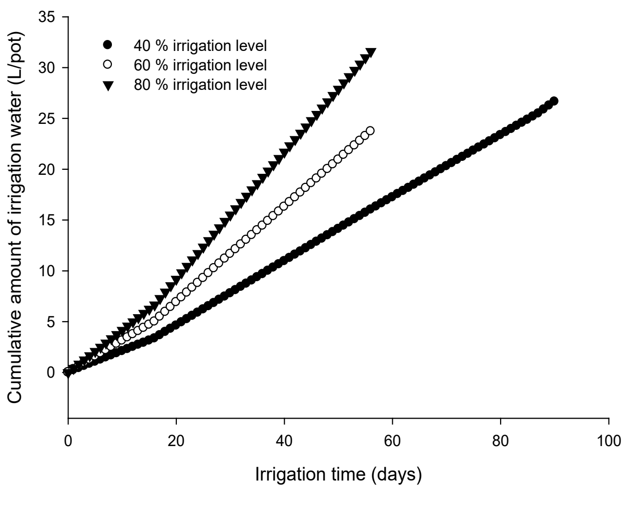

Fig (1): Cumulative amount of water used for the irrigation level per pot.

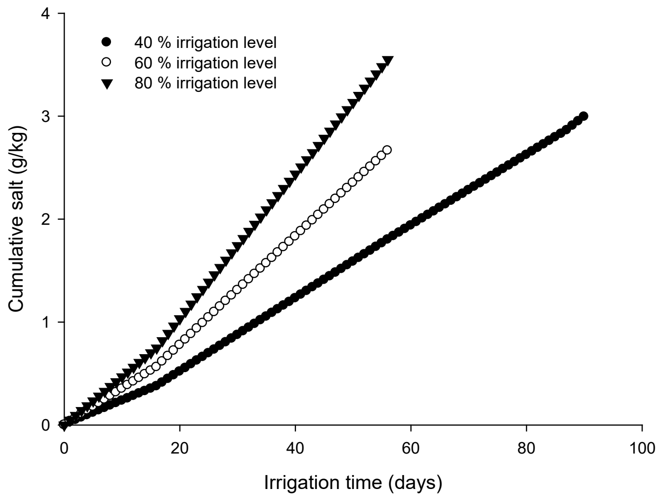

Fig (2): Cumulative amount of soluble salt for the irrigation levels.

Figure (3) presents the measured final soluble salt concentration in the 1:1 soil extract under the three irrigation levels. The salt concentrations were 2.9928, 2.6638 and 3.5504 g/kg for 40, 60 and 80 % irrigation levels, respectively. This salinity existed in a short time of maize growth in 60 and 80% irrigation levels that caused maize plants to wilt. The high salinity of the irrigation water at 40 % ET occurred after 108 growth days. Wei *et al.* (2019)'s results showed that irrigation with 3.5–5.0 gL^{-1} water salinity increased the soil salinity compared to the irrigation using 1.1–2.0 gL^{-1} water salinity. The soil water content with 5.0 gL^{-1} brackish water irrigation was significantly higher than that of 1.1 – 3.5 gL^{-1} water salinity due to the effect of salinity on the crop water uptake. They also indicated that the irrigation with 5.0 g/L increased soil water and salt content (EC1:5), which accelerated soil salinization and resulted in negative influences on maize growth.

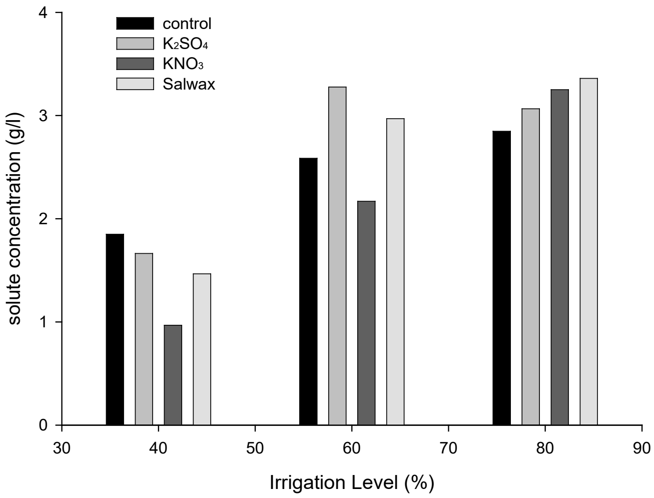

Fig. (3): Effect of irrigation level and potassium treatments on final total soil solute.

Figure (4) presents immortality of maize under the three irrigation levels. Obviously, the plants wilted earlier (56 days) under both 60 and 80 % ET irrigation level while they lasted to the harvesting time (108 days) under the irrigation levels of 40 %. Increasing soil salinity (Figure 3) reduced the available water for plant uptake under the irrigation levels of 60 and 80 %ET. Although the matric potential under 60 or 80 % ET is greater than its value under 40%, the resulted total soil water potential (matric + osmotic potentials) is low that lead to wilting the maize plants under both 60 and 80 % ET. So, management of saline water in irrigation should depend on the total soil water potential as a criterion for irrigation scheduling. Azizian and Sepaskhah (2014) showed that maize under water and salinity stress had longer vegetative stage period by 11 and 16% compared to the control, respectively. The most sensitive trait under water, salinity and nitrogen stress was grain yield which decreased by 52.3, 25.2 and 28.0%, for irrigation at 0.50 ETc +0.125ETc as leaching, 4.0 dS m^{-1} and 0 kg N ha^{-1}, respectively. Yuan *et al.* (2019) reported that irrigation schedule with irrigation water amount of about 370 mm and irrigation water salinity below 3 g/L are recommended in the Shiyang river basin of northwest China.

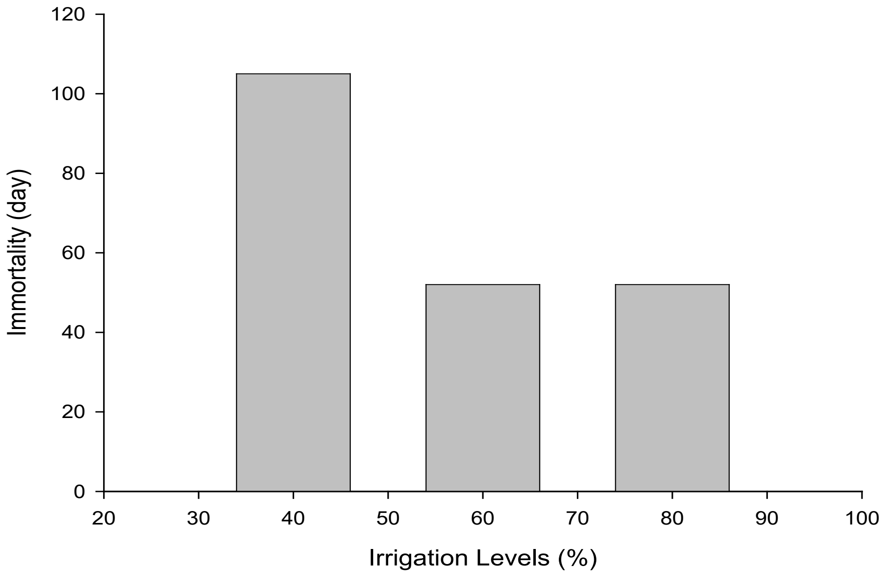

Fig. (4):Immortality of maize under three levels of irrigation

Germination analysis

Table (2) shows effects of the irrigation level and potassium salt type on the maize germination percentages. The maize germination percentage ranged from 93.3% (K_2SO_4 and Salwax) to 100 % (control and KNO_3). Similarly, Adnan (2020) indicated that potassium ions did not affect the maize seed germination stage, but the soil water content greatly affected this stage. Contrarily, potassium is the most one of macronutrients that is required for proper growth, development, and sustainable crop yield.

Table 2 . Effect of irrigation level and potassium treatments on maize germination and some growth characteristics.

Treatment	level	Germination (%)	Stem diameter (mm)	Chlorophyll content (SPAD value)
Irrigation	80% ET	95	8.1	39.3
	60% ET	95	8.2	40.9
	40% ET	100	8.4	42
$LSD_{0.05}$	----	NS	NS	1.76
Potassium salt	0.0	100	8.1	40.06
	K_2SO_4	93.3	7.9	40.4
	KNO_3	100	8.6	41.6
	Salwax	93.3	8.3	40.7
$LSD_{0.05}$	-----	NS	NS	0.95

C: Maize growth analysis

Table (2) presents the stem diameter at 46 days of sowing under three irrigation levels and four potassium salt types including zero potassium level (the control). The irrigation levels showed the greatest effect on the stem diameter under 40 % ET of irrigation while the 80 % ET level possessed the lowest. The stem diameter was 8.4, 8.2 and 8.1 mm for the irrigation level of 40, 60, and 80 % ET, respectively. The mean differences in stem diameter were not significant (Table 2). It might be due to the high salinity added via the irrigation water (Figures 2 and 3). The use of potassium nitrate salt gave the highest stem diameter followed by Salwax. The mean differences among the potassium salts were not significant (Table 2). Li *et al.* (2019) indicated that using a soil matric potential of −20 kPa and irrigation water of 22.5 mm, the irrigation water salinity showed negative impacts on maize emergence and morphological characteristics (plant height, leaf area index, stem diameter, and dry matter), as irrigation water salt concentrations exceeded 3 gL^{-1}. They recommended an irrigation water salinity of 3 gL^{-1} for maize mulched with drip irrigation.

The chlorophyll at 50 days of growth under three irrigation ET levels and four potassium salt types including the control is presented in Table 2. The greatest effect on the chlorophyll content was shown under 40 % of irrigation level while the 80% ET irrigation one possessed the lowest with significant differences among the means of the three irrigation levels. This trend might be due to the high salinity added via the irrigation water (Figures 3 and 4). The potassium nitrate salt gave the highest stem diameter, and then followed by Salwax. The differences in chlorophyll contents under potassium treatments were significant (Table 2). The chlorophyll content behaved like the stem diameter under the investigated treatments. Potassium nitrate salt gave the highest chlorophyll content. The mean differences among the potassium salt treatments were significant (Table 2).

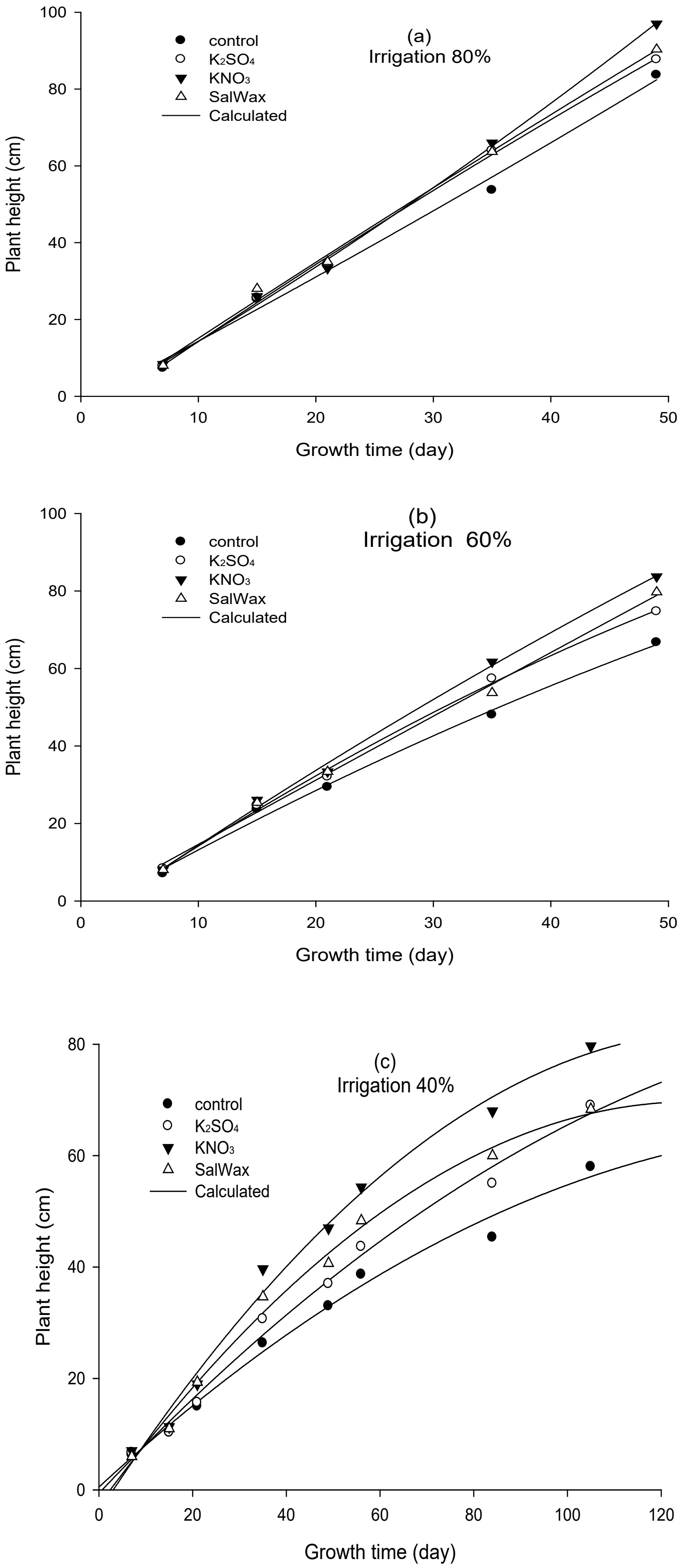

Fig. (5): Plant height as a function of growth time under irrigation levels of (a) 80%,(b) 60%, and (c) 40%; and potassium salts (symbols), and calculated values (-).

The plant height as a function of time for the three ET irrigation levels under the potassium salt types is shown in Figure 5. The observed plant height was described using a second polynomial degree (Eq.2). The polynomial well described the observed values with determination coefficient (R^2) value of more than 0.99 (Table 3) for all potassium types under the three irrigation levels. The polynomial was used to differentiate between the time effects on the change rate of plant height. These rates were calculated for 30 and 45 days of plant growth time. They differed among the irrigation levels and potassium salt types at the two times. The 80 % ET irrigation level possessed the greatest growth rate compared to the other irrigation levels. So, as the available water for plant uptake is high, the vigorous of plant is boosted. Yu *et al.* (2014) showed that with the increase of irrigation water salinity and soil initial salt content, the maize height decreased. So, the salinity of water can reduce the production of maize. The type of potassium salt has also an effect on the growth rate at 30 days of growth. The growth rate increased followed the order of KNO_3>Salwax> K_2SO_4> control. It is concluded that potassium enhanced the growth rate. The corresponding rates of the plant height were 2.10, 1.92, 1.88 and 1.72cm/day for the irrigation level of 80%, (Table 3). In general, the change in the growth rates after 45 days were not consistent with those after 30 days, but most of them were lower than growth rate, after 30 days for all the three irrigation levels. However, the change in the growth rate after 45 days for the KNO_3 increased. It might be due to successful use of KNO_3 for counteracting the negative effect of drought on the maize growth. The drought effect is related to osmotic effect on the availability of water uptake by plants. The reduction in change growth rates after 45 days might be attributed to the negative effect of the accumulated salt from irrigation water (Figure 3). Similar findings were reported by Meena *et al.* (2018) who found that the addition of potassium enhanced the salinity tolerance of peanut (*Arachis hypogaea*) in growth terms (plant height, branches, root length and weight).

The change rates of leaf numbers as function of time is shown in Figure (6) for all studied irrigation levels and potassium salt types. The leaf number was described using the second-degree polynomial (Eq.2). The determination coefficient (R^2) and the change rates are shown in Table (3). The R^2 ranged from 0.99 to 0.98. The change rate of leaf number was calculated at 30 and 45 days of sowing. The rates at 30 days were obviously greater than after 45 days. It is obvious that the rates decreased with time due to the successive accumulation of salinity in the root zone. Existing a high salinity in the root zone results in a low water availability for plant water uptake. The rates of leaf numbers were coincided with those of stem height. Similar findings were indicated by Daniells *et al.* (2001) who found a 50% yield reduction in grain sorghum grown on sodic soils at an average root zone salinity level (ECs) of 2.8 dS/m. Wei *et al.* (2019) used brackish water to determine its impacts on soil and maize growth. Their results indicated that brackish irrigation water aggravated the degree of soil salinization and alkalization.

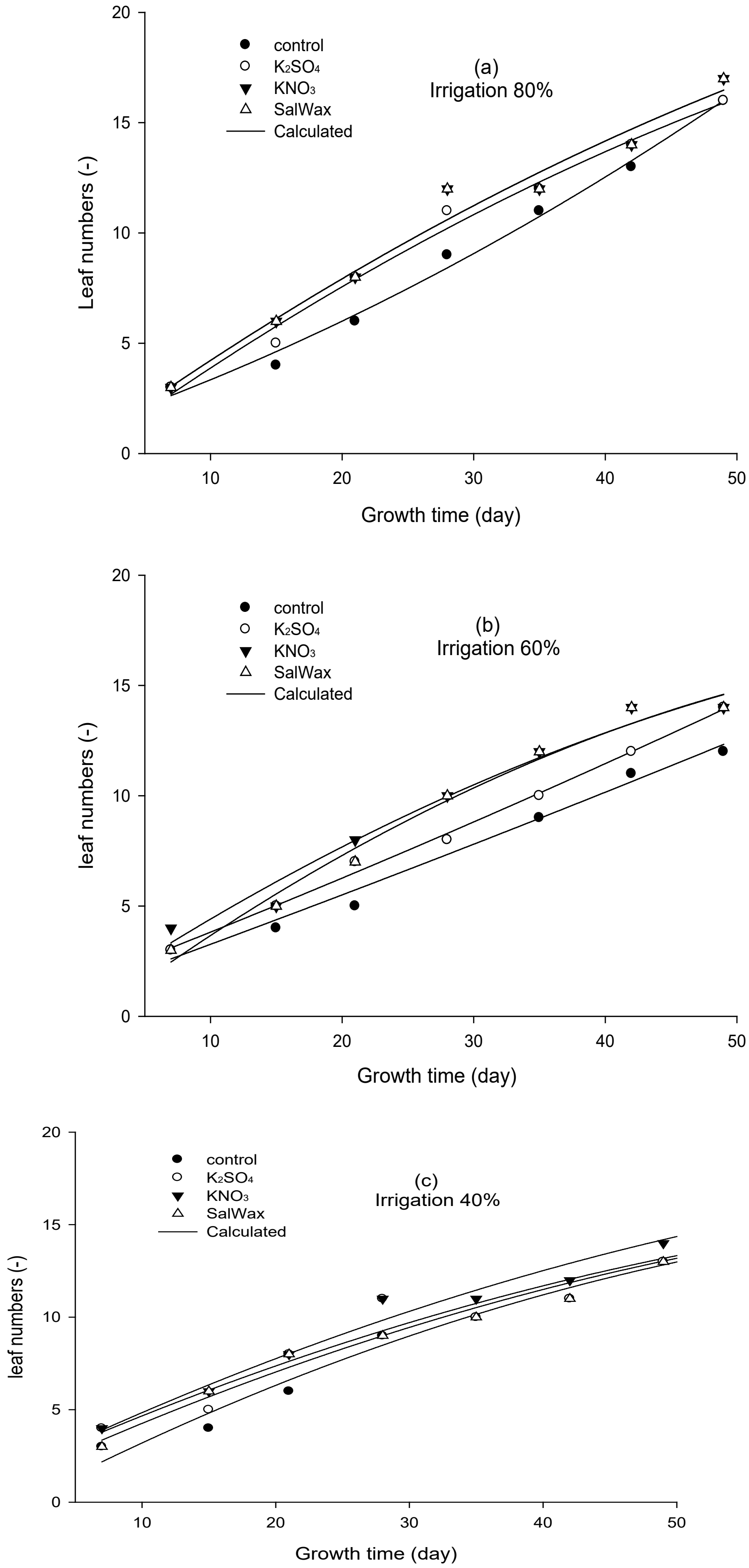

Fig.(6): leaf number as a function of growth time under irrigation levels of (a) 80%, (b) 60%, and (c) 40%; and potassium salts (symbols), and calculated values (-).

Table 3. R^2 and dy/dx for height and leaf number using polynomial equation 2.

Treatment		Plant height			Leaf number		
Irrig. level	K -salt	R^2	dy/dx* (cm/day)	dy/dx** (cm/day)	R^2	dy/dx* (cm/day)	dy/dx** (cm/day)
80 % ET	control	0.992	1.72	1.78	0.992	0.33	0.39
	K_2SO_4	0.998	1.88	1.76	0.989	0.31	0.25
	KNO_3	0.997	2.10	2.28	0.976	0.31	0.26
	SalWax	0.996	1.92	1.86	0.976	0.31	0.26
60 % ET	control	0.994	1.41	1.26	0.979	0.23	0.24
	K_2SO_4	0.997	1.59	1.35	0.996	0.26	0.27
	KNO_3	0.997	1.79	1.64	0.973	0.28	0.22
	SalWax	0.995	1.65	1.63	0.982	0.33	0.27
40 % ET	control	0.988	0.66	0.60	0.977	0.25	0.18
	K_2SO_4	0.991	0.77	0.71	0.933	0.25	0.16
	KNO_3	0.990	1.05	0.93	0.971	0.26	0.20
	SalWax	0.993	0.91	0.79	0.979	0.24	0.18

*at 30 day** at 45 s, days. D: yield and yield components using the irrigation level of 40% ET

Some yield traits of maize with using different potassium salt treatments using the irrigation level of 40% ET are show in in Table 4. Fresh weight, dry weight, 100-seed weight, cob length, and leaf water content of maize significantly differed among the potassium salt treatments, but the cob number did not. It is obvious that the KNO_3 treated soil possessed the greatest values in most investigated maize traits, but the control treatment exhibited the lowest ones. Therefore, the potassium treatments enhanced the growth of maize under the conditions of the present study. These enhancements might be attributed to the role of potassium in stomata closure as well as encouraging the absorption of water and nutrients by maize plants. Xu *et al.* (2020) suggested that an appropriate K supply of 6 mM was optimal as it enhanced photoassimilate transport from leaves to roots and increased nitrogen use efficiency by influencing photosynthesis, C and N metabolizing enzyme activities, nitrate assimilation gene activities, and nitrate transport in apple dwarf.

Table 4. Some yield traits of maize under potassium salts treatments at the irrigation level of 40 % ET.

Treatment	level	cob/ plant	100- seed weight (g)	Cob length (cm)	Fresh weight (g)	Dry weight (g)	Leaf water content (%)
K- salt	control	1.6	14.9	12.4	140	45	62.67
	K_2SO_4	2	14.8	11.4	202	59	69.00
	KNO_3	2	16.9	13.2	230	72	83.67
	Salwax	1.6	17.6	13.8	213	65	78.33
$LSD_{0.05}$	----	NS	0.59	1.28	6.16	10.31	5.57

The differences in N, P, K, Ca, and Mg of the above-ground maize biomass among K salt treatments under the 40 % ET irrigation level were significant. The nutrient contents of maize were low because the plants were subjected to water and salinity stresses. These differences coincided with both fresh and dry weights of maize plants. It is concluded that potassium boosted the growth of maize under water and salt stresses or in other word the potassium alleviated the salt and water stresses that faced maize growth. Wei *et al.* (2019) reported that the corn yields using 2.0 - 5.0 g salt/L treatment were decreased by 7.60 - 23.93 % in 2017 and 13.86 - 31.47 % in 2018 compared to those under 1.1 g/L salt treatment. Their results suggested that reducing irrigation water salinity may be an effective way to alleviate soil salinization degree and increase yield.

Table 5. Chemical composition (mg/Kg) of above-ground biomass of maize plants irrigated using 40 % ET and different K salt treatments

Treatment	levels	K	P	N	Ca	Mg
Potassium salt	0.0	1404	800	14000	60	36
	K_2SO_4	5779	700	14000	40	120
	KNO_3	5992	900	21000	36	122.4
	Salwax	6089	900	21000	64	81.6
$LSD_{0.05}$	-----	1023.265	108.58	2506.2	6.34	5.19

Conclusion

It could be concluded that potassium salts did not affect the maize seeds germination in comparison to the control (zero-potassium level). The polynomial equation well described the plant height and leaf number as a function of growth time with an approximated R^2 of 0.99. In addition, the plant height and leaf number of maize plants increased as the irrigation level increased but the stem did not. The stem height and leaf growth rates decreased with time using all studied treatments. The irrigation levels at 80 and 60 % ET rapidly increased the soil salinity compared to that at 40 % ET. So, the plants irrigated at 60 and 80 % ET were hampered after 56 days of growth, while those irrigated at 40 % ET continued to grow till 108 days (harvesting time). The KNO_3 showed the best salt among other potassium salt types in boosting the maize plant growth in most of growth characters. So, the KNO_3 could alleviate the degree of soil salinization and drought tolerance. Accordingly, it is recommended that the total water potential (matric and osmotic) is considered as a good criterion for defining drought maize tolerance.

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تأثير التراكم المتعاقب للملوحة والجفاف والبوتاسيوم على إنبات ونمو الذرة

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الملخص

تم إجراء تجربة البيوت المحمية على الذرة (بايونير P444) في منطقة بدر بمحافظة البحيرة مصر، للتحقق من استخدام الملوحة المتتالية ومستويات الري وتأثير البوتاسيوم على الإنبات ونمو الذرة. تم تضمين ثلاثة مستويات من الري (80 و 60 و 40 من البخر نتح المحتمل (ET)) كعامل رئيسي وأربعة أملاح بوتاسيوم (الكنترول، كبريتات البوتاسيوم، نترات البوتاسيوم، والسول واكس) كعامل فرعي مع ثلاثة مكررات. تم استخدام مياه ذات ملوحة معتدلة (≈4 ديسيسيمنز/م). تم رصد إنبات البذور ومعايير نمو الذرة. تم تطبيق معادلة كثيرة الحدود من الدرجة الثانية لوصف بعض معاملات النمو. أظهرت النتائج أن أملاح البوتاسيوم لم تؤثر على إنبات البذور بالمقارنة بالكنترول. وصفت معادلة عديدة الحدود ارتفاع النبات وأعداد الأوراق كدالة للوقت بشكل جيد مع R^2 تقريبي 0.99. زاد ارتفاع النبات وعدد الأوراق مع زيادة مستويات الري ولكن اتبعت أقطار الساق بشكل مختلف، كما انخفض ارتفاع الساق ومعدلات الأوراق مع مرور الوقت لجميع المعاملات المدروسة. أدى الري عند 80٪ و 60٪ من البخر نتح إلى زيادة ملوحة التربة بسرعة مقارنة بالري عند 40٪. لذلك فقد تم إعاقة النباتات التي حصلت على الماء بنسبة 60 أو 80٪ ET بعد 56 يومًا من النمو. بينما استمرت النباتات المروية بنسبة 40٪ ET في النمو حتى 108 يوم (وقت الحصاد)، كانت نترات البوتاسيوم الأفضل بين أنواع أملاح البوتاسيوم الأخرى في تعزيز نمو النبات في معظم خصائص النمو. وفقًا لذلك، يوصى باستخدام جهد الماء الكلي (الشد والإسموزي) كمعيار جيد لتحديد تحمل الذرة للجفاف.