Response of Maize Plants to Skip Irrigation and Nano Potassium Treatments in Salty Soil

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Abstract

A field experiment was conducted in Maamirah, Babylon, (33-32 north latitude and 45-42 east longitude), 10 km south of Hilla, Iraq, in loam clay soil in the fall 2018 season to study the effect of skip irrigation and potassium fertilizer treatments on maize yield. A split plot arrangement within a randomized complete block design with three replications was used. The main plots included three irrigation treatments(control (S0), skip one irrigation at eight leaves-stage (S1) and skip irrigation at silk stage (S2), while sub-plots included 6 potassium treatments, control without adding K fertilizer (K0), adding potassium fertilizer recommendation of 50 kg K.ha^{-1} (K1) to the soil, spraying of nano K fertilizer (2000 mg per liter) (K2), Spraying 1500 mg of nano potassium + soil K fertilizer of 12.5 kg.ha^{-1} (K3), Spraying 1000 mg of nano potassium + soil K fertilizer of 25 kg.ha^{-1} (K4), and spraying 500 mg per liter of nano potassium + soil K fertilizer of 27.5 kg.ha^{-1} (K5). The results indicated that skip irrigation caused a significant reduction in plant height, plant leaf number, chlorophyll, plant leaf area, N, P and K percentages in leaf, and prolin content compared to control. Skip irrigation at 8 leaves stage was more effective in decreasing plant leaf number, chlorophyll, plant leaf area, leaf N percentage, and prolin compared to skip irrigation at the silk stage. Potassium fertilizer caused a significant effect on plant height, plant leaf area, chlorophyll, leaf N, P, and K percentage, and prolin content. In general, the effect of spraying nano-potash and its combinations with mineral fertilizer did not differ from the recommendation for mineral fertilizer.

***Keywords**: nano-potassium, mineral potassium, skip irrigation, maize.*

Introduction

Maize (*Zea mays* L.) is a C4 plant, it is one of the most important cereal crops of the world with an ideal crop owing due to its quick growth with high yield. The cultivated areas in Iraq decreased due to the dry climate and the lack of water. (Desai et al., 2017) found that water stress decreased plant height and plant leaves number. (Timuçin, 2021) noticed that skip irrigation treatment gave the lowest chlorophyll content, plant height, and plant leaf number compared to complete irrigation. (El-Gedwy, 2020) found that skip irrigation at the vegetative stage caused a reduction in maize plants compared to full irrigation. (Ali Hussein Jasim et al., 2015) found that skip irrigation led to reduce significantly plant height, number of leaves, chlorophyll content, and leaf area.

Essential nutrient fertilizer is important for crop productivity and soil fertility, but overuse of chemical fertilizers causes pollution of soil, environment, groundwater, and air. Nano-fertilizers are nutrients of nano-scale ranging from 1 – 100 nm that give them a wide surface area which improves their absorption and contributes to increasing the yield. (Verma et al., 2022) explain that nano-fertilizers may enhance nutrient uptake and plant growth by regulating the fertilizer`s availability in the rhizosphere; improve stress resistance by improving nutritional capacity and mitigate environmental stresses. (Méndez-López et al., 2022) represented that nano-materials can be effective in stimulating antioxidant defense compounds and enhancing defense mechanisms to withstand various abiotic stress conditions. (Ghahremani et al., 2014) found that potassium nano fertilizers significantly increased leaf area and chlorophyll content. (A. Ali et al., 2020) and (S. Ali et al., 2019) found that potassium caused a significant increase in plant height. (Bhattacharjee et al., 2022), (Banerjee et al., 2021) found that potassium improved plant height, chlorophyll, and plant leaves number. (Gnanasundari et al., 2019) found that plant height, chlorophyll, and plant leaf area showed a significant response to potassium applied. This study aims to estimate some of maize plant growth parameters and N, P, and K uptake at skip irrigation and two types of K fertilizer as mineral applied or nano as leaf spraying.

Materials and methods

Maize seed (Hybrid Euphrates) was planted on linens 75 cm apart and 25 cm between hills on 7/22/2015 (three seeds per hill and thinned to one plant per hill in loam soil ((able 1). Phosphorus and nitrogen fertilizers were adjusted to 30 kg P_2O_5 ha^{-1} at the seeding stage and 100 kg N ha^{-1} uniformly for all experimental units by adding super phosphate (46% P_2O_5) and Urea (46% N). N fertilizer was separated into three doses (at seeding, 8 leaves stage, and male flowering respectively). Nano-potassium was sprayed in the morning. The soil was prepared and divided according to the split-plot arrangement within a randomized complete block design (RCBD) with three replications. Each replicate contained 18 experimental units (5 m × 3 m) including four lines. The main plots include three treatments, which are normal irrigation (control S0), skip irrigation at the 8 leaves stage (S1) and skip irrigation at the silk stage (S2). The sub-plots included six treatments as follows: 1-Control without K fertilizer (K0) 2- add 50 $kg.ha^{-1}$ of K as soil chemical fertilizer (K1). 3- spray of nano K fertilizer (2000 mg per liter) (K2). 4- Spray 1500 mg of nano potassium + soil K fertilizer of 12.5 $kg.ha^{-1}$ (K3). 5- Spray 1000 mg of nano-potassium + soil K fertilizer of 25 $kg.ha^{-1}$ (K4). 6- spray 500 mg per liter of nano potassium + soil K fertilizer of 27.5 $kg.ha^{-1}$ (K5). At flowering, plant height, plant leaves number, plant leaf area, chlorophyll, and leaf N, P and K content were taken. The data were analyzed statistically using the Genstat statistical program, and the averages were compared according to the least significant difference ($LSD_{0.05}$) test.

Table 1 Some physical and chemical field soil properties

sample	Soil texture	pH	EC ($dScm^{-1}$)	N ($Mg\ kg^{-1}$)	P ($Mg\ kg^{-1}$)	K ($Mg\ kg^{-1}$)
10-30 cm	loam	7.7	8.4	33.1	8.9	154
30-50 cm	loam	7.7	8.9	29.6	11.8	126

Results and discussion

Table (2) shows that skip irrigation at 8 leaves or silk stages caused a significant reduction in plant height (171.6 and 161.8 cm, respectively), compared to the full irrigation treatment, which gave the highest average of 196.8 cm. This result may be related to less water uptake, photosynthesis disruption, unbalanced hormones, and the activity of enzymes. The expansion and division of cells are affected by the water deficit, and the expansion of the cell is more affected than its division, which leads to a reduction in the elongation of the stem. Cell expansion is more affected by its division, in addition to water stress leads to inhibition of the action of IAA (Indole-3-Acetic Acid) which reduces plant height, (Desai et al., 2017). This result was agreed with (Weisany et al., 2021), (Timuçin, 2021) and (El-Gedwy, 2020). The table also showed that all the potassium addition and spraying led to a significant increase in the height of the plants compared to control treatment. The combination of nano and mineral K fertilizer treatments were higher significantly compared to adding each of them alone. The Treatment of K5 was superior by giving the highest average of 187.2 cm, compared to the control treatment (K0), which gave the lowest average of 164.7 cm. This increase may be due to the spraying of nano-potassium, which even at low levels, it may contribute effectively to increasing the rates of rate of photosynthesis, as well as, the transport of the photosynthetic product from source to sink. As well as potassium action in delayed leaf senescence, and better vegetative growth (Swetha et al., 2017). These results were agreed with (Desai et al., 2017), (Patel et al., 2022), (Poudel & Shrestha, 2021), (Rani et al., 2021), and (Kandil et al., 2020). This result was agreed also with (Shi et al., 2020), (Suhaib et al., 2018), (Ali Husain Jasim & Ghanee, 2016)(Ali Husain Jasim & Rashid, 2016), and (Abbasi et al., 2015) who found that potassium alleviate the harmful effect of abiotic stress on plant height. The interaction between the two workers had no significant effect on this trait.

Table (2) Effect of irrigation and potassium treatments on plant height (cm)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**169.7**	**161.3**	**163.0**	**164.7**
K1	**200.8**	**170.5**	**169.7**	**180.3**
K2	**199.4**	**170.3**	**171.0**	**180.2**
K3	**203.5**	**172.6**	**173.0**	**183.0**
K4	**202.1**	**179.3**	**173.7**	**185.0**
K5	**205.6**	**175.6**	**180.3**	**187.2**

Irrigation average	**196.8**	**171.6**	**171.8**	
LSD $_{0.05}$	Irrigation=1.7 interaction=n.s			2.4

Table (3) shows that skip irrigation at 8 leaves or silk stage gave a significant reduction in this trait (12.77 leaf plant-1 and 13.14 leaf plant^{-1}, respectively compared to full irrigation (S0) which gave the highest average of 15.87 leaf plant^{-1}. This may be due to the lack of water available to the plant during the elongation stage, which leads to a decrease in the rate of leaf emergence, and perhaps the obvious decrease in plant height (table 1) caused a reduction in plant leaf number. This result agreed with (Weisany et al., 2021), (Timuçin, 2021), (Sah et al., 2020), and (Desai et al., 2017). Or it may be due to a decrease in photosynthesis and an increase in respiration, which in turn affects the oxidation of photosynthetic pigments, and then negatively reflected in the process of photosynthesis and plant growth. Potassium treatments and the interaction between the two factors had no significant effect on this trait.

Table (3) Effect of irrigation and potassium treatments on plant leaf number

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**15.00**	**12.33**	**12.63**	**13.32**
K1	**16.03**	**13.77**	**13.87**	**14.56**
K2	**16.47**	**12.30**	**13.27**	**14.01**
K3	**16.60**	**13.03**	**12.63**	**14.09**
K4	**15.63**	**12.37**	**13.57**	**13.86**
K5	**15.50**	**12.80**	**12.90**	**13.73**
Irrigation average	**15.87**	**12.77**	**13.14**	
LSD $_{0.05}$	Irrigation=0.18 interaction=n.s			n.s

Table (4) showed that skip irrigation caused a significant reduction in chlorophyll and the skip at 8 leaves stage gave significantly the lowest average of 47.98 (SPAD), while skip irrigation at the silk stage gave an average of 49.49 compared to the full irrigation treatment, which gave the highest average of 56.70 (SPAD). This reduction may be related to the destruction of chloroplast, chlorophyll photo-oxidation, degradation of chlorophyll synthesis, and activation of chlorophyllase enzyme. This is consistent with the results of (Timuçin, 2021), (Rani et al., 2021), and (Moharramnejad et al., 2019) who showed a decrease in chlorophyll in the leaves of maize plants when subjected to skip irrigation at the vegetative stage. Potassium treatments and the interaction between the two factors had no significant effect on the leaf chlorophyll content. All potassium adding caused a significant increase in leaf chlorophyll content compared to the control treatment, which gave the lowest average of 46.94 (SPAD). Nano fertilizer in K2 and K3 were superior significantly compared to all other treatments by giving 54.31 and 53.44, respectively. This result was due to that K is associated with the activities of some enzymes that are involved in ROS detoxification (Hasanuzzaman et al., 2020), (Johnson et al., 2022). This result was agreed with (Rani et al., 2021) and (Al-Falahi & AbdulKafoor, 2021), who found that K increased chlorophyll, and (Shi et al., 2020) who found that potassium alleviate the harmful effect of abiotic stress on chlorophyll.

Table (4) Effect of irrigation and potassium treatments on chlorophyll (SPAD)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**51.97**	**43.60**	**47.53**	**47.70**
K1	**57.47**	**48.63**	**46.83**	**50.98**
K2	**59.47**	**51.73**	**51.72**	**54.31**
K3	**59.50**	**49.80**	**51.03**	**53.44**
K4	**54.97**	**48.20**	**50.17**	**51.11**
K5	**56.83**	**48.63**	**49.93**	**51.80**
Irrigation average	**56.70**	**48.43**	**49.54**	
LSD $_{0.05}$	Irrigation=1.09	interaction=n.s		1.54

The treatments of skip irrigation at 8 leaves or silk stage led to a significant decrease in the leaf area (5429 and 5666 cm2, respectively) compared to the full irrigation treatment (S0), which gave 6857 cm2 (Table 5). This reduction may be due to the lack of leaves (Table 3), and the decrease in cell water potential, which reduces their ability to elongate and swell and then reduce cell size. These results agreed with (Rajasekar & Prabhakaran, 2020), and (Sah et al., 2020) who found that water stress reduced plant leaf area. The potassium addition treatments caused a significant increase in plant leaf area, and the K1 treatment was superior and gave the highest leaf area of 6612 cm2, followed by K5, which gave an average of 6400 m2 compared to the control treatment, which gave the lowest plant leaf area of 4690 cm2. This result may be due to the role of potassium fertilizer in increasing the enzyme activity and improving growth by delaying the aging of plant tissues. This result was similar to (Poudel & Shrestha, 2021),(Al-Falahi & AbdulKafoor, 2021), and (Gnanasundari et al., 2019). This result was agreed with (Ul-Allah et al., 2020) and (Abbasi et al., 2015) who found that potassium alleviates the harmful effect of abiotic stress on leaf area, by improving root growth, and cell turgor and osmotic pressure, which reflected on leaf expansion. The interaction had no significant effect on this trait.

Table (5) Effect of irrigation and potassium treatments on leaf area (cm^2)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**4956**	**4312**	**4804**	**4690**
K1	**7693**	**6118**	**6024**	**6612**
K2	**6620**	**5776**	**5472**	**5956**
K3	**7249**	**5593**	**5476**	**6106**

K4	**7058**	**5084**	**6270**	**6137**
K5	**7564**	**5688**	**5949**	**6400**
Irrigation average	**6857**	**5429**	**5666**	
LSD $_{0.05}$	Irrigation=1.22 interaction=n.s			1.73

Table (6) shows that skip irrigation treatments at 8 leaves or silk stage caused a significant reduction in the percentage of nitrogen in the leaves (1.58 and 1.63%, respectively), compared to the full irrigation treatment that gave the highest average of 1.72%. This result was due to the lack and the slow movement of water and the carried elements towards the roots and then the irregularity of the various metabolic processes within the plant, including the decrease in the activity of the nitrate reductase enzyme, which converts nitrates into ammonium ions and their entry into the building of amino acids (Mandi et al., 2018). This result agrees with (El-Gedwy, 2020) and(Bharathi et al., 2018), who found a significant decrease in the percentage of nitrogen in maize plants as a result of skip irrigation at the vegetative stage. All potassium treatments caused a significant effect on the percentage of nitrogen in the leaves compares to the control treatment (K0), which gave the lowest average of 1.33%. Nano-potassium treatments (K2 and K3) excelled by giving significantly the highest average percentage of the nitrogen element, reached to 1.75 and 1.74%, respectively. This result was due to that potassium has a vital role related to stimulating the activities of enzymes responsible for the transfer of mineral elements from roots to the newly developed parts (Tränkner et al., 2018). As well as to synergetic interaction between N and K that enhances the utilization of applied nitrogen in the presence of sufficient potassium, by enhancing nitrogen translocation from roots to leaves. This result agreed with (El-Gedwy, 2020). The interaction between the two factors had no significant effect on this trait.

Table (6) Effect of irrigation and potassium treatments on leaf N percentage (%)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**1.37**	**1.29**	**1.33**	**1.33**
K1	**1.81**	**1.47**	**1.69**	**1.66**
K2	**1.80**	**1.70**	**1.76**	**1.75**
K3	**1.92**	**1.64**	**1.67**	**1.74**
K4	**1.80**	**1.69**	**1.64**	**1.71**
K5	**1.63**	**1.70**	**1.71**	**1.68**
Irrigation average	**1.72**	**1.58**	**1.63**	
LSD $_{0.05}$	Irrigation=0.025 interaction=n.s			0.036

Table (7) showed that skip irrigation treatments at the eight-leaf stage or at the silk stage gave the two lowest averages of 0.37 and 0.36% P in leaves compared to the full irrigation treatment, which gave the highest average of 0.50%. Water stress leads to a decrease in the growth and depth of the roots, and thus a reduction in the absorption of water and nutrients. The absorption of nutrients by the plant depends on the root surface area, and the poor root growth caused by water stress reduces its ability to absorb phosphorus due to limited phosphor movement in the soil (Bharathi et al., 2018).

Table (7) Effect of irrigation and potassium treatments on leaf P percentage (%)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**0.32**	**0.23**	**0.27**	**0.27**
K1	**0.55**	**0.44**	**0.43**	**0.47**
K2	**0.57**	**0.36**	**0.31**	**0.41**
K3	**0.49**	**0.42**	**0.38**	**0.43**
K4	**0.48**	**0.39**	**0.39**	**0.42**
K5	**0.59**	**0.41**	**0.40**	**0.46**
Irrigation average	**0.50**	**0.37**	**0.36**	
LSD $_{0.05}$	Irrigation=0.016		interaction=n.s	0.022

This result agreed with (Hussain et al., 2019), who found a decrease in the percentage of phosphorous in leaves as a result of water stress. Table 6 showed also that potassium treatments had a significant effect, as the K1 and K5 treatments excelled and gave the highest average of 0.47% and 0.46%, respectively compared to the control treatment without spraying (K0), which gave the lowest average of 0.27%. This may be due to the role of potassium in increasing root growth as well as due to the synergistic influence and translocation of other nutrients by the applied potassium (Kumar et al., 2015). This result was consistent with (Misskire et al., 2019), and (Gnanasundari et al., 2019). The interaction between the factors had no significant effect on this trait.

Table (8) showed that the skip irrigation treatments at the eight-leaf stage or at the silk-stage gave the lowest average of leaf K percentage (1.27 and 1.29%) compared to full irrigation treatment (SO) which gave the highest average of 1.48%. This result may be due to a decrease in root development and proliferation by water stress (Bharathi et al., 2018). This result agreed with (Hussain et al., 2019). Table 8 showed also that all potassium addition treatments caused a significant increase and gave an average of 1.33 -1.36% compared to the control treatment (K0) which gave 1.27%. This result may be due to the sufficient K amounts and rapid absorption by the large and distribution root. These results agreed with (Desai et al., 2017),(Patel et al., 2022), (Kandil et al., 2020), (Shi et al., 2020), (Xu et al., 2020) and (Abbasi et al., 2015) who found that potassium alleviate the harmful effect of salt stress on K absorption. The interaction between the two factors had no significant effect on this trait.

Table (8) Effect of irrigation and potassium treatments on leaf K percentage (%)

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**1.43**	**1.14**	**1.24**	**1.27**
K1	**1.48**	**1.23**	**1.35**	**1.35**
K2	**1.56**	**1.22**	**1.22**	**1.33**
K3	**1.47**	**1.30**	**1.30**	**1.36**
K4	**1.46**	**1.30**	**1.33**	**1.36**
K5	**1.49**	**1.23**	**1.30**	**1.34**
Irrigation average	**1.48**	**1.27**	**1.29**	
LSD $_{0.05}$	Irrigation=0.027		interaction=n.s	0.038

The skip irrigation treatments at the eight-leaves stage or the silk-stage caused a significant increase in the proline content of the leaves reached 0.23 and 0.24 µg gm-1, compared to the full irrigation treatment which gave the lowest average of 0.17 µg gm^{-1} (table 9). This may be because water stress caused an increase in protease enzymes, which contributes to an increase in the accumulation of the proline, or a lack of protein synthase, so ammonia accumulates, and here the plant tends to synthase proline to modify osmosis. This result agreed with (Saudy et al., 2022) and (Hussain et al., 2019), who indicated that the amount of proline increased with increasing moisture stress.

Table (9) Effect of irrigation and potassium treatments on prolin (µ g^{-1})

K treatments	Irrigation treatments			Average of K fertilizer
	Control (S0)	Skip irrigation at 8 leaves stage (S1)	Skip irrigation at the silk stage (S2)	
K0	**0.15**	**0.20**	**0.22**	**0.19**
K1	**0.16**	**0.23**	**0.24**	**0.21**
K2	**0.18**	**0.24**	**0.24**	**0.22**
K3	**0.17**	**0.24**	**0.26**	**0.22**
K4	**0.17**	**0.23**	**0.24**	**0.21**
K5	**0.17**	**0.23**	**0.25**	**0.22**
Irrigation average	**0.17**	**0.23**	**0.24**	
LSD $_{0.05}$	Irrigation=0.014		interaction=n.s	0.021

These results agreed with (Ghaffari et al., 2021), and (Sampathkumar et al., 2014) who found that skip irrigation leads to an increase in the leaf content of proline. Table 9 also showed that potassium application caused a significant effect and gave the highest average of proline content (0.21 - 0.22 µg gm-1, while the control treatment (K0) gave the lowest average of 0.19 µg gm-1. This may be due to nano fertilizer (as shown at full irrigation treatment). This result agreed with (Banerjee et al., 2021). The interaction between the factors had no significant effect.

Conclusion

We conclude from the study that skips irrigation during maize vegetative growth caused a shortage in plant growth (height, plant leaf number, and plant leaf area) as well as low accumulation percentage of N, P, and K in plant leaf). This requires that to avoid cutting of irrigation during the vegetative growth period. Potassium fertilizer treatments caused a significant increase in plant growth and mineral accumulation. This indicates that potassium reduces the damage of drought and salinity on the plant. Spraying nano fertilizer alone or in combination with mineral K fertilizer did not differ significantly from the mineral potassium fertilizer recommended in most traits. Still, it caused a significant increase in chlorophyll content. Spraying nano-potassium fertilizer alone or with low quantities of mineral potassium reflected positively in reducing the cost and in decreasing the environmental pollution from adding huge amounts of mineral fertilizer. It is clear that potassium is a stress-alleviator plant nutrient that alleviates the negative impacts of abiotic stresses by regulating the physiological and biochemical processes.

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