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Effect of Water Stress, Nitrogen and Potassium Fertilizers on Maize Yield Productivity

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Abstract

Two field experiments were carried out at the Farm of Agric. Res. and Exp. Center of Fac. of Agric. Moshtohor, Benha University, Toukh Directorate, Qalyubia Governorate, Egypt, during two successive summer growing seasons of 2015 and 2016 to study the effect of three water stress, *i.e.* normal irrigation, skipping the second irrigation (skipping one irrigation during vegetative growth stage) and skipping the fifth irrigation (skipping one irrigation during kernels filling stage) and four nitrogen fertilizer rates, *i.e.* 0, 50, 100 and 150kg N/fed as well as three potassium fertilizer rates, *i.e.* 0, 24 and 48 kg K_2O/fed on growth, yield and its components as well as some kernels chemical properties of maize (white single cross hybrid 2031 for Misr hytech Seed Int.,). Results of combined analysis of the two seasons showed that kernels filling stage was the most sensitive to water deficit stress and preventing irrigation at this stage (skipping the 5th irrigation) caused marked decrease in mean values of allmost maize yield and its components, while, full irrigation treatment appeared to be the best irrigation treatment sine it enhanced all maize traits under study. Planting maize under water stress by skipping the 2nd irrigation and skipping the 5th irrigation significantly decreased mean values of grain yield/fed (kg) by 25.49 and 41.04 % respectively, compared to mean values of grain yield/fed (kg) of maize under normal irrigation. Planting maize when received 150 kg N/fed caused significant increase in all mean values of maize traits under study such as plant height (cm), ear height (cm), No. of ears/fed, ear diameter (cm), ear length (cm), No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), kernels shelling (%), 100-kernel weight (g), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg), biological yield/fed (kg), harvest index (%), kernels nitrogen content (%), kernels crude protein (%), nitrogen uptake/fed (kg) and protein yield/fed (kg) Meanwhile, the highest mean values of potassium use efficiency (KUE) which were recorded from growing maize when received 100 kg N/fed. Growing maize under the higher potassium rate (48 kg K_2O/fed) was produced the maximum mean values of plant height (cm), No. of ears/fed, ear length (cm), No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), 100-kernel weight (g), kernels shelling (%), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg), biological yield/fed (kg), harvest index (%), kernels potassium content (%), nitrogen uptake/fed (kg) and protein yield/fed (kg) while, the highest mean values of KUE which were recorded from growing maize when received 24 kg K_2O/fed. The first order interactions between (normal irrigation X 150 Kg N/fed), (normal irrigation X 48 kg K_2O/fed) and (150 Kg N/fed X 48 kg K_2O/fed) as well as the second order interaction between normal irrigation X 150 Kg N/fed X 48 kg K_2O/fed) were significantly recorded the greatest mean values of maize yield and its components as compared with the others interactions. It could be summarized that grown maize under full irrigation and fertilization by 150 Kg N + 48 kg K_2O/fed in order to maximizing its productivity.

Keywords: Maize, water stress, skipping irrigation, nitrogen fertilizer and potassium fertilizer.

Introduction:

In Egypt, maize (*Zea mays*, L.) is considered as one of the main cereal crops, comes the third after wheat and rice. Maize is very essential either for the human food or animal feeding and a common ingredient for industrial products. It plays a vital source of daily human food because their flour mixed with wheat flour by 20 % for bread making. Also, maize is used as a feed for livestock whether fresh, silage or grains. Therefore, a great attention should be paid to raise maize productivity by maximizing yield per unit area in order to reduce the gap between its production and consumption. Where, maize is well known for its high demand for nutrients and other production inputs. Thereby, among factors that enhances maize productivity through growing high yielding hybrids under the optimum plant population density and applying the optimum nitrogen fertilizer rate. World cultivated area of maize in 2018 year reached 461.27 million fed (fed = 4200 m^2); the total production was 1147.62 million tons, with an average productivity of 2487.95 kg grain/fed while, the growing area of maize in Egypt is about 2.228 million fed with a total grain yield of 7.30 million tons, with an average production/fed was about 3274.62 kg (www.fao.org). The total production supplies 40-50 % of the require consumption with a reduction gap of 50-60 % which has to be filled via importation.

Water is the most abundant constituent of living things. The living tissues of plants usually contain more than 70 % by weight of water and maintenance of satisfactory water content is essential for the plant tissues water content can markedly influence processes of growth and metabolism. All land plants are to some degree adapted to the unfavorable water regime of their habitat, but some species can tolerate far more unfavorable drought stresses than can other species **(Cattivelli*et al.* 2008).** Generally there are three basic types of adaptation which can occur, the control of water loss from the plant may be more efficient, the uptake of water may be more efficient and the plant may have a greater ability to grow and metabolize or survive when its tissues are suffering a water deficit **(Hall 1978)**. On the other hand, **Hall 1982 and Esfandiari*et al.* 2008** claimed that water stress influences enzyme activity and this way can influence all metabolic processes. Moreover, lowering potential often synthetic processes are reduced more than breakdown processes. He mentioned also, the level of auxin and cytokinins in the tissue are decreased while the level of abscisic acid and ethylene are increased the auxin change is due to at least partly to raised IAA oxidase activity. Parallely, the period of drought often causes yellowing and later browning of leaves, symptoms similar to senescence. On the other hand, the tolerance to draught under field conditions was studied barely cultivars. It was found that higher proline accumulation during draught were the more tolerant to draught. **Derby *et al.* 2005; Muhammad 2005 and Barnabas *et al.* 2008** claimed that the unfavorable growth conditions such as water stress, salinity or even heat stress can be tolerated by plants in juvenility rather than those at maturity. this is because plants in juvenile have high concentration of growth promoters such as GA, IAA and CKs It helps significantly in compensating and reduce happen in photosynthesis pathway, mineral absorption and production of inhibitors such as ethylene and ABA when stressed occurred. On the other hand, **Al-Kaisi and Yin 2003** found that plants at maturity generally have high concentrations of the inhibitors comparing with the promoters this encourages assimilates transportation from sources to sinks accompanied with fruity parts. the previous discussion clarify results obtained in this study, taking into consideration the hazard effects of water stress on maize plants growth, chemical composition and hence yield and its components especially at the end of the juvenility compare with the early juvenile growth period. Many researchers have reported maize growth, yield, its components and kernels chemical properties decreases when maize grown under water stress at any period of growth periods, *i.e.* vegetative, flowering and seed filling periods **(Cakir 2004; Cakmak 2005; Derby *et al.* 2005; Rimski-Korsakov *et al.* 2009; Shirazi*et al.* 2011;Waraich*et al.* 2011; Aslam*et al.* 2013; Haghjoo*et al.* 2013;Gheysari*et al.* 2015; Hammad*et al.* 2015; Paschalidis*et al.* 2015; Amanullah*et al.* 2016; Azab 2016; Mi*et al.* 2018;Ul-Allah *et al.* 2020 and Wang *et al.* 2020).**

Nitrogen is the component of protoplasm, chlorophyll, proteins, nucleic acids and plays a vital role in both vegetative and reproductive phase of crop growth. Maize has been recognized as a heavy feeder and uses more of nitrogen than any other nutrient element. Many reports indicated that nitrogen fertilizer has more influence on the allmost growth and yield maize traits than any other plant nutrient because it is the nutrient most often deficient in the Egyptian soils. Thus, increasing application of nitrogen fertilizer rates led to significant increases in allmost growth, yield and its attributes and kernels quality traits of maize plants **(Derby *et al.* 2005; Law-Ogbomo and Law-Ogbomo 2009; Rimski-Korsakov *et al.* 2009; El-Gedwy*et al.* 2011; Shirazi*et al.* 2011;Waraich*et al.* 2011; Zingore 2011; Haghjoo*et al.* 2013;Gheysari*et al.* 2015; Hammad*et al.* 2015; Paschalidis*et al.* 2015; Azab 2016; Gharibi*et al.* 2016; Sapkota*et al.* 2017; Hirniak 2018; El-Habbak*et al.* 2019; El-Hosary*et al.* 2019 a & b and Wang *et al.* 2020)**

Potassium is one of the principle plant nutrients underpinning crop yield production and quality determination, although it is not an integral component of any cellular organelle or structural part of the plant. While involved in many physiological processes, potassium's impact on water relations, photosynthesis, assimilate transport, protein synthesis and enzyme activation can have direct consequences on crop productivity. Potassium deficiency can lead to a reduction in both the No. of leaves produced and the size of individual leaves. Coupling this reduced amount of photosynthetic source material with a reduction in the photosynthetic rate/unit leaf area, and the result is an overall reduction in the amount of photosynthetic assimilates available for growth **(Jordan-Meille L. and S. Pellerin, 2004).** The production of less photosynthetic assimilates and reduced assimilate transport out of the leaves to the developing kernels greatly contributes to the negative consequences that deficiencies of potassium have on yield and quality production. Goals aimed toward increasing crop productivity and improved qualities dictate either increased potassium supply or more efficient use of potassium. Many researchers have reported maize growth, yield, its components and kernels chemical properties increases in response to increasing potassium fertilization **(Cakmak 2005; Bruns and Ebelhar 2006; Wiebold and Scharf 2006; Pettigrew 2008; Law-Ogbomo and Law-Ogbomo 2009; Niu*et al.* 2011; Tabatabaii, *et al.* 2011; Waraich*et al.* 2011; Zingore 2011; Ahmad *et al.* 2012; Aslam*et al.* 2013; El-Dissoky*et al.* 2013; Paschalidis*et al.* 2015; Amanullah*et al.* 2016; Hirniak 2018; Jiang*et al.* 2018;Jasar*et al.* 2019 and Ul-Allah *et al.* 2020).**

The aim of this investigation was designed to study the effect of water stress treatments with soil fertilized by nitrogen and potassium fertilizer rates on growth, yield components, yield and kernels chemical properties of maize.

Materials and Methods:

Two field experiments were carried out at the Farm of Agric. Res. and Exp. Center of Fac. of Agric. Moshtohor, Benha University, Toukh Directorate, Qalyubia Governorate, Egypt, during two successive summer growing seasons of 2015 and 2016 to study the effect of water stress with soil fertilized by nitrogen and potassium rates on the growth traits, yield components, yield and kernels chemical properties of maize single cross hybrid 2031 for Misr Hytech Seed Int. (S.C. 2031).

Soil analysis:

Soil texture of the experimental site was clay textured of pH nearly of 8.0. Soil samples were taken before sowing of crop to depth of 0-30 cm for chemical and mechanical properties analyses of the experimental soil were determined according to the standard procedures described by **Rowell (1995)** and represented in **Table 1**.

Table 1: Chemical and mechanical properties of the experimental soil units at planting maize (Average the 2015 and 2016 seasons.

Chemical analysis									
E.C. (ds/m)	**pH (1 :2.5)**	**$CaCo_3$ (%)**	**O.M (%)**	**Total (%)**			**Available (mg/kg)**		
				N	**P**	**K**	**N**	**P**	**K**
2.36	8.08	3.19	2.29	0.165	0.122	0.156	59.52	24.51	230.21

Soluble cations and anions (ppm)							
Ca^{++}	**Mg^{++}**	**K^+**	**Na^+**	**Cl^-**	**Co_3^{--}**	**$H Co_3^-$**	**So_4^{--}**
185.47	47.39	50.46	201.57	237.26	0.00	336.78	531.65

Mechanical analysis (Particle size distribution)				
Course sand (%)	**Find sand (%)**	**Silt (%)**	**Clay (%)**	**Texture grade**
5.07	24.95	13.05	56.93	**Clay**

Each experiment included thirty six treatments, which were the combination of three water stress treatments, four nitrogen fertilizer rates and three potassium fertilizer rates.

The levels of these factors were as follows:

A- Water stress treatments:

1) Normal irrigation (NI), maize grown under full irrigation, Irrigation at 10 (El-mohayah), 25, 40, 55, 70, 84 and 100 days after sowing.
2) Skipping the second irrigation (SCI), maize grown under irrigation at 10, 40, 55, 70, 84 and 100 days after sowing (water stress at vegetative stage).
3) Skipping the fifth irrigation (SFI), maize grown under irrigation at 10, 25, 40, 55, 85 and 100 days after sowing (water stress at kernels filling stage).

B- Nitrogen fertilizer rates:

1) Without nitrogen added (control).
2) 50 kg N/fed.
3) 100 kg N/fed.
4) 150 kg N/fed.

Nitrogen fertilizer was applied in form of urea (46 % N) and divided into two equal parts and applied side dressed before the first and third irrigations in each season.

C- Potassium fertilizer rates:

1) Without potassium added (control).
2) 24 kg K_2O/fed.
3) 48 kg K_2O/fed.

Potassium fertilizer was applied in form of potassium sulphate (48% K_2O) in one dose before the first irrigation in each season.

The preceding winter crop in two seasons was wheat (*Triticumaestivum*, L.). The experimental design was laid out using split-split plot design in four replications. Each of the three water stress were distributed in the main plots, whereas the four nitrogen fertilizer rates were arranged at random in sub-plots and the three rates of potassium fertilizer were assigned at random in sub-sub plots. The sub-sub plot area was 19.88 m^2 and contained seven ridges of 4 m long and 71 cm apart. Phosphorous fertilizer was applied in form of calcium super phosphate (12.5 % P_2O_5) at a rate of 100 kg/fed during soil preparation in each season. Maize planting was done by the local method of dibbling 2 kernels in each hill by hand with distance between hills was 25 cm apart on May 21th and 26th of in the first season (2015) and the second season (2016), respectively. Maize plants were thinned at 24 days after sowing to one plant/hill. Maize plants were harvested on 20th and 25th of September in the first and the second seasons, respectively. The other agricultural practices were kept the same as normally practiced in maize fields according to the recommendations of Ministry of Agriculture and Land Reclamation, except for the factors under study.

Studied traits:

At harvest, Ten plants were chosen from the five center ridges at random from each sub-sup plots to determine plant height (cm) and ear height (cm). Whereas, No. of ears/fed were estimated from the whole plants in the five center ridges. As well as, ten ears were chosen from the five center ridges at random from each sub-sub plots to determine ear diameter (cm), ear length (cm), No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), 100-kernel weight (g) and kernels shelling (%). Whereas, ear yield/fed (kg), stover yield/fed (kg), grain yield/fed (kg), biological yield/fed (kg) and harvest index (%) were estimated from the whole plants in the five center ridges, as well as calculated nitrogen use efficiency (NUE) and potassium use efficiency (KUE).NUE (kg grains/kg N)andKUE (kg grains/kgK**)** were calculated according to **Barbar (1976),** as follows:

$$\text{NUE} = \frac{\text{Grain yield of treatment (kg/fed)} - \text{Grain yield of control (kg/fed)}}{\text{Nitrogen applied (kg/fed)}}$$

$$\text{KUE} = \frac{\text{Grain yield of treatment (kg/fed)} - \text{Grain yield of control (kg/fed)}}{\text{Potassium applied (kg/fed)}}$$

Maize kernels samples were taken after harvest at random from all kernels of ten ears to determine:

1- Kernels nitrogen content (%) was determinate according to the modified micro Kjeldahl**method (A. O. A. C., 1990).**

2- Kernels potassium content (%) was assayed using a flame spectrophotometer (Corning 400, UK) using the standard method outlined by **Jackson (1973).**

3- Kernels crude protein content (%) was calculated by multiplying kernels nitrogen content (%) X 6.25 (A. O. A. C., 1990).

4- Nitrogen uptake (kg/fed) = Grain yield/fed (kg) x kernels nitrogen content (%).

5- Protein yield (kg/fed) = Grain yield/fed (kg) x Kernels crude protein content (%).

Statistical analysis:

Analysis of variance was performed using MSTATC statistical software package (Freed, 1991). Before conducting a combined analysis over years, error variances were tested for homogeneity by using Bartlett test and mean combined comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% by **Gomez and Gomez (1984).**

Results and Discussion:

1) Effect of water stress:

Results in **Table 2** indicated that there were significant differences among irrigation treatments, *i.e.* (normal irrigation, skipping the second irrigation and skipping the fifth irrigation), but the differences in mean values of ear diameter (cm), kernels shelling (%) and kernels potassium content (%) between water stress by skipping the second irrigation and normal irrigation, also the differences in mean values of plant height (cm), ear height (cm) and stover yield/fed (kg) between water stress by skipping the fifth irrigation and normal irrigation treatment, as well as the differences in mean values of ear length (cm), No. of rows/ear, biological yield/fed (kg), kernels nitrogen content (%) and kernels potassium content (%) between water stress by skipping the fifth and the second irrigation not reach the level of significance in the combined analysis of 2015 and 2016 seasons. Data reveal that normal irrigation treatment appeared to be the best irrigation treatment sine it enhanced all maize traits, *i.e.* ear diameter (4.755 cm), ear length (20.46 cm), No. of rows/ear (11.72 rows), No. of kernels/row (36.25 kernels), No. of kernels/ear (429.47 kernels), ear weight (187.23 g), kernels weight/ear (146.49 g), kernels shelling (76.50 %), 100-kernel weight (33.33 g), ear yield/fed (3465.52 kg), grain yield/fed (2725.96 kg), biological yield/fed (7510.36 kg), harvest index (34.44 %), NUE (20.79 kg grains/kg N), KUE (18.45 kg grains/kg K), kernels nitrogen content (1.981 %), kernels potassium content (0.546 %), kernels crude protein (12.38 %), nitrogen uptake/fed (56.68 kg) and protein yield/fed (354.24 kg) followed by the other treatments including (skipping the second irrigation then skipping the fifth irrigation). While, in mean values of plant height (283.99 cm), ear height (142.55 cm), No. of ears/fed (24.49 thousand ears) and stover yield/fed (4044.84 kg) planting maize under normal irrigation treatment significantly surpassed the other two irrigation treatments followed by skipping the fifth irrigation and skipping the second irrigation, in a descending order. The decreases ratios between planting maize under water stress by skipping the second irrigation and skipping the fifth irrigation as compared with normal irrigation treatment were 15.67 and 0.94 % for plant height; 21.66 and 2.50 % for ear height; 8.49 and 4.94 % for No. of ears/fed; 2.52 and 12.09 % for ear diameter; 13.54 and 20.82%

for ear length; 4.35 and 7.17 % for No. of rows/ear; 14.81 and 21.66 % for No. of kernels/row; 18.33 and 26.97 % for No. of kernels/ear; 21.51 and 37.89 % for ear weight; 22.23 and 40.56 % for kernels weight/ear; 0.97 and 4.63 % for kernels shelling;4.98 and 19.05 % for 100-kernel weight; 24.93 and 38.50 % for ear yield/fed; 25.49 and 41.04 % for grain yield/fed; 10.48 and 2.78 % for stover yield/fed; 17.15 and 19.26 % for biological yield/fed; 10.80 and 28.28 % for harvest index; 21.60 and 37.95 % for NUE; 19.30 and 36.80 % for KUE; 6.16 and 8.28 % for kernels nitrogen content; 8.61 and 16.30 % for kernels potassium content; 6.14 and 8.24 % for kernels crude protein; 30.10 and 45.85 % for nitrogen uptake/fed in addition to 30.10 and 45.86 % for protein yield/fed, respectively.It was clear that the decreases in mean values of allmost maize traits under water stress at filling kernels may be due to the this period showed the highest sensitivity to drought stress and gave the lowest values of yield, its components and some chemical properties of maize kernels. These results are in compatible with those found by**Cakir 2004; Cakmak 2005; Derby *et al.* 2005; Rimski-Korsakov *et al.* 2009; Shirazi*et al.* 2011;Waraich*et al.* 2011; Aslam*et al.* 2013; Haghjoo*et al.* 2013;Gheysari*et al.* 2015; Hammad*et al.* 2015; Paschalidis*et al.* 2015; Amanullah*et al.* 2016; Azab 2016; Mi*et al.* 2018;Ul-Allah *et al.* 2020 and Wang *et al.* 2020.**

2) Effect of nitrogen fertilizer rates:

Results illustrated in **Table 3** indicated that allmost growth, yield and its component traits as well as some chemical properties of maize kernels were significantly increased with increasing nitrogen fertilizer rates from 0 up to 150 kg N/fed under study, but the differences between nitrogen fertilizer rates of 100 and 150 kg N/fed on mean values of ear height (cm) and No. of rows/earas well as, the differences in mean values of KUE (kg grains/kg K) between 0 and 50 kg N/fed also, among 150 and 0 kg N/fed not reach the level of significance. Meanwhile, mean values of NUE (kg grains/kg N) and kernels potassium content (%) of maize were not significantly affected by rising nitrogen fertilizer rates in the combined analysis of both seasons. Planting maize under soil fertilized by the highest nitrogen rate (150 kg N/fed) significantly gave the maximum mean values of plant height (295.90 cm), ear height (144.60 cm), No. of ears/fed (26.58 thousand ears), ear diameter (5.114 cm), ear length (21.65 cm), No. of rows/ear (12.02 rows), No. of kernels/row (40.05 kernels), No. of kernels/ear (482.86 kernels), ear weight (211.99 g), kernels weight/ear (172.91 g), kernels shelling (81.32 %), 100-kernel weight (36.04 g), ear yield/fed (4191.64 kg), grain yield/fed (3419.75 kg), stover yield/fed (4978.56 kg), biological yield/fed (9170.19 kg), harvest index (36.94 %), kernels nitrogen content (2.124 %), kernels crude protein (13.27 %), nitrogen uptake/fed (73.26 kg) and protein yield/fed (457.87 kg). However, the highest mean value of KUE (19.79 kg grains/kg K) which was recorded from growing maize when received 100 kg N/fed. The superiority ratios between sowing maize when received 150 kg N/fed and each of 100, 50 and 0 kg N/fed were 4.70, 12.53 and 27.76 % for plant height; 4.84, 12.48 and 27.73 % for ear height; 6.02, 18.71 and 36.10 % for No. of ears/fed; 9.21, 17.98 and 32.54 % for ear diameter; 9.79, 24.21 and 58.38 % for ear length; 3.62, 9.07 and 15.13 % for No. of rows/ear; 12.50, 35.62 and 80.41 % for No. of kernels/row; 16.44, 47.57 and 106.61 % for No. of kernels/ear; 21.23, 61.92 and 155.84 % for ear weight; 25.51, 80.49 and 204.15 % for kernels weight/ear; 3.72, 12.00 and 19.64 % for kernels shelling; 8.29, 23.13 and 49.85 % for 100-kernel weight; 27.14, 90.02 and 238.95 % for ear yield/fed; 31.57, 111.48 and 302.47 % for grain yield/fed; 9.86, 38.03 and 112.13 % for stover yield/fed; 17.14, 57.76 and 155.89 % for biological yield/fed; 13.00, 35.41 and 61.38 % for harvest index; 6.63, 17.48 and 31.19 % for kernels nitrogen content; 6.59, 17.43 and 31.13 % for kernels crude protein; 39.73, 147.17 and 424.03 % for nitrogen uptake/fedin addition to 39.72, 147.18 and 423.94 % for protein yield/fed, respectively. The increase in growth traits associated with increasing nitrogen fertilization rates may be attributed to the role of nitrogen in enhancement meristematic activity and cell division, which caused increase in internodes length, No. of internodes and both of them. The increase in maize yield and its attributes because of increasing nitrogen fertilizer rates up to 150 kg N/fed can be easily ascribed to the role of nitrogen in activating growth of plants, consequently enhancement yield components (ear dimension, No. of kernels/row, No. of kernels/ear, ear weight, weight of kernels/ear, as well as 100-kernel weight) and consequently increasing grain yield/unit area. In addition, the increases in kernels nitrogen content % or kernels crude protein content % by raising nitrogen rates may be due to the fact that nitrogen for essential for building up to the protoplasm amino acids and proteins. These results are in compatible with those found by **Derby *et al.* 2005; Law-Ogbomo and Law-Ogbomo 2009; Rimski-Korsakov *et al.* 2009; El-Gedwy*et al.* 2011; Shirazi*et al.* 2011;Waraich*et al.* 2011; Zingore 2011; Haghjoo*et al.* 2013;Gheysari*et al.* 2015; Hammad*et al.* 2015; Paschalidis*et al.* 2015; Azab 2016; Gharibi*et al.* 2016; Sapkota*et al.* 2017; Hirniak 2018; El-Habbak*et al.* 2019; El-Hosary*et al.* 2019 a & b and Wang *et al.* 2020.**

Table 2: Mean values of agronomic traits of maize as affected by water stress in the combined analysis of 2015 and 2016 seasons.

Trait	Water stress			L.S.D. at 5 %
	Normal irrigation	Skipping the 2nd irrigation	Skipping the 5th irrigation	
Plant height (cm)	283.99	239.50	281.33	**4.88**
Ear height (cm)	142.55	111.67	138.99	**3.73**
No. of ears/fed (1000 ears)	24.49	22.41	23.28	**0.41**
Ear diameter (cm)	4.755	4.635	4.180	**0.197**
Ear length (cm)	20.46	17.69	16.20	**1.86**
No. of rows/ear	11.72	11.21	10.88	**0.34**
No. of kernels/row	36.25	30.88	28.40	**1.55**
No. of kernels/ear	429.47	350.76	313.63	**5.63**
Ear weight (g)	187.23	146.96	116.29	**6.11**
Kernels weight/ear (g)	146.49	113.92	87.08	**5.22**
Kernels shelling (%)	76.50	75.76	72.96	**0.83**
100-kernel weight (g)	33.33	31.67	26.98	**0.89**
Ear yield/fed (kg)	3465.52	2601.48	2131.24	**185.12**
Grain yield/fed (kg)	2725.96	2031.09	1607.18	**173.11**
Stover yield/fed (kg)	4044.84	3620.80	3932.36	**146.72**
Biological yield/fed (kg)	7510.36	6222.28	6063.60	**277.72**
Harvest index (%)	34.44	30.72	24.70	**1.53**
NUE (kg grains/kg N)	20.79	16.30	12.90	**0.98**
KUE (kg grains/kg K)	18.45	14.89	11.66	**1.29**
Kernels nitrogen content (%)	1.981	1.859	1.817	**0.088**
Kernels potassium content (%)	0.546	0.499	0.457	**0.047**
Kernels crude protein (%)	12.38	11.62	11.36	**0.22**
Nitrogen uptake/fed (kg)	56.68	39.62	30.69	**2.75**
Protein yield/fed (kg)	354.24	247.63	191.79	**6.88**

Table 3: Mean values of agronomic traits of maize as affected by nitrogen fertilizer rates in the combined analysis of 2015 and 2016 seasons.

Trait	Nitrogen fertilizer rate (kg N/fed)				L.S.D. at 5 %
	0	50	100	150	
Plant height (cm)	231.61	262.96	282.63	295.90	**10.15**
Ear height (cm)	113.21	128.56	137.92	144.60	**7.09**
No. of ears/fed (1000 ears)	19.53	22.39	25.07	26.58	**0.52**
Ear diameter (cm)	3.881	4.360	4.710	5.144	**0.175**
Ear length (cm)	13.67	17.43	19.72	21.65	**1.63**
No. of rows/ear	10.44	11.02	11.60	12.02	**0.41**
No. of kernels/row	22.20	29.53	35.60	40.05	**2.93**
No. of kernels/ear	233.71	327.20	414.69	482.86	**10.15**
Ear weight (g)	82.86	130.92	174.87	211.99	**14.33**
Kernels weight/ear (g)	56.85	95.80	137.77	172.91	**11.69**
Kernels shelling (%)	67.97	72.61	78.40	81.32	**2.25**
100-kernel weight (g)	24.05	29.27	33.28	36.04	**2.69**
Ear yield/fed (kg)	1236.67	2205.89	3296.79	4191.64	**365.62**
Grain yield/fed (kg)	849.69	1617.08	2599.11	3419.75	**278.37**
Stover yield/fed (kg)	2346.96	3606.86	4531.64	4978.56	**310.55**
Biological yield/fed (kg)	3583.63	5812.75	7828.43	9170.19	**489.17**
Harvest index (%)	22.89	27.28	32.69	36.94	**2.61**
NUE (kg grains/kg N)	--	15.35	17.50	17.14	**N.S.**
KUE (kg grains/kg K)	13.23	14.41	19.79	12.57	**1.61**
Kernels nitrogen content (%)	1.619	1.808	1.992	2.124	**0.126**
Kernels potassium content (%)	0.468	0.491	0.512	0.531	**N.S.**
Kernels crude protein (%)	10.12	11.30	12.45	13.27	**0.32**
Nitrogen uptake/fed (kg)	13.98	29.64	52.43	73.26	**4.87**
Protein yield/fed (kg)	87.39	185.24	327.71	457.87	**12.18**

3) Effect of potassium fertilizer rates:

Results in **Table 4** showed that growth, yield, its attributes and kernels chemical properties of maize, *i.e.* plant height (cm), ear length (cm), No. of ears/fed, No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), kernels shelling (%), 100-kernel weight (g), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg), biological yield/fed (kg), harvest index (%), KUE (kg grains/kg K), kernels potassium content (%), nitrogen uptake/fed (kg) and protein yield/fed (kg) were significantly affected by potassium fertilizer rates, *i.e.* 0, 24 and 48 kg K_2O/fed, but, the differences between potassium fertilizer rates of 24 and 48 kg K_2O/fed on mean values of kernels potassium content (%) not reach the level of significance. While, mean values of ear height (cm), ear diameter (cm), No. of rows/ear, NUE (kg grains/kg N), kernels nitrogen content and kernels crude protein were not significant in the combined analysis of both seasons. In general, the higher potassium rate (48 kg K_2O/fed) was more effective in increasing mean values of allmost studied traits, also, produced the maximum mean values of plant height (273.78 cm), No. of ears/fed (24.28 thousand ears), ear length (19.10 cm), No. of kernels/row (34.46 kernels), No. of kernels/ear (399.02 kernels), ear weight (167.62 g), kernels weight/ear (131.60 g), kernels shelling (76.95 %), 100-kernel weight (32.29 g), ear yield/fed (3111.83 kg), grain yield/fed (2455.01 kg), stover yield/fed (4078.38 kg), biological yield/fed (7190.21 kg), harvest index (32.56 %), kernels potassium content (0.530 %), nitrogen uptake/fed (49.60 kg) and protein yield/fed (310.00 kg), meanwhile, the highest mean value of KUE (15.65 kg grains/kg K) which were recorded from growing maize when received 24 kg K_2O/fed.The increases ratios with planting maize when received 48 kg K_2O/fed over each of 24 and 0 kg K_2O/fed were1.77 and 4.49 % for plant height; 4.12 and 7.53 % for No. of ears/fed; 5.06 and 11.89 % for ear length; 6.65 and 19.78 % for No. of kernels/row; 7.73 and 22.98 % for No. of kernels/ear; 9.94 and 28.56 % for ear weight; 11.82 and 34.01 % for kernels weight/ear; 2.12 and 5.53 % for kernels shelling; 4.67 and 11.96 % for 100-kernel weight; 12.84 and 33.64 % for ear yield/fed; 14.59 and 38.95 % for grain yield/fed; 5.16 and 12.00 % for stover yield/fed; 8.35 and 20.44 % for biological yield/fed; 7.35 and 20.73 % for harvest index; 4.33 and 14.22 % for kernels potassium content; 15.91 and 43.35 % for nitrogen uptake/fed in addition to 15.92 and 43.37 % for protein yield/fed, respectively. The increase in maize traits associated with increasing potassium fertilization rates may be attributed to the role of potassium in many physiological processes, *i.e.* water relations, photosynthesis, assimilate transport, protein synthesis and enzyme activation can have direct consequences on maize productivity. These results are in compatible with those found by**Cakmak 2005; Bruns and Ebelhar 2006; Wiebold and Scharf 2006; Pettigrew 2008; Law-Ogbomo and Law-Ogbomo 2009; Niu*et al.* 2011; Tabatabaii, *et al.* 2011; Waraich*et al.* 2011; Zingore 2011; Ahmad *et al.* 2012; Aslam*et al.* 2013; El-Dissoky*et al.* 2013; Paschalidis*et al.* 2015; Amanullah*et al.* 2016; Hirniak 2018; Jiang*et al.* 2018;Jasar*et al.* 2019 and Ul-Allah *et al.* 2020.**

4) Effect of interaction between water stress and nitrogen fertilizer rates:

Results in **Table 5** showed that interaction effect among water stress treatments (normal irrigation, skipping the second irrigation and skipping the fifth irrigation) and nitrogen fertilizer rates (0, 50, 100 and 150 kg N/fed) induced significant different on allmost maize traits under study except, for mean values of ear height (cm), ear diameter (cm), No. of rows/ear, kernels shelling (%) and kernels potassium content (%) in the combined analysis of both seasons. Growing maize under full irrigation when received 150 kg N/fed markedly produced the maximum mean values of plant height (311.88 cm), No. of ears/fed (27.37 thousand ears), ear length (24.55 cm), No. of kernels/row (45.01 kernels), No. of kernels/ear (561.93 kernels), ear weight (262.71 g), kernels weight/ear (216.98 g), 100-kernel weight (39.23 g), ear yield/fed (5180.71 kg), grain yield/fed (4280.22 kg), stover yield/fed (5208.46 kg), biological yield/fed (10389.17 kg), harvest index (41.15 %), kernels nitrogen content (2.243 %), kernels crude protein (14.02 %), nitrogen uptake/fed (96.07 kg) and protein yield/fed (600.44 kg). Meanwhile, the highest mean values of NUE (21.79 kg grains/kg N) and KUE (23.77 kg grains/kg K) which were recorded from growing maize with normal irrigation treatment when received 100 kg N/fed. Planting maize under water stress by skipping the 5^{th} irrigation without nitrogen added significantly gave the lowest mean values of ear length (12.34 cm), No. of kernels/row (19.05 kernels), No. of kernels/ear (192.06 kernels), ear weight (61.68 g), kernels weight/ear (40.84 g), 100-kernel weight (21.25 g), ear yield/fed (919.50 kg), grain yield/fed (609.50 kg), harvest index (17.80 %), KUE (9.25 kg grains/kg K), kernels nitrogen content (1.581 %), kernels crude protein (9.88 %), nitrogen uptake/fed (9.74 kg) and protein yield/fed (60.85 kg). While, the lowest mean values of plant height (208.83 cm), No. of ears/fed (18.37 thousand ears), stover yield/fed (2079.17 kg) and biological yield/fed (3215.46 kg) were recorded from sowing maize under water stress by skipping the 2^{nd} irrigation without nitrogen added. Meanwhile, planting maize under water stress by skipping the 5^{th} irrigation when received 50 kg N/fed gave the lowest mean value of NUE by 11.39 kg grains/kg N. Results reported here are in harmony with those obtained by **Derby *et al.* 2005; Rimski-Korsakov *et al.* 2009; Shirazi*et al.* 2011;Waraich*et al.* 2011; Haghjoo*et al.* 2013;Gheysari*et al.* 2015; Hammad*et al.* 2015; Paschalidis*et al.* 2015; Azab 2016; and Wang *et al.* 2020,** found that mean values of maize yield and its components were significantly affected by interaction between water stress and nitrogen fertilizer rates.

Table 4: Mean values of agronomic traits of maize as affected by potassium fertilizer rates in the combined analysis of 2015 and 2016 seasons.

Trait	Potassium fertilizer rate (kg K_2O/fed)			L.S.D. at 5 %
	0	24	48	
Plant height (cm)	262.02	269.02	273.78	**4.22**
Ear height (cm)	127.98	131.47	133.76	**N.S.**
No. of ears/fed (1000 ears)	22.58	23.32	24.28	**0.16**
Ear diameter (cm)	4.347	4.544	4.680	**N.S.**
Ear length (cm)	17.07	18.18	19.10	**0.78**
No. of rows/ear	11.06	11.31	11.44	**N.S.**
No. of kernels/row	28.77	32.31	34.46	**1.75**
No. of kernels/ear	324.45	370.38	399.02	**5.11**
Ear weight (g)	130.38	152.47	167.62	**6.15**
Kernels weight/ear (g)	98.20	117.69	131.60	**5.19**
Kernels shelling (%)	72.92	75.35	76.95	**1.15**
100-kernel weight (g)	28.84	30.85	32.29	**0.79**
Ear yield/fed (kg)	2328.59	2757.81	3111.83	**151.33**
Grain yield/fed (kg)	1766.80	2142.42	2455.01	**167.42**
Stover yield/fed (kg)	3641.49	3878.15	4078.38	**153.55**
Biological yield/fed (kg)	5970.08	6635.96	7190.21	**269.85**
Harvest index (%)	26.97	30.33	32.56	**1.57**
NUE (kg grains/kg N)	16.01	16.74	17.24	**N.S.**
KUE (kg grains/kg K)	--	15.65	14.34	**0.98**
Kernels nitrogen content (%)	1.832	1.893	1.932	**N.S.**
Kernels potassium content (%)	0.464	0.508	0.530	**0.025**
Kernels crude protein (%)	11.45	11.83	12.07	**N.S.**
Nitrogen uptake/fed (kg)	34.60	42.79	49.60	**2.69**
Protein yield/fed (kg)	216.22	267.43	310.00	**6.73**

Table 5: Mean values of agronomic traits of maize as affected by interaction between water stress and nitrogen fertilizer rates on in the combined analysis of 2015 and 2016 seasons.

Trait	Water stress												L.S.D. at 5 %
	Normal irrigation				Skipping the 2nd irrigation				Skipping the 5th irrigation				
Nitrogen (kg N/fed)	0	50	100	150	0	50	100	150	0	50	100	150	
Plant height (cm)	244.33	279.46	300.29	311.88	208.83	232.46	249.21	267.50	241.67	276.96	298.38	308.33	**17.58**
Ear height (cm)	122.75	140.33	150.67	156.46	97.46	108.42	116.08	124.71	119.42	136.92	147.00	152.63	**N.S.**
No. of ears/fed (1000 ears)	20.80	23.67	26.13	27.37	18.37	21.42	24.07	25.80	19.43	22.10	25.00	26.57	**0.90**
Ear diameter (cm)	4.117	4.575	4.933	5.396	3.917	4.446	4.838	5.342	3.608	4.058	4.358	4.696	**N.S.**
Ear length (cm)	15.24	19.77	22.29	24.55	13.42	16.96	19.25	21.13	12.34	15.56	17.62	19.28	**2.82**
No. of rows/ear	10.91	11.44	12.03	12.48	10.38	10.97	11.56	11.95	10.04	10.65	11.22	11.62	**N.S.**
No. of kernels/row	26.10	33.86	40.03	45.01	21.44	28.76	34.93	38.41	19.05	25.97	31.83	36.74	**5.07**
No. of kernels/ear	285.75	388.09	482.10	561.93	223.33	316.15	404.18	459.37	192.06	277.38	357.80	427.29	**17.58**
Ear weight (g)	106.81	163.34	216.04	262.71	80.09	128.96	173.30	205.49	61.68	100.45	135.26	167.76	**24.82**
Kernels weight/ear (g)	74.33	122.10	172.54	216.98	55.37	94.58	137.26	168.48	40.84	70.73	103.50	133.26	**20.25**
Kernels shelling (%)	69.19	74.53	79.73	82.56	68.81	73.13	79.11	82.00	65.90	70.18	76.37	79.40	**N.S.**
100-kernel weight (g)	26.08	31.80	36.20	39.23	24.82	30.23	34.38	37.24	21.25	25.78	29.26	31.65	**4.66**
Ear yield/fed (kg)	1654.21	2858.83	4168.33	5180.71	1136.29	2086.71	3164.58	4018.33	919.50	1672.13	2557.46	3375.88	**633.27**
Grain yield/fed (kg)	1153.06	2139.50	3331.05	4280.22	786.51	1532.76	2508.39	3296.70	609.50	1178.98	1957.90	2682.34	**482.15**
Stover yield/fed (kg)	2532.13	3734.17	4704.63	5208.46	2079.17	3430.71	4289.29	4684.04	2429.58	3655.71	4601.00	5043.17	**537.89**
Biological yield/fed (kg)	4186.33	6593.00	8872.96	10389.17	3215.46	5517.42	7453.88	8702.38	3349.08	5327.83	7158.46	8419.04	**847.27**
Harvest index (%)	26.98	32.24	37.38	41.15	23.91	27.63	33.50	37.85	17.80	21.97	27.19	31.83	**4.52**
NUE (kg grains/kg N)	--	19.73	21.79	20.85	--	14.93	17.22	16.74	--	11.39	13.49	13.82	**2.89**
KUE (kg grains/kg K)	17.78	18.32	23.77	13.94	12.67	14.09	19.82	12.96	9.25	10.80	15.77	10.82	**2.79**
Kernels nitrogen content (%)	1.6675	1.9088	2.1038	2.2425	1.6075	1.7825	1.9688	2.0788	1.5808	1.7329	1.9033	2.0504	**0.2182**
Kernels potassium content (%)	0.5142	0.5388	0.5588	0.5708	0.4617	0.4871	0.5104	0.5383	0.4271	0.4483	0.4671	0.4846	**N.S.**
Kernels crude protein (%)	10.42	11.93	13.15	14.02	10.05	11.14	12.30	12.99	9.88	10.83	11.90	12.82	**0.55**
Nitrogen uptake/fed (kg)	19.38	40.94	70.32	96.07	12.83	27.46	49.58	68.62	9.74	20.51	37.40	55.09	**8.44**
Protein yield/fed (kg)	121.11	255.90	439.51	600.44	80.20	171.61	309.85	428.84	60.85	128.21	233.77	344.34	**21.10**

5) Effect of interaction between water stress and potassium fertilizer rates:

Mean values of plant height (cm), ear length (cm), No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), 100-kernel weight (g), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg), biological yield/fed (kg), harvest index (%), NUE (kg grains/kg N), KUE (kg grains/kg K), nitrogen uptake/fed (kg) and protein yield/fed (kg) of maize were significantly affected by interaction between water stress treatments (full irrigation, skipping the 2nd irrigation and skipping the 5th irrigation) and potassium fertilizer rates (0, 24 and 48 kg K_2O/fed). While, mean values of ear height (cm), No. of ears/fed, ear diameter (cm), No. of rows/ear, kernels shelling (%), kernels nitrogen content (%), kernels potassium content (%) and kernels crude protein (%) were not significant by interaction between water tress and potassium fertilizer rates in the combined analysis of both seasons, as shown in **Table 6.** Planting maize with full irrigation treatment when received 48 kg K_2O/fed significantly produced the maximum mean values of plant height (289.13 cm), ear length (21.60 cm), No. of kernels/row (39.04 kernels), No. of kernels/ear (467.30 kernels), ear weight (208.12 g), kernels weight/ear (165.92 g), 100-kernel weight (35.12 g), ear yield/fed (3932.72 kg), grain yield/fed (3146.46 kg), stover yield/fed (4268.03 kg), biological yield/fed (8200.75 kg), harvest index (37.19 %), NUE (21.17 kg grains/kg N), nitrogen uptake/fed (66.15 kg) and protein yield/fed (413.42 kg). Meanwhile, the highest mean values of KUE (19.01 kg grains/kg K) which were recorded from growing maize with full irrigation treatment when received 24 kg K_2O/fed. On the other hand, the lowest mean values of ear length (15.31 cm), No. of kernels/row (25.40 kernels), No. of kernels/ear (276.04 kernels), ear weight (100.05 g), kernels weight/ear (73.14 g), 100-kernel weight (25.40 g), ear yield/fed (1805.31 kg), grain yield/fed (1330.14 kg), biological yield/fed (5535.72 kg), harvest index (21.90 %), NUE (12.11 kg grains/kg N), nitrogen uptake/fed (24.91 kg) and protein yield/fed (155.71 kg), which were obtained from sowing maize under water stress by skipping the 5th irrigation without potassium added, while, the lowest mean value of KUE (11.32 kg grains/kg K) which was recorded from growing maize with the same water stress when received 48 kg K_2O/fed. While, sowing maize under water stress by skipping the 2nd irrigation without potassium added recorded the minimum mean values of plant height (232.06 cm) and stover yield/fed (3380.59 kg). These results agree with those reported by **Cakmak 2005; Waraich*et al.* 2011; Aslam*et al.* 2013;Paschalidis*et al.* 2015; Amanullah*et al.* 2016 and Ul-Allah *et al.* 2020,** found that mean values of maize yield and its components were significantly affected by interaction between water stress and potassium fertilizer rates.

6) Effect of interaction between nitrogen and potassium fertilizer rates:

Results in **Table 7** showed that interaction effect among nitrogen fertilizer rates (0, 50, 100 and 150 kg N/fed) and potassium fertilizer rates (0, 24 and 48 kg K_2O/fed) induced significant different on all maize yield and its related traits except, for mean values of ear diameter (cm), No. of rows/ear and kernels potassium content (%) in the combined analysis of both seasons. The highest mean values of plant height (299.29cm), ear height (146.21cm), No. of ears/fed (27.03thousand ears), ear length (22.32cm), No. of kernels/row (41.58kernels), No. of kernels/ear (505.89kernels), ear weight (222.90g), kernels weight/ear (184.53 g), kernels shelling (82.60 %), 100-kernel weight (36.73 g), ear yield/fed (4446.96 kg), grain yield/fed (3681.83 kg), stover yield/fed (5155.88 kg), biological yield/fed (9602.83 kg), harvest index (38.04 %), kernels nitrogen content (2.157 %), kernels crude protein (13.48 %), nitrogen uptake/fed (79.96 kg) and protein yield/fed (499.74 kg) were recorded from maize plants which fertilized by 150 kg N and 48 kg K_2O/fed. While, the highest mean values of NUE (18.74 kg grains/kg N) and KUE (20.96 kg grains/kg K) which were obtained from maize under soil fertilized by 100 kg N/fed when received 48 and 24 kg K_2O/fed respectively. On the other hand, growing maize without nitrogen and potassium fertilizers added markedly recorded the lowest mean values in plant height (220.83 cm), ear height (107.92 cm), No. of ears/fed (18.40 thousand ears), ear length (12.14 cm), No. of kernels/row (17.09 kernels), No. of kernels/ear (175.95 kernels), ear weight (58.07 g), kernels weight/ear (38.23 g), kernels shelling (65.68 %), 100-kernel weight (21.73 g), ear yield/fed (812.54 kg), grain yield/fed (535.05 kg), stover yield/fed (2083.54 kg), biological yield/fed (2896.08 kg), harvest index (18.28 %), kernels nitrogen content (1.551 %), kernels crude protein (9.69 %), nitrogen uptake/fed (8.39 kg) and protein yield/fed (52.41 kg). While, the lowest mean value of NUE (14.75 kg grains/kg N) which was recorded when planting maize under soil fertilized by 50 kg N/fed without potassium fertilizers added. Meanwhile, sowing maize under soil fertilized by 150 kg N and 48 kg K_2O/fed significantly recorded the lowest mean value of KUE by 11.58 kg grains/kg K. Such results are in accordance with those obtained by **Law-Ogbomo and Law-Ogbomo 2009; Waraich*et al.* 2011; Zingore 2011; Paschalidis*et al.* 2015 and Hirniak 2018,** which reported that there was significantly difference among interaction between nitrogen and potassium fertilizer rates of mean values of maize yield and its components.

Table 6: Mean values of agronomic traits of maize as affected by interaction between water stress and potassium fertilizer rates on in the combined analysis of 2015 and 2016 seasons.

Trait	Water stress									L.S.D. at 5 %
	Normal irrigation			Skipping the 2nd irrigation			Skipping the 5th irrigation			
Potassium (kg K_2O /fed)	0	24	48	0	24	48	0	24	48	
Plant height (cm)	278.41	284.44	289.13	232.06	240.31	246.13	275.59	282.31	286.09	**7.31**
Ear height (cm)	139.84	142.72	145.09	108.19	112.06	114.75	135.91	139.63	141.44	**N.S.**
No. of ears/fed (1000 ears)	23.68	24.35	25.45	21.50	22.51	23.23	22.58	23.10	24.15	**N.S.**
Ear diameter (cm)	4.588	4.778	4.900	4.441	4.656	4.809	4.013	4.197	4.331	**N.S.**
Ear length (cm)	19.24	20.55	21.60	16.66	17.76	18.65	15.31	16.24	17.05	**1.35**
No. of rows/ear	11.52	11.75	11.88	10.99	11.25	11.39	10.67	10.91	11.07	**N.S.**
No. of kernels/row	32.93	36.79	39.04	27.98	31.32	33.35	25.40	28.81	30.98	**3.03**
No. of kernels/ear	384.67	436.43	467.30	312.63	356.33	383.30	276.04	318.39	346.46	**8.85**
Ear weight (g)	163.39	190.17	208.12	127.70	149.18	163.99	100.05	118.05	130.76	**10.65**
Kernels weight/ear (g)	124.71	148.83	165.92	96.75	115.81	129.21	73.14	88.43	99.68	**8.99**
Kernels shelling (%)	74.22	76.78	78.50	73.65	76.10	77.54	70.90	73.18	74.81	**N.S.**
100-kernel weight (g)	31.33	33.54	35.12	29.78	31.87	33.35	25.40	27.15	28.40	**1.37**
Ear yield/fed (kg)	2976.69	3487.16	3932.72	2203.78	2642.06	2958.59	1805.31	2144.22	2444.19	**262.11**
Grain yield/fed (kg)	2287.66	2743.75	3146.46	1682.58	2065.63	2345.06	1330.14	1617.88	1873.52	**289.98**
Stover yield/fed (kg)	3813.47	4053.03	4268.03	3380.59	3658.56	3823.25	3730.41	3922.84	4143.84	**265.96**
Biological yield/fed (kg)	6790.16	7540.19	8200.75	5584.38	6300.63	6781.84	5535.72	6067.06	6588.03	**467.39**
Harvest index (%)	31.30	34.81	37.19	27.72	31.16	33.29	21.90	25.01	27.18	**2.72**
NUE (kg grains/kg N)	20.40	20.69	21.27	15.50	16.39	17.00	12.11	13.16	13.43	**1.92**
KUE (kg grains/kg K)	--	19.01	17.89	--	15.96	13.80	--	11.99	11.32	**1.70**
Kernels nitrogen content (%)	1.935	1.984	2.023	1.793	1.873	1.912	1.769	1.822	1.859	**N.S.**
Kernels potassium content (%)	0.506	0.553	0.578	0.467	0.507	0.524	0.420	0.462	0.488	**N.S.**
Kernels crude protein (%)	12.09	12.40	12.65	11.21	11.71	11.95	11.06	11.39	11.62	**N.S.**
Nitrogen uptake/fed (kg)	46.86	57.03	66.15	32.01	40.44	46.41	24.91	30.90	36.25	**4.66**
Protein yield/fed (kg)	292.88	356.42	413.42	200.07	252.77	290.03	155.71	193.11	226.55	**11.66**

Table 7: Mean values of agronomic traits of maize as affected by interaction between nitrogen and potassium fertilizer rates on in the combined analysis of 2015 and 2016 seasons.

Trait	Nitrogen (kg N/fed)												L.S.D. at 5 %
	0			50			100			150			
Potassium (kg K_2O /fed)	0	24	48	0	24	48	0	24	48	0	24	48	
Plant height (cm)	220.83	232.88	241.13	257.04	263.75	268.08	277.75	283.50	286.63	292.46	295.96	299.29	**8.44**
Ear height (cm)	107.92	113.83	117.88	125.83	128.88	130.96	135.25	138.50	140.00	142.92	144.67	146.21	**7.02**
No. of ears/fed (1000 ears)	18.40	19.27	20.93	21.43	22.35	23.40	24.37	25.10	25.73	26.13	26.57	27.03	**0.32**
Ear diameter (cm)	3.658	3.929	4.054	4.213	4.358	4.508	4.567	4.708	4.854	4.950	5.179	5.304	**N.S.**
Ear length (cm)	12.14	13.58	15.29	16.47	17.58	18.25	18.71	19.91	20.53	20.97	21.67	22.32	**1.56**
No. of rows/ear	10.23	10.50	10.60	10.73	11.06	11.28	11.42	11.62	11.77	11.88	12.05	12.13	**N.S.**
No. of kernels/row	17.09	23.18	26.33	26.95	29.70	31.94	32.78	36.03	37.98	38.25	40.33	41.58	**3.50**
No. of kernels/ear	175.95	244.74	280.45	290.46	329.81	361.35	375.83	419.86	448.39	455.57	487.12	505.89	**10.22**
Ear weight (g)	58.07	85.99	104.52	112.55	132.79	147.41	152.27	176.66	195.67	198.63	214.42	222.90	**12.30**
Kernels weight/ear (g)	38.23	59.11	73.21	78.93	96.74	111.73	116.41	139.95	156.94	159.23	174.96	184.53	**10.38**
Kernels shelling (%)	65.68	68.47	69.75	69.83	72.53	75.48	76.24	78.99	79.97	79.95	81.41	82.60	**2.30**
100-kernel weight (g)	21.73	24.20	26.21	27.29	29.47	31.05	31.14	33.54	35.16	35.20	36.19	36.73	**1.58**
Ear yield/fed (kg)	812.54	1251.88	1645.58	1813.00	2222.67	2582.00	2790.21	3327.38	3772.79	3898.63	4229.33	4446.96	**302.66**
Grain yield/fed (kg)	535.05	860.88	1153.14	1272.33	1620.59	1958.33	2133.80	2636.80	3026.74	3126.01	3451.42	3681.83	**334.84**
Stover yield/fed (kg)	2083.54	2310.71	2646.63	3358.71	3664.63	3797.25	4307.17	4574.00	4713.75	4816.54	4963.25	5155.88	**307.10**
Biological yield/fed (kg)	2896.08	3562.58	4292.21	5171.71	5887.29	6379.25	7097.38	7901.38	8486.54	8715.17	9192.58	9602.83	**539.70**
Harvest index (%)	18.28	23.85	26.56	24.33	27.19	30.32	29.74	33.03	35.30	35.55	37.24	38.04	**3.14**
NUE (kg grains/kg N)	--	--	--	14.75	15.20	16.10	15.99	17.77	18.74	17.28	17.27	16.86	**2.22**
KUE (kg grains/kg K)	--	13.58	12.88	--	14.52	14.30	--	20.96	18.61	--	13.56	11.58	**1.96**
Kernels nitrogen content (%)	1.551	1.628	1.678	1.763	1.812	1.850	1.933	2.000	2.042	2.082	2.133	2.157	**0.164**
Kernels potassium content (%)	0.433	0.473	0.496	0.455	0.500	0.519	0.477	0.518	0.541	0.493	0.538	0.563	**N.S.**
Kernels crude protein (%)	9.69	10.17	10.48	11.02	11.32	11.56	12.08	12.50	12.76	13.01	13.33	13.48	**0.42**
Nitrogen uptake/fed (kg)	8.39	14.10	19.46	22.69	29.66	36.56	41.64	53.24	62.42	65.67	74.15	79.96	**5.38**
Protein yield/fed (kg)	52.41	88.10	121.64	141.83	185.41	228.49	260.22	332.78	390.12	410.42	463.45	499.74	**13.46**

7) Effect of interaction between water stress, nitrogen and potassium fertilizer rates:

Results in **Tables 8, 9 and 10** showed significant interaction effect between water stress treatments (normal irrigation, skipping the 2nd irrigation and skipping the 5th irrigation), nitrogen fertilizer rates (0, 50, 100 and 150 kg N/fed) and potassium fertilizer rates (0, 24 and 48 kg K_2O/fed) under study on mean values of plant height, No. of ears/fed, No. of kernels/ear, ear weight (g), kernels weight/ear (g), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg), biological yield/fed (kg), nitrogen uptake/fed (kg) and protein yield/fed (kg) of maize. While, mean values of ear height (cm), ear length (cm), ear diameter (cm), No. of rows/ear, No. of kernels/row, kernels shelling (%), 100-kernel weight (g), harvest index (%), NUE (kg grains/kg N), KUE (kg grains/kg K), kernels nitrogen content (%), kernels potassium content (%) and kernels crude protein (%) were not significantly affected by interaction in the combined analysis of both seasons. The maximum mean values of plant height (314.25 cm), No. of ears/fed (27.90 thousand ears), No. of kernels/ear (589.56 kernels), ear weight (277.04 g), kernels weight/ear (232.04 g), ear yield/fed (5469.00 kg), grain yield/fed (4582.23 kg), stover yield/fed (5423.13 kg), biological yield/fed (10892.13 kg), nitrogen uptake/fed (103.99 kg) and protein yield/fed (649.93 kg) which were obtained by planting maize with normal irrigation treatment under soil fertilized by 150 kg N/fed and 48 kg K_2O/fed. Planting maize under water stress by skipping the 2nd irrigation without soil fertilized by nitrogen and potassium gave the lowest mean values of plant height (198.25 cm), No. of ears/fed (17.10 thousand ears), stover yield/fed (1842.75 kg) and biological yield/fed (2575.63 kg). Results recorded that sowing maize under water stress by skipping the 5th irrigation without nitrogen and potassium add gave the minimum mean values of No. of kernels/ear (142.71 kernels), ear weight (42.46 g), kernels weight/ear (27.13 g), ear yield/fed (603.25 kg), grain yield/fed (385.52kg), nitrogen uptake/fed (5.87 kg) and protein yield/fed (36.67 kg). Results agree with those reported by**Waraich*et al.* 2011 and Paschalidis*et al.* 2015.**

Conclusion:

From the obtained results of this study it could be concluded that planting maize under full irrigation with soil fertilized by 150 kg N + 48 kg K_2O/fed in order to maximizing its productivity.

Table 8: Mean values of plant height (cm), ear height (cm), No. of ears/fed, ear diameter (cm), ear length (cm), No. of rows/ear, No. of kernels/row and No. of kernels/ear of maize as affected by interaction between water stress, nitrogen fertilizer rates and potassium fertilizer rates in the combined analysis of 2015 and 2016 seasons.

Treatment		Trait	Plant height (cm)	Ear height (cm)	No. of ears/fed (1000 ears)	Ear diameter (cm)	Ear length (cm)	No. of rows /ear	No. of kernels /row	No. of kernels /ear
Water stress X Nitrogen (kg N/fed) X Potassium (kg K_2O/fed)										
Normal irrigation	**0**	**0**	233.88	117.50	19.60	3.938	13.43	10.71	20.38	218.59
		24	244.63	122.88	20.50	4.175	15.08	10.95	27.46	300.95
		48	254.50	127.88	22.30	4.238	17.21	11.08	30.48	337.70
	50	**0**	275.25	138.50	22.70	4.425	18.48	11.19	31.15	348.69
		24	279.63	140.38	23.50	4.575	20.06	11.50	34.08	392.13
		48	283.50	142.13	24.80	4.725	20.78	11.64	36.36	423.44
	100	**0**	295.38	148.38	25.50	4.788	21.23	11.85	37.29	442.20
		24	301.25	151.00	26.10	4.925	22.49	12.04	40.33	485.61
		48	304.25	152.63	26.80	5.088	23.16	12.20	42.49	518.50
	150	**0**	309.13	155.00	26.90	5.200	23.85	12.34	42.89	529.20
		24	312.25	156.63	27.30	5.438	24.58	12.51	45.31	567.02
		48	314.25	157.75	27.90	5.550	25.24	12.59	46.84	589.56
Skipping the 2nd irrigation	**0**	**0**	198.25	92.38	17.10	3.663	11.94	10.15	16.39	166.55
		24	210.38	98.25	18.40	3.988	13.36	10.43	22.45	234.31
		48	217.88	101.75	19.60	4.100	14.96	10.55	25.49	269.14
	50	**0**	223.63	104.38	20.50	4.288	16.18	10.64	26.14	278.29
		24	234.00	109.00	21.45	4.425	17.04	11.03	28.79	317.57
		48	239.75	111.88	22.30	4.625	17.68	11.24	31.35	352.58
	100	**0**	243.88	113.63	23.20	4.688	18.09	11.39	32.26	367.68
		24	249.38	116.25	24.30	4.838	19.53	11.58	35.50	411.18
		48	254.38	118.38	24.70	4.988	20.13	11.71	37.01	433.69
	150	**0**	262.50	122.38	25.20	5.125	20.44	11.80	37.11	438.03
		24	267.50	124.75	25.90	5.375	21.11	11.99	38.55	462.26
		48	272.50	127.00	26.30	5.525	21.83	12.08	39.56	477.81
Skipping the 5th irrigation	**0**	**0**	230.38	113.88	18.50	3.375	11.05	9.81	14.51	142.71
		24	243.63	120.38	18.90	3.625	12.29	10.13	19.63	198.97
		48	251.00	124.00	20.90	3.825	13.69	10.18	23.03	234.51
	50	**0**	272.25	134.63	21.10	3.925	14.76	10.36	23.56	244.40
		24	277.63	137.25	22.10	4.075	15.63	10.65	26.24	279.72
		48	281.00	138.88	23.10	4.175	16.29	10.95	28.11	308.03
	100	**0**	294.00	143.75	24.40	4.225	16.81	11.03	28.79	317.61
		24	299.88	148.25	24.90	4.363	17.73	11.24	32.26	362.79
		48	301.25	149.00	25.70	4.488	18.31	11.40	34.45	392.99
	150	**0**	305.75	151.38	26.30	4.525	18.63	11.49	34.75	399.46
		24	308.13	152.63	26.50	4.725	19.33	11.64	37.11	432.09
		48	311.13	153.88	26.90	4.838	19.90	11.74	38.35	450.31
L.S.D. at 5%			**14.62**	**N.S.**	**0.55**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**17.70**

Table 9: Mean values of ear weight (g), kernels weight/ear (g), kernels shelling (%), 100-kernel weight (g), ear yield/fed (kg), grain yield/fed (kg), stover yield/fed (kg) and biological yield/fed (kg) of maize as affected by interaction between water stress, nitrogen fertilizer rates and potassium fertilizer rates in the combined analysis of 2015 and 2016 seasons.

Treatment		Trait	Ear weight (g)	Kernels weight /ear (g)	Kernels shelling (%)	100-kernel weight (g)	Ear yield/fed (kg)	Grain yield/fed (kg)	Stover yield/fed (kg)	Biological yield/fed (kg)
Water stress X Nitrogen (kg N/fed) X Potassium (kg K_2O/fed)										
Normal irrigation	**0**	**0**	76.40	50.71	66.47	23.53	1101.50	731.48	2224.00	3325.50
		24	111.49	77.69	69.70	26.25	1683.25	1173.16	2513.63	4196.88
		48	132.55	94.60	71.39	28.46	2177.88	1554.54	2858.75	5036.63
	50	**0**	141.91	101.61	71.63	29.64	2373.88	1700.12	3553.38	5927.25
		24	165.87	123.60	74.54	32.02	2872.00	2140.46	3742.38	6614.38
		48	182.26	141.09	77.41	33.76	3330.63	2577.92	3906.75	7237.38
	100	**0**	190.32	147.25	77.41	33.86	3574.63	2766.79	4483.25	8057.88
		24	217.16	174.40	80.33	36.49	4177.00	3355.20	4747.13	8924.13
		48	240.64	195.96	81.44	38.27	4753.38	3871.16	4883.50	9636.88
	150	**0**	244.93	199.25	81.36	38.31	4856.75	3952.27	4993.25	9850.00
		24	266.18	219.65	82.53	39.40	5216.38	4306.16	5209.00	10425.38
		48	277.04	232.04	83.77	39.99	5469.00	4582.23	5423.13	10892.13
Skipping the 2nd irrigation	**0**	**0**	55.36	36.85	66.60	22.42	732.88	488.16	1842.75	2575.63
		24	83.17	57.68	69.41	24.98	1165.75	808.53	2034.88	3200.63
		48	101.74	71.59	70.42	27.06	1510.25	1062.84	2359.88	3870.13
	50	**0**	109.72	77.19	70.41	28.18	1699.50	1195.96	3078.25	4777.75
		24	130.41	95.23	73.09	30.43	2104.25	1537.88	3567.88	5672.13
		48	146.75	111.31	75.90	32.07	2456.38	1864.44	3646.00	6102.38
	100	**0**	151.08	116.29	77.03	32.16	2662.50	2050.23	4051.38	6713.88
		24	175.93	140.20	79.75	34.65	3234.13	2578.24	4345.13	7579.25
		48	192.88	155.29	80.55	36.33	3597.13	2896.71	4471.38	8068.50
	150	**0**	194.65	156.68	80.56	36.37	3720.25	2995.99	4550.00	8270.25
		24	207.21	170.13	82.16	37.40	4064.13	3337.88	4686.38	8750.50
		48	214.60	178.65	83.30	37.96	4270.63	3556.25	4815.75	9086.38
Skipping the 5th irrigation	**0**	**0**	42.46	27.13	63.95	19.23	603.25	385.52	2183.88	2787.13
		24	63.32	41.96	66.30	21.38	906.63	600.93	2383.63	3290.25
		48	79.26	53.44	67.45	23.12	1248.63	842.04	2721.25	3969.88
	50	**0**	86.03	58.00	67.45	24.06	1365.63	920.90	3444.50	4810.13
		24	102.09	71.40	69.96	25.95	1691.75	1183.41	3683.63	5375.38
		48	113.22	82.79	73.14	27.32	1959.00	1432.64	3839.00	5798.00
	100	**0**	115.40	85.69	74.29	27.40	2133.50	1584.37	4386.88	6520.38
		24	136.90	105.25	76.91	29.48	2571.00	1976.95	4629.75	7200.75
		48	153.49	119.58	77.92	30.89	2967.88	2312.36	4786.38	7754.25
	150	**0**	156.33	121.76	77.92	30.92	3118.88	2429.78	4906.38	8025.25
		24	169.89	135.11	79.55	31.78	3407.50	2710.21	4994.38	8401.88
		48	177.05	142.91	80.73	32.25	3601.25	2907.03	5228.75	8830.00
L.S.D. at 5%			**21.30**	**17.98**	**N.S.**	**N.S.**	**524.22**	**579.96**	**531.91**	**934.79**

Table 10: Mean values of harvest index (%), NUE (kg grains/kg N), KUE (kg grains/kg K), kernels nitrogen content (%),kernels potassium content (%),kernels crude protein (%), nitrogen uptake/fed (kg) and protein yield/fed (kg) of maize as affected by interaction between water stress, nitrogen fertilizer rates and potassium fertilizer rates in the combined analysis of 2015 and 2016 seasons.

Treatment		Trait	Harvest index (%)	NUE (kg grains /kg N)	KUE (kg grains /kg K)	Kernels nitrogen content (%)	Kernels potassium content (%)	Kernels crude protein (%)	Nitrogen uptake /fed (kg)	Protein yield/fed (kg)
Water stress X Nitrogen (kg N/fed) X Potassium (kg K_2O/fed)										
Normal irrigation	**0**	**0**	22.03	--	--	1.618	0.481	10.11	11.85	74.05
		24	27.98	--	18.41	1.668	0.518	10.42	19.58	122.36
		48	30.93	--	17.15	1.718	0.544	10.73	26.71	166.93
	50	**0**	28.71	19.38	--	1.874	0.498	11.71	31.87	199.17
		24	32.38	19.35	18.35	1.909	0.546	11.93	40.86	255.38
		48	35.64	20.47	18.29	1.944	0.573	12.15	50.10	313.15
	100	**0**	34.35	20.36	--	2.039	0.518	12.74	56.41	352.58
		24	37.60	21.83	24.52	2.109	0.566	13.18	70.77	442.30
		48	40.18	23.17	23.01	2.164	0.593	13.52	83.78	523.64
	150	**0**	40.13	21.47	--	2.209	0.528	13.80	87.32	545.74
		24	41.29	20.89	14.75	2.250	0.583	14.06	96.90	605.64
		48	42.03	20.19	13.13	2.269	0.603	14.18	103.99	649.93
Skipping the 2nd irrigation	**0**	**0**	18.96	--	--	1.518	0.430	9.48	7.44	46.51
		24	25.28	--	13.36	1.618	0.466	10.11	13.10	81.87
		48	27.49	--	11.98	1.688	0.489	10.55	17.95	112.21
	50	**0**	25.12	14.16	--	1.718	0.450	10.73	20.56	128.51
		24	27.17	14.59	14.25	1.798	0.499	11.23	27.65	172.80
		48	30.61	16.04	13.93	1.833	0.513	11.45	34.16	213.53
	100	**0**	30.56	15.63	--	1.899	0.480	11.87	38.95	243.41
		24	34.03	17.70	22.01	1.989	0.519	12.43	51.29	320.56
		48	35.91	18.34	17.64	2.019	0.533	12.62	58.49	365.58
	150	**0**	36.24	16.72	--	2.039	0.509	12.74	61.10	381.85
		24	38.16	16.87	14.25	2.089	0.545	13.05	69.74	435.87
		48	39.15	16.63	11.68	2.109	0.561	13.18	75.01	468.82
Skipping the 5th irrigation	**0**	**0**	13.85	--	--	1.518	0.389	9.48	5.87	36.67
		24	18.28	--	8.98	1.598	0.436	9.98	9.61	60.08
		48	21.26	--	9.51	1.628	0.456	10.17	13.73	85.79
	50	**0**	19.16	10.71	--	1.698	0.416	10.61	15.65	97.81
		24	22.03	11.65	10.94	1.729	0.456	10.80	20.49	128.04
		48	24.72	11.82	10.66	1.773	0.473	11.08	25.41	158.78
	100	**0**	24.30	11.99	--	1.863	0.433	11.64	29.55	184.68
		24	27.45	13.77	16.37	1.904	0.470	11.90	37.67	235.47
		48	29.82	14.71	15.17	1.944	0.499	12.15	44.98	281.15
	150	**0**	30.28	13.63	--	1.999	0.443	12.49	48.59	303.67
		24	32.27	14.07	11.68	2.059	0.486	12.87	55.82	348.85
		48	32.93	13.77	9.95	2.094	0.525	13.09	60.88	380.48
L.S.D. at 5%			**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**9.32**	**23.31**

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تأثير الإجهاد المائي، السماد الأزوتي و البوتاسي على إنتاجية الذرة الشامية

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أجريت تجربتان حقليتان في مزرعة مركز البحوث و التجارب الزراعية بكلية الزراعة بمشتهر جامعة بنها (مركز طوخ ـ محافظة القليوبية ـ مصر) خلال الموسمين الصيفيين 2015 و 2016 لدراسة تأثير أربعة معدلات من السماد الأزوتي (0، 50، 100 و 150 كجم أزوت للفدان) و ثلاثة معدلات من السماد البوتاسي (0، 24 و 48 كجم بو$_2$أ للفدان) على صفات النمو الخضري، مكونات المحصول، المحصول وبعض الصفات الكيميائية لحبوب محصول الذرة الشامية(هجين فردي أبيض 2031 من إنتاج شركة مصر هاي تك الدولية للبذور) تحت ظروف الإجهات المائي [(الري التقليدي (الري طوال الموسم)، تفويت الرية الثانية (إجهاد مائي في مرحلة النمو الخضري) و تفويت الرية الخامسة (إجهاد مائي في فترة إمتلاء الحبوب)].و من خلال التحليل التجميعي لموسمي الدراسة يمكن تلخيص أهم النتائج فيما يلي:-

أوضحت النتائج أن مرحلة إمتلاء الحبوب هي أكثر فترة حساسة لنقص الماء و منع الري خلال هذة الفترة (تفويت الرية الخامسة) أحدث نقص معنوي في متوسط قيم جميع صفات الذرة الشامية المدروسة ، بينما زراعة الذرة الشامية مع الري التقليدي شجع نمو نباتات الذرة الشامية و الحصول معنوياً على أعلى متوسط قيم في حميع صفات الذرة الشامية المدروسة. زراعة نباتات الذرة الشامية مع تفويت الرية الثانية أو الرية الخامسة أحدث نقص معنوي في محصول الحبوب بمقدار 25,49 و 41,04 % على التوالي مقارنةً بمحصول الحبوب الناتج من نباتات الذرة الشامية تحت الري التقليدي.

زراعة الذرة الشامية مع التسميد الأزوتي بمعدل 150 كجم نيتروجين/فدان أحدث زيادة معنوية في متوسط قيم معظم صفات الذرة الشامية المدروسة مثل عدد الكيزان/فدان، إرتفاع النبات (سم)، إرتفاع الكوز (سم)، سمك الكوز (سم)، طول الكوز (سم)، عدد صفوف الكوز، عدد حبوب الصف، عدد حبوب الكوز، وزن الكوز (جم)، وزن حبوب الكوز (جم)، وزن 100 حبة (جم)، تصافي الحبوب (%)، محصول الكيزان للفدان (كجم)، محصول الحبوب للفدان (كجم)، محصول الحطب للفدان (كجم)، محصول البيولوجي للفدان (كجم)، دليل الحصاد (%)، محتوى الحبوب من الأزوت (%)، محتوى الحبوب من البروتين (%)، الأزوت الممتص للفدان (كجم) و محصول البروتين/فدان (كجم). بينما أعلى متوسط قيم في صفة كفاءة إستخدام البوتاسيوم (كجم حبوب/كجم بوتاسيوم) تم الحصول عليها من زراعة نباتات الذرة الشامية مع إضافة 100 كجم أزوت للفدان.

زراعة نباتات الذرة الشامية مع تسميد التربة بأعلى معدل من السماد البوتاسي (48 كجم بو$_2$أ للفدان) أعطت معنوياً أعلى متوسط قيم في صفات عدد الكيزان/فدان، إرتفاع النبات (سم)، طول الكوز (سم)، عدد حبوب الصف، عدد حبوب الكوز، وزن الكوز (جم)، وزن حبوب الكوز (جم)، وزن 100 حبة (جم)، تصافي الحبوب (%)، محصول الكيزان للفدان (كجم)، محصول الحبوب للفدان (كجم)، محصول الحطب للفدان (كجم)، محصول البيولوجي للفدان (كجم)، دليل الحصاد (%)، محتوى الحبوب من البوتاسيوم (%)، الأزوت الممتص للفدان (كجم) و محصول البروتين/فدان (كجم). بينما أعلى متوسط قيم في صفة كفاءة إستخدام البوتاسيوم (كجم حبوب/كجم بوتاسيوم) تم الحصول عليها من زراعة نباتات الذرة الشامية مع إضافة 24 كجم بو$_2$أ للفدان.

التفاعلات من الدرجة الأولى (الري التقليدي × 150 كجم أزوت للفدان)، (الري التقليدي × 48 كجم بو$_2$أ للفدان) و (150 كجم أزوت للفدان × 48 كجم بو$_2$أ للفدان) و التفاعل من الدرجة الثانية (الري التقليدي × 150 كجم أزوت ×48 كجم بو$_2$أ للفدان) حققت معنويا أعلى محصول حبوب مقارنة بالتفاعلات الأخري.

توصي النتائج بأن زراعة الذرة الشامية هجين فردي أبيض 2031 تحت الري التقليدي (الري طول الموسم) مع التسميد بـ 150 كجم أزوت + 48 كجم بو$_2$أ للفدان حيث عظمت إنتاجية محصول الحبوب بوحدة المساحة.