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MAIZE NUTRIENT UPTAKE AND SOIL AVAILABLE K IN SOIL AS AFFECTED BY SOURCE AND RATE OF K-FERTILIZER AND SOIL WATER STRESS CONDITIONS.

BY

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ABSTRACT

Two pot experiments were conducted on a sandy soilto study the effects of soil water stress, and rate and type of K-fertilizer on nutrients uptake two Maize (*Zea mays* L.) hybrids S.C 10 and T W.C310 and K soil availability two pot experiments were conducted. Three soil water regimes (100, 75 and 50% of soil field capacity), four K application rates (0, 50, 100 mg K/kg soil.) and four types of K sources (KCl, K_2SO_4, KNO_3 and a 1:1:1 mixture of them) were studied in a 3-factor randomized complete block design, 3 replicate. Soil-water stress had significant effects on the CONCENTRATION OF EACH OF Na, K, Ca, Mg, P, and N in plant of the studied nutrient in the two maize hybrids. Potassium fertilizer sources had significant effects on all nutrients content except calcium and magnesium in both hybrids. Available K in soil was highest at 100% field capacity and in treatment receiving highest K rate. The findings suggest that available K in soil can be altered by adjusting the level of K-fertilizer and the level of soil moisture.

INTRODUCTION

Water stress, potassium rates and source have been some the most important factors affecting maize (*Zea mays* L.) growth, physiological characters and plant nutrient content. The effect of the factors and their interactive effects on maize plant productivity and soil K had received the attention of several works in the major maize growing countries as reported here.

Engles *et al.* (1994), in Germany, concluded that drying the topsoil led to rapid decrease of root growth, and a decrease shoot P concentration in maize, whereas the concentrations of N, K and Ca were not affected despite enriched fertilizer levels in the topsoil. Szlovak (1996), in Hungary, showed that at optimum watering, the dry matter production of maize and Ca uptake of cv. MV580 reached a maximum. Ashraf and Rehman (1999), in Pakistan, stated that K and P maize plant contents in the flooded soils increased whereas Ca and Mg contents remained unaffected. They added that a considerable decrease in N, P and K contents leaves was observed as a result of flooding, whereas in roots the reverse was true. Lizaso *et al* (2001), in Venezuela, reported that the level of oxygen in soils affects the bioavailability of nutrients as well as the ability of root system to uptake and transport water and nutrients. Melendez *et al.* (2001), in Venezuszzela, reported that flooding reduced shoot biomass by between 20 and 30%, and decreased N, P, K, Ca and Mg contents by 40, 32, 48, 52 and 40%, respectively.

Forster and Mengel (1989) reported that potassium enhanced phosphorus uptake by excised roots from inorganic sources. Bar-Tal *et al.* (1991) stated that K increased maize yield under salinity in sandy soils low in K. Resende *et al.* (1997), in Brazil, reported that in a green house pot trial, maize accumulated N, P, K, Ca, S and Mg in the aboveground parts with increasing N rate; K accumulation increased with increasing K rate, while accumulation of Ca and Mg decreased. Banga *et al.* (1998) showed that maize grain yield was increased with application of N and P, and that variation in K uptake in maize was most closely related to water-soluble K. Zou *et al.* (1999), in China, applied up to 3300 mg k/kg soil and found that maize 1240 mg/kg was optimum. Mallarino *et al.* (1999), in USA, applied several P and K rates (0-56 kg P/ha; 0-132 kg K/ha) to different maize cultivars and found that banded K (deep or shallow) seldom affected early growth, but usually increased K uptake and yield.

Maier (1986) reported that increasing potassium sulphate increased potassium and to some extent sulphur concentrations, but decreased chloride concentration in both petioles and tubers in sweet potato, and was superior to KCl. Kochian and Lucas (1988) indicated that SO^{-2}_4 uptake is slow compared to Cl^-, and this can limit K^+ uptake. They added that charge compensation, by organic acid anions such as malate, is necessary to maintain K^+ uptake rate when SO^{-2}_4 is the predominant accompanying anion. The capacity for charge compensation depends on availability of organic acid anions which will limit the K^+ - H^+ exchange (normally required to compensate for lower absorption of SO^{-2}_4, relative to Cl^-) and hence limit K^+ uptake. Magat and Goh (1988) stated that chloride application stimulated potassium uptake in tops and roots of fodder beet compared to that of sulphate. Buwalda and Smith (1991), in New Zealand, found that leaf K concentration in kiwi fruit was higher of vines receiving KCl compared to those receiving K_2SO_4, but for a limited period of 6 weeks.

The main objectives of the present investigation were to study the effect of soil water stress and potassium source and rate, on nutrients uptake by two maze hybrids SC10 and TWC310 and on contents of available K in soil.

MATERIALS AND METHODS

The present study was conducted (on a sandy soil) at the Faculty of Agriculture, Saba Basha, Alexandria University. Two pot experiments were carried out in the greenhouse to study the effect of soil moisture content, potassium fertilizer levels and sources on soil K and nutrient uptake by two maize (*Zea mays* L.) cultivars single cross (S.C.10) and three way cross (T.W.C.310) and availability of K in the soil. The two experiments were laid out in a randomized complete block, factorial design involving 3 factors (water stress, K-rates and K-source). Treatments were executed three replicates.

Soil and plant samples (each of a plant/pot) were collected in triplicates after 45, 60 and 75 days of sowing representing 1st, 2nd and 3rd growth stages, respectively. The three soil samples were taken for nutrient availability analysis. Plant samples were, washed with distillated water, oven dried at (65°C) to obtain dry weight and ground to pass through 40 mesh screen and wet-digested with concentrated H_2SO_4-H_2O_2 and Ca, Mg, Na, K and P were determined; N was determined by Kjaldahl for analysis of (Chapman and Pratt, 1961)

Soil samples were air-dried, and analyzed according to Black (1965) and Jackson (1958). Soil electrical conductivity, and pH of the soil paste extract recorded 0.5 dS/m and 8.5, respectively. Soil moisture content at field capacity and bulk density were 9.5%w/w and 1.56, respectively. Available N, P and K were 20, 5 and 40 mg/kg soil, respectively. Soil organic matter content recorded 0.15%. Data were statistically analyzed according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

1. Potassium Content:

Potassium content in maize plant under the three factors, i.e., water stress, potassium rates and sources in the three growth stages under study are presented in (Table 1). With regard to water stress, potassium content of S.C. 10 plant increased by increasing water deficit from M_1 (100% of water field capacity) to M_3 (50% of field capacity) in the three growth stages. Such increase was significant in the second and third growth stages. The percentages of increase were 22.8, 6.7 and 21.8% at M_3 compared to M_1 in the three successive growth stages respectively. Ashraf and Rehman (1999), Vilela and Bull (1999) and Melendez *et al.* (2001) reported that water stress increases K in plant, Premachandra *et al.* (1993) reported increasing sugar, potassium and magnesium concentrations under water deficit.

As for potassium fertilizer levels, data in Table (1) indicate that increasing potassium rate increased potassium content during the three growth stages. The highest potassium contents of (2.93, 3.73 and 4.18%) were detected at 45 mg k/kg soil. in the three growth stages respectively. Ibrahim (1982), Ogunlela and Yusuf (1988), Resende *et al.* (1997) and Mohamed (1998) reported similar results. The increase of plant potassium content of S.C.10 hybrid plants may be due to increased available K in soil. Zou *et al.*, (1999) concluded that potassium fertilizer application increased potassium uptake by plant.

With respect to effect of potassium fertilizer source on potassium content, data in Table (1) show that potassium chloride produced the highest plant potassium contents; giving (3.09, 3.91 and 3.98%) in the three growth stages, respectively. The mixture of the three potassium forms, i.e., chloride, sulphate and nitrate recorded potassium content of 3.09% in the first growth stage, only. Potassium sulphate in the first stage and the mixture of the three potassium forms in the second stage and the third one produced low potassium contents of (2.30, 3.10 and 3.54%), respectively, in S.C.10 maize. High potassium content with potassium chloride might be due to a stimulation effect of chloride for potassium uptake compared to that of sulphate anion (Magat and Goh, 1988). These results are similar is those of Buwalda and Smith (1991).

Table (1): Means of potassium % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water Stress (% of field capacity)						
100	3.73	3.27 b	3.44 c	2.43	3.64	3.79 b
75	2.73	3.56 a	3.72 b	2.81	3.70	3.68 b
50	2.88	3.49 a	4.19 a	2.63	3.70	4.13 a
L.S.D.$_{0.05}$	--	0.10	0.06	--	--	0.16
K-Rates (mg/kg.)						
0	2.71 b	2.91 c	3.09 d	2.39 c	3.59 b	3.43 c
15	2.89 b	3.45 b	4.09 b	2.59 b	3.64 b	3.60 b
30	2.59 b	3.68 a	3.79 c	2.62 b	3.72 a	4.33 a
45	2.93 a	3.73 a	4.18 a	2.88 a	3.77 a	4.20 a
L.S.D.$_{0.05}$	0.14	0.10	0.04	0.04	0.07	0.10
K-Sources						
KCl	3.10 a	3.91 a	3.98 a	2.86 a	3.77 a	4.08 a
K_2SO_4	2.30 c	3.43 b	3.75 c	2.37 d	3.70 ab	3.96 b
KNO_3	2.64 b	3.33 c	3.87 b	2.80 b	3.66 b	3.73 c
1:1:1	3.09 a	3.10 d	3.54 d	2.45 c	3.59 b	3.69 c
L.S.D.$_{0.05}$	0.13	0.09	0.04	0.06	0.08	0.08

* Means followed by the same letter (s) are not significantly different according to L.S.D.$_{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

Increasing both of water stress and potassium fertilizer levels increased potassium content in plants. Potassium application at 15 mg/kg. produced the highest potassium contents in the second and third growth stages, 4.39 and 4.58% respectively. High potassium in plant could overcome the deleterious effects of soil moisture stress (Yapa *et al.*, 1991). However, Premachandra *et al.* (1993) revealed that high levels of potassium fertilizer may be beneficial for maize plants to tolerate to water stress conditions. Similar results were obtained by Wang-Jing *et al.* (1995) and Vilela and Bull (1999).

Concerning T.W.C. 310 maize hybrid, potassium fertilizer levels and forms had significant effects. With respect to soil moisture content, increasing soil moisture stress up to 50% field capacity did not significantly affect potassium content in T.W.C. 310 maize plants in the first and second growth stage; however, in the third stage increasing water stress from 100% to 50% field capacity increased potassium content from 3.79 to 4.13% (Table 1). Many researchers reported that water stress increases K-content in plant (Premachardra *et al.*, 1993, Vilela and Bull 1999 and Lizaso *et al.*, 2001). Tangilig *et al.* (1985), Kargbo *et al.* (1991), and Engles *et al.* (1994) reported that nutrient content of maize leaves was not affected by irrigation treatments. With regard to potassium fertilization (Table 1), increasing potassium levels from zero up to 45 mg/kg. increased potassium content from 2.39 to 2.88%, 3.59 to 3.77% and 3.43 to 4.20% in the three maize growth stages, respectively. Ibrahim (1982), Ogunlela and Yusuf (1988), Resende *et al.* (1997) and Mohamed (1998) reported decreased K-content in plant with increased K application. These results could be due to its stimulation effect on potassium uptake (Zou *et al.*, 1999).

As for potassium fertilizer forms, potassium chloride increased potassium content in plants giving averages of 2.86, 3.77 and 4.08% in the three growth stages, respectively, followed by nitrate which gave 2.80% in the first stage and sulphate which save 3.70 and 3.96% in the second and third stages, respectively. Nitrate and mixture of the three forms produced low potassium content in plant. Sulphate anion uptake was reported to be slower than chloride. (Kochian and Lucas, 1988). Cheng and Quellete (1968) showed that nitrate anion decreased potassium uptake. The current results are similar to those reported by Magat and Goh (1988) and Buwalda and Smith (1991).

Both 15 and 45 mg k/kg. under the highest water stress (50% field capacity) produced the highest plant potassium contents (4.64 and 4.53%), respectively, in the third growth stage. Under adequate moisture (100 and 75% field capacity) potassium application increased potassium content by lower rates than under inadequate moisture content. Apparent resistance of maize to water stress can be attributed to continued nutrient uptake, especially potassium, which may have allowed osmotic adjustment to occur (Marschner, 1985).

2. Sodium Content:

Water stress and potassium fertilization rates had significant effects in the three growth stages SC10, while potassium fertilizer sources had significant effects in the first and third growth stages. Sodium contents of S.C.10 maize plants are presented in Table (2). Non stressed plants produced the highest sodium content, in the first and second growth stages, (0.70 and 0.60%). Moderate water stress increased sodium content by 0.54% in the third growth stage. Highest water stress decreased sodium content in S.C.10 maize plants to 0.59, 0.49 and 0.49% in the three successive growth stages respectively. Increasing sodium content in plants under adequate water might be due to decreasing sodium concentration in soil solution and became more easier for absorption and accumulated inside maize plant. Sodium decreased by application potassium. Unfertilized treatment produced the highest total sodium contents giving 0.74, 0.55 and 0.62% in stage 1, 2 and 3, respectively. The highest potassium rate produced the lowest sodium content of 0.54, 0.51 and 0.44% in stages 1, 2 and 3, respectively. This could be due to increased contents of potassium in plant on expense of sodium (Bar-Tal *et al.*, 1991).

Table (2): Means of sodium % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water Stress (% of field capacity)						
100	0.70 a	0.60 a	0.51 b	0.72 a	0.61	0.80
75	0.62 b	0.51 b	0.54 a	0.64 b	0.60	0.75
50	0.59 c	0.49 b	0.49 c	0.60 c	0.58	0.55
$L.S.D._{0.05}$	0.01	0.03	0.01	0.03	NS	NS
K-Rates (mg/kg.)						
0	0.74 a	0.55 a	0.62 a	0.72 a	0.70	0.84
15	0.70 b	0.54 a	0.53 b	0.66 b	0.53	0.74
30	0.58 c	0.54 a	0.46 c	0.64 b	0.54	0.61
45	0.54 d	0.51 b	0.44 d	0.60 c	0.61	0.61
$L.S.D._{0.05}$	0.01	0.02	0.01	0.03	NS	NS
K-Sources						
KCl	0.66 b	0.52	0.48 c	0.64 b	0.59	0.65
K_2SO_4	0.68 a	0.54	0.55 a	0.71 a	0.68	0.79
KNO_3	0.57 d	0.54	0.51 b	0.66 b	0.56	0.63
1:1:1	0.64 c	0.53	0.51 b	0.59 c	0.55	0.73
$L.S.D._{0.05}$	0.01	NS	0.01	0.03	NS	NS

* Means followed by the same letter (s) are not significantly different according to $L.S.D._{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

Concerning potassium form, data in Table (2) show that sulphate significantly increased total sodium content in S.C.10 maize plants in three growth stages (0.68, 0.54 and 0.55%); this might be due to sulphate anion uptake being slow, and hence potassium uptake will decrease and encourage sodium uptake.

With respect to T.W.C.310 maize water stress, potassium level and form had significant effects,only in the first growth stage. Increasing water stress from 100 to 50% of field capacity significantly reduced the sodium content from 0.72 to 0.60% in the first growth stage, and from 0.61 to 0.58% and from 0.80 to 0.55% in the second and third growth stages, respectively, the effect was significant in stage 1. Increasing potassium level from zero to 45 kg/fed. decreased sodium content in plants. Ranges of contents due to 0 and 45 mg/kg were 0.72 to 0.60, 0.70 to 0.61 and 0.84 to 0.61%, respectively in the three successive stages. Reductions was significant in the first stage. This could be attributed to Na/K antagonistic relationship (Shukla and Mukhi, 1979), (Bar-Tal *et al.*, 1991). As for potassium sources, the highest sodium content resulted from potassium sulphate application (0.71, 0.68 and 0.79%) in the three stages, respectively. These results agree with those obtained by Kochian and Lucas (1988), who reported that sulphate anion is slower in chloride or nitrate, Buwalda and Smith (1991) reported difference between the leaf potassium in plants receiving potassium chloride or sulphate.

3. Calcium Content:

Increased soil moisture increased calcium in SC10 plot. The lowest calcium contents were giving by 50% yield capacity 1.62; 1.76 and 1.79% in the three successive growth stages, increased to 1.70, 1.79, and 1.84% given by 100% field capacity. Szlovak (1996) and Lizaso *et al.* (2001) reported that calcium concentration in maize depends on the level of oxygen in soils, bioavailability of calcium as well as the ability of root system to uptake and transport water and calcium nutrients. Increasing potassium level, in S.C.10 plants. The highest content was 1.74; 1.85 and 1.88% for non-potassium application in stage 1, 2 and 3, respectively. The highest level of potassium fertilization produced the lowest calcium contents of 1.64; 1.71 and 1.77% for the three stages, respectively. Al-Ani and Ouda (1972); Aslam (1975) and Resende *et al.* (1997) reported decreased Ca in plant due to increased K application. With regard to potassium forms, there was no significant difference between the three forms, on their mixture.

As for T.W.C.310 maize plants soil moisture content and potassium fertilization levels had significant effects. However, potassium form shows little effect. Data in that table show that non-water stressed plants contained the highest calcium contents (1.70; 1.83 and 1.84%) followed by moderate stressed plants, (1.65; 1.77 and 1.81%) with the highest stressed plants, giving the lowest, (1.60; 1.72 and 1.77% for the three growth stages, respectively). These results agree with those obtained by Szlovak (1996) and Lizaso *et al.* (2001). Increased potassium level decreased calcium concentrations in plants. The highest potassium rates produced the lowest calcium contents (1.55; 1.70 and 1.78% in the three successive growth stages, respectively. The non-potassium application produced the highest calcium contents (1.75, 1.82 and 1.85% in the three growth stages, respectively). These results are in agreement with the findings of Al-Ani and Ouda (1972), Aslam (1975) and Resende *et al.* (1997). With respect to potassium FORM, data in Table (3) indicate show no significant difference.

4. Magnesium Content:

For SC10 plants water stress and potassium rate had significant effects on magnesium concentration in plants. Potassium forms had no-significant effect. Increasing moisture stress from 100% to 50% field capacity decreased magnesium contents from being 0.60 to 0.55; 0.59 to 0.54% and from 0.60 to 0.54% in the three growth stages, respectively. On the other hand, increasing it from 100% to 75% decreased the contents to 0.56, 0.55 and 0.58%, respectively, in the three growth stages. Premachandra *et al.* (1993), Ashraf and Rehman (1999), Lizaso *et al.* (2001) and Melendez *et al.* (2001) reported decreased Mg contents in plant upon increasing moisture stress. Increased potassium application rate significantly decreased magnesium in plants. Non-potassium fertilization produced the highest magnesium concentrations in maize plants (0.62, 0.61 and 0.65% in the three growth stages, respectively). The highest potassium rate produced the lowest magnesium concentration (0.45; 0.52 and 0.46% in the three successive growth stages). These results are in agreement with the findings of Al-Ani and Ouda (1972), Aslam (1975) and Resende *et al.* (1997). As for potassium form there was no-significant differences between the three forms.

Table (3): Means of calcium % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water stress (% of field capacity)						
100	1.70 b	1.79 a	1.84 a	1.70 a	1.83 a	1.84 a
75	1.73 a	1.78 a	1.80 b	1.65 b	1.77 b	1.81 b
50	1.62 c	1.76 b	1.79 b	1.60 c	1.72 c	1.77 c
$L.S.D._{0.05}$	0.02	0.02	0.02	0.05	0.01	0.01
K-rates (mg/kg.)						
0	1.74 a	1.85 a	1.88 a	1.75 a	1.82 a	1.85 a
15	1.69 b	1.82 b	1.80 b	1.65 b	1.80 b	1.81 b
30	1.66 c	1.73 c	1.79 c	1.65 b	1.77 c	1.78 c
45	1.64 d	1.71 d	1.77 d	1.55 c	1.70 d	1.78 c
$L.S.D._{0.05}$	0.02	0.02	0.01	0.01	0.02	0.02
K-sources						
KCl	1.68	1.81	1.79	1.64	1.77	1.81
K_2SO_4	1.70	1.76	1.83	1.64	1.78	1.80
KNO_3	1.65	1.79	1.82	1.66	1.76	1.80
1:1:1	1.70	1.75	1.80	1.66	1.79	1.81
$L.S.D._{0.05}$	NS	NS	NS	NS	NS	NS

* Means followed by the same letter (s) are not significantly different according to $L.S.D._{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

As for T.W.C.310 plants soil moisture and potassium rate had significant effects; but potassium rate had no-significant effect. Increasing soil moisture stress from 100 to 50% of field capacity decreased magnesium concentrations in maize plants from being 0.49 to 0.46%, 0.58 to 0.46% and 0.59 to 0.53%, respectively in the three successive growth stages. Some researchers reported decreased magnesium concentration due to water stress (Premachandra *et al.* (1993), Ashraf and Rehman 1999, Lizaso *et al.*, 2001 and Melendez *et al.*, 2001). Vilela and Bull (1999) reported no significant effects for water stress on magnesium content in maize plants. Increased potassium application rate decreased magnesium content particularly in the first and second growth. The highest magnesium concentrations were 0.50, 0.63 and 0.56% at non-potassium fertilization in the three growth stages, respectively. The lowest were 0.45, 0.52 and 0.54% at the highest potassium fertilizer rate. These results agreed with those obtained by Al-Âni and Ouda (1972), Aslam (1975) and Resende *et al.* (1997).

5. Phosphorus Content:

Regarding S.C.10 plants moisture content, potassium fertilization rates and sources had significant effects. Non moisture stressed plants showed P contents of 41, 44 and 0.53% whereas the stressed (50% field capacity) showed 86, 97 and 74% stage 1, 2 and 3 respectively. Resistance of maize plants to water stress can be attributed to continued nutrients uptake which may have allowed osmotic adjustment to occur (Marschner, 1985). Comparable results obtained by Tkebucheva (1974), Kargbo *et al.* (1991), Ashraf and Rehman (1999) and Melendez *et al.* (2001). With regard to potassium fertilizer rates, data show that potassium application significantly decreased phosphorus concentration application stages. Phosphorus concentrations by the no-K treatments averaged 62, 64 and 76% of P in plants, decreased by the highest K rate to become 0.53, 0.57, and 0.54% for stage 1, 2 and 3 respectively. These results agree with those obtained by Lixandru *et al.* (1975), Ibrahim (1982), Sinha and Singh (1982), Karlen *et al.* (1987), Ogunlela and Yusuf (1988), and Zou *et al.* (1999). As for potassium fertilizer form, the sulphate form produced the highest phosphorus content followed by nitrate. Phosphorus concentrations were 0.77, 0.75 and 0.77%, respectively, as a result of potassium sulphate application during the three growth stages. Phosphorus concentrations were 0.77, 0.75 and 0.77%, respectively, as a result of potassium sulphate application during the three growth stages. These results might be due to the acidity effect of sulphate anion on the soil solution, where the highest phosphorus availability needs pH equal 6.5.

Table (4): Means of magnesium % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water Stress (% of field capacity)						
100	0.60 a	0.59 a	0.60 a	0.49 a	0.58 a	0.59
75	0.56 b	0.55 b	0.58 b	0.49 a	0.58 a	0.54
50	0.55 b	0.54 c	0.54 c	0.46 b	0.56 b	0.53
L.S.D.0.05	0.02	0.01	0.01	0.01	0.02	NS
K-Rates (mg/kg.)						
0	0.62 a	0.61 a	0.65 a	0.50 a	0.63 a	0.56
15	0.57 b	0.57 b	0.60 b	0.49 b	0.58 b	0.56
30	0.55 c	0.54 c	0.58 c	0.48 c	0.56 c	0.55
45	0.54 d	0.52 d	0.46 d	0.45 d	0.52 d	0.54
L.S.D.0.05	0.01	0.01	0.01	0.01	0.01	NS
K-Sources						
KCl	0.57	0.57	0.57	0.46	0.58	0.55
K_2SO_4	0.58	0.55	0.56	0.49	0.57	0.54
KNO_3	0.56	0.54	0.58	0.50	0.58	0.57
1:1:1	0.57	0.58	0.58	0.47	0.56	0.55
L.S.D.0.05	NS	NS	NS	NS	NS	NS

* Means followed by the same letter (s) are not significantly different according to $L.S.D._{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

With respect to T.W.C.310 plants there were significant effects. Increasing water stress increased phosphorus content in plant with no-stress, P concentration averaged 0.59, 0.78 and 0.21%, increased by the highest water-stress to reach 0.65, 0.80 and 0.41 for stage 1, 2 and 3 respectively.

These results could be due to that maize plant tended to increase nutrient uptake which would allow osmotic adjustment to occur (Marschner, 1985). These results agree with those obtained by Tkebucheva (1974), Kargbo *et al.* (1991), Ashraf and Rehman (1999) and Melendez *et al.* (2001).

Concerning effect of potassium, data show a significant decrease due to increasing potassium rate. Phosphorus concentrations at highest K-rate were 0.54 0.65 and 0.29% compared to 0.69, 1.03 and 0.40% under non-potassium fertilization in the three growth stages, respectively. Lixandru *et al.* (1975), Ibrahim (1982), Sinha and Singh (1982), Karlen *et al.* (1987), Broges and Mallarino (1998) and Zou *et al.* (1999) reported decreased P content in plant due to increatal K application. With regard to potassium form the sulphate form produced the highest phosphorus concentrations (0.67, 0.84 and 0.38%) followed by the nitrate one (0.61, 0.79 and 0.35%) in the three successive growth stages. This might be due the acidic effect of sulphate anion on the soil solution.

Table (5): Means of phosphorus % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water Stress (% of field capacity)						
100	0.41 c	0.44 b	0.53 b	0.59 c	0.78	0.21 c
75	0.46 b	0.43 b	0.74 a	0.61 b	0.79	0.31 b
50	0.86 a	0.97 a	0.74 a	0.65 a	0.80	0.41 a
L.S.D.0.05	0.02	0.03	0.04	0.02	NS	0.04
K-Rates (mg/kg.)						
0	0.67 a	0.64 a	0.76 a	0.69 a	1.03 a	0.40 a
15	0.55 b	0.63 ab	0.70 b	0.67 b	0.78 b	0.28 b
30	0.56 b	0.61 b	0.68 c	0.57 c	0.70 c	0.27 b
45	0.53 c	0.57 c	0.54 d	0.54 d	0.65 d	0.29 b
L.S.D.0.05	0.02	0.03	0.05	0.01	0.03	0.04
K-Sources						
KCl	0.47 d	0.50 d	0.59 c	0.60 c	0.73 c	0.22
K_2SO_4	0.77 a	0.75 a	0.77 a	0.67 a	0.94 a	0.38
KNO_3	0.55 b	0.67 b	0.75 b	0.61 b	0.79 b	0.35
1:1:1	0.52 c	0.53 c	0.57 c	0.59 d	0.70 d	0.29
L.S.D.0.05	0.02	0.03	0.15	0.01	0.03	NS

* Means followed by the same letter (s) are not significantly different according to $L.S.D._{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

6. Total Nitrogen Content:

Results for S.C.10 reveal that soil water nitrogen content to plant (Table 6). The highest moisture stress produced the highest nitrogen contents (2.92, 2.67 and 2.22% in stage 1, 2 and 34 respectively). The lowest moisture stress produced the lowest nitrogen contents (2.68, 2.50 and 2.17%, respectively) in plants. Plants increased their nutrients uptake to increase the osmotic pressure to overcome moisture stress (Tangiling *et al.*, 1985). These results are in general agreement with those obtained by Tkebucheva (1974), Lizaso *et al.* (2001) and Melendez *et al.* (2001).

As for potassium fertilization levels, data show that potassium the studied levels, significantly increased nitrogen content. There were positive relationship between potassium application levels and nitrogen concentrations in maize plants. The highest potassium fertilization level produced the highest nitrogen contents (3.00, 2.84 and 2.39% in the three stages, respectively). No potassium fertilization showed the lowest nitrogen contents (2.46, 2.25 and 1.84% during the three successive growth stages, respectively). Ibrahim (1982), Faizy *et al.* (1986), Ogunlela and Yusuf (1988) and Mohamed (1998) reported increased N contents by applying K. With regard to potassium fertilizer form potassium nitrate produced the highest nitrogen contents (3.02, 2.82 and 2.34%) followed by potassium sulphate (2.82, 2.61 and 2.20% during the three stages, respectively). Nitrate anion is source of nitrogen.

Regarding T.W.C.310 plants, there were significant main effects of the three studied factors. First and second order interactions were not significant during the three studied growth stages of maize plants. Means of nitrogen content in T.W.310 corn plants as affected by soil moisture content, potassium fertilizer levels and sources during the three growth stages are presented in Table (6). Data in show that Nitrogen content in plants increased by increasing the water stress. Increasing the stress from 100% to 50% of field capacity. Caused plants to add extra 0.18, 0.20 and 0.06% M in their tissues in stages 1, 2 and 3, respectively. These results agree with those obtained by Tkebucheva (1974), Tangilig *et al.* (1985), Lizaso *et al.* (2001) and Melendez *et al.* (2001).

As for potassium fertilizer rates, there were significant positive effects. The highest potassium fertilizer rate produced the highest nitrogen contents (3.03, 2.83 and 2.38% in the three stages, respectively). Non-potassium fertilization produced the lowest nitrogen contents (2.65, 2.26 and 1.83%, respectively). These results are in agreement with the findings of Ibrahim (1982), Faizy *et al.* (1986), Ogunlela and Yusuf (1988) and Mohamed (1998).

Nitrate form of increased nitrogen contents by (3.06, 2.82 and 2.34%) followed by sulphate (2.90, 2.65 and 2.19% in the three stages). The nitrate source contains nitrogen beside potassium.

A- Effect on available potassium in soil:

Results are shown in Table 6 and Fig. 1 to 6. Regarding soil where S.C.10 maize hybrid was grown there were significant effects. Effect of water stress, potassium fertilization levels and forms in the three growth stages are presented in Figure (1). Increasing water stress increased available potassium in soil at the three growth stages. Under 100% field capacity available potassium was 108.02, 57.53 and 66.31 mg/kg soil in stage 1, 2 and 3, respectively. As compound with, 123.72, 61.89 and 69.72 mg/kg, respectively soil under the soil water stress respectively.

Table (6): Means of total nitrogen % of S.C.10 and T.W.C.310 maize hybrids plants in the three growth stages@.

Treatments	S.C.10			T.W.C.310		
	1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
Water stress (% of field capacity)						
100	2.68 c	2.50 c	2.17 b	2.78 c	2.50 c	2.161 c
75	2.85 b	2.64 b	2.23 a	2.82 b	2.64 b	2.217 b
50	2.92 a	2.67 a	2.22 a	2.96 a	2.70 a	2.219 a
$L.S.D._{0.05}$	0.04	0.02	0.02	0.01	0.06	0.001
K-rates (mg/kg)						
0	2.46 d	2.25 d	1.84 d	2.65 d	2.26 d	1.83 d
15	2.86 c	2.58 c	2.28 c	2.79 c	2.61 c	2.28 c
30	2.95 b	2.74 b	2.32 b	2.94 b	2.75 b	2.31 b
45	3.00 z	2.84 a	2.39 a	3.03 a	2.83 a	2.38 a
$L.S.D._{0.05}$	0.03	0.01	0.01	0.02	0.04	0.01
K-sources						
KCl	2.77 c	2.50 c	2.14 c	2.81 c	2.50 c	2.13 c
K_2SO_4	2.82 b	2.61 b	2.20 b	2.90 b	2.65 b	2.19 b
KNO_3	3.02 a	2.82 a	2.34 a	3.06 a	2.82 a	2.34 a
1:1:1	2.65 d	2.48 d	2.15 c	2.64 d	2.48 d	2.12 d
$L.S.D._{0.05}$	0.04	0.02	0.01	0.02	0.04	0.01

* Means followed by the same letter (s) are not significantly different according to $L.S.D._{0.05}$

@ 1st, 2nd, 3rd stages represent the first, second and third harvests on the plants aged 45, 60 and 75 days old, respectively.

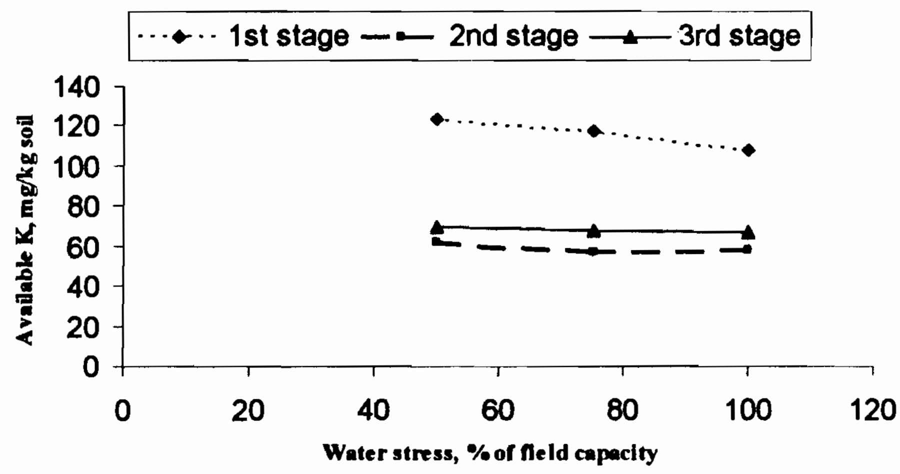

Fig. (1): The effect of soil moisture stress on available K at the three growth stages of S.C. 10 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

With respect to the effect of potassium rate available potassium increased by 17.18, 10.76 and 3.37% in stage 1, 2 and 3 as a result of adding the highest potassium rate. As for potassium source, results reveal that potassium nitrate surpassed other potassium forms on available potassium in soil. Available potassium was 132.70, 63.53 and 72.67 mg/kg for stage 1, 2 and 3 respectively as a result of potassium nitrate application.

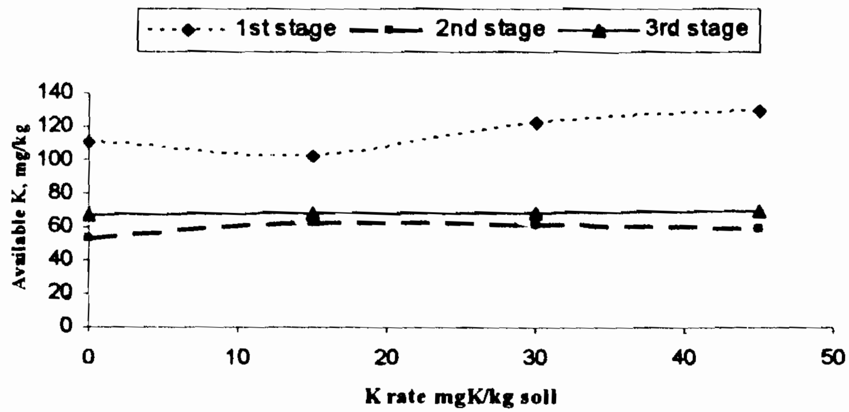

Figure (2): The effect of K application rate on available K at the three growth stages of S.C. 10 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

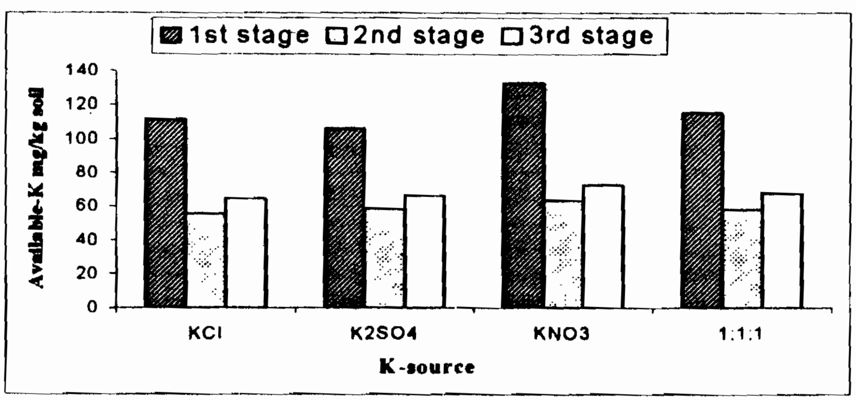

Fig. (3): The effect of K sources on soil K availability at the three growth stages of S.C. 10 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

With regard to the T.W.C.310 hybrid, results show increasing soil moisture stress increased available potassium in soils during the three growth stages contents of available K under 100% field capacity increased by 12.29, 9.06 and 73.4%, respectively, in the three successive growth stages as related to 50% field capacity.

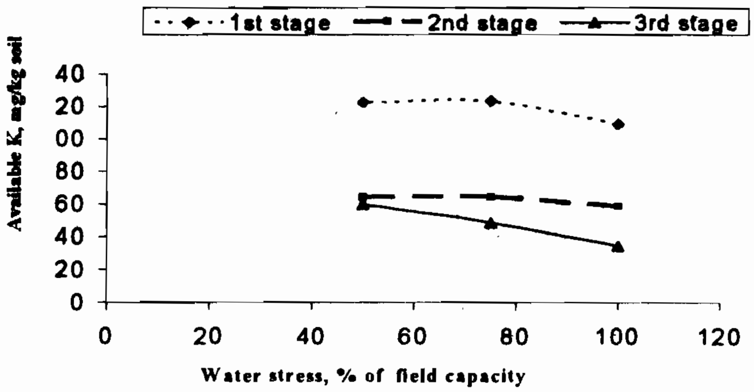

Figure (4): The effect of soil moisture stress on available K at the three growth stages of T.W.C. 310 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

Figure (5) shows the effect of potassium fertilization rate on K availability in soil. Potassium application increased available potassium in soil during the three growth stages. Available potassium in soil increased at 45 kg K/fed. by 18.16, 14.32 and 10.60% compared to non-potassium applications for the three successive stages respectively. With regard to potassium fertilizer forms, data sown that potassium nitrate form significantly increased available potassium in soil only in the first growth stage compared to the other three potassium forms. The differences did not reach the significance level in the second and third stages.

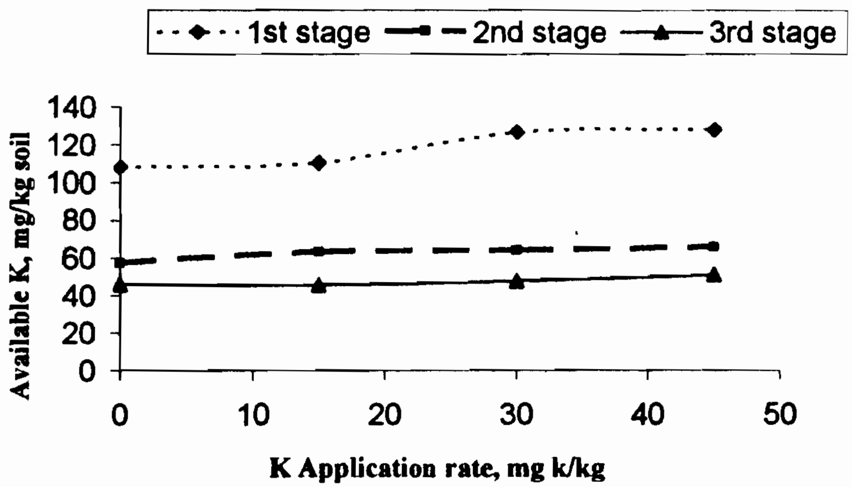

Figure (5): The effect of K fertilization rate on available K at the three growth stages of T.W.C. 310 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

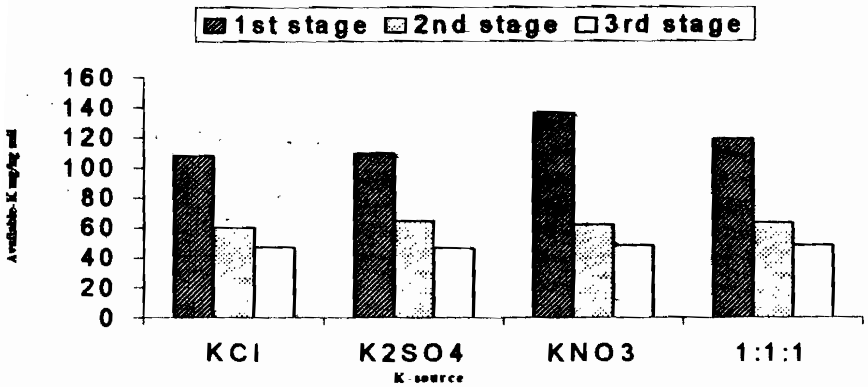

Figure (6): The effect of K source on available K at the three growth stages of T.W.C. 310 cultivar (1st, 2nd and 3rd stages = 45, 60 and 75 days after seeding).

The previous data can be explained on the basis that the original soil contain low amount of available K to be less then the critical level of K in soil for optimum plant growth. Also, soil moisture level at 100% of field capacity was the best level for optimum growth for the two maize hybrids. The K-NH_4OAc method of extraction provided an excellent indication of K availability as evidenced by the significant yield responses that frequently occurred when available K levels were less than 200 mg/kg soil (Haby *et al.,* 1990). The overall goal of this work is to find strategies that growers can use to improve the efficiency of K use for maize crop while safeguarding the environment and maintaining profitability. The finding obtained so for suggest that the available potassium in soil can readily altered by adjusting the level and the soil moisture level. Also, selecting the suitable potassium source have a beneficial effect for better plant growth. Potassium nitrate suppressed the other potassium forms for most of the studied characters for the two maize hybrids. More agronomic work is needed to test this possibility under field conditions.

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مدى تأثير محتوى نبات الذرة الشامية من العناصر الغذائية والبوتاسيوم المتيسر فى التربة بنوع ومعدل إضافة الأسمدة البوتاسية تحت ظروف الشد الرطوبى للتربة

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أجريت هذه الدراسة والتي تضمنت تجربتان في أصص داخل صوبات كلية الزراعة - سابا باشا - جامعة الإسكندرية - بهدف دراسة تأثير كل من الإجهاد الرطوبي للتربة ومستويات وصور السماد البوتاسي على محتوى النبات من العناصر الغذائية وذلك لاثنين من هجن الذرة الشامية هما هجين فردي ١٠ وهجين ثلاثي ٣١٠ تم زراعتهما في أصص مملوءة بتربة جيرية رملية جلبت من منطقة البستان بالنوبارية وكذلك علي البوتاسيوم المتيسر في التربة.

وقد استخدم تصميم القطع المنشقة مرتين في ثلاث مكررات في كلا التجربتين. وقد وزعت معاملات الإجهاد الرطوبي للتربة (١٠٠ ، ٧٥ ، ٥٠%) من السعة الحقلية عشوائيا على القطع الرئيسية. في حين وزعت مستويات السماد البوتاسي الأربعة وهي (صفر ، ١٥ ، ٣٠ ، ٤٥ مجم/كجم) عشوائيا علي القطع الفرعية. أما صور السماد البوتاسي (كلوريد ، سلفات ، نترات ، مخلوط بنسب متساوية من الصور الثلاثة) فقد احتلت القطع تحت الفرعية. وقد تم تقدير الصفات خلال ثلاث فترات للنمو وهي ٤٥ ، ٦٠ ، ٧٥ يوما بعد الزراعة. وقد شمل ذلك المحتوى الكلي للنبات من البوتاسيوم – الصوديوم – الكالسيوم – الماغنسيوم، الفوسفور والنتروجين.

اوضحت النتائج تأثيرا معنويا للإجهاد الرطوبي علي المحتوي الكلي للنبات من العناصر الغذائية وذلك في كلا الهجينين في مراحل النمو المختلفة. كما أثر التداخل بين الإجهاد الرطوبي ومعدل السماد البوتاسي معنويا علي المحتوى الكلي من البوتاسيوم في مرحلتي النمو الثانية والثالثة لنباتات الهجين الفردي وخلال مرحلة النمو الثالثة فقط لنباتات الهجين الثلاثي. وكان لمعدلات السماد البوتاسي المضاف تأثيرا معنويا علي جميع الصفات تحت الدراسة في هذه المجموعة وذلك لكلا الهجينين. أدت زيادة معدلات السماد البوتاسي المضاف (صفر إلى ٤٥ مجم/كجم) إلى زيادة في المحتوى الكلي من البوتاسيوم، النيتروجين، البوتاسيوم الميسر بالتربة. في حين أدت إلي نقص في المحتوى الكلي من الصوديوم، الكالسيوم، الماغنسيوم والفوسفور خلال مراحل النمو الثلاث للهجينين. كما أثرت صورة السماد البوتاسي المضاف علي جميع الصفات التي درست في هذه المجموعة عدا محتوى النبات من الكالسيوم والماغنسيوم في أطوار النمو الثلاثة لكلا الهجينين. وأدت إضافة نترات البوتاسيوم إلى زيادة محتوى النبات من النيتروجين في حين أدت سلفات البوتاسيوم إلى زيادة محتوى النبات من الصوديوم ، الفوسفور. أما إضافة كلوريد البوتاسيوم فقد أدت إلى زيادة محتوى النبات من البوتاسيوم لنبات كل من الهجين الفردي والثلاثي. وعموما فإن النتائج المتحصل عليها من هذه الدراسة تقترح أن البوتاسيوم المتيسر في التربة من الممكن أن يتغير بضبط مستوى السماد البوتاسي ومستوى الرطوبة في التربة . أيضا باختيار المصدر المناسب من البوتاسيوم له تأثير مفيد في الحصول علي أفضل نمو نباتي وكان من الواضح أن نترات البوتاسيوم أعطت القيم الأعلى لمعظم الخصائص المدروسة.