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Short-Run Effect of Potassium Source on the Soil Characteristics and Growth of Sugar Beet and Maize

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ABSTRACT

A greenhouse pot experiment was conducted to assess the effect of muriate of potash (MOP) and sulphate of potash (SOP) on the sandy and clay loam soil characteristics and growth parameters of two successive crops, sugar beet and maize. The anions associated with MOP and SOP caused a net addition of salts that likely produced a slight osmotic potential which was neither harmful nor caused any salinity hazards. Root volume and shoot fresh and dry weights of sugar beet plants were greater following the application of MOP at a rate of 196 $kg.ha^{-1}$ in both soil types while root diameter and root fresh and dry weights were best when SOP at a rate of 240 $kg.ha^{-1}$ was applied, although differences were not significant. Fresh and dry weights of maize plants grown on sandy soils were also lower than those of plants grown on clay loam soil. However, SOP and 50% SOP+50% MOP (120 $kg.ha^{-1}$ + 88 $kg.ha^{1-}$, respectively) produced higher fresh and dry weights than other treatments for maize plants grown on sandy soil. On the other hand, the fresh weight of plants grown on clay loam soil responded better to MOP+SOP (88 $kg.ha^{-1}$ + 120 $kg.ha^{1-}$, respectively) and MOP (196 $kg.ha^{-1}$) treatments. The results clearly show that both sugar beet and maize plants respond differently depending on soil type and potassium source.

Keywords: MOP, plant growth parameters, soil properties, SOP

INTRODUCTION

Potassium (K) is important for osmotic and ionic regulation in plants. It is also responsible for a large number of enzymes related to carbohydrate and protein synthesis and metabolism (Marschner 1995). K also activates the membrane-bound pumping of NAD(P)H oxidases (Cakmak 2005). This makes K the most important mineral element in cell extension and osmoregulation. In higher plants, K affects photosynthesis at various levels. It plays a key role in CO_2 fixation and affects photosynthesis in leaves via stomatal opening regulation (Cochrane and Cochrane 2009).

Worldwide, production of potassium chloride, also known as muriate of potash (MOP), ranged between 31 to more than 50 million tons/year (IFA 2011). More than 90% of total KCl consumption is used for fertilizer production. Other non-fertilizer uses of KCl include food/foodstuff additives, supplement of animal feed (Fernandez *et al*. 1989), pharmaceutical products, laboratory chemicals, deicing agents and photochemicals (Okada 2007). Due to its relatively lower price (about US$ 0.35.kg^{-1} compared to US$ 0.5.kg^{-1} SOP) and high K content (60% K_2O) compared to SOP (50% K_2O), KMg-sulphate (22% K_2O) and potassium nitrate (44% K_2O), the majority of crops in Egypt can be fertilized with KCl. Khadr *et al*. (2004) concluded that there was no significant difference in sugar cane (*Succharum officinarum*) productivity when the crop was fertilized with potassium sulphate (SOP) or MOP. Keshavarz *et al*. (2004) reported that the maximum yield of cotton (*Gossypium barbadense*) balls under saline conditions was obtained using SOP (25% increase in yield over MOP) and in non-saline conditions by MOP (10% increase in yield over SOP). Both potassic fertilizers are inorganic and have anions associated with K in their molecules. The fear of salt injury due to anions is the main concern. As MOP is used as a potassium source, chloride toxicity is often seen in some chloride-sensitive crops, hindering crop growth, yield and quality (Vis 1990). However, when SOP is used, sulphur is considered as an important nutrient of lower salt hazard (Haque 2006).

Sugar beet is considered as the second sugar source after sugar cane, while maize is one of the main cereal crops in Egypt. Based on this background, this study aimed to assay the effect of MOP *versus* SOP, when applied as a fertilizer in sandy and clay loam soils, on some soil properties and growth of two successive crops, sugar beet and maize.

MATERIALS AND METHODS

A pot experiment was conducted in the greenhouse of the Micronutrient Project, National Research Centre, Dokki, Cairo, Egypt, with two soil types (sandy and clay loam soils) to assess the effect of potassium source, potassium sulphate (SOP) and potassium chloride (MOP), on soil properties and plant growth parameters throughout two successive seasons during 2007/2008, using sugar beet and maize. Soil chemical and physical characteristics are shown in **Table 1**.

Experimental plants

Seeds of the most popular varieties in Egypt of sugar beet (*Beta vulgaris* L. var. 'Pleno') and maize (*Zea maize* var. 'Monohybrid 129') were purchased from the seed collection of the Agricultural Research Centre, Ministry of Agriculture, Giza, Egypt.

Cultivation

The experimental design was a split-split plot in 4 replicates. Seedlings of the two crop plants were thinned twice 15 and 30 days down to 2 plants/pot.

Sugar beet seeds were sown in the first half of December in Mitscherlich pots containing 10 kg of soil. Before sowing, each pot received 4.0 g ammonium sulphate (20.6% N) in addition to

Received: 25 March, 2011. Accepted: 1 April, 2011.

Research Note

Table 1 Physical and chemical characteristics of the soils used prior to culture.

Soil property	Sandy soil	Clay loam soil
pH	8..02	8.56
EC ($dS.m^{-1}$)	0.11	0.79
$CaCO_3$ %	1.8	1.2
OM %	0.2	0.4
Sand %	88.0	15
Silt %	3.0	27
Clay %	9.0	58
Texture	Sand	Clay loam
Macro-nutrients ($mg.100g^{-1}$)		
P	3.0	5.0
K	12.9	106.4
Ca	540	520
Mg	16	38
Na	13.8	82.8
Micronutrients ($mg.kg^{-1}$)		
Fe	2.0	12
Mn	5.0	8.0
Zn	1.5	4.3
Cu	1.0	10

2.0 g super mono-phosphate (15.5% P_2O_5).

Maize seeds were sown in the same pots in June after removing sugar beet plants. Every pot received 6.7 g ammonium sulphate (20.6% N) in addition to 2.0 g super mono-phosphate (15.5% P_2O_5). Ca, Mg, Fe, Mn and Cu fertilizers were added in the sulphate form at 4.3, 4.3, 0.85, 0.22, 0.11 g pot^{-1}, respectively; boron was added as boric acid at 0.1 g pot^{-1} while molybdenum was added as ammonium molybdate at 0.1 g pot^{-1}.

Treatments

Since the original soils contain reasonable concentrations of K, K treatments were added randomly 3 weeks after cultivation for the two successive crops as follows:

1. 0.5 g (100% K) in the form of SOP (50% K_2O, 18% S, 99% purity);
2. 0.25 g (50% K) in the form of SOP (50% K_2O, 18% S) + 0.22 g (50% K) in the form of MOP (60% K_2O, 46% Cl, 99% purity);
3. 0.43 g (100% K) in the form of MOP (60% K_2O, 46% Cl);
4. Zero K with growing plants;
5. Zero K without growing plants.

Sampling and analysis

Representative soil samples (before fertilization and after plant harvest) were air-dried and passed through 2-mm sieve pores. Soil fractions were determined using the hydrometer method (Bauyoucos 1954). Electrical conductivity (EC) and pH were determined in a soil/water extract (1:2.5) according to Jackson (1973). The $CaCO_3$ content was determined using the calcimeter method according to Black (1965). Organic matter was determined using the potassium dichromate method according to Walkely and Black (1934). Soil P was extracted using sodium bicarbonate ($NaHCO_3$) (Olsen *et al.* 1954). K was extracted using ammonium acetate ($C_3H_3O_2NH_4$) (Chapman and Pratt 1978). Fe, Mn, Zn and Cu were extracted using DTPA-solution (Linsay and Norvell 1978).

Measurements and determinations

P was spectrophotometrically determined using the molybdate-vanadate method Jackson (1973). K was measured using a Dr. Lang M8D flame-photometer. Mg, Fe, Mn, Zn and Cu were determined using a Perkin-Elmer 100 B atomic absorption spectrophotometer.

Growth parameters

The sugar beet growth parameters determined after harvest were root volume, root diameter, shoot and root fresh weight (FW), and shoot and root dry weight (DW). The growth parameters assessed for maize were shoot FW and DW.

Statistical analysis

Data were subjected to statistical analysis as specified by Snedecor and Cochran (1990. Treatment means were calculated and subjected to one-way ANOVA and means were compared by the multiple Student-Newman Keul's (SNK) and LSD tests using Costate 2 Program (Cohort software).

RESULTS AND DISCUSSION

Effect of potassium source on soil characteristics

MOP has minor effects on soil properties and can be used safely as a low-priced potassic fertilizer for field crops. Physical and chemical properties of the soil were slightly affected by the application of MOP or SOP (**Table 2**). The pH of sandy soil increased slightly after removing sugar beet but decreased to 7.0 or less after maize was removed. The same trend was true for the EC of the soil. This may be because maize plants removed fertilizer salts more than sugar beet or because of faster leaching of the remaining salts since more irrigation water was added in the maize growth season compared to the sugar beet growth season. The nutrient concentrations of sandy soil were significantly affected by the K source. K, Ca and Na concentrations were significantly increased in soil without sugar beet plants. In a pot experiment with Garlic and cucumber crop rotation Yan *et al.* (2009) concluded that garlic in summer season could improve soil quality and have remediation effects on cucumber soil. However, only Na concentration increased significantly in soil without maize plants. This might also be evidence that maize absorbs higher quantities of these nutrients than sugar beet (Brown 1966; Durrant and Draycott 1971); leaching in summer is likely to wash away soil nutrients more than in winter (Hu *et al.* 2008). A similar trend was mentioned by Hussain *et al.* (2002) with wheat-rice and sugarcane-wheat rotations in Pakistan where most of K-solutes resulting from applied soil amendments as MOP in the rate of $120kg.ha^{-1}$ leached to ground water and then moved laterally. In conditions where soil or irrigation water chloride levels are very high, the addition of extra chloride with MOP can cause toxicity. However, this is unlikely to be a problem, since chloride is readily removed from the soil by leaching, especially in sandy soil (Phillips and Burton 2005).

Clay loam soil pH was significantly differed when MOP was applied as the sole source of K after removing maize while soil EC was significantly affected after both sugar beet and maize were removed (**Table 2**). The highest increment in EC was observed when MOP was applied to sugar beet plants. In contrast to sandy soil, all alkaline nutrients, except for Ca, were significantly different following the application of both K sources, but a significant difference was only observed in the soil in which either crop was grown while there were no significant differences in the nutrient concentrations of the soil between treatments to which MOP or SOP were applied and in which either crop was grown. In wheat-rice and sugarcane-wheat rotations, Sajjad *et al.* (2005) concluded that both chloride and sulphate associated with K fertilizers did not seem to have potential salinity or toxicity hazard. MOP and SOP have associated anions. So, it is evident that in both cases there is a net addition of salts; considering the small quantities of salts, there is a possibility that both anions are likely to produce similar osmotic potential in the soil solution. Certainly, chloride has a high salt index, which is a measure of salt solubility, and will be of importance at relatively higher concentrations considering the solubility of potassium sulphate and chloride salts. A salt index of 20-30 kg per ha in sandy soil should not be of practical significance from the point of view of salinity. However, the high solubility of

Table 2 Physical and chemical properties of the soil after crop removal and affected by the potassium source (n=4).

Crop	Treatment	pH (1:2.5)	EC (dS.m^{-1})	K	Ca	Mg	Na
		Sandy soil					
				mg.100g^{-1} soil			
Sugar beet	1	8.51 b	0.06 a	7.69 a	191 a	14.5 a	7.53 a
	2	8.35 b	0.072 a	7.31 a	252 a	17.0 a	6.99 a
	3	8.43 b	0.062 a	7.45 a	250 a	11.0 a	6.94 a
	4	8.39 b	0.067 a	7.12 a	345 a	11.0 a	8.05 a
	5	7.97 a	0.127 b	12.4 b	605 b	13.0 a	15.6 b
	$LSD_{0.05}$	0.168	0.023	0.864	176.1	NS	2.66
Maize	1	7.0 a	0.07 a	23.5 a	337 a	11.0 a	10.9 a
	2	7.0 a	0.11 a	14.9 a	272 a	10.5 a	11.0 a
	3	6.97 a	0.11 a	15.6 a	412 a	10.5 a	12.3 a
	4	7.01 a	0.10 a	11.7 a	362 a	9.5 a	10.2 a
	5	7.01 a	0.25 b	11.0 a	430 a	33.5	27.1 b
	$LSD_{0.05}$	NS	0.062	NS	NS	NS	6.117
		Clay loam soil					
Sugar beet	1	8.41 a	0.20 a	52.7 a	907 a	68 a	21.9 a
	2	8.44 a	0.18 a	47.9 a	950 a	70.5 a	20.3 a
	3	8.35 a	0.39 c	56.5 a	875 a	67 a	26.0 a
	4	8.34 a	0.26 a	60.3 a	945 a	77.5 a	29.0 a
	5	8.11 a	1.74 b	98.8 b	960 a	120 b	349 b
	$LSD_{0.05}$	NS	0.1.08	16.79	NS	14.58	60.25
Maize	1	7.18 a	0.49 a	77.6 b	785 a	70.0 a	44.6 a
	2	7.09 a	0.41 a	71.7 b	970 a	70.5 a	52.9 a
	3	7.58 b	0.44 a	77.6 b	1170 a	78.0 a	61.6 a
	4	7.02 a	0.37 a	41.6 a	980 a	59.5 a	40.5 a
	5	7.05 a	1.06 b	79.8 b	1315 a	118 b	108 b
	$LSD_{0.05}$	0.342	0.257	21.51	NS	29.85	18.94

NS = non significant
Numbers with different letters in the same column are significantly different at $P \leq 0.05$ (multiple Student-Newman Keul's (SNK) and LSD tests)

Table 3 Sugar beet growth parameters as affected by soil type and potassium source (n= 4)

Treatment	Root volume (cm^3)	Root Diameter (cm)	Root FW (g.pot^{-1})	Root DW (g.pot^{-1})	Shoot FW (g.pot^{-1})	Shoot DW (g.pot^{-1})
Sandy soil						
1	62.0 a	12.3 a	120 a	33.7 a	70.4 a	13.2 a
2	55.7 a	10.3 a	115 a	30.3 a	67.3 a	13.1 a
3	67.2 a	11.0 a	89.7 a	34.6 a	93.2 a	13.7 a
4	55.7 a	10.2 a	85.0 a	32.9 a	67.5 a	12.8 a
5	No plants	-------	-------	-------	--------	--------
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS
Clay loam soil						
1	105 a	11.4 a	154 a	49.6 a	103 a	17.9 a
2	76.6 a	10.5 a	124 a	34.5 a	103 a	17.3 a
3	82.5 a	10.9 a	129 a	38.1 a	104 a	23.0 a
4	72.7 a	10.4 a	121a	36.7 a	91.4 a	15.9 a
5	No plants	------	------	------	------	------
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

T = Treatment, V = Volume, D = Diameter, NS = non significant
Numbers with different letters in the same column are significantly different at $P \leq 0.05$ (multiple Student-Newman Keul's (SNK) and LSD tests)

MOP will bring K into solution readily and help earlier removal of Cl- ions from the root zone since its dissolution is high even at lower temperature (IPI 2001). In a long-term experiment with cotton (*Gossypium hirsutum* L.), Makhdum *et al*. (2006) concluded that application of K fertilizer in the form of MOP caused more than a 3-fold increase in the level of Cl- in the soil; however, chloride ion was leached down to lower horizons.

Plant growth parameters as affected by soil type and K-source

There were no significant differences in the growth parameters of sugar beet plants supplied with SOP or MOP, or their combinations; however, maize growth parameters responded better to SOP and the combination of SOP+MOP fertilizers. Generally, sugar beet growth parameters were better in the clay loam soil than in sandy soil (**Table 3**). While root volume and shoot FW and DW were higher when MOP was applied in both soil types, root diameter and root FW and DW were the best when SOP was applied, but values were not significant. FW and DW of maize plants grown on sandy soils showed lower values than of plants grown on clay loam soil (**Fig. 1**). However, SOP and the combination of SOP+MOP produced higher FW and DW than other treatments for maize plants grown on sandy soil. On the other hand, the FW of plants grown on clay loam soil was higher than that of plants grown with the MOP+SOP combination and MOP treatments. Thus, plants respond differently according to soil type and crop to the K source. Akhtar *et al*. (2010) concluded that K applied at 100 kg ha^{-1} as MOP produced only significantly higher marketable tomatoes (*Lycopersicon esculentum*) than SOP and control. In an experiment with onion (*Allium cepa*) plants, Nabi *et al*. (2010) found that SOP fertilizer significantly produced tallest plants, firmer bulbs, higher dry matter, more pungent bulbs, higher TSS of bulbs, small and medium size bulbs than MOP fertilizer. Kumar and Kumar (2008) investigated the effects of MOP and SOP on banana (*Musa acuminata*) fruit yield and quality and concluded that SOP was

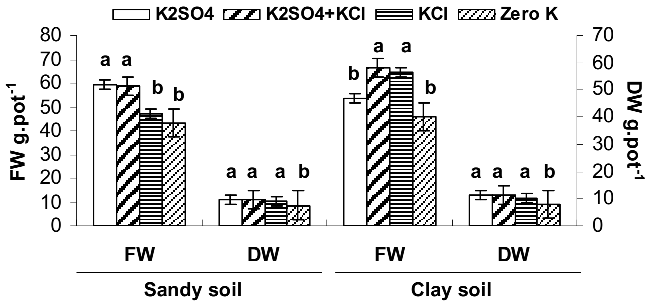

Fig. 1 Fresh (FW) and dry weight (DW) of maize plants as affected by soil type and K-source. Values represent the mean ± standard deviation (n = 4). Columns with the same letters are not significantly different at $P \leq 0.05$.

more beneficial in increasing bunch size with better quality fruits than MOP. The chloride anion is harmful to chloride-sensitive crops such as potatoes strawberry, mango, citrus, cucumber, melon, onion, and lettuce, while K-sulfate was reported to be good for these crops, or for soils with a salinity hazard like that irrigated with water contains high saline ions (Vis 1990). Hence, plants differ remarkably in their response to MOP or SOP in different soil types; crop plants should be supplied with a proper potassium source after assessing the effect of available K-sources on crop yield and quality.

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