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Effect of Potassium Fertilisation and Salicylic Acid on Yield, Quality and Nutrient Uptake of Sugar Beet (*Beta vulgaris* L.) Grown in Saline Soil

Merwad, A.M.A.*

Zagazig University, Faculty of Agriculture, Soil Science Department, 44511 Zagazig, Egypt

ABSTRACT

A field experiment on sugar beet (*Beta Vulgaris* L.) grown in saline soil was carried out during the 2014 growing season to study the effect of potassium (K) fertilisation rates of 0, 100, 150 and 200 kg ha^{-1} and foliar spray of salicylic acid (SA) solution of 1000 mg L^{-1} (sprayed twice at the rate of 1200 L per ha each time) on yield, quality, nutrient contents, and uptake. The application of 200 kg ha^{-1} of K in combination with salicylic acid foliar spray gave the highest root length, root diameter, shoot and root yield, sucrose, juice purity percentage, gross sugar yield and possible extractable white sugar, nitrogen (N), phosphorous (P) and K content and uptake. The highest increase in sucrose (20%) as well as possible extractable white sugar (184%) were obtained by the addition of 200 kg ha^{-1} of K in combination with salicylic acid foliar spray. The K, sodium (Na) and α-amino N contents in sugar beet decreased with the application of K with SA foliar spray. The highest values of K, Na and α-amino N contents were observed in the non-treated plants. Potassium, N and α-amino N contents decreased by 48.5%, 68% and 76.6%, respectively, when treated with 200 kg ha^{-1} of K with the addition of SA spray.

Keywords: **Nutrient uptake, potassium fertilisation, salicylic acid, sugar beet.**

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is the second largest crop for sugar production in Egypt after sugar cane. Sugar beet has been an important crop in Egyptian crop rotation as a winter crop both in poor and fertile soils.

Salinity of soil is a major abiotic stress that has adverse effects on physiological and metabolic processes of plants leading to diminished growth and yield of plants (David, 2007; Yokoi *et al*., 2002; Azizpour *et al*., 2010). Plant growth is suppressed severely at high salinity stress due to factors such as osmotic stress, mineral nutrition absorption imbalance, and specific ion toxicity, all combining to reduce nutrient uptake consquentially causing physiological drought to plants (Yusuf *et al.*, 2007; David, 2007). Fertilisation plays an important role in promoting plants to tolerate salt stress (Ghoulam *et al*., 2002).

*Corresponding author : E-mail: abdo.soil@yahoo.com

Salicylic acid (SA) is used for raising plants' resistance to the undesirable effects of biotic and abiotic stresses and participates in regulating their physiological processes. Salicylic acid has a significant effect on different aspects of plant growth and development, photosynthesis, evaporation, ion transmission and absorption, and also causes changes in leaf anatomy and chloroplast structure (Sakhabutdinova *et al*., 2003). Salicylic acid is recognised as a plant hormone (Hayat and Ahmed, 2007). It plays diverse physiological roles in plants including plant growth, photosynthesis, and nutrient uptake. (Janda *et al.*, 2007). Among abiotic stresses, SA alleviates water stress (Singh and Usha, 2003), heat stress (Tasgin *et al*., 2003) and salinity stress (Khodary, 2004; El-Tayeb, 2005).

Potassium (K) is an essential element for plant growth with respect to its physiological and biochemical functions. It is necessary for activating starch synthetase enzyme (Fathy *et al*., 2009; Ibrahim *et al*., 2002). Wang *et al*., (2013) report that K plays an essential role in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance. Mehrandish *et al.,* (2012) showed that the application of K increased root yield, shoot yield, sugar yield, sugar content and other qualitative characteristics of sugar beet crops. Salami and Saadat (2013), and Shahidi and Khalafi (2010) found that K increased shoot yield, root yield, sucrose, juice purity percentage, gross sugar yield, and nitrogen (N), phosphorous (P) and K content and uptake.

Neseim *et al*., (2014) found that K in combination with yeast foliar spray increased root and white sugar yield and gave a decrease in sodium and α- amino N content of sugar beet crop. The objective of this study was to test the effect of K and foliar spray of SA in sugar beet grown in saline soil.

MATERIALS AND METHODS

A field experiment was carried out during the 2014 growing season in Port Said Governorate, Egypt to study the effect of K fertilisation and foliar spray of SA on yield, quality, and nutrient uptake by sugar beet (*Beta vulgaris* L.) grown in a saline soil. The physical and chemical properties of the soil were determined according to Piper (1951), Black *et al*., (1965) and Jackson (1973) are shown in Table 1.

The experimental design was a randomised complete block design in three replications. The plot area was 21 m^2 (3 m × 7 m). Each plot had five rows 60 cm apart and 7 m long. Before planting, all plots were were fertilised with 31 kg P ha^{-1} as ordinary super phosphate (65 g P kg^{-1}). An amount of 60 kg N ha^{-1} as ammonium sulphate (205 g N kg^{-1}) were then applied in two equal doses. The first dose was after thinning and the second dose was before the second irrigation. The first factor concerned K fertilisation. Treatments were applied before the first irrigation in 0, 100, 150, 200 kg ha^{-1} dose of K in the form of potassium sulphate (410 g K kg^{-1}). The second factor concerned SA foliar spray. Sprayings of SA at 1000 mg L^{-1} (1200 L ha^{-1}) were done 40 days and 80 days after seeding. No K fertilisation was given to the plants concerned as the second factor.

TABLE 1
Seleceted physical and chemical properties of the investigated soil

Soil characteristics	Values
Soil particles distribution	
Sand ,%	82.92
Silt,%	13.64
Clay,%	3.44
Textural class	Sandy
Field capacity (FC),%	10.85
$CaCO_3$, (g kg^{-1})	17.6
Organic matter,(g kg^{-1})	5.62
pH*	8.01
EC,(dS m^{-1}) **	7.62
Soluble cations and anions, ($mmol_c$ L^{-1}) **	
Ca^{++}	35.56
Mg^{++}	12.71
Na^{+}	19.23
K^{+}	8.50
$CO_3^{=}$	-
HCO_3^{-}	21.66
Cl^{-}	28.54
$SO_4^{=}$	25.80
Available nutrient , (mg kg^{-1}soil)	
N	95.62
P	7.25
K	78.59

* Soil paste ** Soil paste extract

At harvest (195 days after seeding), ten plants were taken at random from each plot. The shoot and roots were separated and dried at 70^{o}C in an oven. Dry plant samples of shoot were ground and analysed for nutrient contents (N, P and K). Total N was determined using the micro-Kjeldahl method by Chapman and Pratt (1961). Phosphorous and K were determined by digesting in concentrated $H_2SO_4/HClO_4$ (Chapman and Pratt, 1961). Measurements of P was done colourimetrically using ascorbic acid (Watanabe and Olsen, 1965), whilst K was measured by flame photometer (Chapman and Pratt, 1961). The α- amino N, Na and K concentrations were determined according to the procedure by Bhador *et al.,* (2010). Sucrose was estimated in fresh samples of sugar beet root by using a saccharometer according to the method by Ahadi and Sobhani (2005).

RESULTS AND DISCUSSION

Effect of K Fertilisation and Foliar Spraying of SA on Root Length, Root Diameter and Yield of Sugar Beet Crop Grown on Saline Soil

Potassium fertilisation as well as foliar spray with SA caused positive and significant effects on root length, root diameter, shoot and root yield of sugar beet crop grown in saline soil (Table 2) . The highest values of root length and root diameter (31.63 and 15.30 cm, respectively) were obtained by K fertilization at 200 kg K ha^{-1} and sprayed with SA, while the lowest values were obtained in plants not receiving K as well as SA. Application of K at 200 kg ha^{-1} with foliar spray of SA gave the highest fresh shoot and root weights (15.87 and 80.32 Mg ha^{-1}, respectively). The lowest fresh shoot and root weights (8.65 and 39.19 Mg ha^{-1}, respectively) were obtained from the untreated plants. Increased fertilisation with K gave increased weights of fresh shoot and root weights, increasing by up to 58% and 89.6 %, respectively, at the highest K dosing rate. Foliar spray with SA increased the fresh shoot and root weights by 12% and 14%, respectively. These results are in agreement with those obtained by Attia (2004) and Ahadi and Sobhani (2005). Potassium helps in maintaining a normal balance between carbohydrates and proteins (Moneral *et al*., 2007). Salami and Saadat (2013) applied up to 95 kg ha^{-1} of K to sugar beet and increased shoot and root fresh and dry weight.

TABLE 2
Effect of potassium fertilisation and foliar spray of salicylic acid on root length, root diameter and yield of sugar beet crop grown on saline soil

Potassium fertilization (A)	Salicylic acid spray (B)	Root length (cm)	Root diameter (cm)	Shoot yield (Mg ha^{-1})		Root yield (Mg ha^{-1})	
				Fresh weight	Dry Weight	Fresh weight	Dry weight
K0	Without	20.47	10.17	8.65	2.88	39.19	8.16
	With	24.20	10.83	10.32	3.44	41.43	8.63
Mean		22.33	10.50	9.48	3.16	40.31	8.39
K1	Without	25.43	11.20	11.19	3.73	43.73	9.11
	With	27.13	11.57	11.91	3.97	53.02	11.05
Mean		26.28	11.38	11.55	3.85	48.37	10.08
K2	Without	27.50	12.10	12.70	4.23	56.35	11.74
	With	28.83	13.43	13.81	4.60	67.30	14.02
Mean		28.17	12.77	13.25	4.41	61.83	12.88
K3	Without	29.57	13.73	14.13	4.71	72.62	15.13
	With	31.63	15.30	15.87	5.29	80.32	16.73
Mean		30.60	14.52	15.00	5.00	76.47	15.93
Mean of salicylic acid spray							
	Without	25.74	11.80	11.67	3.89	52.97	11.04
	With	27.95	12.78	12.98	4.33	60.52	12.61
LSD	A	0.215		0.464	0.155	1.58	0.328
	B	0.236		0.328	0.109	1.11	0.232
	AB	0.325		NS	NS	2.23	0.464

K0: Without potassium fertilisation, K1: 100 kg K ha^{-1}, K2: 150 kg K ha^{-1} , K3: 200 kg K ha^{-1} ,
Mg = mega gram= 10^6 g

Root length, root diameter, shoot and root yield increased when treated with SA. Gutrierrez-Coronado *et al*. (1998) reported increases in the growth of shoots and roots of soybean plant in response to SA treatment. SA enhanced growth in wheat (Singh and Usha, 2003) and maize (Khodary, 2004) under water stress, and barley under salt stress (El-Tayeb, 2005).

Salicylic acid is a strong ameliorator for stress conditions (Hayat and Ahmed, 2007). It plays diverse physiological roles in plant growth, photosynthesis and the uptake of nutrients (Janda *et al.*, 2007; Merwad, and Abdel-Fattah, 2015).

Effect of K Fertilisation and Foliar spraying of SA on Quality of Sugar Beet Crop Grown on Saline Soil.

The effects of K fertilisation and foliar spray of salicylic acid on sucrose content, juice purity percentage, gross sugar yield and possible extractable white sugar are shown in Table 3. All parameters increased significantly with K fertilisation as well as foliar spray with SA. The highest values of sucrose content, juice purity, gross sugar yield and possible extractable white sugar (19.68%, 85.82%, 15.8 and 13.56 Mg ha^{-1}, respectively) were obtained under the highest rate of K fertilisation treatment (200 kg K ha^{-1}) in combination with SA acid spray.

TABLE 3
Effect of potassium fertilisation and foliar spray of salicylic acid on some quality of sugar beet crop grown on saline soil

Potassium fertilization (A)	Salicylic Acid spray (B)	Sucrose (%)	Juice purity (%)	Gross sugar yield (Mg ha^{-1})	Possible extractable white sugar (Mg ha^{-1})
K0	Without	15.56	78.30	6.10	4.77
	With	16.80	80.00	6.96	5.57
Mean		16.18	79.15	6.53	5.17
K1	Without	18.14	81.65	7.93	6.48
	With	18.53	82.30	9.83	8.09
Mean		18.340	81.98	8.88	7.28
K2	Without	18.91	82.60	10.66	8.80
	With	18.98	83.31	12.78	10.64
Mean		19.95	82.96	11.72	9.72
K3	Without	19.13	84.16	13.89	11.69
	With	19.68	85.82	15.80	13.56
Mean		19.40	84.99	14.85	12.63
			Mean of salicylic acid spray		
	Without	17.93	81.68	9.65	7.94
	With	18.50	82.86	11.34	9.49
LSD 0.05%	A	0.184	0.492	0.328	0.297
	B	0.143	0.348	0.232	0.195
	AB	0.286	0.464	0.464	0.389

K0: Without potassium fertilisation, K1: 100 kg K ha^{-1}, K2: 150 kg K ha^{-1}, K3: 200 kg K ha^{-1}

The highest increase in sucrose content was 20% whilst the highest possible extractable white sugar was 184.3% and both were achieved with K fertilisation of 200 kg ha^{-1}. These results agree with those obtained by Salami and Saadat (2013) who obtained a 17% increase in sucrose content in sugar beet upon applying K at a rate of 95 kg ha^{-1}. The results obtained by this study were also similar to those obtained by Shahidi and Khalafi (2010) and Neseim *et al.* (2014). The white sugar yield is an important parameter of sugar beet. Most of the quality parameters such as sucrose content, juice purity and gross sugar yield have been reported to increase upon K fertilisation (Zaifi zaden and Amjadi, 2001). Ibrahim *et al*., (2002) found that application of K at 95 kg ha^{-1} increased of the contents of sugar, sucrose, juice purity, gross sugar yield and possible extractable white sugar of sugar beet. Moussa and Khodary (2003) reported that foliar spraying SA to salinity-stressed maize stimulated plant growth rate via accelerating their photosynthesis and carbohydrate metabolism.

Effect of K Fertilisation and Foliar Spraying of SA on Impurity Components in a Paste of Sugar Beet Crop Grown in Saline Soil.

Contents of K, Na and α-amino N in beet paste (Table 4) decreased with K application as well as with foliar spray with SA. The average decreases in K content due to K application were 11.1%, 18.6% and 25.2% caused by K1, K2 and K3, respectively. Comparable respective decreases in Na contents were 13.0%, 27.9% and 34.0%. Comparable respective decreases in α-amino N contents were 4.5%, 19.6% and 35.8%. The non-K fertilized, non-SA sprayed plants showed the highest contents of K, Na and α-amino N (5.60, 2.57 and 1.89 mmol 100 g^{-1} beet paste, respectively). Plants that received the highest K in combination with foliar SA spray showed decreases of 32.6%, 40.5% and 43.4% in K, Na and α-amino N, respectively. These results agreed with those obtained by Salami and Saadat (2013) who applied 95 kg K ha^{-1} and obtained decreases in K, Na and α-amino N contents in sugar beet. The current results were similar to those reported by Eskandar Zadeh (1999), El-Yamani (1999), Hellal *et al*. (2009), Neseim *et al*.,(2014) and Merwad and Abdel-Fattah (2015).

The average decrease in K content due to foliar spray with SA were 10.7%. Comparable decreases in Na and α-amino N contents were 13.0% and 13.1 %, respectively. Plants sprayed with SA but not fertilized with K contained K, Na

TABLE 4

Effect of potassium fertilisation and foliar spray of salicylic acid on impurity components in paste of sugar beet crop grown on saline soil

Potassium fertilisation (A)	Salicylic acid spray (B)	K content (mmol kg^{-1} beet paste)	Na content (mmol kg^{-1} beet paste)	α-amino N (mmol kg^{-1} beet paste)
K0	Without	56.0	25.7	18.9
	With	50.3	23.7	16.3
Mean		53.2	24.7	17.6
K1	Without	49.7	23.7	17.7
	With	45.0	19.3	15.8
Mean		47.3	21.5	16.8
K2	Without	46.3	19.3	15.5
	With	40.3	16.3	12.7
Mean		43.3	17.8	14.1
K3	Without	42.0	17.2	11.9
	With	37.7	15.3	10.7
Mean		39.8	16.3	11.3
			Mean of salicylic acid spray	
	Without	48.5	21.5	16.0
	With	43.3	18.7	13.9
LSD 0.05%	A	0.129	0.104	0.090
	B	0.091	0.074	0.064
	AB	NS	NS	NS

K0: Without potassium fertilisation, K1: 100 kg K ha^{-1}, K2: 150 kg K ha^{-1}, K3: 200 kg K ha^{-1}

and α-amino N lower by 10.2%, 7.8% and 13.8%, respectively, in comparison with those not sprayed with SA and not fertilised with K. Armin and Asgharipour (2012) found that the application of boric acid decreases K, Na, α-amino N content in sugar beet. This study's results are similar to those reported by Javaheripour *et al*. (2005) and Kristek *et al.* (2006).

Effect of K Fertilisation and Foliar Spraying of SA on Contents and Uptake of N, P and K in Shoots of Sugar Beet Crop Grown on Saline Soil.

Potassium fertilization rates as well as foliar spraying of SA caused a positive and significant effect on the uptake of N, P and K nutrients and contents in shoots (Table 5). The highest values of N, P and K contents of sugar beet (3.67%, 0.48% and 4.47%, respectively) and N, P and K uptake (194.2, 25.6 and 236.1 kg ha^{-1}, respectively) were obtained with a K-fertilisation rate of 200 kg K ha^{-1} combined with the spraying of SA. However, untreated plants showed the lowest contents (2.7%, 0.16% and 1.8%) and uptake (59.6, 4.54 and 51.8 kg ha^{-1}) of N, P and K, respectively.

Increased application of K increases the N, P and K contents by up to 47%, 150% and 120%, respectively, and was comparable to increases in uptake of up to 132%, 277% and 248%, respectively compared to without K application. These results agreed with those obtained by Fathy *et al.* (2009) and Salami and Saadat (2013) who reported that the application of K at a rate of 95 kg ha^{-1} increase contents and uptake of N, P and K of shoot sugar beet crop. These results are similar to findings reported by Horn and Furstenfeld (2001), Etemadi (2000) and Mack *et al*., (2007). Positive response to its application is a manifestation of K

TABLE 5

Effect of potassium fertilisation and foliar spray of salicylic acid on contents and uptake of N, P and K in shoots of sugar beet crop grown on saline soil.

Potassium fertilization (A)	Salicylic acid spray (B)	Contencentration (g kg^{-1})			Uptake (kg ha^{-1})		
		N	P	K	N	P	K
K0	Without	20.7	1.6	18.0	59.66	4.54	51.80
	With	25.7	2.1	20.7	88.23	7.33	71.03
Mean		23.2	1.8	19.4	73.95	5.94	61.41
K1	Without	24.0	2.7	29.3	89.63	9.96	109.42
	With	28.3	3.0	30.7	112.33	11.91	121.72
Mean		26.2	2.85	30.0	100.9	10.94	115.57
K2	Without	28.0	3.4	34.7	118.65	14.41	146.75
	With	31.0	3.8	37.3	142.73	17.50	171.80
Mean		29.5	3.6	36.0	130.69	15.95	159.27
K3	Without	31.7	4.1	40.7	149.18	19.31	191.56
	With	36.7	4.8	44.7	194.18	25.57	236.14
Mean		34.2	4.5	42.7	171.68	22.44	213.85
				Mean of salicylic acid spray			
	Without	26.1	2.9	30.7	104.28	12.06	124.88
	With	30.4	3.4	33.3	134.37	15.58	150.17
LSD0.05%	A	0.166	0.023	0.113	11.22	1.302	6.537
	B	0.117	0.016	0.080	7.936	0.920	4.016
	AB	NS	NS	NS	NS	1.841	9.245

K0: Without potassium fertilisation, K1: 100 kg K ha^{-1}, K2: 150 kg K ha^{-1}, K3: 200 kg K ha^{-1}

maintaining a balance between carbohydrate and proteins (Moustafa and Darwish, 2001; Moneral *et al.*, 2007).

Spraying SA increased the contents of N, P and K by an average of 16.5%, 17.2% and 8.5%, respectively, and N, P and K uptake by an average of 28.9%, 29.2% and 20.3%, respectively, compared to without SA. These results agree with those obtained by Zahra *et al*., (2010) and Merwad and Abdel-Fattah (2015).

CONCLUSION

Potassium application and SA spray had significant positive effects on shoot and root yields, quality, and N, P and K contents and uptake by sugar beets. The highest values were obtained at the highest rate of potassium fertilisation applied together with the spraying of SA. The highest yield and quality (sucrose, juice purity, gross sugar yield and possible extractable white sugar) were obtained with a potassium dose of 200 kg ha^{-1} in conjunction with spraying with SA. This study recommends the application of potassium combined with foliar spray with with SA to obtain a high quality of sugar from the sugar beet crop grown on saline soils.

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