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Comparative Efficiency of Foliar and Soil Potassium Application on Sugar Beet Productivity and Quality

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Abstract: In this study the efficiency of soil and foliar potassium fertilizer was examined under North Delta conditions to develop potassium management recommendations that maximize yield and quality of sugar beet to increase net profit and stop land degradation and decrease pollution of water and environment caused by soil fertilization. Studies were conducted at Belqas, Dakhlia, Governorate, Egypt during two successive winter seasons 2008/2009 and 2009/2010 to evaluate the effects of soil and foliar potassium application during different growth stages on sugar beet (cv. Raspoly) productivity and quality. The experiment includes 6 potassium fertilizer treatments, applied either as soil (114 Kg K_2O/ha) or foliar (3 % K_2O) applied as (full dose or split into two doses) during root formation or at sugar storing stages in addition to the control treatment (without K_2O). All potassium treatments significantly increased yield characters i.e. root, top, sugar yield and recoverable sugar yield (RSY) as well as root weight and dimensions compared with the untreated one (control). However, K_3 (soil application of 114 kg K_2O/ha in two doses (1/2 at root formation +1/2 at sugar storing) surpass all the other treatments. Potassium application significantly increased sucrose %, purity, quality index and recoverable sugar %, while it decreased all impurities contents i.e. K, Na and α-amino nitrogen as well as sucrose loss to molass values in sugar beet juice extraction. Moreover, soil potassium application was more efficient than foliar one. Application of potassium fertilizer during root formation stage produced the highest root yield, while applying it at sugar formation stage produced the highest sugar % and consequently the highest values of (RSY). Furthermore, splitting potassium fertilizer dose maximizes sugar beet yield and quality. The best strategy would be to split 114 kg K_2O/ha into two doses applied to the soil (at root formation and at sugar storing). This treatment recorded the highest potassium use efficiency (KUE) values.

Key words: Sugar beet · Soil and foliar potassium application · Root yield · Root quality · Potassium use efficiency (KUE)

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is a member of the family *Chenopodiaceae*. It ranks second to sugar cane as a source of sucrose in the world. Improving its productivity is urgent demand to meet the consumption of the ever growing population and to fill the gap between production and consumption. This urgent need requires continuous scientifically based implementation of effective agricultural practices on the limited cultivable land area. During the last decades, researches efforts have been concentrated to improve fertilizer use efficiency by applying various techniques including foliar fertilization (FF) of nutrients in both conventional and alternative production systems to increase yield and improve the quality of crop products [1]. This procedure can also improve nutrient utilization and lower environmental pollution through reducing the amount of fertilizers added to soil [2].

Fertilizer is considered as a limiting factor for obtaining high yield and quality, thus application of suitable potassium fertilizers may be one of the favorable factors for the production of sugar beet. Many investigators have confirmed the role of K in increasing the yield and quality of sugar beet by enhancing the biosynthesis of organic metabolites and improving nutritional status [3, 4]. In this concern, Tawfik *et al.* [5] found that the highest yield, sucrose percentage and juice purity were achieved with application of 114 kg K_2O ha^{-1}. Moreover, potassium plays important roles in photosynthesis, protein synthesis, translocation of assimilates as well as increasing plant growth and yield.

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In this concern, Amer *et al.*[6] found that adding potassium up to 90 kg K_2O/fed resulted a significant increase in N %, P % and K % in beet root, as well as root and sugar yields/fed, TSS, sucrose and purity %. In this concern, El-Harriri and Gobarah [7] found that adding 48 kg of K_2O significantly increase sucrose %, purity and extractable sugar yield (ton/ fed) compared with lower K_2O level (24 kg /fed). Much more K is required to fulfill other major functions in plants. Potassium is essential for growth and is the main element used to maintain cell turgor (rigidity) and to regulate the water content of the plant [8]. Aparna [9] added that K is considered to be the most important cation not only from the viewpoint of its relative amounts but also from the viewpoint of its physiological and chemical functions. This could be because K^+ is usually absorbed as a single charge cation by an active mechanism and it can translocate along electrochemical potential gradient [10].

Therefore, this investigation aims to evaluate the efficiency of soil and foliar potassium fertilizers application under North Delta conditions, Egypt.

MATERIALS AND METHODS

Two field experiments were conducted at Belqas, Dakhlia Governorate, Egypt to find out appropriate rate and time of potassium fertilizer on sugar beet productivity and quality. Seeding rate was approximately 50 kg /ha. The field was planted to corn in the preceding year in both seasons. Seeds of sugar beet (*Beta vulgaris* L.) cv. Raspoly were sown in hills 20 cm apart on 10^{th} and 15^{th} October 2008 and 2009, respectively. Plants were thinned to leave one plant per hill after 30 days from sowing. Phosphorus fertilizer was applied before sowing at the rate of 71 k / ha in the form of super phosphate (15.5% P_2O_5). Nitrogen fertilizer was added at the recommended rate of 190 Kg N / ha in the form of urea (46% N) in two equal doses. The first one was applied after thinning and the second after 30 days later. Potassium fertilizer was added as follow:

- K_0 = Control (without K_2O).
- K_1 = Soil application of 114 Kg K_2O /ha at root formation.
- K_2 = Soil application of 114 Kg K_2O /ha at sugar storing.
- K_3 = Soil application of 114 kg K_2O / ha [1/2 at root formation +1/2 at sugar storing].
- K_4 = Foliar application of 3% K_2O /ha at root formation.
- K_5 =Foliar application of 3% K_2O /ha at sugar storing.
- K_6 = Foliar application of 3% K_2O / ha [1/2 at root formation +1/2 at sugar storing].

Foliar solution was prepared at 3.0 % K_2O in the form of potassium sulphate (48 % K_2O) and applied by using hand sprayer. The other agronomic practices were done as recommended. The experimental design was randomized complete block design (RCBD) with four replications and six treatments of potassium in addition to the control treatment. Soil texture of the experiments was clay loam. Chemical analysis of soil samples at 30 cm depth in experimental sites before soil preparation is presented in Table 1.

At harvest time (195 days from sowing) ten guarded plants were taken at random from each plot in the two seasons to determine root dimensions cm (length and diameter) and fresh root weight (kg). Plants were harvested from the four middle rows of each plot to determine top and root yields (ton/ha). Three roots were chosen randomly to determine sucrose percentage as described by Le-Docte [11]. Sugar yield was obtained by multiplying sugar % by root yield. Juice purity percentage according to the method of Silin and Silina [12]. Recoverable sugar % was calculated for each treatment according to Reinfeld *et al.* [13] and recoverable sugar yield (RSY) was calculated for each treatment. Potassium and sodium were measured in the root dry weight at harvest time by using the Flame photometer. K/Na was calculated for each treatment. Alpha-amino nitrogen was also calculated by double beam filter photometry using the blue number method described by Sheikh Al Eslami [14]. Sugar loss to molasses (MS) was calculated with the method of Reinfeld *et al.* [13]: $MS = 0.343 \times (K + Na) + 0.0393\ \alpha\text{-amino-N} + 0.31$. [K, Na and α-amino-N in meq/100 g beet]. Potassium use efficiency (KUE) was determined according to Janssen [15]. Quality index was calculated as (sugar recoverable % x 100)/sucrose %.

Table 1: Chemical analysis of experimental soils in both seasons

Season	pH	EC dSm^{-1}	O.M%	$CaCO_3$%	P	K	Na	Mg	Fe	Mn	Zn	Cu
					mg/100g				ppm			
2008/09	8.38	0.84	1.93	2.23	4.16	40.14	79.20	187.3	8.25	4.40	1.03	2.24
2009/10	8.17	0.99	2.10	2.50	3.51	43.38	68.14	209.0	7.50	4.50	1.79	2.56

Statistical Analysis: Data collected for yield and quality of sugar beet were subjected to the statistical analysis according to Gomez and Gomez [16] and all means were compared at 5% level of probability.

RESULTS AND DISCUSSION

Effect of Potassium Fertilizer on Yield and Yield Parameters: Data in Table 2 and Fig. 1 showed that all potassium fertilizer treatments significantly increased all the studied characters of root and sugar yield parameters in both seasons compared with control treatment. However K_3 treatment i.e. soil application of 114 kg K_2O / ha in two doses (1/2 at root formation +1/2 at sugar storing) surpasses all the other treatments in both seasons. All these parameters were lower in the control treatment. These results are supported by Bernard *et al.* [17] who stated that if K is deficient or not supplied in adequate amounts, sugar beet plants can be stunted, become susceptible to disease and have reduced yields. They also added that, potassium is considered a major osmotically active solute of plant cell, where it enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency. However, soil application treatments surpass foliar ones for all the previous characters. These results are in agreement with those obtained by Abdel-Mawly and Zanouny [18]. The positive action of potassium fertilizer application on sugar beet yield might be related to its effect on water– plant relationship as well as metabolic and physiological activities of sugar beet plant. In this concern, Carter [19] stated that, addition of potassium increases the water retaining capacity of cells, decreasing the transpiration rate of leaves through improving stomatal opening and closure and increasing photosynthesis rate and translocation of assimilates which, in turn, enhances yield and quality of sugar beet. Furthermore, Tsialtas and Maslaris [20] added that potassium enhances many enzyme actions, aids in photosynthesis and food formation, helps translocations of sugars and starches, increases protein content of plants, maintains turgor and reduces water loss.

Furthermore, data also showed that splitting potassium fertilizer dose had more pronounced effect on yield and yield component. It significantly increased root length, diameter and weight as well as top, root and sugar yields (ton/ha). This could be because split applications are often advocated to minimize leaching losses. The advantage of split application of potassium fertilizer in sugar beet was studied by Jocic and Saric [21]. Moreover, addition of potassium fertilizers at root formation stage produced the highest root and consequently sugar yield as compared with the other treatments. However, soil application of K was proven to be more effective way compared with foliar application. In this concern, Terrance and Donald [22] stated that the effectiveness of FF appeared to be limited by the holding capacity of leaf surface area for the liquid fertilizer. It was concluded that FF may partially compensate for insufficient uptake by the roots, but requires sufficient leaf area to become effective. The favorable effect of potassium fertilizer which improved yields may be due to the vital role of potassium in building up metabolites and activating starch synthetase enzymes and carbohydrates accumulation which transferred from leaves to developing roots consequently enhanced root and chemical constituents [23]. They added that, this increment due to potassium application could be due to its effect on leaf photosynthesis, transpiration and water use efficiency during the season. Bringer [24] added that bitter K nutrition improve nitrogen metabolism by stimulating the activity of nitrate reductase to promote the formation of peptides and protein. In this study soil application treatments had a pronounced positive impact than foliar potassium, splitting potassium application had bitter yield than single basal application.

Table 2: Effect of potassium treatments on yield and yield components in 2008/2009 and 2009/ 2010 seasons

	2008/2009						2009/2010					
	Root parameters			Yield parameters			Root parameters			Yield parameters		
Potassium fertilizer treatments	Root diameter cm	Root length cm	Root weight kg/plant	Top yield ton/ha	Root yield ton/ ha	Sugar yield ton/ ha	Root diameter cm	Root length cm	Root weight kg/plant	Top yield ton/ha	Root yield ton/ ha	Sugar yield ton/ ha
K_0	13.80	37.70	1.28	29.00	69.05	13.31	13.70	34.80	1.20	31.19	71.21	13.25
K_1	16.17	41.03	1.64	34.98	81.98	16.54	15.93	40.30	1.53	36.19	79.17	15.96
K_2	15.33	40.23	1.48	33.15	77.35	16.00	15.43	38.57	1.51	34.37	76.13	15.67
K_3	16.77	45.57	1.69	37.33	84.38	17.78	16.63	41.87	1.67	36.43	83.60	17.59
K_4	15.27	39.47	1.32	33.49	76.22	14.95	14.67	38.07	1.38	34.01	73.33	14.34
K_5	14.90	38.53	1.26	33.02	73.64	15.07	14.83	36.97	1.37	32.94	72.82	14.49
K_6	15.67	41.27	1.42	34.21	77.97	16.11	15.33	40.83	1.50	35.25	75.52	15.44
LSD 5%	1.06	2.49	0.12	1.05	2.11	1.20	1.12	2.47	0.09	1.22	2.24	1.38

Table 3: Effect of potassium fertilizer treatments on some sugar beet quality during 2008/2009 and 2009/ 2010 seasons

Potassium fertilizer treatments	2008/2009					2009/2010				
	Sucrose %	Purity %	Sucrose loss to molas	Recoverable sugar%	Quality index	Sucrose %	Purity %	Sucrose loss to molas	Recoverable sugar%	Quality index
K_0	19.28	81.70	3.53	15.75	81.69	18.61	80.73	4.03	14.58	78.34
K_1	20.17	83.29	3.38	16.79	83.24	20.16	83.59	3.32	16.85	83.58
K_2	20.69	83.52	3.41	17.28	83.52	20.58	83.34	3.43	17.15	83.33
K_3	21.07	84.41	3.29	17.78	84.39	21.04	83.87	3.38	17.65	83.89
K_4	19.61	83.28	3.28	16.33	83.27	19.55	80.20	3.07	16.47	84.25
K_5	20.47	84.24	3.23	17.25	84.27	19.90	82.49	2.79	17.12	86.03
K_6	20.66	82.78	3.56	17.10	82.77	20.45	82.04	2.94	17.50	85.57
LSD 5%	1.22	NS	NS	1.15	NS	1.28	3.66	0.21	1.12	4.02

Table 4: Effect of potassium fertilizer treatments on root impurities during 2008/2009 and 2009/2010 seasons

Potassium fertilizer treatments	2008/2009			2009/2010		
	K (meq/100 g)	Na (meq/100 g)	"-amino nitrogen	K (meq/100 g)	Na (meq/100 g)	"-amino nitrogen
K_0	6.39	1.98	3.9	7.35	2.46	4.12
K_1	6.06	1.84	3.96	5.78	1.90	4.11
K_2	5.99	2.02	3.92	6.12	2.02	3.72
K_3	5.81	1.72	4.01	6.36	1.79	3.41
K_4	5.67	1.83	4.39	4.68	2.07	4.99
K_5	5.41	1.96	4.35	4.07	2.01	4.38
K_6	6.54	1.93	3.84	4.49	2.07	4.28
LSD 5%	NS	NS	0.23	0.29	NS	0.21

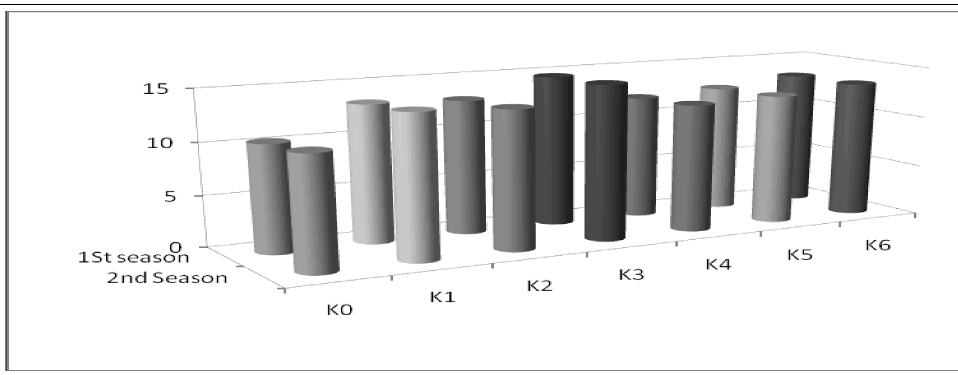

Fig. 1: Effect of potassium fertilizer treatments on recoverable sugar yield (RSY) during 2008/2009 and 2009/ 2010 seasons. LSD 5% 1st season = 0.75, 2nd season = 0.83.

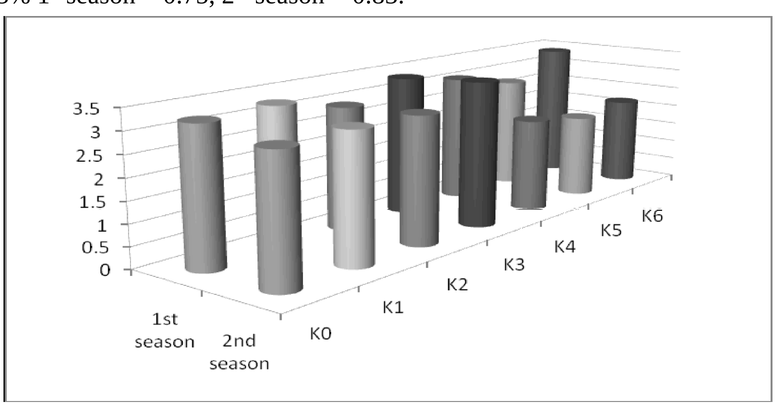

Fig. 2: Effect of potassium fertilizer on K/Na ratio in (2008/2009) and (2009/2010) seasons. LSD 5% 1st season = 0.15, 2nd season = 0.13.

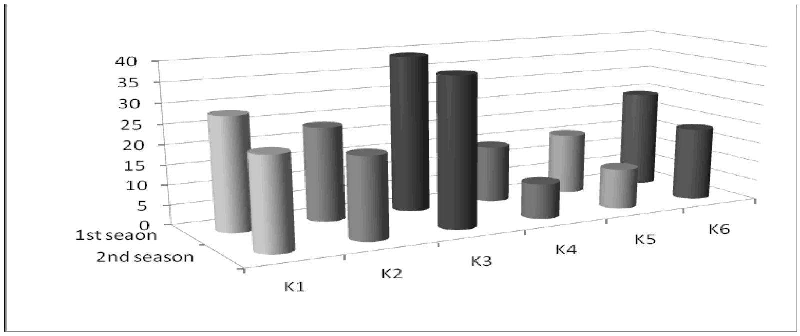

Fig. 3: Potassium use Efficiency (KUE) kg sugar/kg K_2O. LSD 5% 1^{st} season = 3.39, 2^{nd} season = 3.29

Effect of Potassium Fertilizer on Some Sugar Beet Quality: Improving sugar beet quality is one of the most important means for maximizing profitability in sugar beet industry. Sugar beet quality is complicated process influenced by several factors. The technical quality of sugar beet is essential for economical sugar manufacturing. Sugar %, purity, sucrose loss to molass, recoverable sugar % and quality index are among the most quality feature of sugar beet. Data in Table 3 showed that all potassium treatments significantly increased sugar %, purity, recoverable sugar % and quality index as compared with untreated ones in both seasons. However, foliar or soil application of 114 kg KO_2/ha at sugar storing recorded the highest values for all the previous characters in both season. However, soil potassium application was more effective than foliar ones. Furthermore, addition of potassium at sugar storing stage surpasses the other treatments. These results are in a harmony with those obtained by Ulgen *et al*. [25] who found that potassium positively effects sugar content because of its specific physiological effects during synthesis, transport and storage of sugars. They added that potassium enhances many enzyme actions aids in photosynthesis process and sugar formation and translocation. Furthermore, Karam *et al*. [26] pointed that potassium also has another equally important role in the transfer of sugars produced in the leaves to the storage root. They added that, in its passage from leaf to storage root each molecule of sugar has to pass through innumerable cell membranes and K^+ ions are an essential component of the 'molecular pump' within the cell membranes that facilitate this passage. These results are in agreement with those obtained by Mekki and El-Gazzar [3]. Grzebisz *et al*. [27] proved an evidence of the role of potassium in improving juice quality and sugar recovery as well as root yield.

Effect of Potassium Fertilizer on Total Impurities: The technical beet quality i.e. the process ability in the sugar factory however is determined not only by sucrose concentration, but also by the concentrations of other constituents that impair white sugar recovery. These are called root impurities. Soluble substances such as potassium, sodium, amino acids and other nitrogenous compounds, which cannot be eliminated before the sugar is crystallized (Table 4) shows that, all potassium treatment significantly decreased K, Na and "-amino nitrogen concentration in sugar beet juice extraction as compared with control treatment. Similar results were obtained by Tawfik *et al*. [5]. In this concern, Carter [19] stated that "-amino nitrogen (Neutral amino acid, glutamine, asparagines, pyrrolidone carbonic acid, amino-butyric acid) is consider one of the main impurities and undesirable character which decrease the quality as their concentration in juice increases. They interfere with the crystallization process, which causes a greater proportion of the sugars to be recovered as molasses with a reduction in refined sugar. They added that, both K and Na are impurities and their ratio interferes with the crystallization process, which causes a greater proportion of the sugars to be recovered as molasses with a reduction in refined sugar. Moreover, Malbaša *et al*. [28] found that these nitrogenous compounds affect the industrial purification of sucrose and contributes to the actual sugar so they affect the quality of sugar beet. Moreover, Furthermore, Van der Poel *et al*. [29] said that, the molassigenic substances such as potassium, sodium, raffinose and N compounds such as amino-N and betaine increase the molasses loss, whereas invert sugar and glutamine lead to color formation during evaporation and crystallization as a consequence of the Maillard reaction. This is regarded as a major quality impairing factor for white sugar. As for K/Na ratio, Fig 2 proves that K_3 treatment produce the highest values, on the other hand, K_5 gave the lowest values. Tawfik *et al*. [5] came to the same results.

Effect of Potassium Fertilizer on Potassium Use Efficiency (KUE): Improvement of nutrient efficiency in crops is an important issue in modern agriculture both for reducing cost in agriculture production and for protecting the environment. Efficient use of nutrients is the relative ability of plant to produce maximal amounts of dry matter for each increment of nutrients accumulated or it is plant yield (productivity) per unit nutrient supply [30]. In our experiment, the final product was sugar yield. Data in Fig. 2 showed that KUE was positively affected by K application at different development stages. However, soil application was more efficient than foliar ones. Moreover, splitting k fertilizer into two doses has a positive effect on KUE especially at K_3 and K_6 treatment. Similar results were obtained by Karam *et al* [26].

CONCLUSION

Balanced application of K fertilizers became an important task to stimulate its consumption by plant and develop an effective technology to optimizing input of K fertilizers of sugar beet. The findings of this study indicated that splitting of soil applied 114 Kg K_2O ha^{-1} into two equal doses (1/2 at root formation and 1/2 at sugar storing) could be recommended for maximizing sugar beet productivity and quality under agroecological conditions of Belqas district, Dakahlia Governorate, Egypt. Because of the variability in research results and practical field experience with foliar feeding, opinions on its usefulness vary according to the soil type and plant kind. Overall, the economics of foliar fertilization is dependent, first, on how successful applications are and, second, on whether or not the same nutrition might have been supplied more economically through another means. If soil pH limits nutrient availability and ground applied fertilizers are not taken up, foliar fertilizers may be a valid option.

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