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RESPONSE OF SUGAR BEET (*Beta vulgaris* L.) PRODUCTIVITY AND QUALITY TO POTASSIUM FERTILIZATION

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ABSTRACT

To study the effect of soil (0, 12, 24, 36; 48 kg K_2O/fad.) and foliar (0, 0.5; 1.0 kg K_2O/fad.) applications of potassium fertilizer on productivity and quality of sugar beet, cv. "Maribo", two field experiments were conducted during 2010/2011 and 2011/2012 seasons at El-Manyal village, Talkha district, Dakahlia Governorate. A split-plot experiment in a randomized complete block design with four replicates was used. The main results could be summarized as follows: Increasing potassium levels from 0 to 12, 24, 36 and 48 kg K_2O/fad., as a soil application significantly increased root fresh weight, root length and diameter (cm.), root yield (ton/fad.), sugar loss (%), lost sugar yield (ton/fad.) and root content of potassium in both seasons. On the other hand, it caused gradual significant decrease in root content of sodium (Na) and α-amino nitrogen in both seasons. Adding 24 kg K_2O/fad., gave the highest values of gross sugar percentage (18.87 and 18.93), gross sugar yield (7.047 and 7.071 ton/fad.), extractable white sugar percentage (14.79 and 14.87) and white sugar yield (5.526 and 5.536 ton/fad.) in the first and second seasons. Raising potassium foliar application from 0 to 0.5 and 1.0 kg K_2O/fad., markedly increased root fresh weight, root length and diameter (cm.), gross sugar (%), yields of root, gross sugar, white sugar and lost sugar (ton/fad.) as well as root potassium content in both seasons. On the other hand, it decreased sodium (Na) and α-amino nitrogen percentages in both seasons.

Key words: Sugar beet, potassium levels, soil application, foliar application, yield, quality.

INTRODUCTION

Investigators working on sugar crops usually aiming to maximize each of root yield/fad., and root sucrose content to give high sugar yield/fad.. But, this is not enough specially with using potassium as a factor in their studies. Because high amounts of potassium in roots prevent crystallization of some sucrose in juice during the extraction and thus it causes loss of sucrose that go out with the molasses. Moreover, the high expensive price, so this investigation tends to determine the lowest amount of potassium (K) that allows to obtain the highest productivity and quality of sugar beet.

Several researchers working in that field as Khalil *et al.* (2001) found that sucrose, total soluble solids and purity of sugar beet juice increased with increasing potassium level, but decreased with salinity stress. El-Harriri and Gobarh (2001) found that quality and quantity of sugar in sugar beet roots, was enhanced by potassium fertilization. Abdel-Mawly and Zanouny (2004) showed that total soluble solids, refineable sugar, purity percentage of root juice, total root yield and top yield of sugar beet plants increased as potassium fertilizer increased. Amer *et al.* (2004) found that increasing potassium levels up to 72 kg K_2O/fad., resulted in significant increases in K (%), in beet roots, as well as root and sugar yields/fad., and the percentages of total soluble solids (TSS), sucrose and purity. Ismail and Abo El-Ghait (2004)., stated that increasing potassium levels from 0 up to 48 kg K_2O/fad., significantly increased root length and root and sugar yields/fad., in the two seasons and root sucrose percentage in the second season. Seadh *et al.*

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(2007) fertilized sugar beet plants with 0, 24, 48 and 72 kg K_2SO_4/fad., and found that the most studied characters were significantly increased by increasing potassium sulphate levels as a source of potassium and sulfur up to 72 kg K_2SO_4/fad. On the other hand, the highest values of TSS and sucrose percentages were obtained with the addition of 48 kg K_2SO_4/fad. Abdel-Motagally and Attia (2009) stated that increasing K rates from 0 to 57 and 114 kg K_2O/ha, significantly increased root, foliage fresh and dry weights and sugar yield (ton/ha) of sugar beet plants. They added that adding the highest rate of K (114 kg K_2O/ha) significantly increased sucrose content, recoverable sugar yield (ton/ha) and some quality traits. Fathy *et al.* (2009) showed that increasing of consumption values of potassium, increased root and sugar yield/ha, they added that, adding highest level of potassium (114 kg K_2O/ha.) caused significant increase in content of sugar, yield of recoverable sugar during the research. Abo-Shady *et al.* (2010) found that increasing potassium levels from 0 to 24 and 48 kg K_2O/fad., led to significant increases in all studied traits, except Na and α-amino nitrogen contents. Mahdi *et al.* (2012) fertilized sugar beet plants by 0, 50 and 100 kg K_2O/ha, they found that potassium rates had significant effects on all investigated characteristics, except root dry weight. Potassium application increased root yield, shoot yield, impure sugar percent and sugar yield. Maximum and minimum root yield, impure sugar percent, pure sugar percent and sugar yield were observed with the application of 100 kg K_2O/ha and control treatments, respectively. They added that application of 100 kg K_2O/ha improved quantitative and qualitative characters of sugar beet.

MATERIALS AND METHODS

This investigation was conducted at El-Manyal village, Talkha district, Dakahlia Governorate during the two successive winter seasons of 2010/2011 and 2011/2012. It aimed to evaluate the effect of soil and foliar applications of potassium fertilizer on sugar beet variety "Maribo" productivity and quality.

Split-plots in a randomized complete block design with four replicates were used. The main plots were occupied with five potassium levels (0, 12, 24, 36 and 48 kg K_2O/fad.) as a soil application in the form of potassium sulphate (48% K_2O) which were added after ridging and classification of the field area to plots.

While, the sub-plots were devoted to three potassium foliar rates: 0, 0.5 and 1.0 kg K_2O/ fad., that it were dissolved in 200 liters of water/ fad., for each dose and it was sprayed 90 days after sowing.

Each experimental basic unit included five ridges, each of 60 cm. width and 3.5 m. length, comprising an area of 10.5 $m.^2$ (1/400 fad.). The previous crop was maize (*Zea mays* L.) in both seasons. Soil samples were taken at random from the experimental field area at a depth of 0-30 cm. from soil surface and prepared for both mechanical and chemical analyses. The physical (mechanical) and chemical properties of the experimental soil are presented in Table 1.

The experimental field area was well prepared through three ploughings, leveling, compaction, division and then dividing into the experimental units. Calcium superphosphate (15.5% P_2O_5) was applied at a rate of 31 kg P_2O_5/fad., before the last ploughing, then ridging and division were done.

Sowing of dry sugar beet balls took place in the dry soil during the second week of September in both seasons. The experimental field area was irrigated immediately after sowing. Plants were thinned to secure one plant/hill at 30 days from sowing. Nitrogen in the form of Urea (46.5% N) was applied at the rate of 80 kg N/fad., in two equal doses, before the first and second irrigations after thinning. Plants were kept free from weeds, which were manually controlled by hand hoeing for three times. All normal agricultural practices with the exception of the studied factors were conducted as usually done by farmers in the district for growing sugar beet according to the recommendations of Ministry of Agriculture and Land Reclamation.

Studied Characters

Root yield and its attributes

At harvest time (210 days after sowing), ten guarded plants were randomly chosen from the

Table 1. Mechanical and chemical soil properties at the experimental filed during the two growing seasons of 2010/2011 (I) and 2011/2012 (II)

Soil analysis	I	II
Mechanical properties		
Fine sand (%)	9.20	19.00
Coarse sand (%)	5.20	4.40
Silt (%)	36.00	27.00
Clay (%)	49.60	49.60
Texture	Clayly	Clayly
Chemical analysis		
Soil reaction pH	7.40	7.60
Available N (ppm)	42.50	47.30
Available P (ppm)	12.00	12.00
Exchangeable K (ppm)	150.00	120.00

three inner ridges of each sub-plot to determine the following characters:

1. Root fresh weight (g.).
2. Root length (cm.).
3. Root diameter (cm.).

Root yield (ton/fad.)

To estimate root yield, all plants that produced from the three inner ridges of each sub-plot were collected and cleaned. Roots and tops were separated and weighed in kilograms, then converted to ton/fad.

Quality parameters and sugar yield

All estimated percentages, as gross sugar, potassium (K%), sodium (Na%) and α-amino nitrogen were determined in Dakahlia Sugar Company Laboratories at Bilkas district, Dakahlia Governorate. All studied quality parameters were calculated as follows:

1. Gross sugar yield (ton/fad.). It was determined by multiplying root yield (t/fad.) × gross sugar (%).
2. Extractable white sugar (%). Correct sugar content (white sugar) of beet roots was calculated by linking the beet non-sugar, K, Na and α-amino nitrogen (expressed as a milliequvalent/100 g of beet) according to Harvey and Dutton (1993) using the following equation:

$$ZB = Pol - [0.343\ (K+Na) + 0.094\ Am\ N + 0.29]$$

Where:

ZB = corrected sugar content (% per beet) or extractable white sugar.

Pol = Gross sugar (%).

AmN = α-amino nitrogen determined by the "Blue number method".

3. White sugar yield= Root yield (ton/fad.) × white sugar (%).
4. Lost sugar percentage and sugar losses yield (ton/fad.):

- Sugar loss (%)= gross sugar (%)-white sugar (%).
- Lost sugar yield (ton/fad.)=root yield (ton/fad.) × sugar loss (%).

Statistical Analysis

All obtained data were statistically analyzed according to the technique of analysis of variance (AOV) of the split-plot design as outlined by Gomez and Gomez (1984) using means of "MSTAT-C" computer software package. Baysian Least Significant Difference

(BLSD) method was used to compare the treatment means at 5% level of probability as described by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Effect of Soil Application of Potassium

Results listed in Tables 2 and 3 show that increasing of soil application of potassium levels from 0 up to 48 kg K_2O/fad., had significant effects on all studied characters in both seasons. It resulted in gradual increases in root fresh weight, root length and diameter, root yield (ton/fad.), sugar loss (%), lost sugar yield (ton/fad.) and root potassium (%), in the two growing seasons. On the other hand, it caused gradual decreases in root contents of sodium (Na) and α-amino nitrogen in both seasons. However, the highest values of gross sugar (%) (18.87 and 18.93), gross sugar yield (7.047 and 7.071 t/fad.), extractable white sugar (%) (14.79 and 14.87) and white sugar yield (5.526 and 5.536 ton/fad.) were obtained with the addition of 24 kg K_2O/fad., in the first and second seasons, respectively.

These results are in agreement with those stated by Khalil *et al.* (2001), El-Harriri and Gobarh (2001), Abdel-Mawly and Zanouny (2004), Amer *et al.* (2004), Ismail and Abo El-Ghait (2004), Seadh *et al.* (2007), Abdel-Motagally and Attia (2009), Fathy *et al.* (2009),; Abo-Shady *et al.* (2010) and Mahdi *et al.* (2012).

The gradual increase in root fresh weight, root length and diameter and root yield (ton/fad.) that associated with the increase in the applied levels of potassium as a soil application may be due to the common role of potassium in cells division, growth and tallness of the different plant parts. While, the increase in sugar loss (%) that happened as a result to increase of potassium levels may be due to the fact that high amounts of potassium in roots prevent crystallization of some sucrose in juice during the extraction and thus it causes loss of sucrose that go out with the molasses.

The highest values of gross sugar (%) and gross sugar yield/fad., which were obtained by adding 24 kg K_2O/fad., may be due to the role of potassium in encouragement canopy growth and translocation of sugars produced from photosynthesis in the same time, then when plants arrive suitable size its consumption of sugar increased, and hence root sugar percentage tends to decrease.

The decrease of sodium (Na) and α-amino nitrogen contents in beet roots associated with the increase in potassium fertilizer levels may be due to the role of potassium in decreasing Na absorption in the first case and increasing nitrogen transformation inside plants in the second case.

Effect of Foliar Application of Potassium

Results presented in Tables 2 and 3 reveal that increasing foliar rates of potassium fertilizer from 0 up to 1.0 kg K_2O/fad., resulted in significant effects in all studied characters in both seasons, except for sugar loss (%) in both seasons and potassium content in roots in the first season, which were insignificant. Where it resulted in gradual increases in root fresh weight, root dimensions (length and diameter), the percentages of gross sugar, the extractable white sugar and potassium (K) in roots and the yields of roots, gross sugar, white sugar and lost sugar/fad., in both seasons. On the other hand, it resulted in gradual decreases in sodium (Na) and α-amino nitrogen content in beet roots in both seasons.

The gradual increase in root fresh weight, root length and diameter and root yield (ton/fad.) that associated with the increase in the applied levels of potassium as a foliar application may be due to the common role of potassium in cells division, growth and tallness of the different plant parts.

While, the gradual increase in gross sugar percentage in beet roots associated with the increase in potassium foliar application that caused increasing gross sugar yield/fad., may be due to the role of potassium in encouragement canopy growth and translocation of sugars produced from photosynthesis.

Effect of the Interaction

Results in Tables 2 and 3 reveal that all studied characters were not significantly affected by the interaction between soil and foliar potassium applications, except for gross sugar yield (ton/fad.) and white sugar yield (ton/fad.) in the second season only.

Table 2. Root fresh weight, root length and diameter, root yield/fad., gross sugar (%) and gross sugar yield/fad., as affected by potassium fertilizer levels as soil and foliar applications and their interaction during 2010/2011 (I) and 2011/2012 (II) seasons

Characters	Root fresh weight (g)		Root length (cm.)		Root diameter (cm.)		Root yield (ton/fad.)		Gross sugar (%)		Gross sugar yield (ton/fad.)	
Seasons	I	II	I	II	I	II	I	II	I	II	I	II
Soil application levels of potassium												
0 kg K_2O/fad.	892.5	885.0	30.37	29.50	12.25	11.66	31.345	31.115	17.01	17.03	5.340	5.305
12 kg K_2O/fad.	1025.0	1025.0	31.41	32.25	13.25	13.58	36.030	36.258	18.66	18.86	6.736	6.847
24 kg K_2O/fad.	1055.0	1060.0	33.00	32.83	14.50	14.16	37.319	37.348	18.87	18.93	7.047	7.071
36 kg K_2O/fad.	1073.3	1075.0	33.01	32.85	14.83	14.91	37.357	37.733	18.40	18.63	6.916	7.031
48 kg K_2O/fad.	1075.0	1090.0	33.25	33.50	15.00	15.08	37.582	38.398	18.06	18.30	6.743	7.023
F. test	*	*	*	*	*	*	*	*	*	*	*	*
LSD (5 %)	71.9	81.1	1.17	1.02	1.45	0.91	2.300	0.951	0.59	0.39	0.414	0.140
Foliar rates of potassium												
0 kg K_2O/fad.	973.0	974.0	31.15	30.50	13.15	13.05	34.064	34.264	17.66	17.90	6.033	6.147
0.5 kg K_2O/fad.	1025.5	1022.0	32.32	32.55	14.00	14.05	36.104	36.033	18.27	18.40	6.604	6.638
1.0 kg K_2O/fad.	1074.0	1085.0	33.15	33.51	14.75	14.55	37.611	38.214	18.68	18.76	7.032	7.181
F. test	*	*	*	*	*	*	*	*	*	*	*	*
LSD (5 %)	69.9	70.3	0.97	0.98	1.05	0.47	2.110	1.076	0.68	0.35	0.256	0.19
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*

Table 3. Extractable white sugar (%), white sugar yield, sugar loss (%), lost sugar yield, Potassium (K), sodium (Na) and α-amino nitrogen percentages in juice of sugar beet as affected by potassium fertilizer levels as soil and foliar applications and their interaction during 2010/2011 (I) and 2011/2012 (II) seasons

Characters	Extractable white sugar (%)		White sugar yield (ton/fad.)		Sugar loss (%)		Lost sugar yield (ton/fad.)		K (%)		Na (%)		α-amino nitrogen (%)	
Seasons	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Soil application levels of potassium														
0 kg K_2O/fad.	13.29	13.26	4.173	4.132	3.72	3.77	1.167	1.173	5.27	5.29	3.45	3.58	4.66	4.68
12 kg K_2O/fad.	14.65	14.84	5.288	5.389	4.01	4.02	1.448	1.458	6.43	6.44	3.22	3.24	4.37	4.38
24 kg K_2O/fad.	14.79	14.87	5.526	5.536	4.07	4.11	1.521	1.535	6.95	6.99	3.00	3.03	3.96	4.07
36 kg K_2O/fad.	14.23	14.48	5.352	5.466	4.16	4.15	1.564	1.564	7.35	7.37	2.89	2.80	3.83	3.90
48 kg K_2O/fad.	13.87	14.08	5.178	5.401	4.19	4.22	1.565	1.623	7.80	7.95	2.56	2.47	3.72	3.73
F. test	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LSD (5 %)	0.55	0.44	0.342	0.149	0.15	0.14	0.096	0.066	0.39	0.41	0.21	0.27	0.19	0.22
Foliar rates of potassium														
0 kg K_2O/fad.	13.64	13.87	4.648	4.753	4.01	4.03	1.385	1.394	6.64	6.63	3.16	3.17	4.28	4.32
0.5 kg K_2O/fad.	14.24	14.36	5.145	5.177	4.03	4.04	1.459	1.461	6.77	6.79	3.01	3.01	4.08	4.14
1.0 kg K_2O/fad.	14.63	14.67	5.517	5.624	4.05	4.06	1.515	1.557	6.87	7.00	2.90	2.89	3.97	4.00
F. test	*	*	*	*	NS	NS	*	*	NS	*	*	*	*	*
LSD (5 %)	0.68	0.34	0.195	0.158	-	-	0.096	0.048	-	0.14	0.13	0.12	0.14	0.09
Interaction	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Results in Table 4 and illustrated in Fig. 1 show that the highest values of gross sugar and white sugar yields/fad., (7.693 and 6.110 ton/fad.) were obtained with the addition of 24 kg K_2O/fad., as a soil application + 1.0 kg K_2O/fad., as a foliar application in the second season. The highest values of gross sugar and white sugar yields/fad., in the second season which were obtained by adding 24 kg K_2O/fad., as a soil application + 1.0 kg K_2O/fad., as a foliar application may be due to the role of potassium in encouragement canopy growth and translocation of sugars produced from photosynthesis in the same time, then when plants arrive suitable size its consumption of sugar increased so root sugar percentage tends to decrease.

Conclusion

In general, it could be reported that application of 24 kg K_2O/fad., as a soil application + 1 kg K_2O/fad., as a foliar application is the suitable recommendation to obtain the highest values of productivity and quality of sugar beet under the conditions of this investigation in Dakahlia Governorate.

Table 4. Gross sugar and white sugar yields (ton/fad.) as affected by the interaction between potassium fertilizer levels as soil and foliar applications during 2011/2012 season

Characters	Gross sugar yield (ton/fad.)			White sugar yield (ton/fad.)		
	Foliar rates of potassium					
Soil application levels of potassium	0 kg K_2O/fad.	0.5 kg K_2O/fad.	1.0 kg K_2O/fad.	0 kg K_2O/fad.	0.5 kg K_2O/fad.	1.0 kg K_2O/fad.
0 kg K_2O/fad.	4.804	5.352	5.758	3.676	4.183	4.537
12 kg K_2O/fad.	6.165	6.684	7.601	4.803	5.254	5.992
24 kg K_2O/fad.	6.574	7.038	7.693	5.106	5.509	6.110
36 kg K_2O/fad.	6.511	7.122	7.458	5.027	5.540	5.832
48 kg K_2O/fad.	6.682	6.995	7.394	5.153	5.401	5.648
F. test		*			*	
LSD (5 %)		0.259			0.220	

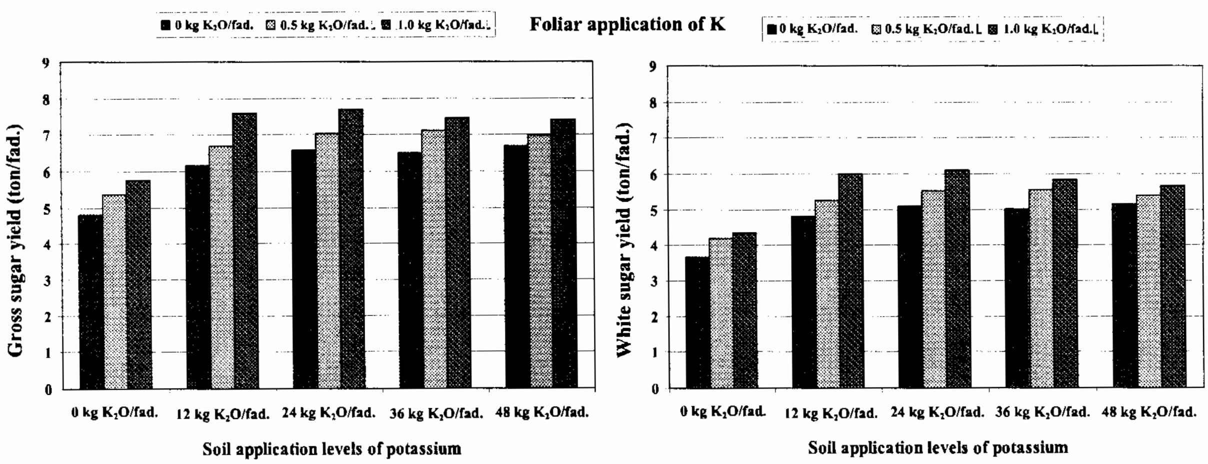

Fig. 1. Gross sugar and white sugar yields (ton/fad.) as affected by the interaction between potassium levels as soil and foliar applications during 2011/2012 season

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استجابة إنتاجية وجودة بنجر السكر للتسميد البوتاسى

محمد على الدسوقى عبده

معهد بحوث المحاصيل السكرية - مركز البحوث الزراعية - الجيزة - مصر

أقيمت تجربتان حقليتان بقرية المنيل - مركز طلخا - محافظة الدقهلية خلال موسمى الزراعة ٢٠١٠/٢٠١١ و٢٠١١/٢٠١٢ م - لدراسة مدى استجابة إنتاجية وجودة بنجر السكر (صنف ماريبو) للإضافات الأرضية (صفر، ١٢ ، ٢٤ ، ٣٦، ٤٨ كجم بو٢أ/فدان وكذلك الإضافات الورقية (صفر ، ٠,٥ ، ١كجم بو٢أ/ فدان) من السماد البوتاسى، نفذت التجارب فى تصميم القطع المنشقة مرة واحدة فى قطاعات كاملة العشوائية فى أربع مكررات، ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلى: أدت زيادة مستويات السماد البوتاسى الأرضى من صفر إلى ٤٨ كجم بو٢أ/ فدان إلى زيادة معنوية فى صفات الوزن الغض للجذر، طول وقطر الجذر، محصول الجذور (طن / فدان) ، محتوى الجذور من السكروز، النسبة المئوية للسكر المفقود فى المولاس ومحصول السكر المفقود (طن/فدان) فى كلا الموسمين. بينما تحقق أعلى محصول من السكر الأبيض (طن/فدان) مع إضافة ٢٤ كجم بو٢أ/ فدان، أدت زيادة معدلات الرش الورقى بالبوتاسيوم من صفر إلى ١,٠ كجم بو٢أ/ فدان إلى زيادة معنوية لكل من الوزن الغض للجذر، طول وقطر الجذر، محصولى الجذور والسكر (طن/فدان) ، وكذلك النسبة المئوية للسكروز بالجذور، النسبة المئوية لإستخلاص السكر من الجذور، محصول السكر المفقود (طن/فدان) فى المولاس أثناء الإستخلاص وكذلك محصول السكر الأبيض المستخلص فى كلا الموسمين ومحتوى الجذور من البوتاسيوم فى الموسم الثانى، كما أدت هذه الزيادات من التسميد الورقى بالبوتاسيوم إلى نقص محتوى الجذور من الصوديوم والألفا أمينو نيتروجين، أظهرت النتائج وجود تأثيراً معنوياً للتفاعل بين الإضافة الأرضية والورقية للسماد البوتاسى فى الموسم الثانى، حيث تم الحصول على أعلى القيم لصفتى محصول السكر ومحصول السكر الأبيض (المستخلص) عند التسميد البوتاسى الأرضى بمعدل ٢٤ كجم بو٢أ/ فدان والرش بمعدل ١,٠ كجم بو٢أ/فدان، بصفة عامة توصى هذه الدراسة بالتسميد البوتاسى لبنجر السكر بمعدل ٢٤ كجم بو٢أ/ فدان كإضافة أرضية مع الرش الورقى بمعدل ١,٠ كجم بو٢أ/ فدان للحصول على أعلى محصول من السكر الأبيض (المستخلص) تحت ظروف التجربة بمحافظة الدقهلية.

المحكمـــــون:

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