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Effect of Rate and Time of Potassium Fertilization on Growth and Physiological Characters of Sugar Beet Plants

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TWO FIELD experiments were carried out in 2002/2003 and 2003/2004 seasons at Sakha Agricultural Research Station, Kafrelsheikh Governorate to study the effect of rate and time of potassium fertilization on growth, and physiological characters of sugar beet (Oscar poly variety). Potassium fertilization treatments included the combination between three rates 24, 48 and 72 kg K_2O/fed and 7 application time each added as, full rate at sowing , 30 days and 60 days after sowing or in two equal portions at sowing and 30 days , at sowing and 60 days , at 30 and 60 days and finally at 30 and 90 days after sowing. In addition to unfertilization treatment. Applying 72 kg K_2O/fed in two equal portions the 1st one at 30 days and the 2nd one at 60 or 90 days after sowing significantly increased length and fresh weight of root, leaf area and dry weight / plant. Potassium fertilization treatments had also significant effect on crop growth rate, relative growth rate and net assimilation rate at different growth periods (105-120, 120-135 and 135-150 days after sowing).While, root diameter and number of leaves were insignificantly affected by potassium fertilization.

Keywords: Sugar beet, Potassium fertilizer, Growth, CGR, NAR.

Fertilization is one of the most important factors, which had a distinct role on production of all crops. Potassium does an important nutrition element, but its functions are not yet fully understood. King *et al.* (1965) indicated that potassium does not inter into the formation of solid material in the plant but remains in solution in the cell sap. The main function of potassium appears to be in connection with the assimilation of carbon dioxide from the air and the subsequent formation and translocation of sugars within the plant. It also apparently controls water movement in the plant and it is responsible for osmotic regulation. Evans & Sorger (1966) reported that potassium is especially involved in conversion of solar energy into chemical energy and is required for the active conformation of many enzymes participating in intermediately, metabolism and biosynthesis .

Hassanin (1979) found that application of 48 kg K_2O/fed gave the highest relative growth rate (RGR) and sugar yield, while net assimilation rate (NAR),

was not affected. Table *et al.* (1986) showed that the highest dry mater accumulation, maximum root length and leaf area index at different growth periods were obtained at 80 kg K_2O/fed. However, the highest root/top ratio resulted from the lower level (40 kg K_2O/fed) of potassium. Whereas, root weight and diameter/plant, were not significantly affected by the deferent rates of potassium fertilizer. Nassar (1992) studied the response of growth attributes, of sugar beet to different harvesting dates, viz, 180,195 and 210 days after sowing. Delaying the harvest up to 210 days after sowing increased dry weight/plant, root/top ratio and root weight.

The questions of potassium fertilization for sugar beet has been discussed in the present work through studying the effect of different rate and time of potassium fertilization on yield and quality, compared with unfertilization sugar beet crop for achieving both quantitative and qualitative improvement in beet production.

The purpose of this study is to find out the optimum rate and time of potassium application sugar beet to induce the highest values of growth and physiological characters.

Material and Methods

Two field experiments were conducted at Sakha Agricultural Experimental Research Station, Kafrelsheikh Governorate, during 2002/2003 and 2003/2004 seasons, to study the effect of potassium fertilization and harvesting time, as well as their interaction on growth and physiological characters of sugar beet (Oscar poly cultivar). Where, potassium sulphate (48% K_2O) was used at three rates 24, 48 and 72 kg K_2O per fed each added as follow:

1. Full rate at sowing time.
2. Full rate at 30 days after sowing (DAS).
3. Full rate at 60 DAS.
4. One half rate at sowing and the other one at 30 DAS.
5. One half rate at sowing and the other one at 60 DAS.
6. One half rate at 30 DAS and the other one at 60 DAS.
7. One half rate at 30 DAS and the other one at 90 DAS.

A complete block design with three replications was used, potassium fertilization treatments combination (3 rates x 7 application time) in addition to without potash fertilizer treatment were allocated randomly. Plot area was 21 m^2 (1/200 fed) consisted of 6 ridges, 7 m long and 50 cm apart, spacing between hills were 20 cm. The sowing dates were October 23 and 30 for the first and second season, respectively. Calcium super phosphate (15.5% P_2O_5) was used at rate of 30 kg P_2O_5/fed at seed bed preparation. Whereas, urea (46% N) was used as a source of nitrogen at the rate of 80 kg N/fed in two equal doses, the first one was applied after 30 days from sowing and the second one at 30 days later. The other cultural practices (irrigation used and beet control) of growing sugar beet were carried out at levels to assure optimum production.

Characters studied

Physiological characters

Samples of five plants from each sub plot were taken at 105, 120, 135 and 150 days after sowing to determine the following data:

1- Total dry weight (g/ plant).

2- Physiological analysis was carried out according to following formula (Watson, 1958):

1- Crop growth rate (CGR): $CGR = (W_2-W_1) / (t_2-t_1)$. ($g/m^2$/week).

2- Relative growth rate (RGR): $RGR = (\log_e W_2 - \log_e W_1) / (t_2-t_1)$. (g/g/ week).

3- Net assimilation rate (NAR): $NAR= (W_2-W_1) (\log_e A_2-\log_e A_1) / (A_2-A_1) (t_2-t_1)$.($g/m^2$/week).

where: W_1, A_1 and W_2, A_2, respectively refer to dry weight and leaf area per plant at first time (t_1) and second time (t_2) in week.

At 150 days from sowing, the following data were recorded:

Growth criteria

1. Root length and diameter (cm).
2. Fresh weight of root and shoot (kg/plant).
3. Number of leaves and leaf area per plant (cm^2).

Photosynthetic pigments

Chlorophyll a, b and caroteniodes were determined according to method of Wettstein (1957).

The obtained data were statistically analyzed according to Snedecor & Cochran (1981). Treatment means were compared by using the least significant difference (L.S.D.) at 5 % level.

Results and Discussion

Growth criteria

Root growth characters

Root length: Data shown in Table 1 indicated that in both seasons there was significant increase in root length of plants with potassium fertilizer compared to unfertilized plants. It can be noticed that, applying 72 kg K_2O/fed which added at different application time (Tr. No. 16 to 22) recorded maximum values and clear increases in root length, as compared with the other potassium fertilizer treatments (Tr. No. 1 to 15).

Under potassium fertilization treatments, the tallest root was achieved when sugar beet plants received 72 kg K_2O/fed in two equal portions, the 1st one at 30 days after sowing and the 2nd one at 60 days (Tr. No. 21) which gave 30.60 and 29.34 cm, in both growing seasons. On the other hand, unfertilized plants and plants which received 24 kg K_2O/fed at sowing date (Tr. No. 2) gave the shortest

root length (25.73, 27.16 and 22.30, 23.58 cm, respectively) in 2002/2003 and 2003/2004 seasons. Generally, the average root length values at rate of 24, 48 and 72 kg K_2O/fed over all application time in the first season were 27.85, 29. 11 and 30.10 cm and were 24.60, 27.02 and 28.56 cm, respectively in the second season. Meantime, root length of unfertilized plants recorded 25.73 and 22.30 cm for the first and second seasons. These results are in good agreement with that found by Ibrahim (1998), Agami (2000), Ismail *et al.* (2002), Ismail & Abo El-Ghait (2004), Osman (2005) and Moustafa *et al.* (2006). They reported that all rate of Potassium application increased root length of sugar beet plants compared with unfertilized plants.

TABLE 1. Effect of potassium fertilization treatments on length (cm), diameter (cm) and fresh weight (kg)/ plant of sugar beet root at 150 days after sowing in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Length	Diameter	Fresh weight	Length	Diameter	Fresh weight
1	Unfertilization	25.73	8.48	0.680	22.30	8.12	0.601
2	24 at sowing	27.16	7.83	0.628	23.58	7.81	0.594
3	24 at 30 day after sowing (DAS)	27.43	7.90	0.631	23.78	7.95	0.600
4	24 at 60 DAS	27.66	8.00	0.648	24.08	7.91	0.611
5	12 at sow. + 12 at 30 DAS	27.87	8.07	0.673	24.37	7.97	0.621
6	12 at sow. + 12 at 60 DAS	28.42	8.10	0.700	26.01	8.06	0.640
7	12 at 30 DAS + 12 at 60 DAS	28.26	8.18	0.707	25.68	8.13	0.635
8	12 at 30 DAS + 12 at 90 DAS	28.12	8.06	0.662	24.70	8.05	0.636
9	48 at sowing	28.50	8.30	0.711	26.52	8.19	0.684
10	48 at 30 DAS	28.73	8.41	0.728	26.17	8.22	0.683
11	48 at 60 DAS	29.13	8.88	0.749	27.14	8.25	0.700
12	24 at sow. + 24 at 30 DAS	29.38	8.82	0.755	27.39	8.38	0.720
13	24 at sow. + 24 at 60 DAS	29.62	8.94	0.760	27.50	8.43	0.722
14	24 at 30 DAS + 24 at 60 DAS	29.48	9.02	0.759	27.63	8.57	0.725
15	24 at 30 DAS + 24 at 90 DAS	28.96	8.50	0.740	26.82	8.30	0.709
16	72 at sowing	29.85	9.06	0.772	28.05	8.71	0.745
17	72 at 30 DAS	29.74	9.03	0.778	27.78	8.73	0.737
18	72 at 60 DAS	29.96	9.07	0.782	28.61	8.85	0.751
19	36 at sow. + 36 at 30 DAS	30.24	9.13	0.795	28.82	8.92	0.792
20	36 at sow. + 36 at 60 DAS	30.46	9.19	0.808	29.13	9.06	0.797
21	36 at 30 DAS + 36 at 60 DAS	30.60	9.18	0.816	29.34	9.08	0.801
22	36 at 30 DAS + 36 at 90 DAS	30.12	9.10	0.790	28.22	9.02	0.785
	Mean	28.88	8.60	0.731	26.53	8.40	0.695
	L.S.D. at 0.05	0.42	N.S.	0.080	0.55	N.S.	0.039

Root diameter: Insignificant effect of potassium fertilization treatments on root diameter of sugar beet plants (Table 2) was recorded in both growing seasons with some increasing in root diameter by increasing potassium rates at any time but these increases were not great enough to reach the level of significance. Similar findings were also obtained by Table *et al.* (1986), while, Saif (2000), Hassanin (2001) and Osman (2005) found that application of potassium fertilizer significantly increased root diameter of sugar beet plants.

TABLE 2. Effect of potassium fertilization treatments on leaves number, leaf area (cm^2) and shoot fresh weight (kg) / plant of sugar beet at 150 days after sowing in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Leaves No.	Leaf area	Fresh weight	Leaves No.	Leaf area	Fresh weight
1	Unfertilization	23.67	3464	0.398	23.30	2977	0.395
2	24 at sowing	23.66	3580	0.421	23.00	2935	0.408
3	24 at 30 day after sowing (DAS)	23.78	3794	0.428	23.05	3003	0.412
4	24 at 60 DAS	23.84	3815	0.443	23.66	3041	0.420
5	12 at sow. + 12 at 30 DAS	24.30	3882	0..446	23.66	3137	0.430
6	12 at sow. + 12 at 60 DAS	23.97	3996	0.457	23.67	3164	0.431
7	12 at 30 DAS + 12 at 60 DAS	24.47	4006	0.449	23.78	3098	0.424
8	12 at 30 DAS + 12 at 90 DAS	24.52	3927	0.497	24.00	3193	0.430
9	48 at sowing	24.66	4045	0.473	23.56	3455	0.488
10	48 at 30 DAS	24.62	4118	0.481	23.80	3483	0.486
11	48 at 60 DAS	24.66	4152	0.493	23.86	3546	0.498
12	24 at sow. + 24 at 30 DAS	24.89	4384	0.500	24.10	3731	0.494
13	24 at sow. + 24 at 60 DAS	24.92	4295	0.498	24.26	3751	0.499
14	24 at 30 DAS + 24 at 60 DAS	25.00	4374	0.500	24.30	3766	0.498
15	24 at 30 DAS + 24 at 90 DAS	24.87	4218	0.490	24.00	3581	0.500
16	72 at sowing	25.33	4247	0.560	24.30	3804	0.509
17	72 at 30 DAS	25.31	4743	0.563	24.31	3840	0.501
18	72 at 60 DAS	25.67	4779	0.565	24.33	3857	0.510
19	36 at sow. + 36 at 30 DAS	25.70	4865	0.572	24.48	4084	0.517
20	36 at sow. + 36 at 60 DAS	26.00	4893	0.580	24.64	4259	0.522
21	36 at 30 DAS + 36 at 60 DAS	25.68	5010	0.575	24.47	4373	0.517
22	36 at 30 DAS + 36 at 90 DAS	26.03	4798	0.595	24.65	3868	0.538
Mean		24.80	4245	0.499	23.96	3543	0.474
L.S.D. at 0.05		N.S	271.90	0.060	N.S	380.40	0.037

Root fresh weight: Results of the first season as shown in Table 1 and presented data cleared that insignificant differences were detected between root fresh weight of sugar beet plants with application of 24 or 48 kg K_2O/fed at any application time (Tr. No. 2 to 15) and with unfertilized plants. However, fertilized sugar beet plants by 72 kg K_2O/fed at any application time (Tr. No. 16 to 22) significantly increased root fresh weight of sugar beet than the unfertilized treatment. Also, it can be noticed that the differences between root fresh weight under 72 kg K_2O/fed which due to the application time were not significant. Data of the second season (Table 1) indicated that a gradual and significant increases in root fresh weight of sugar beet plants, with all increase in level of potassium application. These increases were 3.16, 17.47 and 28.62 % with 24, 48 and 72 kg K_2O/fed, respectively over all application time as compared with no K fertilized.

Statistical analysis of data in Table 1 indicated that there were insignificant differences between root fresh weight of unfertilized plants and which received 24 kg K_2O/fed at any application time while, applying 48 or 72 kg K_2O/fed at any application time significantly increased root fresh weight compared with no fertilized treatment.

Generally, the highest root fresh weight in both seasons produced when beet plants received 72 kg K_2O/fed in two equal portions, the first one at 30 days after sowing and the other at 60 days age (Tr. No. 21) which gave (0.816 and 0.801 kg, respectively) in 2002/2003 and 2003/2004 seasons followed by adding 72 kg K_2O/fed in two equal portions the 1st one at sowing and the 2nd one at 60 days later (Tr. No. 20) which gave (0.808 and 0.797 kg/plant, respectively) in the first and second seasons. While the lowest root fresh weight in both seasons was achieved by applying 24 kg K_2O/fed at sowing (Tr. No. 2) which gave (0.628 and 0.594 kg/plant, respectively) in the 1st and 2nd seasons. Therefore it can be concluded that, separated the rates of potassium fertilization to two equal portions at any application time was more effective on root fresh weight than applying it in a single portion at any time. These finding are in line with Ramadan (1997), Agami (2000), Saif (2000), Ismail *et al.* (2002), Osman (2005) and Moustafa *et al.* (2006) who found that fresh weight of sugar beet root was significantly increased by potassium fertilizer treatments. On the other hand, Table *et al.* (1986) reported that root weight/plant was not significantly affected by different rates of potassium fertilizer.

Such increase in fresh weight of sugar beet root by increasing the level of potassium fertilizer application may be due to the important role of potassium in metabolites translocation from leaves to be accumulated in root.

Shoot growth characters

Number of leaves: Although, potassium fertilizer treatments had insignificant effect on number of leaves per plant in two growing seasons, but it can be noticed that plants which received 72 kg K_2O/fed at any time had more number of leaves than the other plants in both seasons (Table 2). These results are in accordance with Agami (2000) who revealed that all potassium fertilizer level had no significant effect on number of leaves /plant. On the other hand, El-Taweel (1999) found that, potassium fertilization significantly increased number of sugar beet leaves per plant.

Leaf area per plant: Data of both growing seasons in Table 2 show a significant difference in leaf area due to potassium fertilizer treatments. In the first season all potassium treatments under study except applying 24 kg K_2O/fed at sowing (Tr. No. 2) significantly increased leaf area per plant as compared with unfertilized treatment, also it can be noticed that, plant which received 72 kg K_2O/fed at any application time except at sowing date (Tr. No. 16) recorded maximum values of leaf area per plant (Table 2). In the second season, leaf area per plant, which fertilized by 24 kg K_2O/fed at any time of application had insignificant differences as compared with no fertilized plants. While applying 48 and 72 kg K_2O/fed at any time significantly increased the leaf area compared with no potassium treatment. In addition, significant differences for leaf area were detected between 48 or 72 kg K_2O/ fed and 24 kg K_2O/fed at any application time (as compared with the same application time).

The maximum leaf area per plant in both seasons, was obtained by applying 72 kg K_2O/fed in two equal portions, the first one at sowing or at 30 days after sowing and the other one at 60 days after sowing (Tr. No. 20 and 21), which gave 4893 and 5010 cm^2, respectively in the first season and 4259 and 4373cm^2, respectively in the second season (Table 2). This finding are in agreement with those obtained with El-Taweel (1999), Agami (2000) and Moustafa *et al.* (2006) who showed that increasing of K fertilizer significantly increased leaf area per plant.

Shoot fresh weight: In both growing seasons (Table 2) a gradual and significant increase in shoot fresh weight was recorded with increasing potassium levels. Average of shoot fresh weight values of 24, 48 and 72 kg K_2O/fed in the first season over all application time were 0.449, 0.491 and 0.573 kg/plant and were 0.422, 0.495 and 0.516 kg/plant in the second season. Meantime, the average of shoot fresh weight with unfertilized treatment were 0.398 and 0.395 kg/plant, respectively for the two seasons.

The treatment of 72 kg K_2O/fed which added in two equal portions, the 1^{st} one at 30 days after sowing and the 2^{nd} one at 90 days later (Tr. No. 22) produced the greatest value of shoot fresh weight in both growing seasons. Therefore, it can be observed from Table 2 that fresh weight of shoot was positively correlated with the highest level of potassium fertilizer 72 kg K_2O/fed and late application time. This treatment, increased fresh weight of shoot of sugar beet plants by 49.50% in the first season and by 36.20% in the second season over the unfertilized treatment.

In both season, Table 2 showed insignificant differences for shoot fresh weight were detected between no potassium and applying 24 kg K_2O/fed at any application time except treatment (No. 8) in the first season. In the first season applying 24 kg K_2O/fed in two equal portions, the first one at 30 days after sowing and the other one at 90 days later (Tr. No. 8) which gave 0.497 kg/plant and caused a significant increase in shoot fresh weight of sugar beet plants compared with unfertilized plants. Meantime, it's exhibited insignificant differences compared with plants which received 48 kg K_2O/fed at any application time (Tr. No. 9 to 15).

Increasing potassium level up to 72 kg K_2O/fed which added at any time under study (Tr. No. 16 to 22) significantly increased fresh weight of shoot compared with the other treatments. Such increase may be due to the increases in leaf area per plant and number of leaves whereas, it is noticed that, the increase in number of leaves was not enough to reach the level of significance as mention before (Table 2).

In the second season, as shown in Table 2 the differences between 48 and 72 kg K_2O/fed at any time (compared with the same application time) were not significant except, applying 72 kg K_2O/fed in two equal portions the 1st one at 30 days after sowing and the 2nd one at 90 days (Tr. No. 22). These results are in line with Basha (1994), El-Taweel (1999), Agami (2000) and Moustafa *et al.* (2006) who found that application of potassium significantly increased shoot fresh weight. On the contrary, El-Maghraby *et al.* (1997) stated that increasing in potassium fertilizer caused a significant decreased in top weight.

Total dry weight (g/plant)

Results in Table 3 indicated that, in both seasons all potassium fertilizer treatments exhibited significant differences in dry weight per plant at four sampling dates, *i.e.* 105, 120, 135 and 150 days after sowing. Also, it can be noticed that, all potassium rates (24, 48 and 72 kg K_2O/fed) at any application time caused a significant increase in plant dry weight at all sampling dates as compared with unfertilized plants, except plants which fertilized by 24 kg K_2O/fed at sowing (Tr. No. 2) at sample of 105 days after sowing. Data in Table 3 also revealed that at all sampling dates plants which received 72 kg K_2O/fed at any time (Tr. No. 16 to 22) significantly increased dry weight /plant as compared with the other treatments (Tr. No. 1 to 15) in two growing seasons.

The highest values of dry weight /plant were achieved when beet plants received 72 kg K_2O/fed in two equal portions the first one at 30 days age and the other one at 60 days after sowing (Tr. No. 21) for all sampling dates which gives 143.36, 256.24, 352.00 and 387.23 g/plant, respectively in the first season, corresponding to the age of 105, 120, 135 and 150 days after sowing and recorded 135.97, 179.18 and 302.78 g/plant, respectively at age 105, 120 and 150 days in the second season, except, the sample at age of 135 days after sowing in the 2nd season the highest value of this trait (270.18 g/plant) was achieved by applying 72 kg K_2O/fed in two equal portions the 1st one at sowing and the other one at 60 days after sowing (Tr. No. 20) with significant differences as compared with the other treatments in both seasons. While the lowest dry weight /plant resulted from unfertilized plants and plants which received 24 kg K_2O/fed at sowing (Tr. No. 2) over all sampling dates in both seasons. These results are in harmony with that reported by Table *et al.* (1986), Ashmaye (1998), El-Taweel (1999), Agami (2000) and Moustafa *et al.* (2006) who reported that dry weight per plant of sugar beet significantly increased with increasing K fertilizer application.

The increase in dry weight per plant as a result of potassium treatments may be due to the essential role of potassium in activating the photosynthesis operation (there is a positive correlation between K application and photosynthesis rate in sugar beet plant (Suciu & Sebok, 1979) and encouraging the translocation of the metabolites from leaves to be accumulated in sugar beet root.

TABLE 3. Effect of potassium fertilization treatments on total dry weight (g /plant) of sugar beet at different dates of sampling in 2002/2003 and 2003/2004 seasons.

No.	Treatments K_2O (kg/fed) and application time	2002 / 2003 Season Days from sowing				2003 / 2004 Season Days from sowing			
		105	120	135	150	105	120	135	150
1	Unfertilization	65.17	149.36	218.62	246.90	60.15	101.11	160.50	185.52
2	24 at sowing	65.69	154.76	231.80	259.12	61.04	110.53	170.06	201.34
3	24 at 30 day after sowing (DAS)	72.88	161.38	239.60	272.10	69.52	113.19	177.89	204.20
4	24 at 60 DAS	74.36	165.59	247.12	279.18	75.21	118.79	183.05	211.30
5	12 at sow. + 12 at 30 DAS	83.19	170.79	252.00	283.50	79.41	121.93	189.18	218.88
6	12 at sow. + 12 at 60 DAS	90.18	178.07	263.11	294.00	87.40	131.19	208.14	234.29
7	12 at 30 DAS + 12 at 60 DAS	96.00	181.13	266.93	299.93	88.33	127.42	210.16	240.19
8	12 at 30 DAS + 12 at 90 DAS	88.78	173.87	258.60	288.15	83.91	124.93	203.12	222.41
9	48 at sowing	97.23	181.52	273.10	303.90	90.23	133.07	215.35	241.69
10	48 at 30 DAS	99.14	187.07	277.09	313.70	90.28	134.63	226.79	249.07
11	48 at 60 DAS	104.59	194.40	288.52	325.00	95.25	143.63	220.79	255.69
12	24 at sow. + 24 at 30 DAS	112.72	206.02	298.39	333.94	101.65	150.40	235.47	267.10
13	24 at sow. + 24 at 60 DAS	115.67	211.81	299.45	336.74	104.82	153.17	240.35	271.52
14	24 at 30 DAS + 24 at 60 DAS	118.35	218.12	308.72	346.17	106.08	158.20	243.26	274.64
15	24 at 30 DAS + 24 at 90 DAS	109.76	201.78	294.18	330.00	99.30	146.81	233.76	264.51
16	72 at sowing	123.48	225.76	312.81	352.65	110.32	162.93	245.92	278.25
17	72 at 30 DAS	124.08	227.54	319.14	360.66	112.80	164.03	247.09	283.51
18	72 at 60 DAS	129.11	239.60	326.81	364.82	117.04	167.16	250.39	287.75
19	36 at sow. + 36 at 30 DAS	135.37	250.12	337.23	371.35	124.03	170.94	259.11	292.53
20	36 at sow. + 36 at 60 DAS	138.77	252.38	340.97	379.87	128.45	173.19	270.18	298.58
21	36 at 30 DAS + 36 at 60 DAS	143.36	256.24	352.00	387.23	135.97	179.18	263.60	302.78
22	36 at 30 DAS + 36 at 90 DAS	132.15	246.77	333.71	367.60	122.23	170.07	256.92	289.93
Mean		105.46	201.46	288.17	322.57	97.43	143.48	223.20	253.42
L.S.D. at 0.05		1.15	1.07	1.11	1.45	1.05	0.97	1.28	1.41

Physiological analysis

Crop growth rate (CGR)

Data shown in Table 4 cleared that, CGR was maximized at the growth period of 105-120 days in the first season and of 120-135 days in the second season, thereafter a clear reduction was observed.

Statistical analysis of data indicated that potassium fertilization treatments resulted significant differences in CGR at the three growth periods in 2002/2003 and 2003/2004 seasons.

TABLE 4. Effect of potassium fertilization treatments on CGR (g/m²/week) of sugar beet at different growth periods in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Days from sowing			Days from sowing		
		105 -120	120 -135	135 -150	105 -120	120 -135	135 -150
1	Unfertilization	42.09	43.63	14.14	20.48	29.69	12.51
2	24 at sowing	44.53	38.52	13.66	24.74	29.76	15.64
3	24 at 30 day after sowing (DAS)	44.25	39.11	16.25	21.83	32.35	13.15
4	24 at 60 DAS	45.62	40.77	16.03	21.79	32.13	14.12
5	12 at sow. + 12 at 30 DAS	43.80	40.61	15.75	21.26	33.63	14.85
6	12 at sow. + 12 at 60 DAS	43.95	42.52	15.45	21.89	38.47	13.07
7	12 at 30 DAS + 12 at 60 DAS	42.57	42.90	16.50	19.54	41.37	15.02
8	12 at 30 DAS + 12 at 90 DAS	42.55	42.36	14.78	20.51	39.09	9.64
9	48 at sowing	42.15	45.79	15.40	21.42	41.14	13.17
10	48 at 30 DAS	43.97	45.01	18.31	22.17	46.08	11.14
11	48 at 60 DAS	44.91	47.06	18.24	24.19	38.58	17.45
12	24 at sow. + 24 at 30 DAS	46.65	46.19	17.78	24.38	42.54	15.82
13	24 at sow. + 24 at 60 DAS	48.07	43.82	18.64	24.17	43.59	15.58
14	24 at 30 DAS + 24 at 60 DAS	49.89	45.30	18.73	26.06	42.53	15.69
15	24 at 30 DAS + 24 at 90 DAS	46.02	46.20	17.91	23.75	43.48	15.38
16	72 at sowing	50.14	44.53	19.92	26.31	41.49	16.16
17	72 at 30 DAS	51.73	45.80	20.76	25.62	41.53	18.21
18	72 at 60 DAS	55.24	43.61	19.00	25.06	41.62	18.68
19	36 at sow. + 36 at 30 DAS	57.38	43.56	17.06	23.46	44.09	16.71
20	36 at sow. + 36 at 60 DAS	56.81	44.29	19.45	22.37	45.00	17.70
21	36 at 30 DAS + 36 at 60 DAS	56.44	47.88	17.61	21.60	44.41	17.39
22	36 at 30 DAS + 36 at 90 DAS	57.31	43.47	16.94	23.92	43.43	16.51
	Mean	48. 00	43.36	17.20	23.04	39.83	15.16
	L.S.D. at 0.05	0.73	0.66	0.76	0.70	0.79	0.57

In the first season (Table 4) at growth period of 105-120 days applying 72 kg K_2O/fed in two equal portions at any time (Tr. No. 19 to 22) gave the highest CGR values and caused significant increase as compared with the other treatments with insignificant differences between them . Concerning, the second season (Table 4), the highest value (46.08) was achieved at 120 - 135 growth period when beet plant received 48 kg K_2O/fed at 30 days after sawing (Tr. No. 10). On the other hand, the lowest CGR value (13.66) at growth period of 135-150 in the first season was produced by adding 24 kg K_2O/fed at sawing (Tr. No. 2) with insignificant differences as compared by unfertilized treatment,

meanwhile, adding 24 kg K_2O/fed in two equal portions, the first one at 30 days and the other at 90 days after sowing (Tr. No. 8) gave the lowest CGR value (9.64) in the second season in growth period of 135-150 days after sowing (Table 4).

Relative growth rate (RGR)

Data in Table 5 indicated that, the maximum RGR value was obtained in the growth periods of 105-120 days in the first season and of 120-135 days in the second season, then the clear reduction was recorded. Same results were obtained by Mohamed (2000) who reported that RGR was declined as the plant developed.

TABLE 5. Effect of potassium fertilization treatments on RGR (g/g/week) of sugar beet at different growth periods in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Days from sowing			Days from sowing		
		105-120	120-135	135-150	105-120	120-135	135-150
1	Unfertilization	0.414	0.191	0.061	0.259	0.231	0.072
2	24 at sowing	0.428	0.202	0.055	0.297	0.215	0.084
3	24 at 30 day after sowing (DAS)	0.397	0.198	0.064	0.244	0.226	0.069
4	24 at 60 DAS	0.400	0.200	0.061	0.229	0.217	0.072
5	12 at sow. + 12 at 30 DAS	0.364	0.195	0.059	0.214	0.220	0.073
6	12 at sow. + 12 at 60 DAS	0.340	0.196	0.056	0.203	0.230	0.059
7	12 at 30 DAS + 12 at 60 DAS	0.317	0.194	0.058	0.183	0.250	0.066
8	12 at 30 DAS + 12 at 90 DAS	0.336	0.199	0.057	0.199	0.241	0.045
9	48 at sowing	0.312	0.204	0.054	0.194	0.240	0.058
10	48 at 30 DAS	0.318	0.197	0.062	0.200	0.262	0.047
11	48 at 60 DAS	0.310	0.197	0.060	0.206	0.215	0.074
12	24 at sow. + 24 at 30 DAS	0.302	0.185	0.056	0.196	0.224	0.063
13	24 at sow. + 24 at 60 DAS	0.303	0.173	0.059	0.198	0.225	0.061
14	24 at 30 DAS + 24 at 60 DAS	0.306	0.174	0.058	0.201	0.215	0.061
15	24 at 30 DAS + 24 at 90 DAS	0.304	0.188	0.058	0.197	0.235	0.062
16	72 at sowing	0.297	0.168	0.059	0.195	0.206	0.062
17	72 at 30 DAS	0.303	0.170	0.062	0.187	0.205	0.069
18	72 at 60 DAS	0.309	0.155	0.055	0.178	0.202	0.073
19	36 at sow. + 36 at 30 DAS	0.307	0.150	0.048	0.161	0.208	0.063
20	36 at sow. + 36 at 60 DAS	0.299	0.151	0.054	0.149	0.210	0.064
21	36 at 30 DAS + 36 at 60 DAS	0.291	0.159	0.048	0.138	0.201	0.061
22	36 at 30 DAS + 36 at 90 DAS	0.312	0.151	0.048	0.165	0.206	0.060
	Mean	0.330	0.182	0.057	0.199	0.222	0.064
	L.S.D. at 0.05	0.008	0.004	0.006	0.008	0.008	0.001

In both season (Table 5) data also revealed that applying 24 kg K_2O/fed at sowing (Tr. No. 2) gave the highest values of RGR at growth period of 105-120

days after sowing which recorded 0.428 and 0.297 in 2002/2003 and 2003/2004 season, respectively. While, the lowest value of RGR (0.047) in the first season (Table 5) was achieved when beet plants received 72 kg K_2O/fed in two equal port one at sowing and the other one at 30 days after sowing (Tr. No. 19) at growth period of 135-150 days after sowing. But in the second season (Table 5) the lowest value of RGR (0.045) was achieved when beet plants fertilized by 24 kg K_2O/fed in two equal portions the 1st one at 30 days age and 2nd one at 90 days after sowing (Tr. No. 8) at the same growth period. In this connection, Hassanin (1979) indicated that the effect of K fertilizer treatments on relative growth rate (RGR) was highly significant and application of 48 kg K_2O/fed significantly increased RGR. El-Taweel (1999) found that, there was some increases in RGR by increasing the application of K fertilizer up to 48 kg K_2O/fed but these increases were not enough to reach the level of significance.

Net assimilation rate (NAR)

Data presented in Table 6 indicated that the highest NAR value in the first season was achieved at growth periods of 105 -120 days, while it was obtained in the second season at growth periods of 120-135 days, thereafter a clear reduction was recorded.

TABLE 6. Effect of potassium fertilization treatments on NAR (g/m^2/week) of sugar beet at different growth periods in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Days from sowing			Days from sowing		
		105 -120	120 -135	135 -150	105 -120	120 -135	135 -150
1	Unfertilization	180.40	114.30	42.06	102.03	120.28	46.03
2	24 at sowing	189.58	124.58	39.14	115.68	110.69	51.70
3	24 at 30 day after sowing (DAS)	185.73	126.12	45.67	97.18	114.18	41.76
4	24 at 60 DAS	182.58	129.13	44.06	95.51	110.75	43.28
5	12 at sow. + 12 at 30 DAS	172.54	125.94	42.78	91.51	112.85	42.77
6	12 at sow. + 12 at 60 DAS	163.90	127.90	41.07	87.46	119.67	36.44
7	12 at 30 DAS + 12 at 60 DAS	156.72	128.45	42.93	78.95	130.91	42.89
8	12 at 30 DAS + 12 at 90 DAS	162.07	128.97	39.08	78.28	127.25	28.00
9	48 at sowing	154.30	134.75	40.21	49.21	127.70	36.41
10	48 at 30 DAS	159.90	132.17	47.42	86.93	138.88	29.32
11	48 at 60 DAS	160.05	137.84	46.23	92.89	116.74	46.88
12	24 at sow. + 24 at 30 DAS	158.46	131.13	44.67	88.68	122.37	41.53
13	24 at sow. + 24 at 60 DAS	161.14	122.36	46.73	85.25	124.07	41.22
14	24 at 30 DAS + 24 at 60 DAS	163.93	124.86	46.46	89.31	121.00	40.28
15	24 at 30 DAS + 24 at 90 DAS	158.75	132.77	45.77	88.83	129.33	40.51
16	72 at sowing	162.31	119.96	48.46	87.08	114.97	42.05
17	72 at 30 DAS	164.19	121.75	50.00	83.29	113.87	46.25
18	72 at 60 DAS	170.05	114.07	44.99	78.96	110.16	47.82
19	36 at sow. + 36 at 30 DAS	162.42	107.89	37.62	69.28	108.46	40.43
20	36 at sow. + 36 at 60 DAS	156.80	104.34	41.79	63.23	109.00	39.65
21	36 at 30 DAS + 36 at 60 DAS	147.79	111.04	37.04	57.99	105.74	39.40
22	36 at 30 DAS + 36 at 90 DAS	171.15	109.22	38.77	72.44	114.35	39.93
	Mean	165.67	123.16	43.32	83.63	118.33	41.12
	L.S.D. at 0.05	1.22	0.87	0.84	1.06	1.02	0.58

Data summarized in Table 6 showed also, that potassium fertilization treatments had significant effect on NAR at various growth periods in both growing seasons. Although, there is inconstant trend was detected by level or application time of potassium fertilizer, but it can be noticed that, in the first season plants which fertilized by 24 kg K_2O/fed at sowing (Tr. No. 2) gave the highest value of NAR (189.58) at growth periods of 105-120 days with significant increases, compared with the other treatments. However, in the second season, the highest value of NAR (138.88) was obtained at 120-135 growth periods from the plants received 48 kg K_2O/fed at 30 days after sowing (Tr. No. 10) which gave significant increases in NAR compared with the other treatments. In contrast, the lowest NAR values (37.04) in the 1st season and (28.00) in the 2nd season at growth stage of 135-150 days were achieved witn plants fertilized by 72 kg K_2O/fed in two equal portions, the first one at 30 days after sowing and the other one at 60 days (Tr. No. 21) in the first season and by applied 24 kg K_2O/fed the first one at 30 days age and the other one at 90 days after sowing (Tr. No. 8) in the second season.

Photosynthetic pigments

The present results in Table 7 showed that, chlorophyll b and carotenoids were not significantly affected by the application of potassium fertilization treatments in both seasons. While, in the first season only chlorophyll a was significantly affected by all potassium fertilization treatments. Generally, increasing the rate of potassium fertilization at any application time caused a gradual increased in chlorophyll a content in sugar beet leaves. The highest chlorophyll a (5.13 mg/g fresh weight) produced when beet plants received 72 kg K_2O/fed in two equal portions, the first one at 30 days after sowing and the other at 60 days age (Tr. No. 21) which increased chlorophyll a by 17.12%, compared with no potassium fertilized treatment. On contrast, the lowest chlorophyll a (4.38 mg/g fresh weight) resulted from unfertilized plants. This trait reached its maximum values with plants fertilized by the highest rate of potassium (72 kg K_2O/fed) at any application time (Tr. No.16 to 22) with no differences between them. In this connection Abdel-Rahman (1996) found that the increase in potassium level from zero to 48 kg K_2O/fed significantly decreased chlorophyll a, b and a + b, while El-Taweel (1999) reported that total chlorophyll were not significantly affected by potassium application.

On the other hand, Suciu & Sebok (1979) indicated that, photosynthetic rate was positively correlated with K fertilization.

TABLE 7. Effect of potassium fertilization treatments on chlorophylls a, b and caroteniodes (mg/g fresh weight of leaves) of sugar beet at 150 days after sowing in 2002/2003 and 2003/2004 seasons.

No.	Treatments	2002 / 2003 Season			2003 / 2004 Season		
	K_2O (kg/fed) and application time	Chlorophyll		Carotenoides	Chlorophyll		Carotenoides
		a	b		a	b	
1	Unfertilization	4.38	3.32	1.61	4.41	2.30	1.41
2	24 at sowing	4.40	3.32	1.60	4.40	2.33	1.39
3	24 at 30 day after sowing (DAS)	4.42	3.33	1.60	4.41	2.34	1.39
4	24 at 60 DAS	4.45	3.35	1.62	4.41	2.37	1.40
5	12 at sow. + 12 at 30 DAS	4.50	3.37	1.65	4.44	2.40	1.41
6	12 at sow. + 12 at 60 DAS	4.56	3.40	1.70	4.47	2.42	1.45
7	12 at 30 DAS + 12 at 60 DAS	4.55	3.41	1.71	4.50	2.44	1.48
8	12 at 30 DAS + 12 at 90 DAS	4.56	3.37	1.66	4.44	2.40	1.41
9	48 at sowing	4.62	3.41	1.71	4.50	2.44	1.48
10	48 at 30 DAS	4.66	3.44	1.72	4.53	2.45	1.49
11	48 at 60 DAS	4.74	3.44	1.74	4.55	2.45	1.49
12	24 at sow. + 24 at 30 DAS	4.86	3.50	1.77	4.60	2.49	1.53
13	24 at sow. + 24 at 60 DAS	4.89	3.53	1.80	4.64	2.54	1.56
14	24 at 30 DAS + 24 at 60 DAS	4.92	3.57	1.80	4.66	2.55	1.58
15	24 at 30 DAS + 24 at 90 DAS	4.83	3.46	1.74	4.58	2.47	1.51
16	72 at sowing	4.95	3.59	1.80	4.70	2.58	1.58
17	72 at 30 DAS	4.99	3.57	1.82	4.74	2.61	1.60
18	72 at 60 DAS	5.00	3.63	1.83	4.79	2.63	1.62
19	36 at sow. + 36 at 30 DAS	5.07	3.64	1.86	4.80	2.66	1.66
20	36 at sow. + 36 at 60 DAS	5.11	3.66	1.88	4.83	2.69	1.67
21	36 at 30 DAS + 36 at 60 DAS	5.13	3.67	1.89	4.86	2.71	1.69
22	36 at 30 DAS + 36 at 90 DAS	5.03	3.62	1.86	4.85	2.66	1.62
	Mean	4.76	3.48	1.74	4.60	2.50	1.52
	L.S.D. at 0.05	0.19	N.S	N.S.	N.S.	N.S.	N.S.

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تأثير معدل وميعاد التسميد البوتاسى على النمو والصفات الفسيولوجية لنباتات بنجر السكر

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بسخا (محافظة كفر الشيخ) خلال موسمي٢٠٠٢ /٢٠٠٣ و ٢٠٠٣/٢٠٠٤ لدراسة تأثير ميعاد ومعدل اضافة السماد البوتاسى على النمو والصفات الفسيولوجيه لنبات بنجر السكر .

من النتائج يتضح أن اضافة ٧٢ كجم بوتاسيوم على دفعتين متساوتين بعد ٣٠ ، ٦٠ أو ٩٠ يوم من الزراعة أعطى أعلى القيم فى صفات النمو والصفات الفسيولوجية لنباتات بنجر السكر .