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Physiological Response of Fodder Beet (*Beta vulgaris* L.) To Soil Dressing of Potassium Fertilization, Foliar Spray of Potassium and in Combination under Calcareous Soil Conditions

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Abstract: A field trail was conducted at Nubaria Agricultural Research Station, EL-Behira Governorate, Egypt during 2017/2018 and 2018/2019 winter seasons on fodder beet(*Beta vulgaris L.)* variety Vorochenger to study the effect of potassium fertilizer as soil dressing i.e 24,36 and 48 kg K_2O /fad and foliar spray i.e 1 and 2% K_2O as well as in combination. Results indicated that the maximum values of crop growth rate (CGR) at two growth periods i.e (90-120) and (120-150) days after sowing (DAS), root length, root diameter, root and shoot dry weight as well as total dry weight (ton/fad) were achieved when plants received 48 kg K_2O /fad followed by adding (36 kg K_2O/fad + spraying 2% K_2O) with insignificant differences between such two treatments. Chemical composition of fodder beet shows that total chlorophyll of leaves and total carbohydrate of roots gave the highest significant values when plant treated by 48 kg K_2O /fad. The maximum values of crude protein (Cp%), digestible protein (Dp%), potassium content(k%) of shoot and root at vegetative stage and harvesting time were obtained when plants treated by 48 kg K_2O/fad. Followed by applying (36 kg K_2O/fad + spraying 2% K_2O) with insignificant difference between such two treatments.

Key words: Fodder beet (*Beta vulgaris* L.) · Potassium fertilization · Growth traits and quality

INTRODUCTION

Fodder beet (*Beta vulgaris L.)* is a new winter forage crop in Egypt, it's considered as one of the highest productive forage crops, it is an ideal fodder for its high performance on dairy cows due to its high nutritive value. Furthermore, it is adapted to saline, sodic and calcareous soils and requires less water compared with other forage crops. Its whole yield, i.e. above and under- ground parts, can directly be used in animal feedings, especially dairy cows or may be processed as qualitative silage. The roots can also be stored in the soil for a period without great damage to be used when it is needed. Thus, its cultivation may help in overcoming the problem of animal feeding in the summer season.

Potassium is one of the essential elements in the plant nutrition and it is commonly insufficient supply in the soil which affects plant growth. Thus, it often needs to be added regularly as a fertilizer. Crops store carbohydrates like fodder beet need an ample supplies of potassium for good production [1]. Furthermore, it's an important nutrient for improving the crop yield per unit area.

Potassium is vital for physiological processes, water availability, photosynthesis, assimilate transport and enzyme activation with a direct effect on crop production. Potassium deficiency significantly reduces the leaves number and size of individual leaf and this resulted in a reduction in photosynthetic activity [2]. Excessive application of potassium fertilization as a soil dressing could raise toxicity by accumulation of heavy metals, environmental pollution and reduction in soil microorganisms which are important for agriculture, as well as increasing potassium fertilization costs. So, foliar application of potassium fertilizer as a supplementary fertilization is considered as active way to increase the absorption of potassium and other nutrients, in addition to enhancing the (K) use efficiency and reduce potassium fertilizer costs [3]. Brabenec and Sroller [4] pointed out that potassium fertilization increased total dry mater of

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fodder beet plants. Abdel Hamid *et al.* [5] stated that foliar application of 400 ppm potassium on fodder beet plant increased total dry matter of roots and leaves as well as total carbohydrates of roots. Geweifel and Aly [6] reported that adequate potassium quantities are thus vital for full fodder beet yield and also for many aspects of product quality. They added that root dry mater yield and crude protein (Cp) content of fodder beet increased directly with increasing K level fertilization.

The present investigation is carried out to study the physiological response of fodder beet plant to soil dressing of potassium fertilization and foliar application of potassium as well as in combination on growth, productivity and chemical composition under calcareous soil conditions.

MATERIALS AND METHODS

A field trail was conducted during the two successive seasons of 2017/2018 and 2018/2019 at Nubaria Agricultural Research Station, El-Behira governorate, Egypt, on fodder beet variety Voroshenger to study the effect of potassium fertilization as soil dressing and foliar spray as well as in combination on growth, productively and chemical composition. The experiment was laid out in a complete randomized block design with four replicates. Each plot area was 12m2 (3x4m) and included 6 ridges, 4m long, 50 cm apart. Some physical and chemical properties of the experimental site in two growing seasons are shown in Table (1) and were done according to Ryan *et al*. [7].

All plots were received 200kg /fad of single superphosphate (15.5%P2O5) and incorporated into soil before sowing. Fodder beet seeds c.v.Voroshenger were planted on 19/10/2017 and 3/11/2018 in the first and second seasons, respectively, in hills spaced 20 cm. Plants were thinned into one plant per hill at 25 days after sowing.

Ammonium nitrate (33.5%N) was added in two equal doses, the first at 25 days after sowing (DAS) and the second at 45 (DAS). The treatments were as follows:

- Spraying 1% K_2O (in the form of potassin, 30% K_2O).
- Spraying 2% K_2O (in the form of potassin, 30% K_2O).
- 24 Kg K_2O /fad.
- 36 Kg K_2O /fad.
- 48 Kg K_2O /fad.
- 24 Kg K_2O /fad. + Spraying 1% K_2O.
- 36 Kg K_2O /fad. + Spraying 1% K_2O.
- 24 Kg K_2O /fad. + Spraying 2% K_2O.
- 36 Kg K_2O /fad. + Spraying 2% K_2O.

Table 1: Physical and chemical properties of the experimental site in two growing seasons

Property	2017/2018	2018/2019
Partial size distribution		
Sand%	50.9	51.6
Silt%	23.8	24.0
Clay%	22.7	23.2
Texture	Sandy clay loom	Sandy clay loom
PH (1:2.5)	8.1	7.9
Organic matter % (O.M.)	0.19	0.22
CaCO3 (%)	18.51	18.93
Available nutrients (mg Kg^{-1})		
N	12.80	12.48
P	4.30	4.19
K	112.09	117.51

Potassium fertilizer treatments as soil dressing in the form of potassium sulphate (48% K_2O) were added in two equal doses at 25 and 45 (DAS). Foliar spray of potassin treatments in the form of potassium solution, 30% K_2O sprayed two times at 35 and 55 (DAS), the volume of water was 1.5 L/plot, 0.5% wetl-ing agent of Tween 20 was used. Cultural practices were practiced according to the methods being adopted for growing fodder beet in the locality.

Growth Analysis Traits: For determine some growth traits five plants were randomly taken from each plot at 90, 120 and 150 days after sowing (DAS). In each sample, plants were separated into their components i.e. leaves and roots, then dried at 60°C for 48h in a ventilated oven in to a constant weight to determine crop growth rate (CGR) at (90-120),(120-150) DAS in g/plant / week according to Watson [8] and calculated as follows:

$$CGR = \frac{W2\text{-}W1}{T2\text{-}T1}$$

where:

W2-W1 = differences in dry mater accumulation between two successive samples in grams.

T2-T1 = The number of days between two successive samples in week.

Harvesting took place at 3/5/2018 and 12/5/2019 in the first and second seasons, respectively. At harvest time, ten guarded plants were randomly chosen from each plot to determine:

- Root length /plant (cm) = distance between the beginning of the root to an end.
- Root diameter /plant (cm) = circumference of circle width of root divided on 3.14.

- Dry weight of roots shoots and total yield of fodder beet.

Chemical Composition: Total chlorophyll content of leaves:

At 100 DAS total chlorophyll of leaves mg/m^2 was determined as SPAD unit using SPAD502 apparatus (Soil and Plant Analysis Department) of Minolta Co. This unit was transformed to mg/ m^2 as described by Monge and Bugbe [9] as follows:

chl. = 80.05+10.4 (SPAD 502).

Total Carbohydrate of Roots (%): In the second season only after 160 (DAS) a root samples were collected from each plot and dried in oven at 60°C for 48 h up to a constant weight, ground and prepared to determine total carbohydrate (%) according to A.O.A.C. [10].

Crude Protein% (Cp): After 160 (DAS) crude protein % of shoot and root were determined according to A.O.A.C. [10].

Digestible Protein% (Dp): Dp= ((Cpx0.9115)-3.62) was determined according to Mcdonald *et al.* [11].

After 160(DAS) digestible protein% of shoot and root were determined according to Bredon *et al*. [12].

Potassium Content % of Shoot and Root: After 100 (DAS)(vegetative stage) and 160(DAS) (harvesting time)potassium % of shoot and root were determined at the second season only according to Anton *et al*. [1].

Data were statistically analyzed according to Snedecor and Cochran [13] and treatment means were compared by least significant difference test (LSD) at 0.05 level of probability. Bartlett test was done according to Bartlett [14] to test the homogeneity of error variance. The test was not significant for all assessed traits, so, the two season's data were combined. The discussions of the results were carried out on the basis of combined analysis for the two seasons.

RESULTS AND DISCUSSION

Growth Traits:

Crop Growth Rate (CGR): Results of Table (2) show that potassium fertilization as a soil dressing and foliar spray as well as in combination on CGR at the first period (90-120) DAS and the second period (120-150) DAS recorded a significant effect. It can be noticed the CGR values were higher in the second period than the first period, such finding may be due to plants directed its effort in the second period for accumulate photosynthesiate compounds which increase dry matter accumulation. The maximum values of CGR at the two growth periods under study were obtained when plants received 48 kg K_2O /fad followed by adding (36 kg K_2O /fad + spraying 2% K_2O) with insignificant differences between such two treatments. It is worthy to mention that the lowest value of CGR was gained at the first period (90-120) DAS when plants sprayed by (1% K_2O). These results are in harmony with obtained by Abdel-Aziz *et al*. [15] who reported that CGR of maize plant increased due to the important role of potassium in carbohydrates

Table 2: Root length, root diameter and crop growth rate (CGR)at (90-120), (120-150) DAS of fodder beet as affected by potassium fertilization in calcareous soil for two seasons and combined analysis

	Characters											
							CGR (g/plant/week)					
	Root length (cm)			Root diameter (cm)			(90-120) DAS			(120-150) DAS		
Treatments	2017/2018	2018/2019	Comb.	2017/2018	2018/2019	Comb.	2017/2018	2018/2019	Comb.	2017/2018	2018/2019	Comb.
Spraying 1% K_2O	37.5	35.5	36.5	12.8	12.7	12.7	4.16	5.10	4.63	11.64	12.55	12.11
Spraying 2% K_2O	36.9	36.7	36.8	13.9	13.9	13.9	4.85	5.37	5.11	13.56	14.92	14.24
24Kg K_2O /fad	41.1	37.9	39.5	14.0	13.8	13. 0	5.68	6.00	5.84	14.53	17.02	15.78
36Kg K_2O /fad	43.7	40.7	42.2	14.7	14.4	14.6	6.97	7.02	6.99	15.65	21.19	18.42
48Kg K_2O /fad	49.5	48.2	48.9	16.3	16.0	16.1	9.78	9.27	9.53	21.97	25.30	23.64
24Kg K_2O /fad +1% K_2O	41.5	38.4	39.9	14.3	14.1	14.2	5.92	7.15	6.54	14.88	17.60	16.24
36Kg K_2O /fad +spraing1% K_2O	45.0	45.0	45.0	15.3	14.9	15.1	6.98	7.32	7.15	19.40	23.55	21.48
24Kg K_2O /fad +spraying2% K_2O	46.8	45.3	46.1	16.0	15.5	15.7	8.39	8.09	8.24	19.14	24.51	21.83
36Kg K_2O /fad + spraying2% K_2O	49.0	47.7	48.3	16.4	15.9	16.2	9.17	9.07	9.12	21.65	25.06	23.36
L.S.D. 5%	3.6	3.4	2.4	0.5	0.5	0.3	1.05	1.05	0.60	1.21	1.18	0.81

Table 3: Dry forage yield for shoot, root and total yield of fodder beet as affected by potassium fertilization in calculators soil for two seasons and combined analysis

Treatments	Shoot 2017/2018	Shoot 2018/2019	Shoot Comb.	Root 2017/2018	Root 2018/2019	Root Comb.	Total 2017/2018	Total 2018/2019	Total Comb.
Spraying 1% K_2O	0.90	0.95	0.93	12.42	13.04	12.73	13.34	13.99	13.66
Spraying 2% K_2O	0.96	1.04	1.00	12.79	14.94	13.87	13.75	15.98	14.87
24Kg K_2O /fad	1.36	1.40	1.38	15.87	17.95	16.91	17.23	19.35	18.29
36Kg K_2O /fad	1.76	1.57	1.67	22.25	20.50	21.37	25.08	22.07	23.58
48Kg K_2O /fad	2.38	2.20	2.29	25.31	25.05	25.18	27.69	27.25	27.47
24Kg K_2O /fad +1% K_2O	1.43	1.46	1.45	19.19	19.28	19.23	20.61	20.74	20.68
36Kg K_2O /fad +spraing1% K_2O	1.81	1.77	1.79	23.31	22.18	22.71	24.10	23.88	23.94
24Kg K_2O /fad +spraying2% K_2O	1.57	1.82	1.69	20.12	22.96	21.54	21.91	24.78	23.35
36Kg K_2O /fad + spraying2% K_2O	2.21	1.95	2.08	24.67	24.65	24.66	26.88	26.60	26.74
L.S.D. 5%	0.37	0.40	0.25	0.97	0.64	0.56	1.27	0.88	0.75

Characters: Dry forage yield (Ton/fad)

synthesis, which in turn increase dry matter and CGR. Akram *et al*. [16] reported that potassium accelerated net assimilation rate (NAR). Tabatabaii *et al*. [17] explained such result that photosynthetic rate was increased by increasing the potassium up take level. Ihsan *et al.*[18] stated that the foliar application of potassium by 250 mgL^{-1} increased the photosynthetic efficiency of mung bean plants.

Root Length and Root Diameter (cm): Results of Table (2) show the effect of potassium fertilization on root length and root diameter which recorded a significant effect. The highest values of root length and diameter were obtained from applying 48 kg K_2O /fad followed by adding (36kg K_2O /fad+ spraying 2% K_2O) with insignificant differences between such two treatments. These results could be attributed to the role of potassium on fodder beet growth which in turn reflected on root length and diameter. In this connection, Anton *et al.* [1] found that the application of 96 kg K2O/fad increased significant root length and diameter of fodder beet plant. In addition they indicated that fodder beet plant needs an ample supplies of potassium for good growth thereby high production. Robert [19] reported that potassium activates at least 60 different enzymes involved in plant growth. It is worthy to mention that the lowest values of root length and diameter were obtained when plant sprayed by 1% K_2O only.

Yield: Data presented in Table (3) show that the maximum yield production of fodder beet plant viz root and shoot dry weight as well as total dry weight (ton/fad) were achieved when plant received 48 kg K_2O /fad followed by (36 kg K_2O /fad+ spraying 2% K_2O) with insignificant differences between such two treatments. Such finding may explain that potassium is associated with the movement of water, nutrients and carbohydrates in plat tissue its involved with enzyme activation within the plant, which affects protein, starch and adenosine triphophate (ATP) production which regulate the rate of photosynthesis [2]. These results are in harmony with those obtained by Abdel Hamid *et al*. [5] who found that the foliar application of 400 ppm potassium stimulated greatly the accumulation of dry matter in roots and leaves of fodder beet plants. Also, Anton *et al*. [1] showed that increased potassium levels from 24 up to 96 kg K_2O /fad increased significantly both fresh and dry weight of fodder beet root, they explained such result that potassium play an important role for dry matter accumulation in the storage organs of plants. Abdel-Gawad *et al*. [20] who reported that potassium fertilization increased root yield of fodder beet. It can be noticed that adding (36 kg K_2O /fad + spraying 2% K_2O) more suitable target oriented and economical technique for increasing potassium fertilizer use efficiency which increase fodder beet production with reduce potassium fertilizer costs (where the price of 50 kg of potassium sulphate (48% K_2O) equal 480L.E. whereas the price of 1 Liter of potassin (30% K_2O) equal 50L.E.) under calcareous soil condition in Nubaria region. It can be obtained that the lowest value of fodder yield was achieved when plants received foliar spray of 1% K_2O only.

Chemical Traits

Total Chlorophyll of Leaves: From Table (4), total chlorophyll of leaves gave the highest significant value when fodder beet plants received (48kg K_2O /fad)

Table 4: Total chlorophyll, crude protein and digestible protein (%) for shoot and root of fodder beet as affected by potassium fertilization in calcareous soil for two seasons and combined analysis

	Characters														
	Total Chlorophyll of leaves (mg /m²)			Crude protein (CP) (%)						Digestible protein (DP%)					
				Shoot			Root			Shoot			Root		
Treatments	2017/ 2018	2018/ 2019	Comb.	2017/ 2018	2018/ 2019	Comb.	2017/ 2018	2018/ 2019	Comb.	2017/ 2018	2018/ 2019	Comb.	2017/ 2018	2018/ 2019	Comb.
Spraying 1% K_2O	647.2	652.4	649.8	12.76	12.65	12.71	9.22	9.31	9.27	12.65	8.70	10.68	9.35	5.38	7.36
Spraying 2%K_2O	673.9	680.1	677.1	13.35	13.28	13.32	10.25	10.22	10.24	13.28	9.25	11.27	10.22	5.61	7.92
24Kg K_2O/fad	747.4	771.7	759.5	14.62	13.99	14.31	10.87	10.75	10.81	13.99	10.14	12.07	10.75	6.18	8.47
36Kg K_2O/fad	833.7	868.4	851.4	15.93	14.89	15.41	11.32	11.23	11.28	14.89	10.76	12.83	11.22	6.73	8.98
48Kg K_2O/fad	1169.3	1206.7	1188.0	16.73	16.79	16.76	12.73	12.66	12.70	16.79	12.59	14.69	12.66	7.95	10.31
24Kg K_2O/fad + 1% K_2O	789.7	846.5	818.1	15.83	15.28	15.56	11.60	11.45	11.53	14.28	11.36	12.82	11.53	6.98	9.25
36Kg K_2O/fad + spraying 1%K_2O	878.8	927.0	902.9	15.62	15.66	15.64	12.09	12.11	12.10	15.57	11.45	13.51	12.11	7.38	9.75
24Kg K_2O/fad +spraying2%K_2O	862.5	895.7	879.1	15.83	16.30	16.07	12.18	12.21	12.19	16.30	12.04	14.17	12.20	7.71	9.96
36Kg K_2O/fad + spraying2% K_2O	1084.0	1112.1	1098.0	16.67	16.95	16.81	12.69	12.60	12.65	16.54	12.22	14.38	12.60	7.89	10.25
L.S.D. 5%	77.1	77.1	48.5	0.66	0.42	0.27	0.25	0.29	0.13	0.95	1.08	0.65	0.16	0.22	0.16

Table 5: Total carbohydrate of roots (%)and potassium content (K)% for shoot and root of fodder beet as affected by potassium fertilization in calcareous soil for two seasons and combined analysis

	Characters				
		K (%)			
		Vegetative stage		Harvesting time	
	Total carbohydrateof roots (%)	Shoot	Root	Shoot	Root
Treatments	2018/2019	2018/2019	2018/2019	2018/2019	2018/2019
Spraying 1% K_2O	61.4	1.44	0.13	2.09	0.21
Spraying 2% K_2O	64.4	2.52	0.16	2.29	0.25
24Kg K_2O/fad	68.0	2.84	0.19	3.11	0.29
36Kg K_2O/fad	70.3	3.41	0.23	3.18	0.33
48Kg K_2O/fad	77.7	3.93	0.29	3.32	0.41
24Kg K_2O/fad +1% K_2O	71.3	3.23	0.21	3.11	0.29
36Kg K_2O/fad +spraing1% K_2O	73.8	3.65	0.25	3.27	0.34
24Kg K_2O/fad +spraying2% K_2O	74.4	3.74	0.25	3.26	0.36
36Kg K_2O /fad + spraying2% K_2O	75.8	3.85	0.28	3.30	0.36
L.S.D. 5%	1.1	0.17	0.17	0.17	0.17

followed by applying (36 kg K_2O /fad+ spraying 2% K_2O). The significant increase of chlorophyll content as a result of potassium application could be due to that potassium increased nitrogen availability, accelerate N uptake and enhancing N metabolism, which lead to increased chlorophyll formation, Haghighi *et al*. [21] found similar results on tomato plants. In this respect Abdo and Anton [22] indicated that adding 24 kg K_2O /fad and spraying 1% K_2O significantly increased total chlorophyll of sesame leaves at 70 and 84 DAS. They explained such finding may be due to that potassium activates the enzymes involved in the formation of leaf pigments.

Crude and Digestible Protein (Cp & Dp%): Data in Table (4) show that crude and digestible protein of shoot and root for fodder beet plants gave significant superior values. The maximum values of crude and digestible protein for shoot and root were obtained by adding 48 kg K_2O /fad followed by (36 kg K_2O /fad+ spraying 2% K_2O) with insignificant difference between such two treatments. These results could be attributed to positive role of potassium in improving biometric characteristics such as photosynthetic activity, enhancing N absorption, N metabolism as well as protein synthesis [23].

Total Carbohydrate of Roots: Total carbohydrate of fodder beet roots at second season (2018/2019) is presented in Table (5) results indicated that the maximum value of such trait was achieved when plants received 48 kg K_2O /fad followed by adding (36 kg K_2O /fad + spraying 2% K_2O). These results are in line with Abdel Hamid *et al*. [5] who found that the foliar spray by 400 ppm potassium increased the amount of carbohydrates in fodder beet roots. Anton *et al*. [1] concluded that total carbohydrates content of fodder beet roots was increased gradually with raising potassium fertilization from 24 up to

96 kg K_2O /fad. They added, such result can be ascribed to the role of potassium fertilizer to those plants which store carbohydrates in some of their organs. Abdo and Anton [22] explained the role of potassium in enzymes activation, involved in ATP production which is more important to regulating the rate of photosynthesis, sugar formation and translocation from source to sink.

Potassium Content (K %): Table (5) show the potassium content (K)% of shoot and root for fodder beet at vegetative stage and harvesting time in the second season only (2018/2019). Results indicated that the highest values of such traits were obtained from treated fodder beet plant by 48 kg K_2O /fad followed by adding (36 kg K_2O /fad+ spraying 2% K_2O) with insignificant difference between such two treatments. These finding may be due to that potassium fertilizer as soil dressing improve physical, chemical and biological conditions in soil, which increase the metabolic activity of K thereby improve plant growth [24]. In addition, foliar application of potassium is considered as active way which lead to increases K absorption and other nutrients which enhancing the crop growth and quality [3]. Such finding are in agreement with those obtained by Erner *et al*. [25] who reported that the foliar spray of potassium increased K content of citrus leaves.

CONCLUSION

In the light of the present results it can be concluded that the maximum fodder beet yield, crop growth rate (CGR),root length and diameter as well as crude and digestible protein of shoots and roots were obtained from plants received (48kg K_2O /fad) followed by adding (36kg K_2O /fad+ spraying 2% K_2O) with insignificant differences between such two treatments. Such finding proved that foliar application of potassium in combination with soil dressing of potassium fertilizer enhancing k use efficiency, reduced potassium fertilizer costs(where the price of 50 kg of potassium sulphate (48% K_2O) equal 480L.E. whereas the price of 1 Liter of potassin (30% K_2O) equal 50L.E.) and soil pollution under Nubaria region conditions.

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