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Growth, Productivity, and Quality Traits of Fodder Beet in Response to Potassium Applications and Drip Water Regimes

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ABSTRACT

Increasing water-use efficiency and reducing its losses have been one of the major challenges in agriculture. To investigate the response to a combination of different sources of potassium application levels of "Voroshenger" fodder beet variety on growth; yield and quality traits under different levels of drip irrigation regimes. Two field experiments were carried out at Nubaria Agricultural Research Station, EL-Behira Governorate, Egypt, during the 2015/2016 and 2016/2017 winter growing seasons. A split-plot design was used in three replicates. The main plots were allocated to the irrigation water regimes (I_1= 100%, I_2= 80%, and I_3= 60%) of potential evapotranspiration (ET_o), whereas the sub-plots were devoted to the sources of potassium application levels (T_1= 0 K_2O, T_2= 106.66 K_2O kg/ha (soil dressing), T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 l/ ha potassien (foliar spray). and T_4= 106.66 K_2O kg/ha (soil dressing), + 4.76 l/ ha potassien (foliar spray)). The results in two seasons revealed that; the final increasing irrigation levels led to a significant increase in growth; yield and quality traits. The maximum values were obtained with irrigation at 100% ET_o while the lowest values were recorded with irrigation at 60% ET_o. As well as, data declared that the potassium application levels affected significantly all traits under study. Using T_4 recorded the highest values followed by treatment T_3, whereas the lowest values were obtained from T_1. The interaction between irrigation regimes and potassium fertilization levels was found to be significant for all traits. The highest values were achieved from wet treatment I_1 in combination with T_4, while the lowest values were revealed for treatment I_3 in combination with T_1 (without potassium). Seasonal applied water was increased as irrigation rate increased, where the values of both seasons recorded (5102.2, 4126.1 and 2974.1 m^3/ha) and (5208.7, 4152.3 and 2853.0 m^3/ha) with 100, 80 and 60% ETo irrigation regimes respectively. Water utilization efficiency was enhanced under irrigation at 80% in the first season whereas 60% ET_o in the second season. The lowest record value for W.Ut.E. registered with 100 % ET_o in both seasons. Generally, it was obvious that irrigated by 80% ET_o and T_4 treatment of potassium application level produced to save 20% which is the major disquiet nowadays for the arid regions.

Keywords: Water utilization efficiency, potassium application, drip irrigation regimes and quality traits.

1. Introduction

The increasing request for animal proteins from the growing population in Egypt is hampered by the shortage of carbohydrate components in animal feeds. On the other hand, the horizontal expansion of the newly reclaimed areas requires the cultivation of crops that provide a source of income satisfaction to the farmers (Al-Sharqawi *et al.,* 2019). Fodder beet (*Beta vulgaris* L.) is one of the highest-yielding forage crops. It is ideal fodder for its high performance on dairy cows due to its high nutritional value, high water and sugar, high dry matter yield, and a good source of carbohydrates. Fodder beet provides a higher yield than any "arable" fodder crop (Kassab *et al.,* 2012). The whole yield, i.e; above and underground parts, can be used directly in feedings or can be processed as silage. The roots can also be stored in soil without great injury. Thus, its cultivation may help in overcoming the problem of animal feeding, especially during the summer when the available forages are limited.

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The roots have excellent nutritional quality and are very palatable to ruminants. It can be grown in saline calcareous soil, newly reclaimed, and requires less water compared to other forage crops (Abd El-Lattief, *et al.,* 2020).

Water scarcity is a major factor in addressing the fundamental issue of increasing crop production while reducing water consumption, particularly in reclaimed lands where the deficit irrigation tactic is one of the practical strategies in numerous field crop irrigation programs to save water, but crop productivity suffers as a result (El–Metwally *et al.,* 2022). Drip irrigation systems, which have a high application efficiency range of 95-98%, were used in growing fodder beet in calcareous soils of Nubaria, and a computer program CROWAT was used to estimate irrigation time based on climate and soil conditions. For calculating reference crop evapotranspiration, the CROWAT program employs the FAO Penman-Monteith method (Smith, 1992).

Soil fertility and mineralization are major environmental factors affecting the development, function, and metabolism of the plant. Fertilization of NPK is the most abundantly acquired mineral element by plants (Yolcu *et al.,* 2011). Potassium plays a vital role in increasing plant yield and quality and is essential in maintaining osmotic capacity and water absorption beside that has a positive effect on oral closure which enhances tolerance to water stress (Hasanuzzaman *et al.,* 2018). Further, Kassab *et al.,* (2012) that potassium has a major role in improving plant tolerance to stress conditions. Also, Potassium plays significant regulatory roles in the numerous plants' physiological processes viz. seed germination and emergence, stomatal regulation, phloem transport, cation-anion balance, protein synthesis, photosynthesis, energy transfer, osmoregulation, enzyme activation, nutrient balance, stress resistance photosynthesis, activation of enzymes, plant water relation and assimilation are affected by potassium supplement (Marschner, 2012).

Foliar application of potassium as a fertilizer application is considered an active method that leads to increased absorption of potassium and other nutrients, as well as improved nutrient use efficiency and crop growth in saline soil by decreasing salt accumulation and maintaining optimal nutrient levels in plant root zones (Amanullah *et al.,* 2010). Foliar applications of micronutrients are most commonly used, but they can also be used for macronutrients such as N, P, and K, but these macronutrients are required in large amounts by crops, so foliar application twice completes the fertilizer requirements of crop plants for macronutrients (Abido et *al.,* 2015).

The current study was carried out to investigate the response of fodder beet plants to three drip irrigation water regimes in combination with different levels of potassium fertilization on growth, productivity, quality, and water utilization efficiency under calcareous soil conductions.

2. Materials and Methods

The present study was done at Nubaria Agricultural Research Station (30° 54′ N, 29° 57′ E, and 25m above sea level), EL-Behiera governorate, Egypt during the two consecutive winter seasons of 2015/2016 and 2016/2017 to investigate the response of growth, yields, its components and quality traits of "Voroshenger" fodder beet variety in sandy loam soil conditions using three drip irrigation regimes to combination between different sources of potassium fertilizer. A split-plot design with three replicates was used. The main plots were allocated to the three drip irrigation regimes (I_1= 100%, I_2= 80%, and I_3= 60%) of potential evapotranspiration was estimated using CROPWAT program, whereas, the sub-plots were devoted to the sources of potassium fertilizer (T_1= 0 K_2O, T_2= 106.66 K_2O kg/ha (soil dressing), T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassium (foliar spray). and T_4= 106.66 K_2O kg/ha (soil dressing), + 4.76 liter/ha potassein (foliar spray)). The analysis of soil physical and chemical properties of the research station is demonstrated in Table (1), according to Page *et al.* (1982).

Seeds were sown on the 16th, and 20th of October in both seasons, respectively. Each plot area was 24 m^2 (4x6m). The normal cultural treatments of growing fodder beet in the location were followed, except for the factors under study. Phosphorus fertilizer was applied to the soil before sowing at a dose of (357.14 kg/ha) in the form of calcium superphosphate (15.5% P_2O_5). Ammonium nitrate (33.5% N) at the rate of (190.47 kg/ha) was added in two doses the first dose was applied 21 and 42 days after sowing. Potassium fertilizer treatments as soil dressing in the form of potassium sulfate (48% K_2O) were added in two equal doses at 25 and 45 (DAS). Foliar spray of potassien (32% K_2O + 8% P_2O_2) treatments in the form of potassium solution, 2.38 or 4.76 l/ ha dissolved in 470 l/ha, spray in two times at 40 and 60 (DAS).

Table 1: Soil physical and chemical properties of the experimental site (Means of both seasons)

Particle size distribution	
Sand %	62.52
Silt %	23.63
Clay %	13.85
Texture	Sandy Loam
Field capacity	23.10
Chemical character	
Soil reaction pH (1:2.5)	8.04
Electric conductivity (dSm^{-1})	0.56
Organic matter (%)	0.23
Calcium carbonate (%)	13.57
Available macronutrients (mg/100g)	
N	14.10
P	12.00
K	23.00
Available micronutrients (ppm)	
Fe	3.37
Mn	2.82
Zn	1.89
Cu	2.78

2.1. Data recorded:

- Growth traits

Five plants were randomly taken from each plot to determine growth traits at 90, 120, and 150 days from sowing (DAS). In each sample, plants were separated into their components i.e.; leaves and roots then dried at 60˚C for 48 h in a ventilated oven or until constant weight to determine crop growth rate (CGR) at (90-120) and (120-150) DAS in g/plant/week according to Watson (1958) and Calculated as:

$$\mathbf{CGR} = (\mathbf{W_2} - \mathbf{W_1}) / (\mathbf{T_2} - \mathbf{T_1})$$

Where:
W_2-W = differences in dry matter accumulation between two successive samples in grams.
T_2-T_1 = the number of days between two successive samples in a week.
-Root length (cm)
- Root diameter (cm)

- Yield component and yield

The following data were recorded at harvest after 200 days from sowing:
- Fresh root and leaves weight (kg/plant)
- Dry root and leaves weight (g/plant)
- Root, foliage, and total yield ton/ha

- Quality traits

The following chemical constituents were studied in the first season only on a dry weight basis. Random samples of roots were shopped into 1-2 cm pieces and thoroughly mixed. A 300 gm sample of freshly chopped roots was dried in an oven at 40 ° C for 2 days and at 70 ° C for 3 days.

- Crude protein (CP) % was estimated by multiplying the total N content in the root by 6.25 (Hymowitz *et al.,* 1972).
- Crude fiber (CF) % was determined of root according to A.O.A.C. (1990).
- Total carbohydrates % was determined in the dry matter in the root, using the method described by Dubois *et al.,* (1956).
- Potassium content (%) of the root: at harvesting time was determined according to Anton *et al.,* (1995).

- Crop water requirements calculation

Water requirements were calculated by CROPWAT model (version 4.3) which is a computer program that uses Penman-Monteith method for calculating reference evapotranspiration (ETo) values (Smith 1992). These estimates are used in crop water requirements and irrigation scheduling calculations. Reference evapotranspiration (mmd^{-1}) values were determined via the metrological data of the El-Nubaria region as illustrated in Table 2.

Table 2: Meteorological data* for El-Nubaria region in the 2015/2016 and 2016/2017 winter seasons.

Month	T.max (ºC)	T.min (ºC)	WS(m s^{-1})	RH(%)	SS (h)	RF (mm)
			2015/2016			
October	27.96	19.01	1.92	64.34	11.42	10.33
November	24.02	15.75	2.15	64.46	10.54	21.45
December	21.81	13.63	2.03	62.78	10.36	2.23
January	18.28	8.86	2.07	66.92	10.47	6.18
February	18.64	9.48	3.01	67.29	11.13	22.82
March	21.23	12.60	2.62	66.56	11.94	1.39
April	23.68	13.32	3.06	64.34	12.96	3.87
May	26.97	16.81	2.72	63.98	14.72	0.00
			2016/2017			
October	28.78	20.96	2.14	61.81	11.19	25.87
November	18.01	16.14	0.85	51.53	13.45	110.82
December	19.64	13.22	2.43	58.97	9.84	33.91
January	17.37	7.06	2.38	62.26	11.67	4.84
February	16.25	8.32	2.74	61.21	11.21	21.37
March	20.07	13.97	2.39	63.47	12.54	0.85
April	22.23	12.83	2.91	61.38	12.93	0.00
May	25.96	15.29	2.93	64.06	13.76	0.00

* Tmax= Maximum temperature; Tmin = Minimum temperature; WS =Wind speed; RH=Relative humidity; SS =Actual sunshine duration; RF = Rain fall.

- ET$_o$ Calculation procedure:

The FAO Penman-Monteith method is expressed as:

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T + 273}\,u2\,(es - ea)}{\Delta + \gamma\,(1 + 0.34\,u2)}$$

Where:
ET$_o$: Reference evapotranspiration (mm day^{-1})
Rn: Net radiation at the crop surface (MJ m^{-2} day^{-1})
G: Soil heat flux density (MJ m^{-2} day^{-1})
T: Mean daily air temperature at 2m height (oC)
u$_2$: Wind speed at 2m height (m s^{-1})
es: Saturation vapor pressure (kPa)
ea: Actual vapor pressure (kPa)
es-ea: Vapor pressure deficit (kPa)
Δ: Slope vapor pressure-temperature curve (kPa oC-1)
γ: Psychrometric constant (kPa oC-1)

- Crop water use

Crop water use (ETcrop) over the growing season was determined from both ET$_0$ and the appropriate crop coefficient (Kc) values according to the following equation:-

Crop water use (ETcrop, mm d^{-1}) = ETo, mmd-1 X Kc

- Irrigation water requirements estimation

Irrigation water requirements are the irrigation water quantities that must be applied to the experimental plot and estimated as follows:-

- Irrigation water requirement= [(ETo X Kc)/ irrigation efficiency] + leaching requirements

Irrigation water quantities conveyed to the experimental plots were measured using a Cutthroat flume.

- Water Utilization Efficiency (W.Ut.E.)

Water utilization efficiency values were calculated as (fresh yield, kgm^{-3} applied water) according to BOS (1980) as follows:

W.Ut .E. (kg m^{-3}) = Final yield (kg /ha) / Applied water (m^3/ha)

2.2. Statistical Analysis

Data were statistically analyzed according to Snedecor and Cochran (1980) and treatment means were compared by the least significant difference test

(LSD) at 0.05 level of significance. Bartlett's test was done to test the homogeneity of error variance. The test was not significant for all assessed traits, so, the two seasons' data were combined.

3. Results and Discussion

3.1. Growth traits:

Results in Table 3 illustrated drip irrigation regimes, potassium application levels, and the interaction effects on the crop growth rate (CGR), root length, and diameter.

3.1.1. Effect of irrigation regimes:

The data of drip irrigation regimes revealed significant effects on the crop growth rate, root length as well as root diameter of fodder beet plants. The maximum values of CGR at the first period (90-120) DAS were obtained under I_1 wet treatment (ET_o) were recorded (7.49 and 7.08) in both seasons, respectively followed by (6.58 and 5.98) for I_2 treatment. While the minimum values were recorded by I_3 dry treatment (6.22 and 5.78) in both seasons, respectively. Also, the highest values at the second period (120-150) DAS of CGR revealed (15.62 and 14.41) in both seasons, respectively for I_1 wet treatment while the minimum values were recorded by I_3 dry treatment (10.83 and 9.94) in both seasons, respectively. The CGR values were higher in the second period compared to the first period, which is likely due to the plants directing their efforts in the second period to accumulate photosynthetic compounds that increase dry matter accumulation. These results coincided with those reported by Seiam *et al.,* (2020) in fodder beet and Abu-Ellail and El-Mansoub, (2020) in sugar beet. These findings have been found to disrupt dry matter accumulation or formation of photosynthesized compounds at all stages of growth, most likely due to the water stress condition. Furthermore, it has been proposed that drought stress causes cellular shrinkage, cell membrane damage, and the production of free radicals that harm the cellular apparatus (Hemati *et al.,* 2022).

Data showed that there was a significant decrease in root length and root diameter of fodder beet plants with water stress by I_2 and I_3 treatments compared to I_1 wet treatments. The highest values of root length obtained under I_1 wet treatment (ET_o) were revealed (37.93 and 36.08 cm) followed by (33.65 and 30.49 cm) for I_2 treatment while the lowest values were recorded by I_3 dry treatment (26.66 and 23.49 cm) in both seasons, respectively. Besides that the highest values of root diameter (14.85 and 14.51 cm) for I_1 wet treatment (ET_o) while the lowest values were recorded by I_3 dry treatment (10.54 and 9.95 cm) in both seasons, respectively. These results are in line with Hussein *et al.,* (2019) and Yolcu *et al.,* (2021) observed that drought stress at the vegetative phase can dampen the root length and root diameter in cultivated beet. These findings can be explained by the fact that water was available in the surface layer under the surface drip irrigation system, and the roots could easily absorb water.

3.1.2. Effect of potassium application levels:

Potassium application treatments (T_1, T_2, T_3, and T_4) had a significant effect on the crop growth rate, root length, and root diameter of fodder beet plants, it can be confirmed that these characteristics had gradual and significant increases as a result of increasing potassium application levels from 0 to 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray) in both seasons. Fertilizing fodder beet plants with T_4 produced the highest values of CGR (9.24 and 8.62) in the first period and (18.15 and 16.76) in the second period, root length (37.59 and 35.23 cm) and root diameter (14.51 and

13.83 cm) for both seasons, respectively, while T_1 treatment was recorded the lowest values of previously mentioned characters in both seasons. These increasing character attributes as a result of increasing potassium fertilizer levels can be ascribed to the role of potassium in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, and regulation of plant stomata (Abido *et al.,* 2015 and EL-gamal *et al.,* 2016); enzyme activation and osmoregulation (Mengel, 2007). Therefore, potassium is an important plant nutrient to sustain high growth (Abd El-Lattief *et al.,* 2020).

Table 3: CGR, root length, and root diameter of fodder beet in response to drip water regimes and potassium application levels in the 2015/16 and 2016/17 seasons

Treatments		**CGR (g/plant/week) (90-120 DAS)**		**CGR (g/plant/week) (120-150 DAS)**		**Root length (cm)**		**Root diameter (cm)**	
Drip irrigation regimes	**Potassium application levels kg/ha**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
I_1	**T_1**	4.99	4.78	10.7	10.3	33.2	31.22	13.76	13.33
	T_2	6.58	6.22	14.1	12.43	36.9	34.89	14.23	13.89
	T_3	8.62	7.96	16.56	16.06	38.5	36.6	15.1	14.92
	T_4	9.78	9.36	21.13	18.83	43.13	41.6	16.3	15.9
	Mean	7.49	7.08	15.62	14.41	37.93	36.08	14.85	14.51
I_2	**T_1**	4.32	3.20	9.86	9.51	28.71	24.45	10.99	10.12
	T_2	5.63	5.19	13.8	12.6	31.8	28.13	12.75	11.99
	T_3	7.37	7.23	15.38	15.11	35.2	32.61	13.59	13
	T_4	9.01	8.31	19.9	19.01	38.9	36.77	14.89	13.87
	Mean	6.58	5.98	14.74	14.06	33.65	30.49	13.06	12.25
I_3	**T_1**	3.89	3.68	7.01	6.5	23.36	19.2	8.56	8.31
	T_2	5.10	4.80	10.5	9.01	25.97	22.06	10.51	9.64
	T_3	6.95	6.42	12.39	11.81	26.58	25.4	10.75	10.12
	T_4	8.95	8.21	13.41	12.44	30.73	27.31	12.33	11.73
	Mean	6.22	5.78	10.83	9.94	26.66	23.49	10.54	9.95
T_1		4.40	3.89	9.19	8.77	28.42	24.96	11.10	10.59
T_2		5.77	5.40	12.8	11.35	31.56	28.36	12.50	11.84
T_3		7.65	7.20	14.78	14.33	33.43	31.54	13.15	12.68
T_4		9.24	8.62	18.15	16.76	37.59	35.23	14.51	13.83
$LSD_{(0.05)}$ I		0.21	0.19	0.23	0.21	0.16	0.15	0.16	0.13
$LSD_{(0.05)}$T		0.37	0.34	0.24	0.21	2.39	2.26	0.77	0.71
$LSD_{(0.05)}$ I* T		0.13	0.11	1.56	1.32	2.76	2.54	0.65	0.62

I_1= 100% I_2= 80% I_3= 60% T_1= 0 K_2O
T_2= 106.66 K_2O kg/ha (soil dressing) T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassein (foliar spray)
T_4= 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)

3.1.3. Effect of interaction:

The interaction between irrigation regimes and potassium application had a significant effect on growth traits in both seasons. As shown from the results the highest values were produced from I_1 wet treatment with T_4 treatment application of CGR (9.78 and 9.36) in the first period and (21.13 and 18.83) in the second period for both seasons, respectively. The root length and diameter take the same trend mentioned in CGR, where the highest values of root length (43.13 and 41.60 cm) and diameter (16.30 and 15.90 cm) were obtained with the previous treatment. Whilst the lowest values of interaction treatment were revealed by I_3 with T_1 treatment in both seasons. Similar results were obtained by Abd El–Mageed *et al.,* (2016) on soybean plants.

3.2. Yield component and yield:

Data for both seasons in Tables (4 & 5) present the drip irrigation regimes, potassium application levels, and interaction effects on the fresh root and leaves weight (kg/plant), dry root and leaves weight (g/plant), root yield ton/ha, foliage yield ton/ha and total yield ton/ha of fodder beet.

3.2.1. Fresh, dry root and leaves weight:

3.2.1.1. Effect of irrigation regimes:

Data presented in table 4 showed that fresh root and leaves weight (kg/ plant) had affected by water regimes, increasing irrigation water regimes significantly increased fresh root and leaves weight while there is a decrease in these characteristics by decreased water regimes, where I_1 treatment ranked first (1.610 and 1.577 kg/ plant) for fresh root weight followed by I_2 treatment (1.418 and 1.365 kg/ plant) and the lowest values revealed by I_3 treatment (1.215and 1.163 kg/ plant) in both seasons respectively. Likewise, the highest values for fresh leaves weight were revealed (0.453 and 0.447 kg/ plant) with I_1 treatment, and the lowest values were recorded (0.305 and 0.294 kg/ plant) with 1_3 treatments. These increases in vegetative growth parameters may be due to increased availability, absorption, and utilization of essential nutrients, and enhanced physiological and biochemical plant activities, which resulted in increased plant growth traits and vice versa in the case of insufficient irrigation water amount.

Table 4: Fresh root and leaves weight (kg/plant) and dry root and leaves weight (g/plant) of fodder beet in response to drip water regimes and potassium application levels in the 2015/16 and 2016/17 seasons

Treatments		**Fresh root weight (kg/plant)**		**Fresh leaves weight (kg/plant)**		**Dry root weight (g/plant)**		**Dry leaves weight (g/plant)**	
Drip irrigation regimes	**Potassium application levels kg/ha**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
I_1	**T_1**	1.350	1.345	0.360	0.351	158.50	157.90	50.40	49.14
	T_2	1.495	1.460	0.401	0.392	203.80	199.30	59.30	57.97
	T_3	1.706	1.681	0.489	0.488	303.60	299.20	68.46	67.48
	T_4	1.890	1.820	0.560	0.556	321.30	309.30	84.00	83.40
	Mean	1.610	1.577	0.453	0.447	246.80	241.43	65.54	64.50
I_2	**T_1**	1.256	1.190	0.326	0.321	152.80	144.80	48.90	48.15
	T_2	1.412	1.362	0.340	0.333	197.60	183.26	51.00	49.95
	T_3	1.470	1.396	0.411	0.406	271.36	269.10	61.65	60.90
	T_4	1.532	1.510	0.430	0.426	282.80	281.70	64.50	63.90
	Mean	1.418	1.365	0.377	0.372	226.14	219.72	56.51	55.73
I_3	**T_1**	0.990	0.973	0.272	0.270	130.18	127.90	38.08	37.80
	T_2	1.131	1.090	0.290	0.283	149.85	144.40	40.60	39.62
	T_3	1.350	1.261	0.312	0.302	245.90	229.75	46.80	45.30
	T_4	1.390	1.327	0.344	0.322	250.60	227.35	51.60	48.30
	Mean	1.215	1.163	0.305	0.294	194.13	182.35	44.27	42.76
T_1		1.199	1.169	0.319	0.314	147.16	143.53	45.79	45.03
T_2		1.346	1.304	0.344	0.336	183.75	175.65	50.30	49.18
T_3		1.509	1.446	0.404	0.399	273.62	266.02	58.97	57.89
T_4		1.604	1.552	0.445	0.435	284.90	272.78	66.70	65.20
$LSD_{(0.05)}$ I		0.064	0.061	0.025	0.025	11.93	11.86	2.72	2.13
$LSD_{(0.05)}$T		0.057	0.052	0.037	0.034	15.87	13.52	3.71	3.42
$LSD_{(0.05)}$ I* T		0.132	0.128	0.114	0.109	9.54	8.91	1.99	1.56

I_1= 100% I_2= 80% I_3= 60% T_1= 0 K_2O
T_2= 106.66 K_2O kg/ha (soil dressing) T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassein (foliar spray)
T_4= 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)

These results are those found by Abd El-All and Makhlouf, (2017) who found that irrigation by 100% ET_o gave the maximum fresh root and leaves weight compared with 75% and 50% of reference crop evapotranspiration.

With respect, dry root and leaves weight (g/plant) take the same trend by decreasing irrigation regimes decreased significant root and leaves weight in both seasons. In this concern, the reduction in vegetative biomass caused by drought results in lower plant surface area which reduces the radiation use efficiency and photosynthetic activities (Badr *et al.,* 2004).

3.2.1.2. Effect of potassium application:

Concerning potassium application, previous data clearly show that T_4 treatment ranked first (1.604 and 1.552 kg/ plant) followed by T_3 treatment (1.509 and 1.446kg/ plant) for fresh root weight while the minimum values (1.199 and 1.169kg/ plant) produced by T_1 treatment (without potassium) in both seasons, respectively. Also, T_4 treatment ranked first (0.445 and 0.435 kg/ plant) followed by T_3 treatment (0.404 and 0.399kg/ plant) for fresh leaves weight whereas the minimum values recorded by T_1 treatment (0.319 and 0.314kg/ plant) in both seasons respectively. These results are in line with Tange *et al.,* (2015) who established that potassium is an essential mineral constituent that plays an integral role in plant growth and expansion processes. T_4 had the highest dry root and leaves weight, followed by T_3 and T_2, and T_1 had the lowest weight by a significant difference. These findings could be explained by the fact that potassium is involved in protein synthesis, carbohydrate metabolism, and enzyme activation, according to Wang *et al.,* (2013). In this regard, Egilla *et al.,* (2001) proposed that a sufficient supply of potassium can improve plant dry weight more than a lower concentration of potassium in soil under drought conditions.

3.2.1.3. Effect of interaction:

The previous data showed a significant interaction between irrigation regimes and potassium application levels on fresh and dry root and leaves weight in the two seasons. Irrigation by 100% ETo with T_4 treatment recorded the greatest values with significant differences between other treatments. The lowest values were revealed by 60% ETo with T_1 treatment.

3.2. Root, foliage, and total yield (ton/ha):

3.2.1. Effect of irrigation regimes:

Root, foliage, and total yield were significantly affected by irrigation regimes (Table 5). I_1 fully irrigated treatment gave higher root yield (62.72 and 58.24 ton/ ha), greater foliage yield (15.33 and 13.82 ton/ ha), and higher total yield (78.05 and 72.06 ton/ ha) in both seasons, respectively. Followed by80% ETo (56.42 and 53.07 ton/ ha) for root yield, foliage yield (12.88 and 11.89 ton/ ha), and total yield (69.29 and 64.96 ton/ ha) while 60%ETo recorded the lowest values for root yield (37.69, and 36.15 ton/ ha), foliage yield (10.05 and 9.21 ton/ ha) and total yield (47.74 and 45.35 ton/ ha) in both seasons, respectively. These findings are consistent with those of Hall *et al.,* (1990), who found that water stress reduces photosynthesis and respiration.

Sakr *et al.,* (2014) and Yolcu *et al.,* (2021) found that irrigation by 100% ETo gave the maximum total forage yields (ton/ fad) in fodder beet compared with other treatments of reference crop evapotranspiration.

3.2.2. Effect of potassium application:

It is clear from previous data that potassium application treatments had a significant effect on yield and its components of fodder beet. Increasing potassium application level treatments gave the maximum values of these characters in both seasons. The maximum values of root yield (59.03 and 56.11 ton/ ha), foliage yield (15.19 and 13.88ton/ ha), and total yield (74.22 and 69.99 ton/ ha) were obtained under T_4 treatment while the lowest values were recorded by T_1 treatment where recorded for root yield (46.15 and 43.50ton/ ha), foliage yield (10.73 and 9.85ton/ ha) and total yield (56.87 and 53.35ton/ ha) in both seasons, respectively. The benefits of increasing potassium fertilization levels can be attributed to potassium's vital regulatory functions in photosynthesis, photosynthesis translocation, improved osmotic adjustment, and activation of plant enzymes and antioxidant defense systems (Rani *et al.,* 2021). These results are in agreement with those indicated by Kassab *et al.,* (2012) and Nashed *et al.,* (2019) who explained that increased potassium levels from 24 to 96 K_2O kg /fad increased significantly both fresh and dry weight of fodder beetroot and that potassium plays an important role in dry matter accumulation in plant storage organs. Xu *et al.,* (2020) suggested that potassium is involved in the activation of a large number of enzymes involved in the production and translocation of photosynthates.

Table 5: Root, foliage, and total yields ton/ha of fodder beet in response to drip water regimes and potassium application levels in the 2015/16 and 2016/17 seasons

Treatments		Root yield ton/ha		Foliage yield ton/ha		Total yield ton/ha	
Drip irrigation regimes	**Potassium application levels kg/ha**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
I_1	**T_1**	56.45	51.66	12.67	11.67	69.12	63.33
	T_2	60.49	55.52	13.86	12.07	74.35	67.59
	T_3	63.54	57.38	15.95	14.70	79.49	72.08
	T_4	70.39	68.40	18.83	16.84	89.22	85.24
	Mean	62.72	58.24	15.33	13.82	78.05	72.06
I_2	**T_1**	49.07	46.49	10.54	9.71	59.61	56.20
	T_2	52.69	49.73	11.16	10.26	63.85	59.99
	T_3	59.31	56.32	14.37	13.38	73.68	69.70
	T_4	64.60	59.74	15.43	14.20	80.03	73.94
	Mean	56.42	53.07	12.88	11.89	69.29	64.96
I_3	**T_1**	32.92	32.35	8.97	8.16	41.89	40.51
	T_2	34.57	33.58	9.71	8.66	44.28	42.24
	T_3	41.18	38.46	10.21	9.40	51.39	47.86
	T_4	42.10	40.19	11.31	10.61	53.41	50.80
	Mean	37.69	36.15	10.05	9.21	47.74	45.35
T_1		46.15	43.50	10.73	9.85	56.87	53.35
T_2		49.25	46.28	11.58	10.33	60.83	56.61
T_3		54.68	50.72	13.51	12.49	68.19	63.21
T_4		59.03	56.11	15.19	13.88	74.22	69.99
$LSD_{(0.05)}$ I		6.18	5.34	1.76	1.55	3.72	3.53
$LSD_{(0.05)}$T		2.43	2.12	0.65	0.62	2.41	2.76
$LSD_{(0.05)}$ I* T		2.96	2.74	0.52	0.46	1.95	1.91

I_1= 100% I_2= 80% I_3= 60% T_1= 0 K_2O
T_2= 106.66 K_2O kg/ha (soil dressing) T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassein (foliar spray)
T_4= 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)

3.2.3. Effect of interaction:

The effect of the interaction between irrigation regimes and potassium application levels was significant on the root, foliage, and total yield (ton/ ha) of fodder beet. However, the highest values for root yield (70.39 and 68.40 ton/ ha), foliage yield (18.83 and 16.84 ton/ha), and total yield (89.22 and 85.24 ton/ha) in both seasons, respectively were found with 100 % ETo irrigation regimes (I_1 wet treatment) in combination with T_4(106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)) potassium application treatment while the lowest values were recorded by 60 % ETo irrigation regimes treatment in combination with T_1 (0 K_2O)potassium application treatment for the same previous traits. Similar results were recorded by Topak *et al.,* (2011) and Aksu and Altay (2020).

3.4. Quality traits:

Crude protein (CP %), crude fiber (CF %), total carbohydrates %, and potassium content (K %) in the root of fodder beet in response to drip water regimes, potassium application levels, and the interaction with them are presented in Table (6).

3.4.1. Effect of irrigation regimes

Data revealed that the highest values of crude protein (9.76 and 9.17 %), crude fiber (11.61 and 10.96 %), total carbohydrates (67.48 and 66.35%), and potassium content (0.383 and 0.366 %) were recorded with I_1 wet treatment. Further decreases in irrigation rate (80 and 60% ETo) resulted in lower values of the above-mentioned nutrients where the lowest values of crude protein (8.34 and 7.80 %), crude fiber (10.12 and 9.47 %), total carbohydrates (64.96 and 63.83 %) and potassium content (0.349 and 0.326 %) were revealed by I_3 dry treatment. These reductions may be attributed to less absorption of nutrients under 80 and 60% ETo irrigation regimes due to less applied irrigation water. These results are most likely due to a decrease in vegetative biomass, photosynthetic activities, and dry matter accumulation, which resulted in a decrease in crud protein and fiber. In this respect, El-Kassas *et al.,* (2008) and Aksu and Altay (2020) found that CP %, CF %, and K% of root were significantly increased under wet conditions at 100 % ETo. Besides, Yang *et al.,* (2021) stated that carbohydrate reduction under water stress conditions, that water scarcity causes stomatal closure, which prevents CO_2 diffusion into the air inside plant tissue, resulting in low photosynthetic efficiency.

Table 6: Quality traits in the root of fodder beet in response to drip water regimes and potassium application levels in the 2015/16 and 2016/17 seasons

Treatments		**Crude protein%**		**Crude fiber %**		**Carbohydrates %**		**K %**	
Drip irrigation regimes	**Potassium application levels kg/ha**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
I_1	**T_1**	8.75	8.08	10.68	10.03	66.55	65.42	0.338	0.321
	T_2	9.22	8.55	11.11	10.46	66.98	65.85	0.372	0.355
	T_3	10.19	9.42	12.12	11.47	67.99	66.86	0.404	0.387
	T_4	10.89	10.62	12.51	11.86	68.38	67.25	0.418	0.401
	Mean	9.76	9.17	11.61	10.96	67.48	66.35	0.383	0.366
I_2	**T_1**	7.29	6.62	9.22	8.57	64.33	63.20	0.325	0.308
	T_2	8.48	7.81	10.41	9.76	65.52	64.39	0.369	0.352
	T_3	9.89	9.22	11.57	10.92	66.68	65.55	0.351	0.334
	T_4	10.31	10.12	12.10	11.45	67.21	66.08	0.391	0.374
	Mean	8.99	8.44	10.83	10.18	65.94	64.81	0.359	0.342
I_3	**T_1**	6.52	5.85	8.43	7.78	63.56	62.43	0.307	0.284
	T_2	7.95	7.28	9.28	8.63	63.98	62.85	0.341	0.318
	T_3	9.11	8.44	11.04	10.39	65.31	64.18	0.362	0.339
	T_4	9.79	9.62	11.72	11.07	66.99	65.86	0.386	0.363
	Mean	8.34	7.80	10.12	9.47	64.96	63.83	0.349	0.326
T_1		7.52	6.85	9.45	8.79	64.81	63.68	0.323	0.304
T_2		8.55	7.88	10.27	9.62	65.49	64.36	0.361	0.341
T_3		9.73	9.03	11.58	10.93	66.66	65.53	0.372	0.353
T_4		10.33	10.12	12.11	11.46	67.53	66.40	0.398	0.379
$LSD_{(0.05)}$ I		0.41	0.35	0.52	0.48	0.84	0.76	0.009	0.003
$LSD_{(0.05)}$T		0.93	0.87	0.42	0.40	0.40	0.35	0.005	0.001
$LSD_{(0.05)}$ I* T		0.44	0.41	0.38	0.32	0.36	0.35	0.029	0.024

I_1= 100% I_2= 80% I_3= 60% T_1= 0 K_2O
T_2= 106.66 K_2O kg/ha (soil dressing) T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassein (foliar spray)
T_4= 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray).

3.4.2. Effect of potassium application

Potassium application levels affected significantly all quality traits under study.T_4 treatment exhibited the maximum values for crude protein (10.33 and 10.12 %), crude fiber (12.11 and 11.46 %), total carbohydrates (67.53 and 66.40 %), and potassium content (0.398 and 0.379 %) whereas the lowest values for of crude protein (7.52 and 6.85 %), crude fiber (9.45 and 8.79 %), total carbohydrates (64.81

and 63.68%) and potassium content (0.323 and 0.304 %) were recorded with T_1 treatment in both seasons, respectively. As previously stated, these increases could be attributed to the role of potassium in enzyme activation involved in ATP production, which is more important in regulating photosynthesis rote, and other important solutes that are translocated and accumulated in the root of fodder beet. These were reported by EL-gamal *et al.,* (2016) and Hamada, (2019).

3.4.3. Effect of interaction:

There is a clear trend of the interaction effect of irrigation regimes levels and potassium applications on crude protein (CP%) crude fiber (CF %), total carbohydrates %, and potassium% in fodder beet where the values of these quality traits are still higher with the application of potassium under all irrigation levels than control treatment (irrigation water alone without potassium). These results might be ascribed to the supporting function of potassium in the improvement of water and efficient nutrient uptake needed for various physiological and biochemical activities with speeding up translocation of assimilates in the presence of the sufficient amount of available water, and consequently increased the chemical content. Furthermore, the quality traits were increased as a result of the treatment of potassium application T_4 combined with irrigation regimes level at I_1 (100% ETo) compared with either those of irrigation treatments. Similar results were obtained by El-saady, (2017) and Aksu and Altay (2020).

3.5. Soil water relations

3.5.1. Amount of applied irrigation water (AIW)

Table 7 demonstrated the monthly and total irrigation water applied by the drip irrigation system to fodder beet based on irrigation treatments for two growing seasons. The results presented that, in the first season, the total amount of irrigation water applied for 100, 80, and 60% of ETo irrigation treatments was 5102.2, 4126.1, and 2974.1 m^3 /ha, respectively, while it was 5208.7, 4152.3 and 2853.0 m^3 /ha in the second season. The Differences in the amount of irrigation water applied between two consecutive seasons due to climatic conditions. Results presented the normal trend of increasing applied irrigation water with the advance in plant growth and decrease at the ripening stage. The findings were consistent with those of EL-Darder *et al.,* (2017).

Table 7: The monthly and total irrigation water applied by a drip irrigation system to fodder beet based on drip irrigation regimes for two growing seasons.

Drip irrigation regimes	**2015/16**									
	16th Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**3rd May**	**Total m^3**	**Total $m^{3/}$/ha**
I_1= 100% ETo	45.72	57.23	43.58	35.87	44.91	68.74	103.15	111.02	510.22	5102.2
I_2= 80% ETo	36.34	45.53	34.67	28.45	35.69	54.48	84.79	92.66	412.61	4126.1
I_3= 60% ETo	21.33	33.84	25.76	21.04	26.48	40.23	60.43	68.3	297.41	2974.1
	2015/16									
	20th Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**7th May**	**Total m^3**	**Total m^3/ha**
I_1= 100% ETo	44.71	58.11	43.51	35.77	46.75	69.14	107.51	115.38	520.87	5208.7
I_2= 80% ETo	35.63	46.24	34.6	28.36	37.17	54.8	85.28	93.15	415.23	4152.3
I_3= 60% ETo	20.31	31.37	22.37	20.44	24.87	39.89	56.09	69.96	285.33	2853.0

3.5.2. Water utilization efficiency (W.Ut.E.)

Water utilization efficiency (W.Ut.E.) is a quantitative term that describes the relationship between crop yield and the amount of water applied. It is an effective indicator for quantifying the impact of irrigation scheduling decisions on water management (Wu *et al.,* 2014). The effect of drip irrigation regimes, potassium application levels, and interaction between them on water utilization efficiency (W.Ut.E.) values for the two growing seasons is presented in Table 8.

3.5.3. Effect of irrigation regimes

The current results indicated that irrigation at I_2 treatment exhibited the maximum W.Ut.E value of 16.79 kg/ $m^3$for I_2 treatment followed by 16.05 kg/ m^3 for I_3 treatment whilst the minimum W.Ut.E. value (15.30 kg/ m^3) was recorded with I_1treatment irrigation regimes in the first season. Otherwise, in the second season, the maximum W.Ut.E value was 15.90kg/ m^3 for I_3 treatment followed by 15.65 kg/

m^3 for I_2 treatment, and the minimum W.Ut.E. value (13.84 kg/ m^3) was revealed with I_1 treatment of irrigation regime. The results show that W.Ut.E. values from the first season were higher than those from the second season. These results are in harmony with those reported by El-Kassas *et al.,* (2008) who observed that increasing soil moisture stress resulted in higher water use efficiency values by fodder beet plants. Furthermore, Djaman *et al.,* (2018) stated that if the supply is within the evapotranspiration limit, water use efficiency is not highly conditional on available water. This is the major physiological reaction of the decreased transpiration in the plants under less water irrigation treatment and so promotes water productivity. Hiekal, (2022) concluded that less irrigation ETo gave higher W.Ut.E. values in fodder beet plants.

Table 8: Water utilization efficiency (W.Ut.E. kg/ m^3) in response to drip irrigation regimes and potassium application levels in both seasons

Treatments		**Total yield ton/ha**		**(W.Ut.E.) Kg /m3**	
Drip irrigation regimes	**Potassium application levels kg/ha**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
	T_1	69.12	63.33	13.55	12.16
	T_2	74.35	67.59	14.57	12.98
I_1	**T_3**	79.49	72.08	15.58	13.84
	T_4	89.22	85.24	17.49	16.36
	Mean	78.05	72.06	15.30	13.84
	T_1	59.61	56.20	14.45	13.53
	T_2	63.85	59.99	15.47	14.45
I_2	**T_3**	73.68	69.70	17.86	16.79
	T_4	80.03	73.94	19.40	17.81
	Mean	69.29	64.96	16.79	15.65
	T_1	41.89	40.51	14.08	14.20
	T_2	44.28	42.24	14.89	14.81
I_3	**T_3**	51.39	47.86	17.28	16.78
	T_4	53.41	50.80	17.96	17.81
	Mean	47.74	45.35	16.05	15.90
T_1		56.87	53.35	14.03	13.30
T_2		60.83	56.61	14.98	14.08
T_3		68.19	63.21	16.91	15.80
T_4		74.22	69.99	18.28	17.33

I_1= 100% I_2= 80% I_3= 60% T_1= 0 K_2O
T_2= 106.66 K_2O kg/ha (soil dressing) T_3= 106.66 K_2O kg/ha (soil dressing) + 2.38 liter/ ha potassein (foliar spray)
T_4= 106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)

3.5.4. Effect of potassium application levels

It is clear from the data presented in Table (8) that the water use efficiency had significantly been affected and increased by increasing potassium application levels**.** The best records values were achieved with T_4 treatments (18.28 and 17.33 kg/ m^3) followed by T_3 treatment (16.91 and 15.80 kg/ m^3) whereas the worst records values registered with T_1 treatment (14.03 and 13.30 kg/ m^3) in both seasons, respectively. These results go in line with those obtained byGrzebisz *et al.,* (2013) who proposed that fertilization practices that provide adequate nutrition for crop plants play a significant role in water resource efficiency and conservation.

The improvement of plant-water relations is probably due to potassium inclusive in important activities within the plant, since they involve in osmotic adjustment, and improves root water and essential elements uptake (El-saady, 2017). Similar results were obtained by Saudy *et al.,* (2022) on wheat, Kassab *et al.,* (2012), and Seiam *et al.,* (2020) on fodder beet who stated that water use efficiency was increased by raising potassium fertilization.

3.5.5. Effect of interaction

The response of fodder beet plants regarding the effect of interaction was the same water use efficiency indicating that the highest significant interaction values were achieved at T_4 potassium application treatment when plants were subjected to water irrigation regimes I_3 (17.96 and 17.81 kg/ m^3) in both seasons, respectively. On the contrary, the lowest significant values in the same connection were shown by T_1 potassium application treatment when obtained the highest amount of irrigation I_1

treatment (13.55 and 12.16 kg/ m^3) in both seasons, respectively. Such results are in harmony with those obtained by Topak *et al.,* (2011) and Seiam *et al.,* (2020) who demonstrated that water use efficiency increased significantly by decreasing the irrigation regimes (water stress) and increasing potassium supply produced the highest values of growth and yield traits as well as W.Ut.E.of fodder beet plants.

4. Conclusion

Our results showed that the maximum fodder beet yield and quality were achieved from I_1wet treatment (irrigated with 100% ETo) in combination with T4 treatment of potassium application level (106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray)) followed by I_2 treatment (80% ETo) and the same level of potassium application level.

On the other hand, the maximum value of water utilization efficiency was enhanced under irrigation at 80%ETo in the first season whereas 60% ETo in the second season plus T_4 treatment of potassium application level in both seasons. Therefore, drip irrigation regimes of 80% ETo in combination with adding (106.66 K_2O kg/ha (soil dressing) + 4.76 liter/ ha potassein (foliar spray))

Generally, it was obvious that irrigated by 80% ETo and T_4 treatment of potassium application level produced to save 20% which is the major disquiet nowadays for the arid regions

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