Arab Universities Journal of Agricultural Sciences
(2022) 30 (2) 185-194
Website: http://ajs.journals.ekb.eg

Effects of Irrigation Systems on Sugar Beet Yield

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https://doi.org/10.21608/AJS.2022.107701.1438

Received 18 December 2021; Accepted 29 July 2022

Keywords:

Drip irrigation system, Subsurface irrigation system, Salinity, Root yield, Water Use Efficiency, Penetration Power

Abstract: The combined data from two growing seasons in a field experiment study by using two irrigation systems (surface and subsurface drip) in terms of additional water for sugar beet plants under saline conditions are used to estimate root and sugar yield, water use efficiency and root penetration power at the time of harvest. Water salinity levels of 6000 and 8000 ppm were applied to irrigate sugar beet from the time of planting on October 3 to the time of harvest on April 22 with three additions of water (limited 1750, moderate 2500 and optimum 3250 m^3/fed). The results are summarized as follows: - The heaviest root and highest sugar yield as well as highest water use efficiency were recorded when using subsurface irrigation system, 6000 ppm water salinity level, and moderate or optimum irrigation water (2500 or 3250 m^3/fed). Oppositely, the highest penetration power values were obtained using drip irrigation systems with low water quantity (1750 m^3/fed) and high-water salinity level (8000 ppm).

1 Introduction

Sugar beet (*Beta vulgaris* L.), which is regarded as Egypt's second largest producer of sugar after the sugar cane crop, can be cultivated under various environmental stresses. This plant accounts for 45% of the world's sugar production area (FAO 2015). Many researches focus on how to increase sugar yield production to cover gap between production and consumption. Water productivity control may be crucial in irrigation to maximize production based on the efficiency of water productivity. Irrigation systems are critical inputs in agricultural practices, particularly in life plant cultivation, aimed toward increasing yield productivity. Improved irrigation systems using current techniques, such as surface and subsurface drip irrigation systems for sugar beet crop production under saline conditions, maximize plant productivity and save water.

Salinity and quantity of irrigation water impact sugar beet crop productivity, particularly under radish soil, which is affected by salt and poor nutrient detail content material of the water or soil. Crop productivity decreased with increasing water salinity stress and water amount up to the recommended rate of irrigation under the same conditions (Eid and Ibrahim 2010).

The objective of the observation was modified to evaluate the impact of the irrigation system, salinity stress, and water quantity on the yield, quantity, some yield characteristics, and penetration power of sugar beet. The goal was to improve the water use efficiency (WUE) for both sugar beet and sugar productivity under saline water and soil conditions in the Ras Sudr region.

2 Materials and Methods

Field experiments were conducted at the Ras Sudr research station at the Desert Research Center in the South Sinai government, Egypt, during the growing seasons of 2017/2018 and 2018/2019. The impact of the irrigation system, quantity of irrigation water applied, and water salinity level on root and sugar yield, WUE, and penetration power under saline soil and water, was investigated.

2.1 Irrigation systems

Two irrigation systems are installed in the experimental area. The two irrigation systems contain the following general components:

Control head: positioned on the source of the water deliver Main line: made from 50-mm diameter, PVC. Sub main line: manufactured from 50-mm diameter PVC and was used to deliver water from the principal line to the manifold. Laterals: made of 16mm P.E and become a built-in drip line with a common discharge 4 L/h at 1 bar **(Fig 1).**

2.2 The cultivated crop

Sugar beet *Beta vilgarus* (SV 184) was sown at the rate of 6 kg/fed and hand-planted at a depth of 3–5 cm on a planting area of 30cm and 50 cm between rows with (2 – 3) seeds per hill on October 3rd. The seedlings were thinned to one plant per hill after thirty days of seeding and harvested on April 22nd. The other agricultural operations are performed as recommended under the same conditions.

2.3 Soil and water analysis

The records of the station's chemical analysis of irrigation water are presented.

2.3.1 Irrigation water analysis

Average growing seasons on the research station's irrigation water were chemically analyzed at 6000 and 8000 ppm **(Table 1)**.

2.3.2 Soil mechanical and chemical analyses

Soil samples were obtained and air-drier before the sowing and planting dates of each examination. The resulting soil solution was used for chemical analysis **(Table 2)**.

2.4 Meteorological

A meteorological unit at the research station (Desert Research Center) recorded the climate data as average during both growing seasons. **(Table 3)**.

2.5 Experimental practical

The area experiments (1260 m²) consisted of plots with 3 replications. Each replicate contained 12 treatments that combined two irrigation systems (surface and subsurface drip) with two water salinity levels (6000 and 8000 ppm) and three irrigation water quantities (1750, 2500, and 3250 m³/fed) under saline soil and water. The main plots had already been occupied (surface and subsurface drip). Each sub-plot was divided into two parts, with the first part irrigated at 6000 ppm and the second at 8000 ppm. Three different water quantity (1750, 2500, and 3250 m³/fed) were used for each salinity level and were distributed *via* complete randomization in all experimental units (24 m²).

Table 4 shows the crop coefficient for each growth stage of the seasons of sugar beet development under the calcareous soil region, according to Allen et al (2006).

2.6 Data measurements and recorded

Random samples (5 plants) were taken from each experimental plot on the harvesting date (April, 22) to evaluate the following:

2.6.1 Crop yield

Root yield (t/fed).
Sugar yield (t/fed) = root yield (t/fed) × sucrose %.

2.6.2 Water use efficiency

WUE was calculated for both root yield and sugar yield.

$$WUE_{root\ yield} = \frac{\text{root yield (ton/fed)}}{\text{water quantity (m}^3\text{/fed)}} \times 1000, kg/m^3$$

$$WUE_{sugar\ yield} = \frac{\text{sugar yield (ton/fed)}}{\text{water quantity (m}^3\text{/fed)}} \times 1000, kg/m^3$$

2.6.3 Penetration power

A bench top substance tasting apparatus (Tinius Olsen- version H5ks-USA) was used to determine the mechanical properties of the sugar beet root.

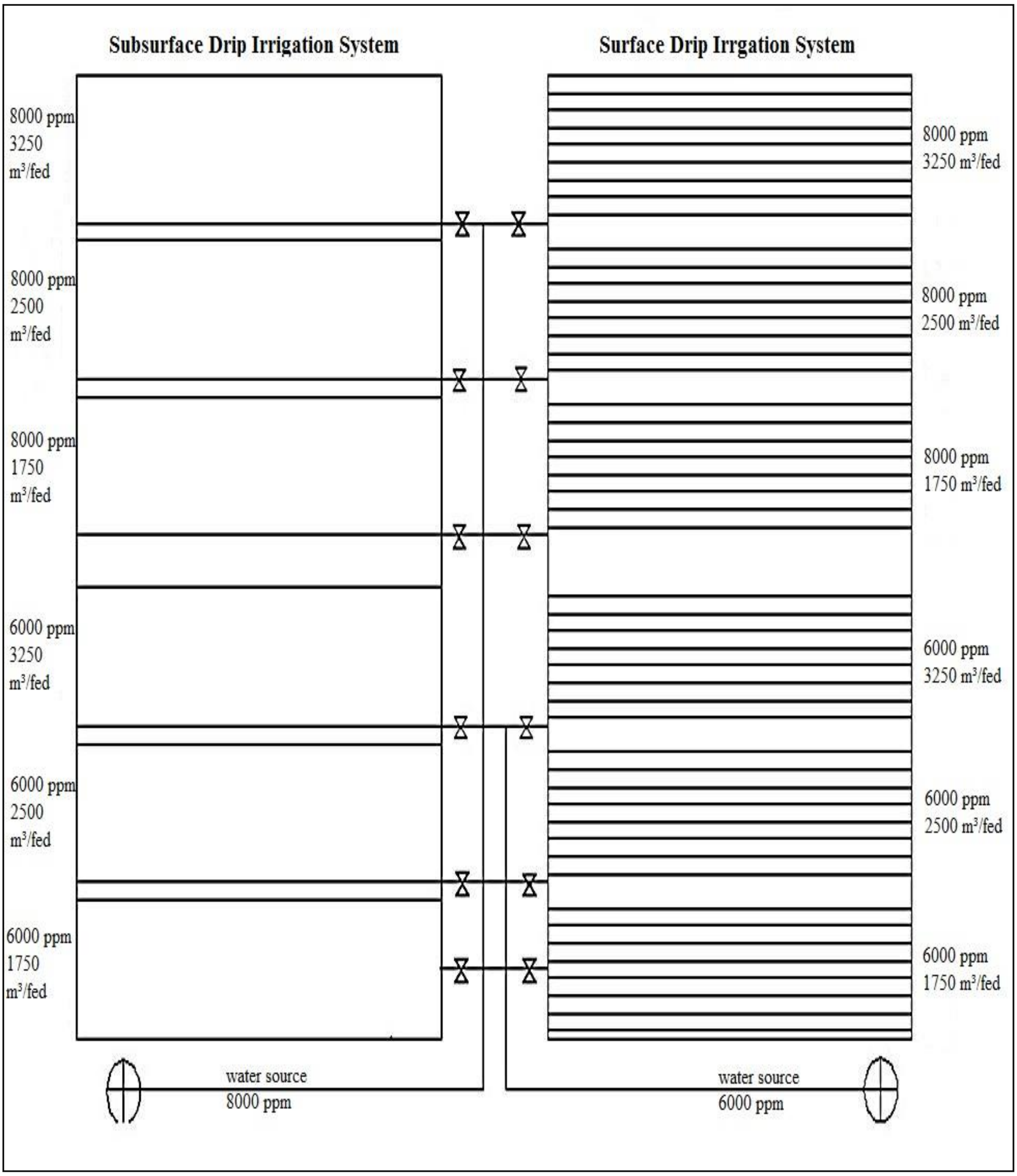

Fig 1. The experimental plan

Table 1. Chemical analysis of irrigation water 6000 and 8000 ppm as average in winter season at Ras Sudr

Salinity level	PH value	EC (dS/m)	T.D.S (ppm)	Cations				Anions		
				Na	K	Ca	Mg	Cl	HCO_3	SO_4
6000 ppm	7.9	9.40	5926	51.75	1.29	23.36	25.55	9.81	2.67	9.45
8000 ppm	8.0	12.53	7936.2	69.36	1.80	31.16	34.75	13.3	3.47	12.67

Table 2. Mechanical and chemical analysis of the studied soil

A- Mechanical analysis				
Sand%	**Silt%**	**Clay%**	**Other**	**Soil texture**
81.10	9.82	8.70	0.38	SANDY

B- Chemical analysis													
Cautions										**Anions**			**TDS p.p.m**
PH	**E.C.**	**$CaCO_3$**	**Ca**	**Mg**	**Na**	**K**	**N**	**P**	**Fe**	**HCO_3**	**Cl**	**SO_4**	
7.85	**8.74**	**56.37**	**24.85**	**5.45**	**57.5**	**51.5**	**26.1**	**5.1**	**4.2**	**6.1**	**61.7**	**26.7**	**5635**

Table 3. The average climate data of the Ras Sudr research station throughout the 2017/2018 and 2018/2019 seasons

Month	Temp. Max.	Temp. Min.	Temp. mean	Relative Hum%	Wind speed	Rain mm
Oct.	32.2	19.0	21.1	58	16.6	3.5
Nov.	28.9	15.3	22.1	64	12.1	3.9
Dec.	24.8	11.1	18.0	60	9.4	15.8
Jan.	21.5	8.9	15.2	61	6.3	26.5
Feb.	20.0	7.8	13.9	56	5.7	22.4
March	21.0	9.2	15.1	53	4.8	7.5
April	23.4	12.7	13.1	47	6.3	4.5

Table 4. Crop factor (Kc) of sugar beet in the semi-arid region

Growth stage	Initial	Crop development	Mid-season	Late-season
Duration	1 up to 30	31 – 90	91 – 160	161 – 200
Total days	30	60	70	40
Kc	0.35	1.2	1.2>Kc<0.7	0.5

2.6.4 Statistical analysis

Research data were collected and recorded using the statistical program (SPSS) software "Ver 20" for Windows (8.1).

3 Results and Discussion

3.1 Root yield

The results presented in **Fig 2** and **Table 5** show that the root yield (t/fed) was affected by the irrigation system. The subsurface irrigation and surface drip systems exhibited the highest and lowest value of the root yield/fed, respectively. Compared with subsurface irrigation, sugar beet plants produced more roots with less water. This result is consistent with those of Topak et al (2011), and Morad et al (2012)**.**

Increasing the water salinity level from 6000 to 8000 ppm significantly reduced the root yield/fed. The highest yield/fed (ton), 18.2 t/fed, was obtained at a salinity level of 6000 ppm, whereas, the yield at 8000 ppm was about 13.3 t/fed. These results showed that the root yield/fed increased due to the low salinity level. These results are consistent with those of Mahmoud and Aboushal (2007), Hajiboland et al (2009), and Eid and Ibrahim (2010). The root yield (t/fed) significantly increased when the applied irrigation water quantities increased from 1750 to 2500 and then to 3250 m^3/fed. The maximum and heaviest sugar beet yield/fed (19.6 t/fed) was obtained at 3250 m^3/fed, whereas the lowest yield (10.85 t/fed) was obtained at 1750 m^3/fed **Table 5 and Fig 2**, which showed that reductions in the quantity of applied irrigation water reduced the root yield (Moursi and Darwesh 2014, Kiymaz and Erlek 2015).

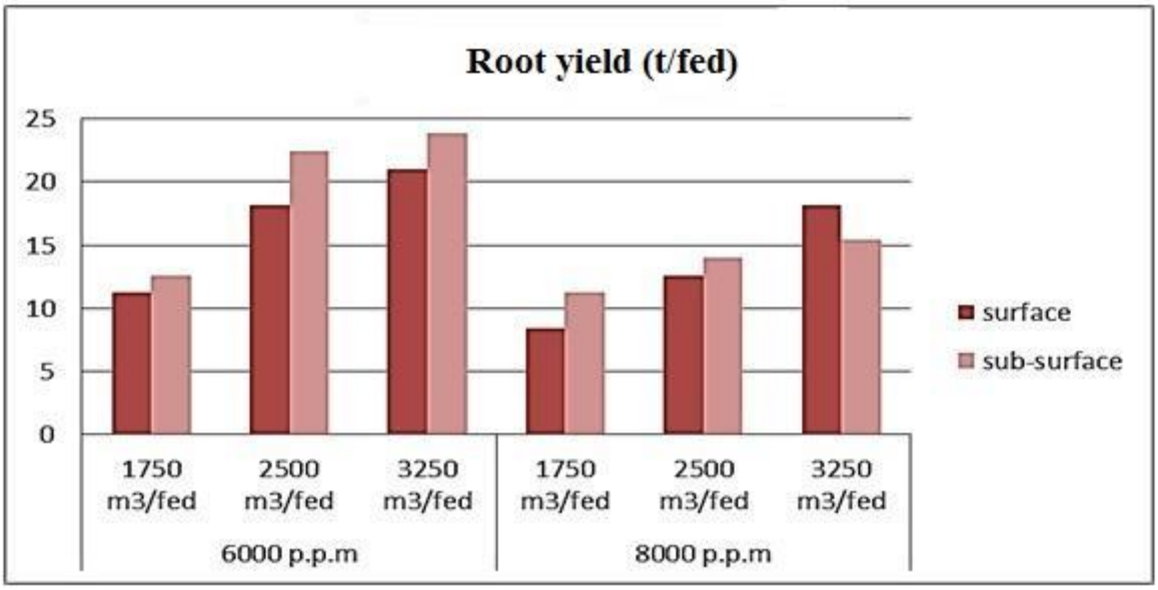

Fig 2. Root Yield (t/fed)

Table 5. Effect of surface and subsurface irrigation system and water salinity and irrigation water quantities on root yield and its quality and water use efficiency (WUE)

Statistics of Variance	Root yield (t/fed)	Sugar yield (t/fed)	WUE of root (kg/m³)	WUE of sugar (kg/m³)	Penetration power (N)
A. Irrigation systems					
Surface drip irrigation.	14.933	4.633	5.92	1.910	95.62
Sub surface irrigation.	16.567	4.314	6.70	1.810	109.62
Significant	*	**	*	**	**
B. Salinity levels					
6000 p.p.m.	18.200	4.633	7.23	1.930	92.83
8000 p.p.m.	13.300	4.313	5.39	1.790	112.41
Significant	**	**	**	**	**
C. Water quantities					
1750 m^3/fed.	10.850	3.812	6.33	2.180	109.63
2500 m^3/fed.	16.800	4.817	6.65	1.930	102.19
3250 m^3/fed.	19.600	4.791	5.95	1.480	96.04
Significant	**	**	N.S.	**	**
D. Interactions					
1- Irr. Sys. × Sali. Level	**	**	N.S.	**	**
2- Irr. Sys. × Water. Qun.	**	**	N.S.	**	**
3- Sali. Level × Water. Qun.	N.S.	**	N.S.	**	**
4-Irr.Sys. × Sali Level ×Water Qun.	**	**	N.S.	**	**

Table 5 shows that the interaction between the various irrigation devices, water salinity level, and irrigation water system had significant effects. However, the interaction between the salinity level and water quantity was insignificant. The interaction between irrigation water quantity and factors, such as (salinity level and water quantity), was rather significant and had a significant impact on the root yield/fed.

3.2 Sugar yield

Table 5 and **Fig 3** show that the surface drip system had the highest average sugar yield (4.633 t/fed) and the subsurface drip system had the lowest value (4.314 t/fed). The impact of irrigation systems on the sugar yield (t/fed) may have also resulted from the corresponding impact of water quantities and salinity levels on sugar plants under saline conditions These results are consistent with those of Tognetti et al (2003), and Hassanli et al (2010).

Table 5 and **Fig 3,** show that high water salinity level decreased the sugar yield. The lowest sugar yield (4.313 t/fed) was obtained at a water salinity level of 8000 ppm, whereas a water salinity level of 6000 ppm produced a sugar yield of 4.633t/fed. However, the yield increased as the water volume increased (the maximum, intermediate, and lowest sugar yields were 4.817, 4.791, and 3.812 t/fed irrigated by 2500, 3250, and 1750 m³/fed/season, respectively). These results are consistent with those obtained by Morad et al (2012), Moursi and Darwesh (2014), Masri et al (2015), and El-Darder et al (2017).

The interactions between the water irrigation treatment conditions (irrigation system, salinity level, and quantity of water) were highly significant for the interactions considered in this examination of sugar yield/fed.

3.3 Water use efficiency

3.3.1 Root yield

The effects demonstrated in **Table 5** and **Fig 4** show that water irrigation systems, i.e., surface and subsurface drip irrigation systems, had a significant impact on the WUE related to the root yield (kg/m³). The surface and subsurface drip irrigation systems produced common root yields of 5.92 and 6.70 (kg/m³), respectively; consequently, the subsurface irrigation system was preferred for irrigating sugar beet under saline conditions. These results are shown alongside those obtained by Morad et al (2012), and El-Darder et al (2017). When a water salinity level of 6000 ppm was used, the WUE was 7.23 kg/m3, whereas the WUE was 5.39 kg/m3 at 8000 ppm.

However, the data in **Table 5** and **Fig 4** show that the impact of irrigation water quantity on WUE for sugar beet plant root yield increases with decreasing water quantities. Water quantities of 1750, 2500, and 3250 m³/fed produced 6.33, 6.65, and 5.95 kg/m³, respectively.

3.3.2 Sugar yield

Table 5 and **Fig 5** demonstrate that sugar yield using surface drip irrigation was higher than that using subsurface drip irrigation systems (1.91 and 1.81kg/m³, respectively). These results are consistent with those presented by Abbas et al (2018), and Feizi et al (2018).

The highest WUE value for the sugar yield (1.93 kg/m³) was obtained at a water salinity level of 6000 ppm, whereas a WUE value of 1.79 kg/m³ was obtained at 8000 ppm. This indicated that water salinity has a significant impact on WUE. These effects are consistent with those obtained using the same method by Mahmoud and Aboushal (2007), Hajiboland et al (2009), and Morad et al (2012).

Table 5 and **Fig 5** also show that increasing the quantity of irrigation water from 1750 to 2500 and 3250 m³/fed negatively impacted the WUE of sugar. Sugar beet yields of 2.18, 1.93, and 1.48 kg/m³ were obtained for irrigation amounts of (1750, 2500, and 3250 m³/fed), respectively. These results are consistent with those obtained by Sahin et al (2014).

The interactions between the irrigation system and each element (water salinity level and quantity of irrigation water) and those between the salinity level and water quantity have demonstrated significant effects. Moreover, a third interactions between the study's treatments had a significant impact on the WUE of sugar yield of sugar beet plants under saline conditions.

3.4 Root Penetration power of sugar beet

Soil and water content from organic and mineral matter improved photosynthesis, plant growth and ultimately vital rooting in plants. The crop sugar beet is severely impacted by the presence of water. In addition, the strength needed to penetrate the sugar beet roots or the flexibility of the production depends on the length and width of the. The results revealed that irrigation treatments, i.e., irrigation systems (surface and subsurface), salinity level (6000 and 8000 ppm), and water quantity (1750, 2500, and 3250 m³/fed), have a significant impact on the root penetration power of sugar beet plants under saline stress. The subsurface drip irrigation system had the highest root penetration power (l09.52 N); whereas the drip irrigation system had a minimum value (95.52N). The sugarbeet root's penetration power (112.41 N) was reduced when the water salinity level reached 8000 ppm. However, decreasing the extent of salinity in the irrigation water to about 6000 ppm reduced the penetration power to 92.83 N. The aforementioned reduction

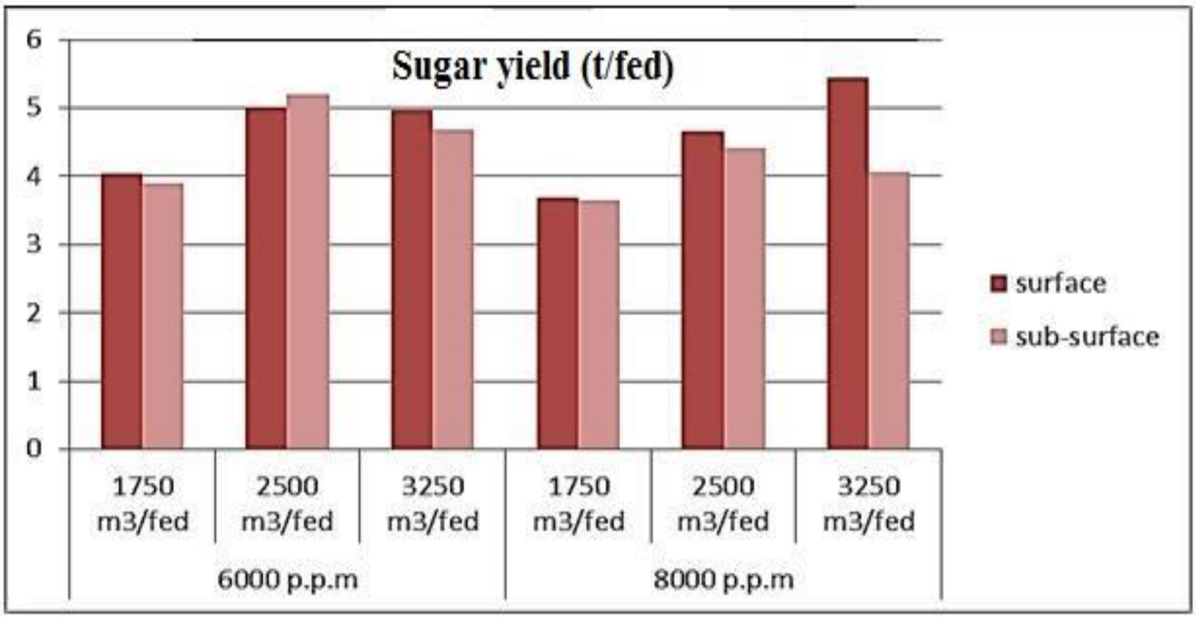

Fig 3. Sugar yield (t/fed)

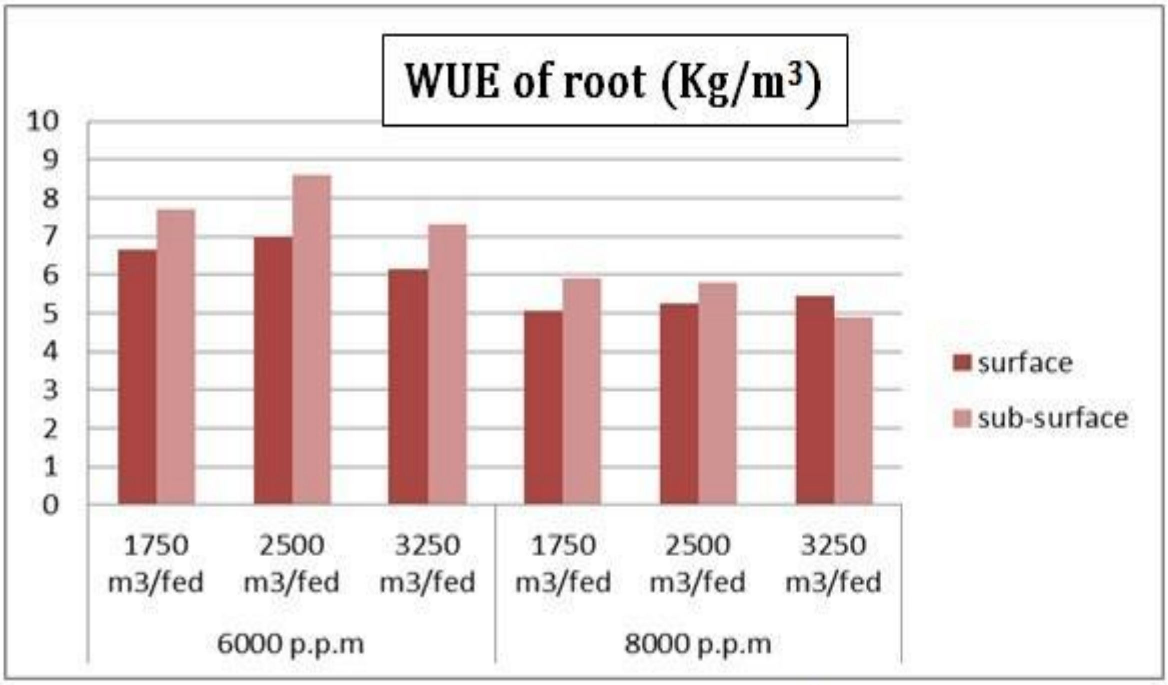

Fig 4. WUE of root (kg/m^3)

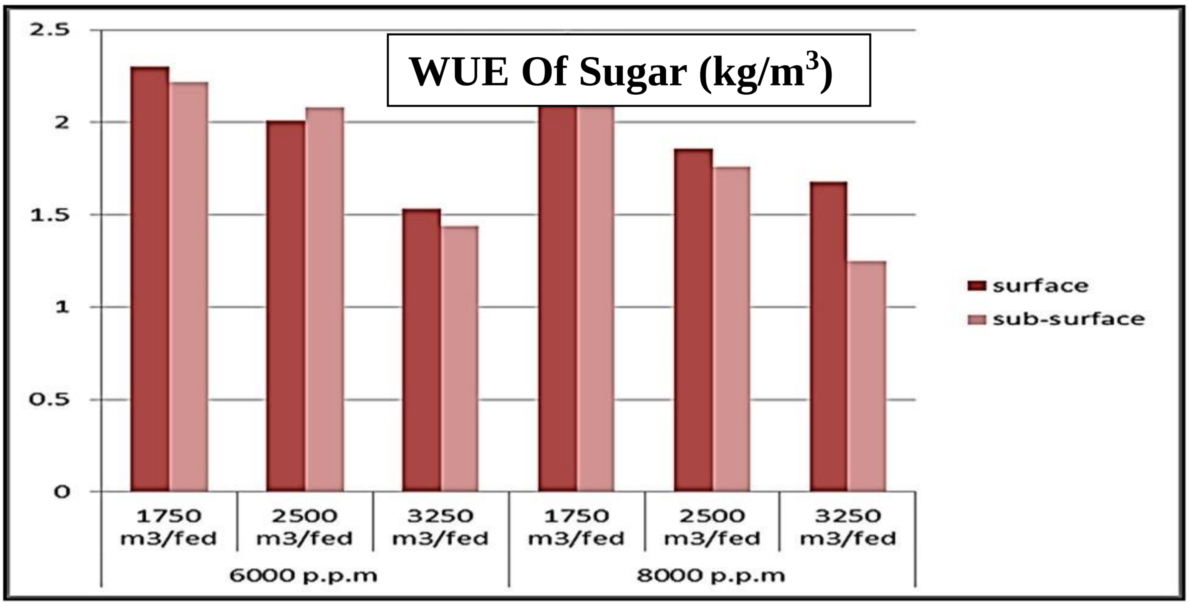

Fig 5. WUE of sugar (kg/m^3)

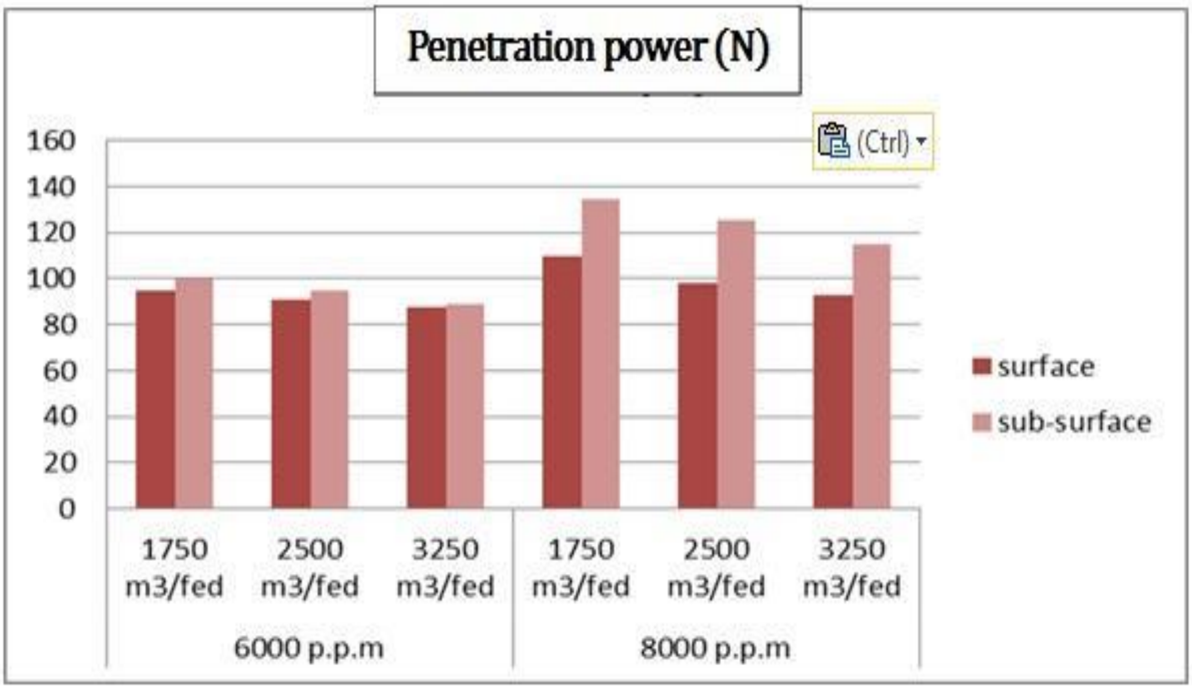

Fig 6. Penetration power (N)

in penetration power resulted from the impact of a low water salinity level on the water uptake and absorption from root cells. Therefore, increasing the content of fiber tissue and solid cells within the roots of sugar beet plants could negatively impact the roots' penetration power under saline conditions.

The gradual increase in the amount of irrigation water from 1750 to 2500, and 3250 m³/fed had a significant impact on the penetration power of sugar beet root under water stress. Low water quantity (1750 m³/fed) yielded excessive penetration power (109.63N), and the lowest value (96.04N) occurred when water irrigation was conducted at a water volume of 3250m³/fed. However, an intermediate penetration force (102.19N) was observed after an irrigation rate of 2500 m³/fed there are no distinctions between them.

The interaction between irrigation systems, salinity, and water quantity, significantly impacted the foundation's penetration power. This was also observed for the interaction between the water quantity and each of those factors, as well as the interactions between the salinity level and water quantity. In other words, the triple interaction of the three irrigation treatments for sugar beet had a highly significant effect on the root's penetration power under saline conditions.

4 Conclusion

It could be concluded that the cultivation of sugar beet yield under saline conditions up to 6000 ppm. could be used with subsurface drip irrigation system and water irrigation rate not less than 2500 m^3/fed. Water irrigation rate and quantity throughout of life the sugar beet plant from seeding to harvesting dates was not less than about 2500 m^3/fed.

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