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# Evaluation of Interaction between Different Levels of Potassium and Water on Sugar Yield of Sugar Beet

Ghasem Tohidloo[1], Mohammad Ali Chegin[2] and Saeed Ghalebi[3]

[1] Islamic Azad University, Karaj Branch, Dept. of Agronomy and Breeding, Iran
[2] Sugar Beet Seed Institute. P.O. Box31585-4114 Karaj, Iran
[3] Soil and Water Research Institute, Karaj, Iran

**Abstract.** The experiments were conducted in light soil by employing Line Source Sprinkler Irrigation System (LSSI) in experimental field of Soil and Water Research Institute during 2002-2003. The experimental design was similar to split block design. The two sides of LSSI was considered as main plot, three levels of potassium (0, 150 and 300 kg/ha) as subplot and 4 irrigation levels (I1 to I4) as sub-sub-plot. The I1 to I4 irrigation treatments received about 11000, 9500, 6700 and 5300 m3/ha. water, respectively. Results showed that the number of harvested roots decreased with decreasing the amount of water. Root yields of $I_1$ to $I_4$ irrigation treatments were 37, 31, 16 and 6 t/ha, respectively. Applying more water had positive effects on sugar content. The white sugar yields of $I_1$ to $I_4$ irrigation treatments were 5.63, 4.55, 2.33 and 0.80 t/ha, respectively. Water use efficiency (WUE) in respect to root yield and white sugar yield increased with increasing the amount of water too. In range of 5000-9000 $m^3$ water, the WUE values were almost the same, however, at lower amount of irrigation WUE increased by increasing potassium fertiliser level. Result showed that root yield and sugar content do not response to the soil potassium concentration in well-irrigated treatment. Soil potassium content of distinguished treatments at the end of experiment was far below than that of at the beginning of experiment. So, in light soils where the available potassium is less than 250 m.eq./100 g soil, more than 300 k/ha potassium should be applied.

**Keywords:** Sugar Beet, Irrigation, Potassium Fertilizer, Water Stress, Water Use Efficiency (WUE), Line Source Sprinkler Irrigation System

## 1. Introduction

Nowadays, increasing WUE is urgent, necessary and inevitable, especially in dry and semi-dry conditions such as IRAN. Potassium is one of the important macro-elements that affects root yield and quality of sugar beet by increasing drought tolorance (Butrus and Nimah 1981). Using fertilizer without considering the soil water content is not possible. So, evaluation of interaction between fertilizers and soil water content is important.

Sugar beet has a long deep tap root and could take up water from 2 meter depth soil and has a wide range of drought tolerance and high osmotic adjustment capacity where, short periods of drought stress do not affects sugar yield. Root yield and sugar yield will not reduce and as long as soil moisture does not drop below wilting point (Winter, 1980). Restuccia *et al.*, (1995) reported that there is no obvious drought sensitive growth stage in sugar beet. Khademi *et al* (1999) reported that leaves which contain a higher concentration of potassium keep more water and remain fresh for long time in stress condition. Behnamfar (2000) reported that higher concentration of potassium in leaves increase WUE by increasing water absorption and decreasing leaf evaporation. In this study the effects of different amounts of potassium at different soil moisture conditions on sugar beet root yield and quality were investigated.

## 2. Materials and Methods

This experiment was conducted in SWRI experimental field in Meshkin-abad Karaj, Iran during 2003-2005. The experiment was carried out in sandy soil and before setting the line-source irrigation system, furrow irrigation had been applied for three times. The experimental design was similar to split block design. Each side of the Line Source sprinkler lines was considered as main plot. These halves were not randomized. The three levels (0, 150 and 300 kg/ha) of potassium sulfate were randomly applied in each side of the sprinkler lines, having vertical angle to the sprinkler line source within 3 replications and was considered as subplot. Each subplot was divided into four levels of irrigation treatments and is considered as sub-subplots. The levels of irrigations were created by line-source sprinkler irrigation system. Because of the nature of the line-source sprinkler irrigation system, irrigation levels which are imposed in strips, cannot be randomized. The irrigation levels increased as the sprinkler line was approached from either side, thus, there were two replications (mirror images) for each irrigation treatment. The $I_1$ to $I_4$ irrigation treatments received about 11000, 9500, 6700 and 5300 m3/ha water during growing period, respectively. In earlier autumn, 150 kg phosphorous ($P_2O_5$) and 100 kg nitrogen were applied before disk and leveler accomplishment. In spring and before the experiment to be conducted, the soil physical and chemicals characteristics (Table1) were determined and then the experimental field were treated with different levels of potassium ($K_2O$) based on randomized plan and then seeds were planted.

Table 1: Physical and chemical characteristics of soil (0-60 soil depth)

| | sand(%) | silt(%) | clay(%) | K(mg/kg) | P(mg/kg) | T.N.(%) | pH | EC |
|---|---|---|---|---|---|---|---|---|
| West side | 53 | 24.4 | 22.6 | 232 | 2.29 | 0.05 | 8.01 | 0.465 |
| East side | 46 | 29.4 | 24.6 | 124 | 0.1 | 0.3 | 8.06 | 0.72 |

The concentration of available potassium within 0 to 60 cm soil depth is shown in Table 2 for first and second year. In both years the potassium concentration was below the critical level (200ppm) of potassium requirement for sugar beet crop.

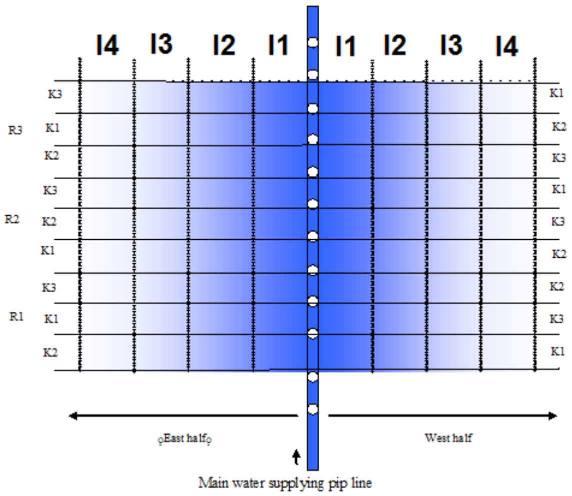
Table 2: Utilized potassium (ppm) by plants and residual potassium (ppm) in soil at the end of experiment

| | | East | | | | | West | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | K.levels | I4 | I3 | I2 | I1 | Mean | I1 | I2 | I3 | I4 | Mean |
| Residual potassium (ppm) at the end of experiment | k1 | 124.8 | 134.4 | 120.0 | 112.8 | 123.0 | 134.1 | 134.4 | 124.8 | 170.4 | 140.9 |
| | k2 | 146.4 | 139.0 | 136.6 | 127.2 | 137.3 | 146.0 | 148.8 | 141.6 | 156.0 | 148.1 |
| | k3 | 153.6 | 165.3 | 156.0 | 122.4 | 149.3 | 152.3 | 167.9 | 148.8 | 158.4 | 156.9 |
| | Mean | 141.6 | 146.2 | 137.5 | 120.8 | 136.5 | 144.1 | 150.4 | 138.4 | 161.6 | 148.6 |
| Utilized potassium (ppm) by plants | k1 | 83.2 | 73.6 | 88.0 | 95.2 | 85.0 | 73.9 | 73.6 | 83.2 | 37.6 | 67.1 |
| | k2 | 77.4 | 84.8 | 87.2 | 96.6 | 86.5 | 77.8 | 75.0 | 82.2 | 67.8 | 75.7 |
| | k3 | 85.9 | 74.2 | 83.5 | 117.1 | 90.2 | 87.2 | 71.6 | 90.7 | 81.1 | 82.7 |
| | Mean | 82.2 | 77.5 | 86.2 | 103.0 | 87.2 | 79.6 | 73.4 | 85.4 | 62.2 | 75.1 |

The constructed irrigation system consists of 13 sprinklers[1] which were fixed on 75 mm pipeline with 6 meter distance. Each sprinkler covered 28 m diameter. Every plot of irrigation treatment consisted of 6 rows of sugar beet with 50 cm distance (picture 1). Irrigation was resumed when 50% of available water depleted in 60cm soil depth in the maximum irrigation level (I1) treatment. Soil water content was measured with notrometer. The received water to each plot was measured using catch-can which was fixed on 80 cm stand in the middle of plot. The accumulative water trend at the end of growing season was almost triangle.

[1] Nelson F33

In order to have good establishment, the first three irrigation stages were done in furrow irrigation system and incoming and outgoing water was measured. The experimental field was thinned to 100000 plants per hectare after 35 days from seed sowing. After thinning, the line source irrigation system was constructed. In harvest time, the root yield and quality (sugar content, K, Na and α-amin nitrogen) were measured.




Picture 1: Field plan of the experiment in rain fed single line irrigation system (line_source)

## 3. Results

The amount of irrigation water via furrow irrigation system was 3300 m3/ha. Results of Table 3 showed that four irrigation treatments were significantly different regarding the amount of received water. Table 3 shows that the east side of the field had received less water than the west side of the field because of wind. Hanks (1980) recommended irrigation via line source should be done when wind speed is less than 3 km/ha according to right angle to the main water supplying pipe line.

Also, Table 3 showes that there is negative correlation between the amount of water and the number of survived plants at harvest time. Low element absorption, pests and diseases are direct or indirect effects of water stress to reduce root size and the number of harvestable root. Results also showed the number of root was not affected by different levels of potassium.

Table 3: Number of roots at harvest time in different irrigation treatments (mean of two years experiment)

| | East side | | | | West side | | | |
|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | I1 | I2 | I3 | I4 |
| amount of water applied via the line source irrigation system | 1994 f | 3513 d | 6105 b | 7873 a | 7822 a | 6264 b | 4179 c | 2966 e |
| Number of roots at harvest time | 71956 c | 88803 b | 95199 ab | 99292 a | 99402 a | 97664 ab | 90613 ab | 69136 c |

Treatments with at least one common letter are not significantly different at 0.05 level.

The results showed there was negative correlation between the amount of water and root yield (Table 4). Results showed that root yield in I1 and I4 were 44.6 and 5.3 t/ha, respectively, and difference among the four irrigation treatments was significant. Calculated single plant weight data also showed that low root yield in I4 was due to low single plant weight and low number of harvestable root. Results showed that single plant weight in I1, I2, I3 and I4 were 622, 473, 275 and 147 g, respectively. Results also showed that by decreasing available water, the effects of potassium on root yield increased.

Results showed there is a positive relation between the amount of water and sugar content (Table 5). These results may differ from the pervious results. In fact, imposing water stress at the end of growing season may increase sugar content. However, imposing water stress during growing period (I3 and I4 irrigation treatments) prevents sucrose accumulation in to the root cells. Results also showed that sugar content was not affected by the soil potassium concentration.

Table 4: Effects of different levels of water and potassium on root yield t/ha (mean of two years experiment)

| K. levels | East side | | | | | West side | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | mean | I1 | I2 | I3 | I4 | Mean |
| K1 | 5.11 H | 11.00 FGH | 27.45 D | 32.88 BCD | 19.11 | 40.03 A | 32.02 BCD | 13.37 EFG | 4.97 H | 22.60 |
| K2 | 5.55 H | 12.56 EFG | 27.20 D | 34.71 ABC | 20.01 | 36.58 AB | 26.81 D | 17.91 E | 6.11 H | 21.85 |
| K3 | 8.43 GH | 16.42 EF | 31.06 BCD | 37.25 AB | 23.29 | 35.02 ABC | 28.78 DC | 17.88 E | 6.54 H | 22.05 |
| Mean | 6.36 D | 13.33 C | 28.57 B | 34.95 A | | 37.21 A | 29.20 B | 16.39 C | 5.87 D | |

Treatments with at least one common letter are not significantly different at 0.05 level.

Table 5: Effects of different levels of water and potassium on sugar content (mean of two years experiment)

| K. levels | East side | | | | | West side | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | mean | I1 | I2 | I3 | I4 | Mean |
| K1 | 14.51 CDE | 16.84 AB | 17.43 A | 16.84 AB | 16.41 | 16.73 AB | 16.53 AB | 16.73 AB | 16.26 AB | 16.56 |
| K2 | 14.16 E | 15.64 BCDE | 16.82 AB | 16.60 AB | 15.80 | 16.58 AB | 16.68 AB | 17.17 AB | 15.81 ABCDE | 16.56 |
| K3 | 14.33 DE | 15.63 BCDE | 16.75 AB | 17.14 AB | 15.96 | 15.73 ABCDE | 15.90 ABCD | 16.18 ABC | 15.77 ABCDE | 15.90 |
| Mean | 14.33 C | 16.04 B | 17 A | 16.86 AB | | 16.34 AB | 16.37 AB | 16.69 AB | 15.94 C | |

Treatments with at least one common letter are not significantly different at 0.05 level.

Results also showed that by decreasing the amount of applied water below 5000m3/ha the K, Na and N in root increased (Table 6). There were not correlation between amount of applied water and K, Na and N concentration above 5000m3/ha. The amount of N, Na and K in the lowest irrigation treatment (I4) compared to the highest irrigation treatment (I1) were more than 133, 74 and 32 percent, respectively. Uptake of more elements in drought stress condition decreases cell water potential and the soil water to be absorbed by higher pressure. The results showed that the trend of variation was similar. The three elements of K, Na and N build 53, 26 and 21 percent of impurity, respectively.

The results showed that by increasing the amount of K, Na and N in root, the molasses increased (Table 7). So, by increasing water shortage, difference between sugar content and white sugar content increased. Results also showed that different levles of potassium do not affect K, Na and N concentration and similarly molasses.

The results showed that every individual irrigation treatment is significantly different from each other (Table 8). Low sugar yield in less irrigated treatment was because of low root yield and low sugar content. Results also showed that increasing the amount of potassium in well-irrigated treatments had no effects on white sugar yield, however in less irrigated treatment, white sugar yield increased by increasing the amount of potassium application. In other words, increasing the amount of potassium reduced the negative effects of drought stress and useful effects of potassium on white sugar yield were confirmed. Ranjith (1997) also showed that by increasing potassium up to 5 CEC, drought tolerance increased. Elements enter the plant roots via water flow. So, element absorption is limited in water shortage condition. To solve the problem, the element concentration of soil water should be increased in water shortage condition. In addition, by decreasing soil moisture content, more soluble potassium converted to the exchangeable potassium. In fact, the activity of potassium is limited in water shortage condition and potassium deficiency clearly is distinguished.

Table 6: Effects of different levels of water and potassium treatments on root K, Na and N (meq/100g root) (mean of two years experiment)

| K. levels | East side | | | | | West side | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | Mean | I1 | I2 | I3 | I4 | Mean |
| K | 4.20 C | 4.36 C | 5.16 B | 5.92 A | 4.91 | 5.36 A | 4.57 B | 4.25 C | 4.32 C | 4.63 |
| Na | 1.65 C | 1.87 C | 2.47 B | 3.10 A | 2.27 | 3.05 AB | 2.22 B | 1.96 C | 1.86 C | 2.27 |
| N | 1.00 C | 1.18 C | 1.70 B | 2.70 A | 1.65 | 2.33 A | 1.46 B | 1.08 C | 1.16 C | 1.51 |

Treatments with at least one common letter are not significantly different at 0.05 level.

Table 7: Effects of different levels of water and potassium treatments on molasses (meq/100g root) (mean of two years experiment)

| K. levels | East side | | | | | West side | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | Mean | I1 | I2 | I3 | I4 | Mean |
| K1 | 2.06 EFG | 1.93 EFG | 2.38 CDEF | 2.68 BCD | 2.26 | 3.45 A | 2.77 BCD | 2.25 DEFG | 1.70 G | 2.54 |
| K2 | 1.86 EFG | 2.03 EFG | 2.02 EFG | 2.96 ABC | 2.21 | 3.15 AB | 2.31 DEFG | 1.80 FG | 1.94 EFG | 2.30 |
| K3 | 1.90 EFG | 1.86 EFG | 2.07 EFG | 2.81 BCD | 2.16 | 2.95 ABC | 2.48 CDE | 1.89 EFG | 1.84 FG | 2.29 |
| Mean | 1.94 C | 1.94 C | 2.16 B | 2.81 A | 2.21 | 3.19 A | 2.52 B | 1.98 C | 1.83 C | 2.38 |

Treatments with at least one common letter are not significantly different at 0.05 level.

Table 8: Effects of different levels of water and potassium treatments on white sugar yield t/ha (mean of two years experiment)

| K. levels | East side | | | | | West side | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I4 | I3 | I2 | I1 | Mean | I1 | I2 | I3 | I4 | Mean |
| K1 | 0.57 J | 1.57 GHIJ | 4.11 DE | 5.01 ABCDE | 2.82 | 6.01 A | 4.80 BCDE | 1.95 FGH | 0.70 IJ | 3.37 |
| K2 | 0.62 J | 1.71 FGHI | 4.13 DE | 5.22 ABCD | 2.92 | 5.42 ABC | 3.95 E | 2.73 F | 0.84 IJ | 3.23 |
| K3 | 1.00 HIJ | 2.17 FG | 4.56 CDE | 5.75 AB | 3.37 | 5.01 ABCDE | 4.16 DE | 2.51 FG | 0.86 IJ | 3.14 |
| Mean | 0.73 D | 1.82 C | 4.27 B | 5.33 A | 3.04 | 5.48 A | 4.30 B | 2.39 C | 0.80 D | 3.25 |

Treatments with at least one common letter are not significantly different at 0.05 level.

## 4. Discussion

Results showed that the trend of water use efficiency (WUE) is different for root yield, shoot yield and sugar yield. When the root yield is concerned, the trend of WUE was polynomial (Fig. 1). By increasing amount of irrigation up to 5700 $m^3$/ha, WUE increased and then by increasing the amount of irrigation WUE gradually decreased. However, when the shoot yield is concerned, there was a negative correlation between amount of irrigation and WUE. Results also showed that there was positive correlation between amount of irrigation and WUE when sugar yield was concerned.

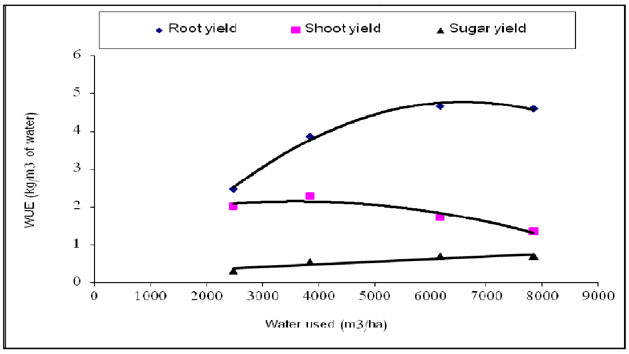



Fig 1: Effects of different irrigation levels on water use efficiency (WUE) of root yield, shoot yield and sugar yield

In this study, positive correlation between rain fed irrigation water level and WUE is observed. However, the negative correlation between amount of irrigation water and WUE is usually reported in furrow irrigation system. When, high amount of water enters the furrow, a large part of it gets out of hand via run-off, evaporation and penetration to soil layers below root zone. But in rain fed irrigation, the large amount of water could be used by plant to produce biomass. In addition, only I1 irrigation treatment had received adequate water during growth period and the rest treatments were under drought stress. So, it is expected that under water stress condition the WUE to be increased. Results of this experiment showed that irrigating sugar beet with 6000 to 8000 m3/ha via rain fed irrigation system is minimum and optimum amount of water, respectively. By applying less than 6000 m3/ha water, plant encountered the water stress condition. Although this research is done in a light soil, and the amount of soil potassium was lower than 180-200 meq/ 100 g soil, however, the interaction between different levels of potassium and different levels irrigation was not significant. Results of soil sampling before seed planting and after root harvesting showed that the amount of potassium at the end of experiment was much lower than that before the experiment to be conducted, even in treatment that 300 kg/ha potassium had been applied. It seems potassium wash down to the soil as a consequence of light soil and over watering by using furrow irrigation prior to rain fed irrigation system had been installed. Potassium wash down had been reported by Krauss (2000). Jaggard (1995) also recommended that potassium should not be used long before seed planting specially in areas where heavy rain is forecasted. These results indicated that in light soil in which the available potassium is less than 250 m.eq./100 g soil, more than 300 k/ha potassium should be applied, especially in furrow irrigation system. Ultimate recommendation is not to use furrow irrigation in light soil.

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