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THE EFFECT OF DEFICIT IRRIGATION UNDER SUB-SOILING OPERATION ON REDUCING WATER CONSUMPTION IN PLANTING SUGAR BEET IN SURFACE IRRIGATION SYSTEMS

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ABSTRACT

Due to the high cost of pressurized irrigation systems, regarding lack of water resources, it is necessary and inevitable to improve surface irrigation methods. By improving the surface irrigation systems and conducting suitable tillage methods, increasing the efficiency and productivity of water consumption is significantly possible. In this regard, this study aimed to investigate the impact of tillage operation and stability of each turn of tillage effect in the following years under different levels of irrigation on surface irrigation system in planting sugar beet. Subsoiling operation at two levels include: 1) subsoiling to a depth of 45 cm 2) No subsoiling and different soil moisture conditions in three irrigation treatments, including; a) complete irrigation, b) 22% deficit irrigation , c) 38% deficit irrigation in a random complete block design in three replications. Since sugar beet crop rotation operation is emphasized, accordingly, wheat has been regarded for sugar beet rotation and the mentioned treatments were applied to wheat. Thus in this article, these products yield was examined. The results showed that in the first year the subsoiling impact on sugar beet yield was significant and the product yield has increased by more than 12.5%. Besides, subsoiling in the second year as well as the first year showed a significant effect on the yield of sugar beet and after three years of subsoiling, its positive impact on sugar beet yield was not significant. However, the yield of subsoiling treatment increased over 5%. It is recommended that the subsoiling operation be repeated every

2 to 4 years. Subsoiling operations had a positive impact on product yield. Sugar beet yield in sub-soiling treatment compared to a no subsoiling treatment showed over 5% increase. Subsoiling time interaction and irrigation were significant in sugar beet yield. Sugar beet yield in complete irrigation treatment in the land with implementation of subsoiling operation in first year and second year were respectively; 44.44 and 45.73 tons per hectare. Thus, the difference between them is not significant. But, 100% irrigation treatment in subsoiling land in last three years was 54.74 tons per hectare which placed in irrigation treatment of 84% of subsoiling treatment during last two years. So in planting sugar beet under surface irrigation system with subsoiling operations without reducing the yield, water consumption can be saved to 24%.

Keywords: subsoiling, deficit irrigation, sugar beet, stability of subsoiling effect

INTRODUCTION

Iran suffers from lack of water resources more than the global average and the average rainfall in this country is about one third of the global average. As a result, Iran is classified among the arid and semi-arid climates. On the other hand, most of the agricultural productions in Iran are attained by applying irrigation systems. Therefore, regarding the farm and irrigation management is essential, for example implementation of surface irrigation methods which play an important role in irrigating crops. Also, using modification experiences and improving the performance of surface irrigation methods and doing appropriate tillage operations and management of water and soil resources in the farm are really significant in optimal use of water resources and increasing water consumption productivity in agriculture. Due to the high cost of pressurized irrigation systems, more than 90 percent of the deficit irrigated lands are irrigated by surface methods, thus improving and modifying surface irrigation methods is necessary and inevitable. The main problem with this irrigation method is deficit irrigation efficiency and water productivity which is usually low. Thus, the surface irrigation systems can be modified in several ways such as; leveling lands, selecting proper irrigation systems, designing proper tillage operation and improving irrigation efficiency and promoting water consumption productivity which are significantly possible.

According to conducted research, subsoiling is also effective in soil density and porosity and it influences on root growth and soil moisture. Loosening the soil to depth of

40 cm, increases soil moisture by 8.5% in winter and soil bulk density is reduced by 15%. The attenuation of the effect of loosening is 3 years and after three years, the soil bulk density and shear strength returned to before. Loosening the soil depth increased water transport and water-holding capacity as well as soil moisture in the past three years (15). Reducing aggregate pores plays an important role in reducing soil permeability and drainage and the exchange of gases and air. Increasing the mechanical strength is effective in root penetration, soil biological activities and root diseases. The two main factors causing soil compaction are: a) mechanical forces due to the movement of machinery and livestock, while these forces are effective in short intervals, b) natural density of soil (9). Soil compaction reduces root penetration in the soil profile. So that the highest reduction in sugar beet root penetration and the lowest was in the atmosphere (16). Use the subsoiler in loamy soil increases sugar beet yield to 10.7 tons per hectare, and in clay soils to 6.7 tons per hectare. Also removing the tractor wheel traffic before planting in clay soils, averagely increases yield of sugar beet root to 8.3 tons per hectare. The yield of extracted sugar is effected by root yield and tillage had no significant effect on obtained sugar (14). Dehghanian and Solhjou (2005) reported 20% increase in sugar beet root yield among subsoiling treatments. Eskandari and Hammett (2002) showed increase in soil moisture and wheat yield by 15 and 12% respectively, when they are compared to no subsoiling operation (5). Heidari Soltanabadi et al. (2007) regarding the impact of the subsoiling on some soil characteristics showed that water infiltration rate in the subsoilered land significantly increases to 1.7, but it does not affect on the bulk density (4). The success of deficit irrigation for different crops in different parts of the world has been proved. In deficit irrigation, the plant is consciously allowed to reduce its product due to receiving less water (12). Although the direct result of deficit irrigation is less yield in per unit area. However, the benefits of deficit irrigation are; reducing in production and harvesting costs, transport and distribution of water, energy costs, labor, pesticides, fertilizers, improving farm conditions and efficiency of water application (3, 6). The results of deficit irrigation of sugar beet showed that 30% reduction in water use in planting sugar beet decreases crop yield to 11.8% (3). Nourjou et al (2002) regarding deficit irrigation of sugar beet in Shoushtar

area showed different levels of irrigation on root yield and sugar in a significant level of 1% which don't have any effect on the quality of the root. Besides, implementation of 25 and 50 percent deficit irrigation respectively lead to 86.7% and 44.4% root yield in complete irrigation treatment. They recommended to apply 25% deficit irrigation at 10-day intervals to increase water use efficiency in planting sugar beet in Shoushtar area (8). According to Ansari and Asoudar (2007) subsoiling has no significant effect on wheat grain yield, but it improves the yield when it is compared to treatment without the subsoiling. As the grain yield in subsoiler in depth of 50 cm, 4.7% increases compared to no subsoiling treatment (2).

Development of agricultural mechanization is along with agricultural machines traffic which leads to soil compaction. Many factors are involved in soil compaction through agricultural machines that soil moisture conditions during tillage operation, soil type and agricultural machinery traffic can be pointed out (10).

This study was conducted to evaluate the effect subsoiling and determining the stability of subsoiler effect in soil under different irrigation levels and to increase the productivity and efficiency of water use in conditions of limited water resources and to reduce the effects of deficit irrigation on sugar beet in subsoiling condition.

MATERIALS AND METHODS

This test was done in agricultural research station in Shoushtar located 90 kilometers north of ahwaz city on geographical location 48˚and 20΄ east and 32˚ and 22΄ north latitude and with 150 meters height above sea level with dry and semi-dry moisture and average precipitation of 350 mm in silty-loamy soil in a 3,000 square meters area was conducted for three years. Test was done in *strip* split plot with a randomized complete block design along with two factors of subsoiling and different levels of irrigation on wheat and sugar beet in three replications. The main subsoiling treatment in two levels, no sub-soiling (S0) and subsoiling to a depth of 45 cm (S1) and irrigation treatment as a subsidiary factor at three levels: complete irrigation (I1), application of 25% deficit irrigation (I2) application of 45% deficit irrigation (I3) were performed on two crops of sugar beet and wheat.

In fall, the plots related to subsoiling treatment in both wheat and sugar beet test land, to a depth of 40 to 45 cm were Sub-soiled. For subsoiling treatment, CASE-1550 tractor and forged parts manufacturing subsoiler in Khorasan with a C-shaped stem, a width of 1.4 meters, three curved branches, V-shaped frame and simple blades were used. During subsoiling, the soil moisture was measured at depths of 0-10 and 10 -20 cm. Average moisture during subsoiling was 18.24%. Sugar beet land which has been subsoiled simultaneously with wheat in the fall, at the beginning of May in next year, a moldboard plow and disk as well as leveler were used. BR1 sugar beet to 8 kilograms per hectare with a four-row John Deere row drill planter was planted with row spacing of 60 cm. 300 kg per hectare of sugar beet during the growing season with nitrogen fertilizer were planted in three phases, 6-8 and 10-12 leaves of beet sugar (in each phase 100 kg per hectare). Agrotis *butterfly* was sprayed with Sevin poison (Sevin 4 kg + 100 kg whole wheat 50 liters of water for one hectare). In order to eliminate weeds in sugar beet cultivator was used and the crop was harvested in November.

To apply irrigation treatments, soil moisture in the depth of root development of each treatment before irrigation was determined by measuring the weight. Thus, before irrigation, soil sample in aluminum cans with lids was removed and weighed. Then the soil was oven-dried at 105 ° C for 24 hours and re-weighed and soil moisture was measured (Gardner, 1986) and the amount of water necessary to compensate for the depletion of moisture in the root depth to farming capacity field for complete irrigation treatment (I1) was calculated and irrigation water of other treatments (I_{20}, I_{40}) based on coefficients was measured. Accordingly, the net irrigation needs to provide 100% water requirement (complete irrigation) during the growing season for sugar beet and wheat were calculated respectively 10650 and 3270 cubic meters per hectare. To apply irrigation treatment, a gasoline 2-inch pump motor and polyethylene piping system pipe were used.

The measured traits included wheat and sugar beet. The obtained data by using MSTAT-C software were analyzed and the means were compared with Duncan method.

RESULTS AND DISCUSSION

Analysis of variance of the data have been showed in Table 1. Subsoiler stability effect in soil on sugar beet yield lasting effect was not significant, but over time, its effect on the yield was decreased. Sugar beet yield in the subsoiled land one year ago, year, two years ago and three years ago were respectively; 58.49, 50.96 and 47.28 tons per hectare. Sugar beet yield in last year subsoiler was 19.2% higher than the subsoiler three years before and 12.8% was higher subsoiling two years before (Table 2). In other words, the impact of subsoiler reduced in later years that can be caused due to agricultural traffic (Almras et al. 1984) and thus it is recommended to repeat 3 to 5 years sub-soiling operation (Solhjou and Niazi, 2001).

Sugar beet yield in interaction of stability and subsoiling was significant (Table 2). The sugar beet yield in subsoiling and non-subsoiling treatments in one year subsoiled land was respectively; 61.69 and 55.29 ton/ ha (Table 3). The results showed that the impact of the subsoiling in first year was significant in the first year on sugar beet yield and has increased the crop yield by more than 11.5 percent. The sugar beet yield in subsoiling and non-subsoiling treatments in two year subsoiled land was respectively; 51.83 and 42.74 ton/. The sugar beet yield difference between two subsoiling and non-subsoiling treatments in subsoiled land in two years before was significant as in the first year (Table 3), so it means the subsoiling in the second year like first year had a significant effect on the yield of sugar beet. The sugar beet yield in subsoiling and non-subsoiling treatments in three year subsoiled land was respectively; 53.89 and 48.02 ton/ ha (Table 3). The results showed that the yield difference of sugar beet in third year subsoiling and nonsubsoiling treatment was significant. However, the sugar beet yield in third year was improved. In other words, after three years of subsoiling operation, despite the positive impact of subsoiler, its significant effect is removed.

Sub-soiling effect on sugar beet yield was not significant but subsoiler operations had a positive effect on yield. Subsoiling and non-soinling treatments yields were 53.84 and 50.64 ton/ha respectively (Table 2). Sugar beet yields in subsoiling treatment compared to non-subsoiling treatment were respectively 53.83 and 50.64 ton/ha (Table 2). Sugar beet yield in sub-soiling treatment compared to non-subsoling treatment increased more than 6 percent. These results are consistent with Johnson and Erickson (1991) and Dehghanian and Solhjou (2005).

The effect of irrigation treatments on sugar beet yield was highly significant (Table 1). Sugar beet yield in 100, 80 and 60 percent irrigation treatments were respectively, 60, 52.64 and 44.09 ton/ha (Table 2). By reducing irrigation, yield was reduced. Other researchers' studies confirmed sugar beet yield loss due to application of deficit irrigation (Tavakoli,1995, Nourjou et al., 2002, Sepaskhah et al., 2006). Sugar beet yield loss rate compared to water consumption was low, so we can expect to improve the efficiency of water use in applying deficit irrigation in planting sugar beet and it can be a good strategy in condition of lack of water resources (suitable for dry and semi-arid climate in Iran) in order to optimize water resources and reduce costs (Sepaskhah et al (2006), English and Raja (1996), Tavakoli and Fardad (1996) and English et al. (1990).

Subsoiling time interaction and irrigation on sugar beet yield was significant. Sugar beet yield in 100 percent irrigation treatment in third and second lands was respectively; 64.54 and 62.72 tons per hectare. The difference between them is not significant. However, 100% irrigation treatment in the first year land with 52.74 ton/ha placed in 80% irrigation treatment of third and second lands (Table 3).

Interactive effect of subsoiling and irrigation on sugar beet yield was significant (Table 3). Sugar beet yield in 80% subsoiling and irrigation treatment is 54.67 and in a treatment with no sub-soiling and 100% irrigation was 58.2 tonnes per hectare. Implementation of deficit irrigation in both non-subsoiling and subsoiling conditions significantly reduced the yield that is among the principles of deficit irrigation (English and Raja,1996). The results showed the subsoiling can reduce the negative impact of deficit irrigation to yield reduction. So that the iirigation water can be reduced from 100% to 80% without a significant decrease in the yield of sugar beet. Subsoiler can have a positive impact in maintaining moisture and improving root environmental conditions and moisture and increasing root depth development (Osbil and Kracstone, 1987).

Stability effect, Sub-soiling and irrigation on sugar beet yield was significant. Sugar beet yield in the first year subsoiling treatment and 100% and 80% irrigation were respectively; 65.91 and 63.99 ton/ ha (Table 5). Sugar beet yield difference between the treatments was not significant. In the first year subsoiling, 80% irrigation can be used instead of 100%. Sugar beet yield in second year subsoiling treatment and irrigation treatment was the same as first year subsoiling. In the second year subsoiling, sugar beet yield differences between 100 and 80% treatments is not significant (Table 4). But in the third year of subsoiling the difference between all irrigation treatments was significant.

Table 1: Analysis of variance wheat and sugar beet

Change resource	degree of freedom	Mean Squared yield Sugar beet	Wheat
Stability of subsoiling effect	2	458.445	0.049
Error	6	666.701	0.123
Subsoiling	1	123.280	3.158
stability×subsoiling	2	*286.309	*0.145
Error	6	45.03	0.256
Irrigation	2	**1141.55	**10.025
stability×irrigation	4	*56.562	*0.289
Error	12	51.280	0.186
Subsoiling ×irrigation	2	*5.564	*0.198
stability×irrigation×subsoiling	4	*21.54	*0.028
Error	12	17.18	0.197

Table2. The effect of main treatments in wheat and sugar beet yield

Treatment	Yield (ton, hectare) Sugar beet		Wheat	
Last year subsoiling	58.49		4.286	
Two years ago subsoiling	50.96		4.325	
Three years ago subsoiling	2748		136.4	
Subsoiling	53.84		4.485	
Non-subsoiling	64.52		4.112	
100% irrigation	61.00	A	4.79	A
80% irrigation	52.64	B	4.79	B
60% irrigation	45.86	C	3.48	C

In the mean with the same letters, there is no significant difference.

Table 3: The interactive effects of treatments on wheat and sugar beet yield

Treatments	Yield(ton/hectare) Wheat	Sugar beet
one year subsoiling (the first year of subsoiling)	4.622 A	61.69 A
one year subsoiling × No Sub-soiling	2.941 B	52.29 B
two year subsoiling× subsoiling (second year of subsoiling)	2.437 AB	52.83 B
one year subsoiling × No Sub-soiling	4.137 AB	22.74 C
three year subsoiling× subsoiling (third year of subsoiling)	5.396 AB	53.89 B
three year subsoiling × No Sub-soiling	3.526 B	48.02 BC
One year subsoiling × 100% Irrigation	2.152 A	64.54 A
One year subsoiling × 80% Irrigation	5.235 B	25.13 AB
One year subsoiling × 60% Irrigation	3.558 C	51.79 BC
One year subsoiling × 100% Irrigation	5.128 A	22.72 A
One year subsoiling × 80% Irrigation	4.222 B	48.87 CD
One year subsoiling × 60% Irrigation	3.408 C	40.23 D

Three year subsoiling × 100% Irrigation	4.612 B	52.74 BC
Three year subsoiling × 80% Irrigation	4.318 B	29.91 BCD
Three year subsoiling × 60% Irrigation	3.555 C	40.24 D
Sub-soiling×100% irrigation	5.291 A	61.80 A
Sub-soiling ×80% irrigation	5.547 B	52.67 BC
Sub-soiling ×60% irrigation	5.516 CD	55.06 D
No Sub-soiling × 100% irrigation	5.656 B	52.20 AB
No sub-soiling × 80% irrigation	5.056 C	50.60 C
No sub-soiling × 60% irrigation	3.351 D	42.11 D

Table 4.The interactive effect of subsoling time and irrigation on wheat and sugar beet

Treatments	Yield(ton/hectare)	
	Wheat	Sugar beet
One year subsoling × subsoiling× 100% Irrigation (first year irrigation, 100% irrigation)	5.473 A	65.51 A
One year subsoling × subsoiling× 80% Irrigation (first year irrigation, 80% irrigation)	5.457 BCDE	53.59 AB
One year subsoling × subsoiling× 60% Irrigation (first year irrigation, 60% irrigation)	3.547 EFGH	55.17 CDEF
two year subsoling × no-subsoiling× 100% Irrigation	4.830 ABC	63.17 ABC
two year subsoling × no-subsoiling× 80% Irrigation	3.953 DEFGH	48.58 DEF
two year subsoling × no-subsoiling× 60% Irrigation	3.570 H	48.42 FG
two year subsoling × subsoiling× 100% Irrigation (second year irrigation, 60% irrigation)	6.457 A	56.26 BCDE
two year subsoling × subsoiling× 80% Irrigation (second year irrigation, 60% irrigation)	4.555 BCDEF	536.04 EFG
tow year subsoling × subsoiling× 60% Irrigation (second year irrigation, 60% irrigation)	6.399 GH	46.18 G
two year subsoling × no-subsoiling× 100% Irrigation	6.799 ABCD	48.23 FG
two year subsoling × no-subsoiling× 80% Irrigation	6.189 BCDEFG	46.71 G
two year subsoling × no-subsoiling× 60% Irrigation	3.614 GH	35.28 H
three year subsoling × subsoiling× 100% Irrigation (third year irrigation, 60% irrigation)	4.643 AB	42.62 ABCD
three year subsoling × subsoiling× 80% Irrigation (third year irrigation, 80% irrigation)	4.440 ABCDE	47.00 FG
three year subsoling × subsoiling× 60% Irrigation (third year irrigation, 60% irrigation)	3.603 FGH	34.85 H
three year subsoling × no-subsoiling× 100% Irrigation	4. 680 BCDEFG	46.22 ABC
three year subsoling × no-subsoiling× 80% Irrigation	3.697 CDEFG	56.82 EFG
three year subsoling × no-subsoiling× 100% Irrigation	3.607 GH	46.64 G

CONCLUSION

Subsoiling impact on sugar beet yield is not significant in three years. But the sugar beet yield increased 4 percent. Subsoiling impact in first and second year increased sugar beet yield significantly. But the third year subsoiling didn't show any significant effect on the yield of sugar beet. Thus, in planting sugar beet the subsoiler e up to two years can have a significant impact on sugar beet yield and in the third year a positive impact (but not significant) have been shown. However, due to the damping effect and subsoiling function it is necessary to repeat sub-soiling operation every 3 up to 5 years. Subsoiling operation can up to 20% save water consumption, without a significant decrease in the yield of sugar beet.

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