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The impact of irrigation method on soil salinity distribution

Ali Reshadsedghi*

Department of Agricultural Engineering Research, East Azarbaijan Agricultural and Natural Resources Research and Education Center, AREEO, Tabriz, Iran

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Key words: Soil salinity distribution, Irrigation methods, Salinity concentration, Water consumption

Abstract

Salinity is a major problem affecting crop production over the world. Modifying water management through appropriate irrigation practices can often lead to increase crop yields under saline soil conditions especially in arid and semi-arid regions.. The objective of this study was to compare three irrigation methods of flood irrigation and furrow irrigation with two different furrow width on soil salinity distribution and water consumption. Experiments were carried out in a field located at east of Urmia salt water lake with a loamy soil texture and soil salinity (EC) of 12 dSm^{-1}.The irrigation methods included: conventional flood irrigation with no furrow; furrow irrigation with 60 cm furrow width; furrow irrigation with 100 cm furrow width. According to the results, reducing the width of the furrow from 100 to 60 cm resulted in better soil leaching from inside the furrows to the ridges so that soil salinity decreased by 37% compared to the initial value and also irrigation water consumption was 30% less than other methods. Therefore, in semi-arid areas with saline soils, planting within the narrow furrows and furrow irrigation is preferable.

***Corresponding Author:** Ali Reshadsedghi ✉ a.reshadsedghi@areeo.ac.ir

Introduction

Salinity is a major problem affecting crop production over the world. So about 20% of cultivated land and 33% of irrigated farms were salt-affected and degraded (Machado *et al.*, 2017). Most of Iran regions have arid and semi-arid climate with a large of areas are covered with sediments of salts and gypsum. In northwestern regions of Iran, on the banks of the Caspian Sea, in the northwest, a significant amount of Lake Urmia basin, as well as large areas of central Iran, salty and sodic soils are dominant. Saline soils and waters are among the agricultural resources that can be used for cultivation by using full knowledge of problem and proper management.

Modifying water management through appropriate irrigation practices can often lead to increase crop yields under saline soil conditions (Abrol *et al.*, 1988; Qadir and Oster, 2004). When suitable agronomic management practices are adopted, the saline soils can also give significantly better yields. Some of the methods that can be adopted are classified as: (i) Irrigation management practices, (ii) leaching out of salts, and (iii) drainage systems (Sree Ramulu, 1998).Most plants require a continuous supply of readily available moisture to grow normally and produce high yields. After an irrigation event the soil moisture content upraise the highest and salt concentration or the osmotic pressure of the soil solution is minimal. As the soil progressively dries out due to evapotranspiration losses, the concentration of salts in the soil solution and therefore its osmotic pressure increases making the soil water increasingly difficult to be absorbed by the plants. If the saline soils are irrigated infrequently, plants would be subjected to very high soil moisture stresses with consequent yield losses.

Irrigation method can play an important role in controlling salts in the root zone. Considerable important factor of a soil is relation of growth of plants with the location of salts in relation to root or seed placement. Irrigation practices can often modified to obtain a more favorable salt distribution in relation to seed location or growing roots. It is well known that salts tend to accumulate in the ridges when using furrow type irrigation. The direction of movement of applied water and dissolved salts (arrows) is shown in Figure 1. With each irrigation, salts leach out of the soil under the furrows and concentrate on the ridges (Abrol *et al.*, 1988). Where soil and farming practices permit, furrow planting may help in obtaining better stands and crop yields under saline conditions (Abrol *et al.*, 1988; Yarami and Sepaskhah, 2015).A mathematical model for simulating soil water and salt transfer under mulched furrow irrigation with saline water was presented by Chen *et al.* (2015). The results demonstrated that during the irrigation interval (192 h and 384 h after the irrigation), more water was maintained below the top of the ridge due to a considerable reduction of evaporation under mulched furrow irrigation. Soil salt mainly comes from saline water irrigation and the soil salt below the top of the ridge mainly increased at the redistribution phase (17 h).In semi-arid regions, switching sowing position from ridge to furrow could increase corn yield, directly, by improving soil moisture early in the growing season and, indirectly, by stimulating the growth of resource-capturing organs (e.g., leaves and roots) (Jin*et al.*, 2010).The pitting and furrow planting methods were the most appropriate methods for alfalfa planting in highly saline soils (Afsharmanesh and Aien, 2014).Deficit irrigation and salinity decreased yield and dry matter of rapeseed and in-furrow planting resulted in higher seed yield and dry matter compared to on-ridge planting (Shabani *et al.*, 2013). According to Dong *et al.* (2010), furrow-bed seeding induced unequal distribution of salts in the surface soil. Under furrow planting, soil salinity was much higher but soil osmotic potential was much lower on the ridge part than the furrows. When irrigation water is applied to the furrows on every side of the bed, it allows salts to leach down from the furrows (Bakker *et al.*, 2010). But the water evaporation during the drying periods results in salt accumulation on the tops and side slopes of the raised beds (Richards, 1954). Such salt movement to the center of the bed may damage (young) plants seeded there (Brady and Well, 2008). According to Meiri and Plaut (1985), Cardon *et al.* (2010) and Devkota *et al.* (2015), with the permanent skip furrow irrigation (PSFI) method in which one of the two neighboring furrows is kept dry, salts are leached from the top of the raised bed and 'pushed' across the bed from the irrigated side of the furrow, where plants are located, to the dry side without plants. This management of root zone salinity improves emergence, stand establishment and finally crop yields in saline fields. This study was conducted with the objective of comparing three irrigation methods (flood irrigation and furrow irrigation with different furrow width) and investigating the effect of furrow width on soil salinity distribution.

Materials and methods

Study area and site description

This study was conducted to compare three irrigation methods (flood irrigation and furrow irrigation with different furrow width) and investigate the effect of furrow width on soil salinity distribution. Experiments were carried out in a field located at37°46' N and 45° 86'E, near Lake Urmiawith loamy soil texture. The average soil salinity (EC) in soiltop 30 cm was 12 dSm^{-1}. Characteristics of soil and irrigation water are shown in Table 1 and 2 respectively.

Study set up and experimental design

The irrigation methods included (i) conventional flood irrigation with no furrow (NOF); (ii) furrow irrigation with 60 cm furrow width (5F); (iii) furrow irrigation with 100cm furrow width (3F). Soil ridges with 10 cm height were constructed by a special grain drill which plants seeds into furrows. The 20-Row drill planter working width was 300 cm, thus to create furrows of the desired width, 5 furrowers with 60 cm width and 3 furrowers with 100 cm width were used on planter (Fig. 2 and 3). Four irrigation applied in each treatment plots at different stages of wheat plant growth (25 Oct. 2016 after planting; 7 May 2017 after tillering stage; 21 May flowering stage and3 June in fill-grain stage). The irrigation mode experiment was laid out in a randomized complete block design (RCBD) with three irrigation treatments and three replications (9 plots with 1 m spacing). Each experimental plot with 6 m width and 18 m length was planted by drill planter in two paths.

Soil sampling

Soils were sampled after three irrigation *viz.* first, second and forth events, when soil drainage was carried out. Soil samples were obtained each time from three points of each plot (top of the ridges 'r', border of the furrows 'b' and middle of the furrows 'm') (Fig. 4). For NOF treatment which had no furrow, soil samples were taken from three consecutive points at intervals of 30 cm from the plot width. All samples were taken from 0-30 cm soil depth using a tube auger (5 cm diameter, 22 cm height). The soil samples were air dried and mixed with sufficient distilled water to produce a saturated paste and then extracted the solution for measurement of electrical conductivity (EC_e)in the irrigation laboratory (Richards, 1954).

Measurement of irrigation water

Irrigation water was applied as surface irrigation methods. Applied water was measured by a WSC flume. Irrigation times were scheduled by crop phonological stages and all plots were irrigated four times from cultivating to maturity.

Statistical analysis of soil EC data

Analysis of variance was conducted using split-split-plot experiment based on RCBD with three factors and three replications (by software SPSS version 19). The main factor was irrigation methods, the second factor was irrigation events and the third factor was related to the position of soil sampling in each plot. Each factor was in three levels. The salinity means were separated by Fisher's protected LSD (least significant difference (P=0.05)).

Results and discussion

Soil salinity distribution in ridges and furrows

In irrigation treatment of furrows with 60 cm width (5F), after each irrigation salts were washed out significantly from middle of furrows toward the ridges and accumulated there, however this does not apply to irrigation treatment of furrows with 100 cm width (3F). In treatment of the conventional flood irrigation which had no furrow (NOF), after each irrigation there was no significant difference of salinity across the plots (Table 3; Figs. 5A. B. C. and 7).

These results are accordance with the findings of Ghane *et al.* (2009), who reported that with the furrow irrigation method (60 cm furrow width), salinity at the root zone (shoulder of raised bed) was lower than that in flood irrigation method.

Table 1. Soil physical and chemical properties.

Depth	EC (dSm^{-1})	pH of paste	T.N.V.%	O.C.%	P(ava.) p.p.m.	K(ava.) p.p.m.	Clay%	Silt%	Sand%
0-30	12	7.6	15	2.18	100	411	17	31	52

Table 2. Characteristics of irrigation water.

SSP	pH	EC (µS/cm)	S.A.R	total Cations	Na^+	Ca^{2+}+Mg^{2+}	total Anions	SO_4^{2-}	Cl^-	HCO_3^-	CO_2^{2-}
27.5	6.9	7420	4.4	91	25	66	84.5	5.2	67.5	11.8	0

Table 3. Analysis of variance of the treatments effects on soil salinity (EC).

Sources of variations	df	M.S.	F value	Probability
Irrigation methods (Factor A)	2	25.672	2.1317	0.2343^{ns}
Irrigation events (Factor B)	2	65.823	19.5124	0.0002^{**}
A×B	4	11.605	3.44	0.0430^{*}
Sampling locations(Factor C)	2	35.923	7.7864	0.0015^{**}
A×C	4	16.693	3.6183	0.0141^{*}
B×C	4	4.224	0.9155	
A×B×C	8	3.835	0.8312	

ns, *, **: Difference is not significant, P<0.05, P<0.01.

As shown in Fig.3, after first irrigation which is the most important stage for seeds germination, the salinity level on the top 30 cm soil in the middle of furrows with 60 cm width (EC=7.59 dSm^{-1}), was lower than the other treatments. Using this method, after an irrigation practice, 37% of the initial salinity (EC=12 dSm^{-1}) has decreased. The results of measuring the electrical conductivity of saturated paste after the second irrigation showed a significant decrease of soil salinity in all three irrigation methods (Figs 5B. and 6). The reason for this was probably the penetration of salts in the depths of soil due to seasonal rainfall before the second irrigation (Wang *et al.*, 2015). Comparison of the effect of three irrigation methods on soil salinity distribution after fourth irrigation (Fig. 5C. and 6) indicates that by increasing furrow width to 100 cm, probably due to an increase in the internal surface of the irrigation furrow, less water flows to the ridges and the salts concentration in the ridges are reduced.

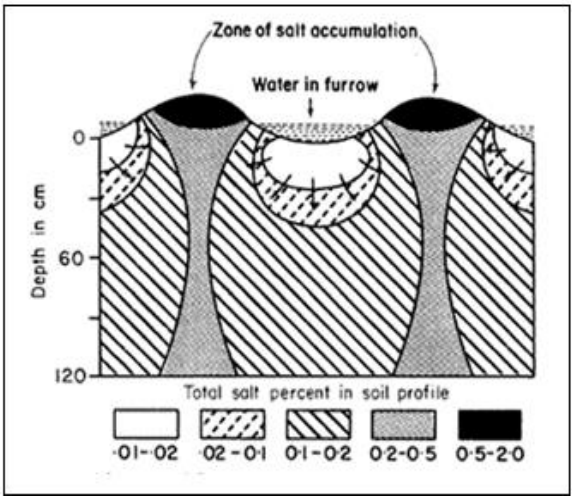

Fig. 1. Direction of salt flow and salt accumulation in furrow irrigation (Abrol *et al.*, 1988).

In this stage, the salinity reduction of the soil in the floor of 60-cm furrows was approximately the same as NOF treatment.

Fig. 2. The 20-Row drill planters which create five furrows with 60 cm width.

Fig. 3. The 20-Row drill planter which create three furrows with 100 cm width.

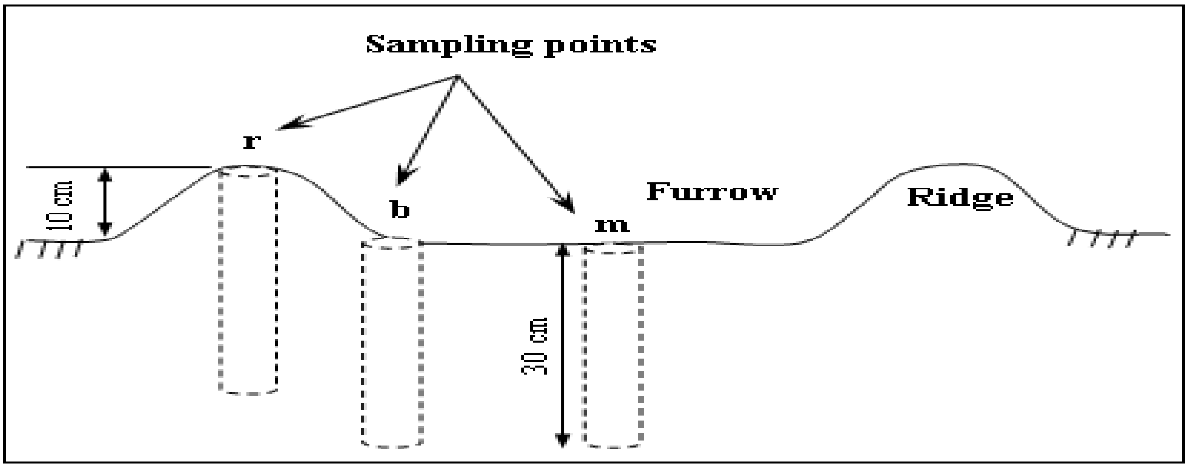

Fig. 4. The position of sampling points in ridge and furrow.

It seems that in furrow irrigation method due to the presence of the ridges, a portion of the soil salts accumulate in the ridges by the horizontal water flow and part of it is penetrated to the soil depths by the gravity flow of water. However, in the flood irrigation method where the soil surface is smooth, soil leaching is carried out after irrigation or precipitation solely by vertical water flow.

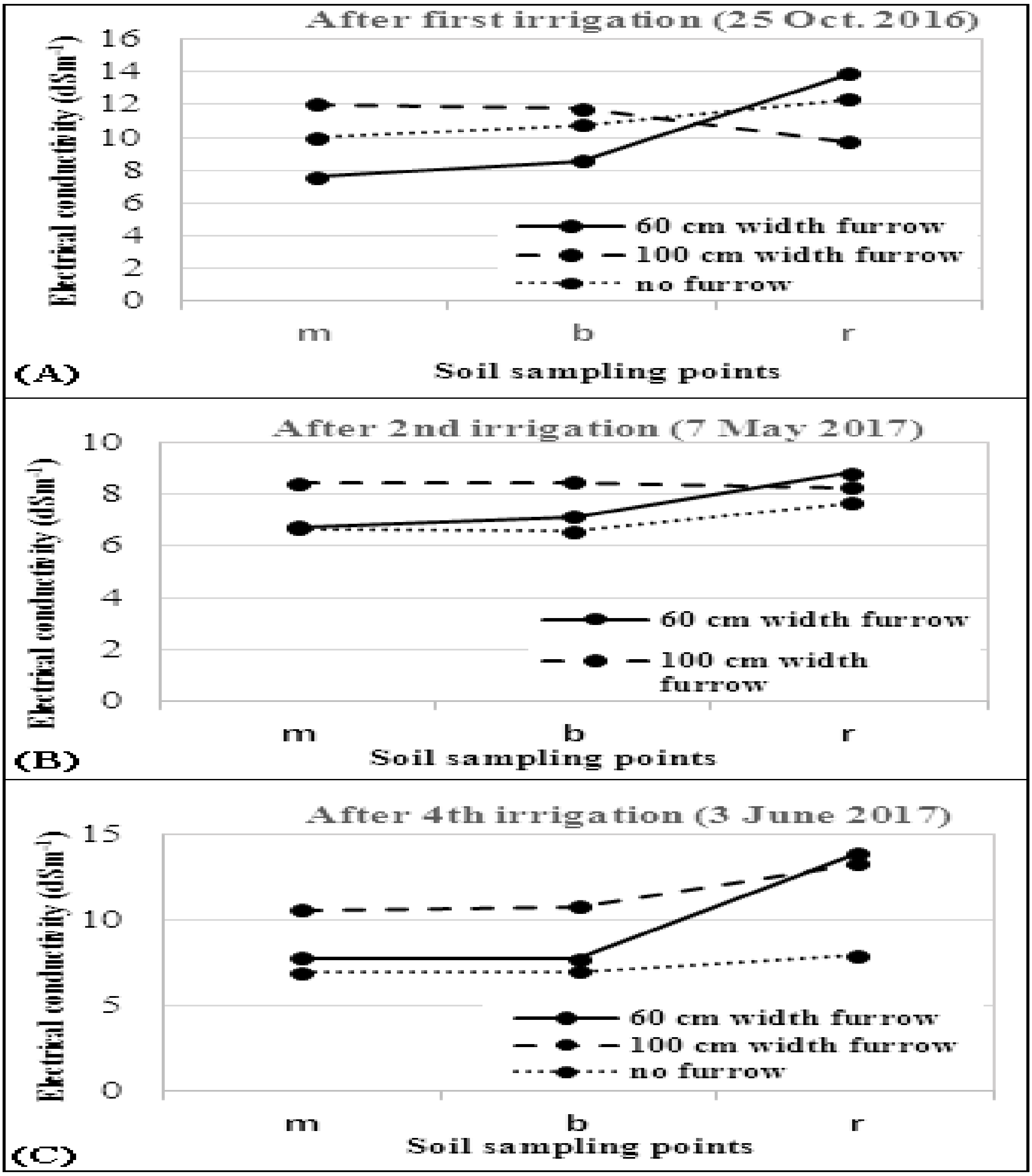

Fig. 5. The effect of different irrigation methods on soil salinity distribution after each irrigation events.

The other reason for the similarity of salinity reduction in both F3 and F5 treatments at the end of the growing season probably needs much time to complete the irrigation practice in plots of NOF treatment compared to the furrow irrigation treatments, therefore, more water is fed to the plots and the soil washed better (Fig. 8).

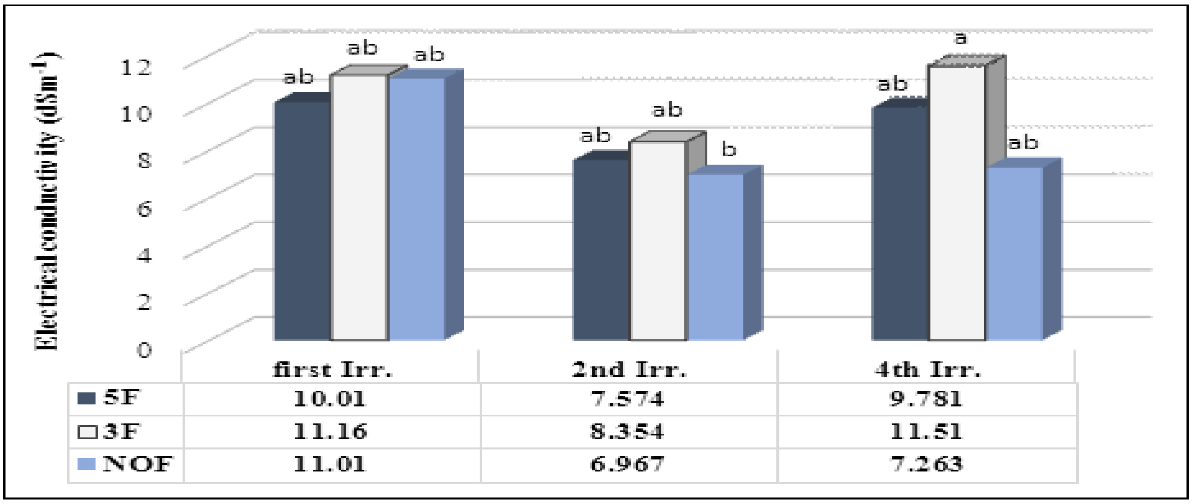

Fig. 6. Reciprocation effects of irrigation methods and irrigation events on soil salinity (EC). Means with dissimilar letters in each column have significant difference (LSD, P= 5%)).

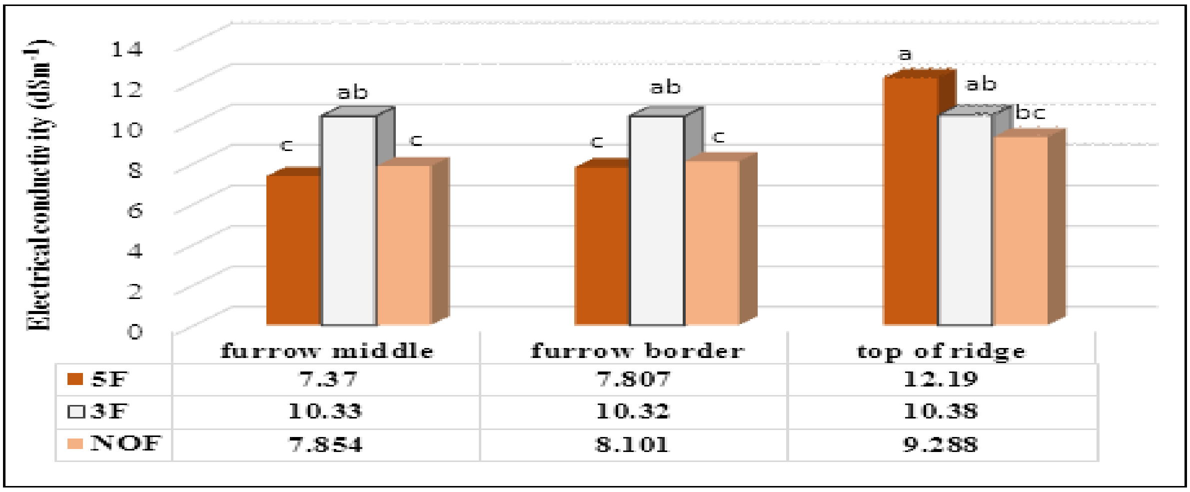

Fig. 7. Reciprocation effects of irrigation methods and sampling position on soil salinity (EC).Means with dissimilar letters in each column have significant difference (LSD, P= 5%).

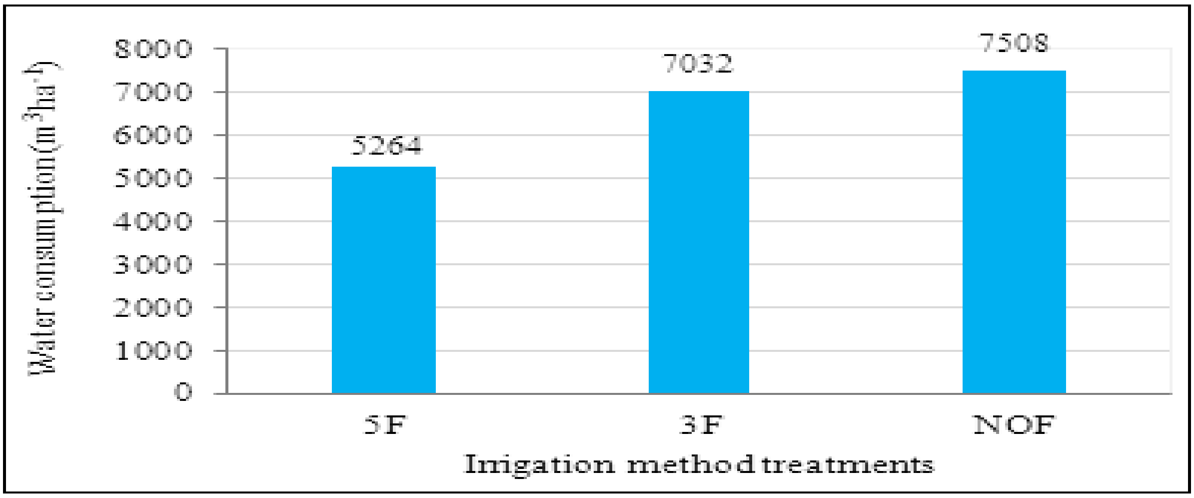

Fig. 8. Water consumption of irrigation method treatments.

Water consumption

Total water consumption of irrigation treatments during the growing season, furrow irrigation treatment with 60 cm furrow width (5F) had less water consumption than the other treatments (Fig. 8). Ghane *et al.* (2009) also achieved similar results. As the width of the irrigation furrows decreases, the space for water expansion inside furrows is limited by the ridges, and this probably leads to an increase in the velocity of water flow into furrows and reduced the time needed to complete the plots irrigation. Therefore, in a constant water flow rate, water consumption reduces as irrigation time reduces.

Conclusion

Reducing the width of the furrow from 100 to 60 cm resulted in better soil leaching from inside the furrows to the ridges and reducing irrigation water consumption. Flood irrigation method has been effective in reducing soil salinity, but due to the high consumption of irrigation water, this method is not recommended for arid areas. Consequently, in semi-arid areas with saline soils, planting within the narrow furrows and furrow irrigation is preferable.

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