SAFFLOWER (CARTHAMUS TINCTORIUS L.) WATER USE FROM SHALLOW GOOD QUALITY AND SALINE WATER TABLES IN LYSIMETERIC EXPERIMENT IN A SEMIARID REGION OF IRAN

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ABSTRACT Lysimetric studies were conducted to describe soil water fluxes in the presence of good and saline, shallow groundwater under a safflower (Carthamus tinctorius L.) crop to measure groundwater contribution. Safflower (Carthamus tinctorius L.) plants were grown in twenty columns. For each treatment four columns with diameters of 40 cm packed with Silty Clay soil were used. The variety of safflower grown was Sina names (PI-537598). In each treatment, ground water-table was maintained at 80cm depth. In one treatment ground water was tap water quality equivalent with EC 1000 (μ mohs/cm) and in the other treatments groundwater salinities were 2, 5, 8 and 10 dS/m respectively. Groundwater use as a part of crop evapotranspiration was characterized by using daily measurements of the water level in a ground water supply tank (Mariotte bottle). During all experiments, the magnitude of irrigation water requirement for each treatment was applied with good tap water quality with EC 1000 (μ mohs/cm) based on daily evaporation values from the Class A pan and daily crop water requirement. For each treatment, groundwater contribution was measured by mariotte siphons separately. The results of all experiments showed that increasing salinity reduced total root water uptake. The results of experiments also showed that for different treatments with good ground water quality, 2, 5, 8 and 10 dS/m, the groundwater contribution achieved 59, 51, 38, 32 and 19% of total plant water requirement respectively.

Keywords: Shallow groundwater, Groundwater contribution, Lysimeters, Salinity, Safflower.

INTRODUCTION

Saline groundwater is often found at shallow depth in irrigated areas of arid and semi-arid regions and is associated with problems of salinisation and water-logging, Ansari and Khanzada (1995). The conventional engineering solution is to lower the water table by artificial drainage, but this ignores the possible beneficial contribution to crop water requirements, Grimes and Henderson (1984). Water table management has been shown by various researchers to encourage the conservation of resources, increase productivity and reduce pollution. The environmental and economical benefits of water table management through reduced pollution and increased yields are well documented, Mejia et al. (2000). In view of increasing concern over water scarcity, there is another reason to re-evaluate the wisdom of the conventional drainage approach in that the shallow saline groundwater should not be seen as a waste product, but rather as a part of the available water resource, (Gowing et al. 2009).

When groundwater use by the crop is included in the irrigation water balance, the rate at which water is depleted from stored soil water is decreased and the irrigation interval can be increased, thus reducing the total number of irrigations and total required depth of applied water, so an energy-efficient water resource for agriculture is a shallow groundwater table sometimes defined as sub irrigation, Benz et al. (1981).

Many researchers have measured the saline and non-saline groundwater contribution for different agricultural crops in different irrigated or dry conditions. They found that the amount of the groundwater used by different crops could be affected by different parameters, such as: the quality and depth of water table, crop type, climatological conditions and soil type, Ayars et al. (2006). But the variation of crops, soils, water table depth, water table quality, climate and different irrigation scheduling make it very difficult to extend and generalise the results. Meek et al. (1980) and Grismer et al. (1988) reported that groundwater contributions are highly variable and difficult to predict. Gowing et al. (2009) suggested that proper management of irrigation requires understanding of direct water use by crops from the shallow water-table.

Successful exploitation of the water table depends on several factors that include water table depth, soil water retention and transmission properties, evapotranspiration demand, and the geometry of the plant root system, Van Bakel (1981). A number of studies have shown that between 20 to 40% of the evapotranspiration requirement of different crops can be met by capillary up flow from water tables at depths of 0.70-1.50 m, Ragab and Amer (1986); Ragab et al. (1988) ; Khandker et al. (1994); Ayars et al. (2006);Ghamarnia and Gowing (2007) and Gowing et al.(2009).

Usually, irrigation scheduling and management decisions do not take into account groundwater contributions to crop water use, Ayars and Hutmacher (1994) and precisely scheduling irrigation in the presence of shallow and saline groundwater requires better understanding of temporal and spatial patterns of water extraction by roots under these conditions. Hutmacher and Ayar (1991) found that the salinity has only a minor effect, up to some level dependent on the tolerance of the crop in question, then higher salinity levels cause groundwater use to decrease markedly. Salt content of the groundwater may affect root development and water extraction patterns and crop responses are difficult to predict when low-salinity irrigation water is used in shallow, saline groundwater areas because varying water qualities exist over time in different parts of the root zone, Rhoades and Loveday (1990).

The amount of water use by different crops in different shallow groundwater during the past 50 years reviewed by Ayars et al. (2006). As they reported, the most of the researches were conducted in non saline groundwater table condition and just a few studies have been conducted in different saline shallow groundwater table conditions.

Available limited researches in Iran and around the world on safflower production under irrigated conditions revealed that it was as a drought and salt-tolerant crop grows Bassil and Kaffka, (2002a,b). Moreover a limited research has been done to find the percent of groundwater contribution, irrigation scheduling and water use efficiency under presence of different good and saline groundwater condition by safflower in regional and global semi- arid region so far. Therefore, the main objectives of these investigation were 1- to find the soil water fluxes and groundwater contribution in the presence of good and saline (2, 5, and 8 and 10 dS/m) groundwater qualities with depth of 0.8 meter and total irrigation requirement under those mentioned conditions for savings in the consumption of water by safflower.

2. Material and Methods The experiments were performed in Irrigation and Water Resources Engineering Research Lysimetric Station in 47° 9' N and 34° 21' E at the elevation of 1319 m in the Faculty of Agriculture, Razi University of Kermanshah, west of Iran during two years 2008 and 2009 (from March to July). The study were conducted with 20 lysimeters installed in the above mentioned lysimetric station (consist of 80 lysimeter). In each experiment five treatments were applied by maintaining groundwater salinities at good tap water quality with EC 1000 (μ mohs/cm) and the other treatments groundwater salinities were 2, 5, and 8 and 10 dS/m respectively. Saline water for different treatments was produced by dissolving NaCl and CaCl2 (1:1 by mass) in tap water. All treatments in each experiment were carried out in four replicates. The 1.20-m height lysimeters were made of 0.40m diameter polyethylene PVC (Polyvinyl Chloride) material pipes, with the bottom closed by polyethylene sealed material and fixed by electrical special equipments to prevent any water leaching. In the bottom of each lysimeter 5 cm layer of gravel and 5 cm layer of sand were placed to promote unrestricted exchange with the groundwater supply (Figure 1). A silty clay soil consisting 54, 42.3 and 3.7 % for clay, silt and sand respectively was used for all lysimeters. In this study the soil was sieved through 1 cm mesh and after that all lysimeters were filled with air dry soil. During the lysimeters filling with 10 cm layers, soil was compacted manually to a wanted bulk density of 1.30 g/cm^3. In these experiments, the safflower variety of Sina names (PI-537598) was used as crop material.

The safflower seeds were planted on March 10th 2008 and 2009 respectively. The planting density was 30 kg per ha. Water requirement and the amount of water moved into the each lysimeter was measured by Mariotte siphons respectively (Figure1). The total concentration of fertilizers including N, P2O5 and K2O were 200, 150 and 200 kg/ha, respectively which was based on soil laboratory advice for both two experimental years. Almost half of P2O5 and K2O were applied during pre-planting while the remaining amounts were applied through the irrigation times. Crop evapotranspiration for each treatment was determined by using

$$ET_c = K_c \times E_{pan} \times K_p \quad (1)$$

where Etc is the crop evapotranspiration, Kc, Epan, Kp are crop coefficient, evaporation from Class A pan and pan coefficient, respectively. Groundwater use by plants in each lysimeter was managed by daily measurements of the groundwater level in related Mariotte siphons.

The volume of Irrigation water requirement for each treatment was calculated with interval two days by subtracting of measured Etc and groundwater contribution (GWC). The shortage magnitude of irrigation water requirement (by interval of two days) for each treatment was applied by good tap water quality with EC 1000 (μ mohs/cm).

Data were subjected to analysis of variance (ANOVA) using statistical analysis system and followed by Duncan's multiple range tests and terms were considered significant at P < 0.05 and 0.01 by MSTAT-C software.

3. Results and Discussion

3.1. Total water use and groundwater contribution During the the two years investigation and before starting of different groundwater salinity treatments, crops have received the same amount of water for seedlings and proper establishment. Twenty days after planting time, when 4 or 5 leaf provided for each plant, the different groundwater salinity treatments were applied. During the two year investigation, the total water used by plants for all treatments were the sum of the surface irrigation water applied and groundwater contribution (GWC). The results of all treatments in the first and second year of investigation) were presented in (Table 1).

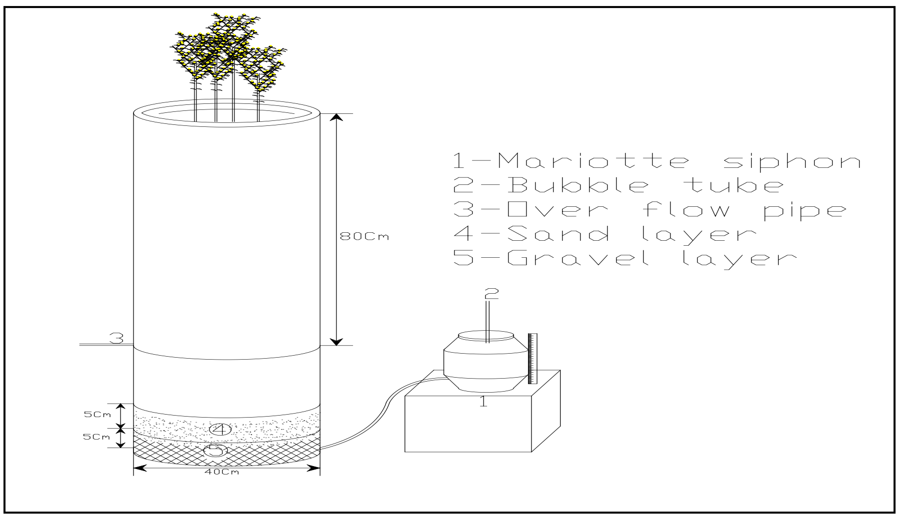

Figure. 1: Schematic of lysimeter (not to scale)

The total water use for all treatments was 667 mm and the lowest and highest surface good quality water used were achieved for treatments tap and 10 dS/m groundwater quality respectively. The sequence for surface water used in the first year investigation was for tap water (283 mm) < 2 dS/m (329 mm) < 5 dS/m (411mm)< 8 dS/m (454 mm)<10 dS/m (574 mm) respectively.

The results showed (Table 1) that when the groundwater salinity increased, the total groundwater used and the percentage of groundwater contribution decreased. The sequence for groundwater used and contribution during the first year investigation were equal to (384 mm with 58%)> (329 mm with 49%)>(256 mm with 48%) > (213 mm with 32%)>(120 mm with 18%) for tap, 2, 5, 8 and 10 dS/m groundwater quality respectively.

The results of all treatments in the second year investigation during year 2009 (Table 1) showed the same results as first year experiment during year (2008). In the second year investigation, the total water use for all treatments was less than first year experiment and equal to 625 mm because of lower meteorological condition during cropping period (data not shown). The sequence for surface water used in the second year investigation for tap water was (247 mm) < 2 dS/m (292 mm) < 5 dS/m (389mm)< 8 dS/m (424 mm)<10 dS/m (509 mm) respectively. Moreover, the sequence for groundwater used and contribution during the second year investigation were equal to (378 mm with 60%) > (333 mm with 53%) >(236 mm with 38%) > (201 mm with 32%)>(123 mm with 20%) for tap water, 2, 5, 8 and 10 dS/m groundwater quality respectively.The results of two year investigation (2008 and 2009) showed that the effects of groundwater quality on surface and groundwater used and contribution was significant (P<0.01). The results showed that the overall total water use of safflower was 646 mm and total groundwater contribution for tap and different 2, 5, 8 and 10 dS/m groundwater salinity treatments were 59%, 51% , 38%, 32% and finally 19% of total seasonal water use respectively (Table2). Soppe and Ayars (2002) found that groundwater contribution by safflower from 14 dS/m ground water quality with depth of 0.80 meter was 25% of crop water requirement. Bargahei and Mosavi (2006) reported that groundwater contribution by safflower in glass room condition from saline ground water quality with depths 0.90 meter was 45.3% of crop water requirement. The results indicated that the groundwater contribution by safflower in these experiments were lower than previously reported by other researchers especially for safflower in high groundwater salinities conditions.

Table1. Summary of total water, surface, groundwater use and groundwater contribution (year 2008 and 2009)

Year	Ground water quality (dS/m)	Total water Use (mm)	Total Surface water use (mm)	Total Ground water use (mm)	Ground water contribution (%)
2008	tap water		283	384	58a
	2 dS/m		329	329	49b
	5dS/m	667	411	256	38c
	8dS/m		454	213	32d
	10dS/m		547	120	18e
2009	tap water		247	378	60a
	2 dS/m		292	333	53b
	5dS/m	625	389	236	38c
	8dS/m		424	201	32d
	10dS/m		502	123	20e

Different letters indicate significant differences at (P < 0.01) using Duncan' s multiple range test

Table2. Summary of average total water, surface, groundwater use and groundwater contribution

Ground water quality (dS/m)	Average total water use (mm)	Average total surface water use (mm)	Average total ground water use (mm)	Average ground water contribution (%)
tap water	646	265	381	59a
2 dS/m		311	326	51b
5dS/m		400	246	38c
8dS/m		439	207	32d
10dS/m		525	122	19e

Figures 2 shows that in year 2008, the groundwater extraction started 25th May (77 days after planting) for treatments good, 2 and 10 dS/m groundwater quality and 28th May (80 days after planting) for treatments 5 and 8 dS/m groundwater quality respectively. Moreover, Figures 3 shows that the groundwater extraction for all groundwater quality treatments started 28th May (80 days after planting) in year 2009 respectively. During the both experimental years, at the beginning of the experiments, the groundwater contribution in the low salinity treatments were higher than higher salinity treatments, probably because of the rooting depth of safflower being closer to the water table in low salinity treatments compare to higher salinity treatments. Therefore, it was expected that the plants at low salinity treatments would take up more water from deeper parts of root zone. The figures 3 and 4 also showed that the groundwater contribution gradually decreased for all treatments, in the later stages of planting period. The results showed that the less saline groundwater, contributed more than higher saline groundwater. Figure4 and 5 shows a sharp increase and decrease of daily groundwater contribution, in the beginning and end of planting time during year 2008 and 2009. The overall results of two year investigation indicated that the groundwater contribution from less saline groundwater had met a greater part of the total crop water needs. It also indicated that groundwater contribution can be maximized by using less saline ground water quality. Our results were similar to the findings of Namken et al.(1969); Chaudry et al. (1974); Hutmacher and Ayars, (1991); Kruse et al. (1993); Smith et al. (1996); Sepaskhah et al.(2003) ; Bargahei and Mosavi, (2006). Ayars et al. (2009); Gowing et al. (2009). The results of groundwater contribution by safflower obtained in this study showed that the largest groundwater contribution in all treatments were occurred at the beginning of groundwater contribution not at the end of planting time. Probably because of salt accumulation in soil lysimeters during the growing period (figures 6 and 7). Our results were different to the finding of Soppe and Ayars (2003) who found that the largest groundwater contribution occurred at the end of safflower growing period.

In the present study the final soil salinity of different lysimeters depths at the end of growing period were presented in figures 6 and 7. As revealed by the results of experiments, more sallinisation were occurred for different depth of soil lysimeters during growing period. The soil profile of all lysimeters affected by saline groundwater upward fluxes and soil salinity. In different depth of all lysimeters salinity, increased during safflower growing period. The lowest and highest salinity levels were achieved for different treatments at depths 20 and 80cm of tap and 10 dS/m groundwater treatments respectively.

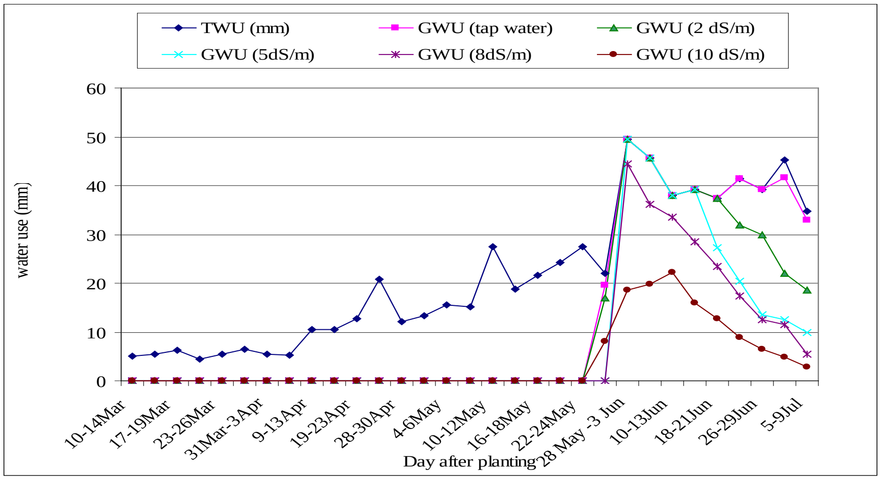

Figure2. Total and groundwater use during planting period (year 2008)

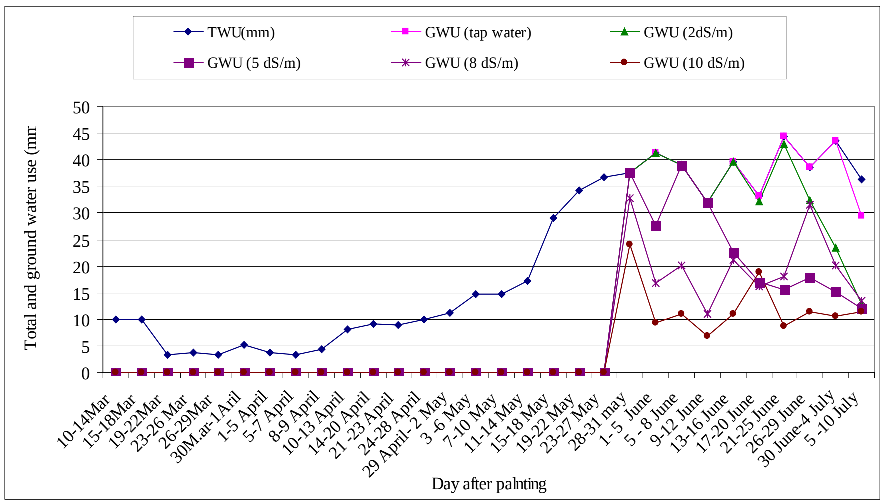

Figure3. Total and groundwater use during planting period (year 2009)

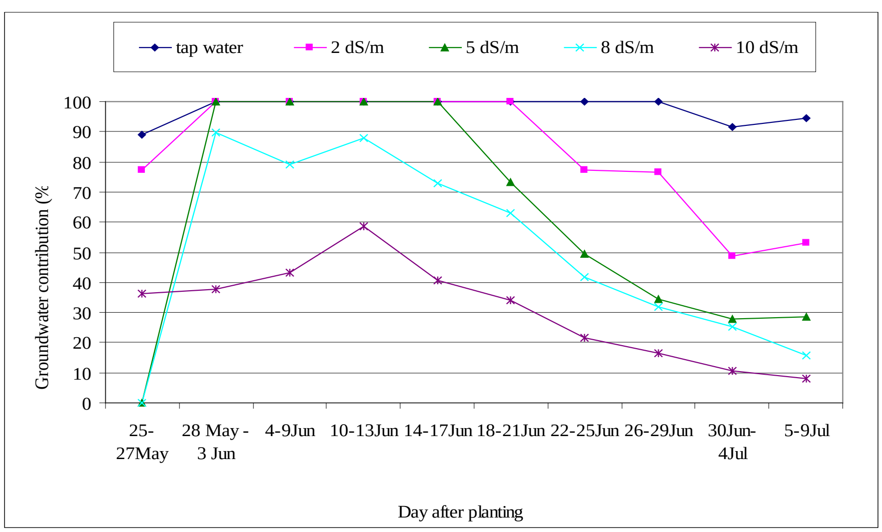

Figure4. Groundwater contribution (%) during planting period (year 2008)

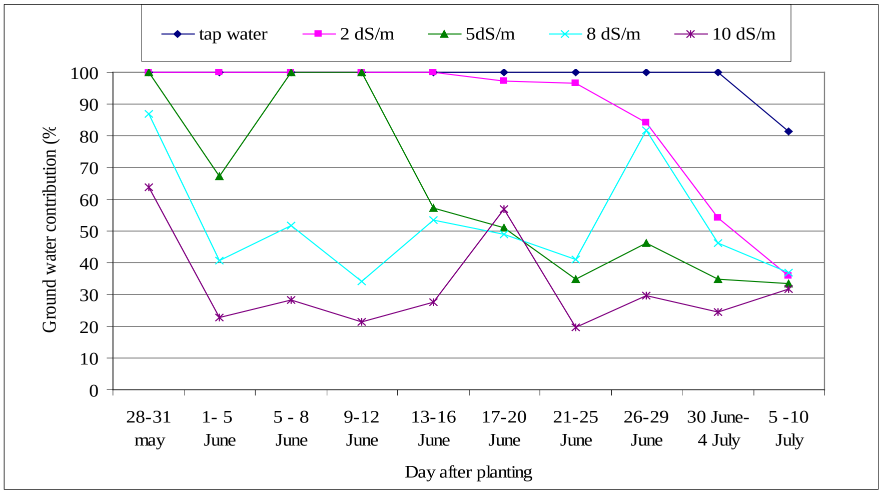

Figure5. Groundwater contribution (%) during planting period (year 2009)

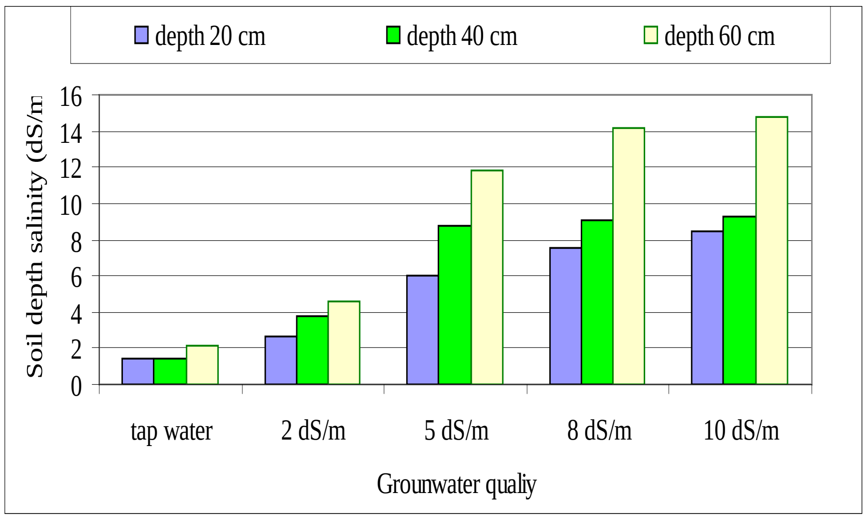

Figure6. The average soil salinity of different lysimeters depths (year 2008)

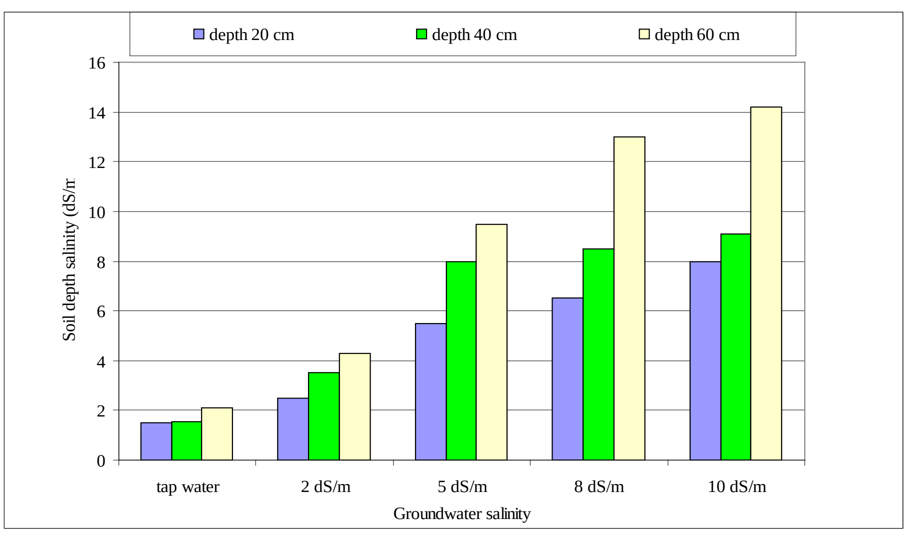

Figure7. The average soil salinity of different lysimeters depths (year 2009)

4. Conclusions Many researchers have measured the saline and non-saline groundwater contribution by different agricultural crops in different irrigated or dry conditions. They found that the amount of the groundwater used by different crops could be affected by different parameters, such as: the quality and depth of water table, crop type, climatological conditions and soil type. But the variation of crops, soils, water table depth, grounwater quality, climate and different irrigation scheduling make it very difficult to extend and generalise the results. In this present study the contribution of good and saline groundwater with different qualities (2, 5, 8 and 10 dS/m) in the presence of good surface quality was studied for safflower (*Carthamus tinctorius L.*) in a semi-arid climate in the presence of constant water table with depth of 0.80 m during two year 2008 and 2009.

The results of all experiments showed that increasing salinity reduced total root water uptake by safflower. The results of experiments also showed that for different treatments with good ground water quality, 2, 5, 8 and 10 dS/m, the groundwater contribution were achieved 59, 51, 38, 32 and 19% of total plant water requirement respectively. Therefore, the seasonal plant water requirement can be decreased and the plant irrigation interval can be increased.

5. References

Ansari, R., and A.N. Khanzada. 1995. Biological amelioration of saline soils. In: Proceeding f a Workshop on Drainage System Performance in the Indus Plain and Future Strategies. Drainage Research Institute of Pakistan, January, PP. 217-222**.**

Ayars, J. E., E. W. Christen, and R. W. Soppe. 2006. The resource potential of in-situ shallow ground water use in irrigated agriculture: a review. Irrig Sci 24: 147–160.

Ayars, J. E., P. Shouse, S. M. Lesch. 2009. In situ use of groundwater by alfalfa. Agricultural Water Management 96: 1579–1586.

Ayars, J.E., and R.B. Hutmacher. 1994. Crop coefficients for irrigating cotton in the presence of groundwater. Irrig. Sci. J. 15: 45-52.

Bargahei, K., and S. Mosavi. 2006. The effect of shallow saline groundwater on safflower(Carthamus tinctorius L.)in glass room condition. Agricultural Sci Nature Resourse. vol 3 (1), 59–69. (in Persion).

Bassil, E.S, and S.R. Kaffka. 2002a. Response of safflower (Carthamus tinctorius L.) to saline soils and irrigation I. Consumptive water use. Agricultural Water Management 54: 67–80.

Bassil, E.S, and S.R. Kaffka. 2002b. Response of safflower (Carthamus tinctorius L.) to saline soils and irrigation II. Crop response to salinity. Agricultural Water Management 54:81–92.

Benz, L.C., E.J. Doering, and G.A. Reichman. 1981. Water table management saves water and energy. Trans. ASAE. 24: 995-1001.

Chaudry, T.N, V.K. Bhatnagar, and S.S Prihar. 1974. Growth response of crops to depth and salinity of ground water, and soil submergence. I. Wheat (triticum aestivum L.). Agron J 66:32–35.

Ghamarnia, H., and Gowing, J.W. 2007. Root water uptake modeling in the presence of surface irrigation and saline shallow water table. In: ICID 22nd European Regional Conference, 2–7 September, Pavia, Italy.

Gowing, J.W, D.A. Rose, and H. Ghamarnia. 2009. The effect of salinity on water productivity of wheat under deficit irrigation above shallow groundwater. Agricultural Water Management. 96: 517-524.

Grimes, D.W., and D.W. Henderson. 1984. Developing the resource potential of a shallow groundwater. Calif. Water Resource Centre Bulletin No. 188, Agust 1984.

Grismer, M.E., T.K. Gates, and B.R. Hanson. 1988. Irrigation and drainage strategies in salinity problem areas. Califor. Agric. 42: 23-24.

Hutmacher, R.B, J.E Ayars. 1991. Managing shallow ground water in arid irrigated areas. Paper 912119. In: Proceedings of ASAE international summer metting Albuquerque, NM, 23–26 June,17 p.

Khandker, M. H. 1994. Crop growth and water use from saline water tables. Ph.D. thesis. University of Newcastle upon Tyne.

Kruse, E.G, D.F Champion, D.L Cuevas, R.L, Yoder,and D Young. 1993. Crop water use from shallow, saline water tables. Trans ASAE 36:696–707.

Meek, B.D., E.C. Owen-Bartlett, L.H. Stolzy, and C.K. Labanauskas. 1980. Cotton yield and nutrient uptake in relation to water table depth. Soil Sci. Soc. Am. J. 44: 301-305.

Namken, L.N., C.L. Weigand, and R.O, Brown. 1969. Water use by cotton from low and moderately saline static water tables. Agron J. 61:305–310.

Ragab, R. A., and f. Amer. 1986. Estimating water table contribution to the water supply of maize. Agricultural Water Management 11: 221-230.

Ragab, R.A., F. Amer, and W. M. El-ghamary.1988. The conjunctive use of rainfall and shallow water table in meeting water requirements of faba beans. Journal of Agronomy and Crop Science. 160: 47-53.

Sepaskhah, A.R., A. Kanooni, and M.MGhasemi .2003. Estimating water table contributions to corn and sorghum water use. Agricultural Water Management 58:67–79.

Smith, D.J, W.S Meyer, H.D Barrs,and E.C, Schwamberger. .1996. Lucerne daily water use and capillary upflow using weighing lysimeters: Effects of soil type and groundwater salinity, Technical Memorandum 96.6, CSIRO, Institute of Natural Resources and Environment, Division of Water Resources, March, 35 p.

Soppe, R.W., J.E, Ayars. 2002. Crop water use by safflower in weighing lysimeters. Agricultural Water Management 60:59–71.

Van Bakel, P. J.T. 1981. Unsaturated zone and evapotranspiration. Tech. Bull. 7, Institute for Land and Water Management Research, Wageningen, Netherland.