IMPACT OF DRAINAGE WATER USE FOR CROP IRRIGATION

Barkat Ali Nindwani[1], Bakhshal Khan Lashari[2], Ashfaq Ahmad Memon[2], Khalifa Qasim Laghari[2], Hafiz Mohkum Hammad[3,*] and Wajid Farhad[4]

e-mail: hafizmohkum@gmail.com

[1]Institute of Water Recourse Engineering & Management, Mehran University of Engineering and Technology Jamshoro, Sindh, Pakistan

[2]Dept. of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro, Sindh, Pakistan

[3]College of Agriculture, Bahadur Campus Layyah, Bahauddin Zakariya University, Multan, Pakistan

[4]Lasbela University of Agriculture, Water and Marine Sciences, Baluchistan

ABSTRACT: *Fresh water scarcity is the major limiting factor for crop production in the semiarid environment of Sindh (Indus Delta Zone). More land can become productive by using drainage water at strategic times for salt tolerant crops and forest. The investigation was conducted at Bareji canal command area of Sindhri. Alfalfa (Medicago sativa) crop sown on November 2009 using randomized complete block deign with three replications. The plot size was 10.06 m × 15.24 m. Five irrigation treatments, i.e., T_1 (control) = 100% canal water, T_2 = 100% drainage effluent, T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water were applied. The quality of canal water determined was good (ECw < 1.5 dS m^{-1}, SAR < 10.0), whereas the quality of drainage effluent determined was of secondary i.e. saline-non sodic (ECw 1.5 – 3.0 dS m^{-1}, SAR < 10.0). The statistical results revealed that maximum yield (2054 kg $Plot^{-1}$) as well as water use efficiency (27.38 kg m^{-3}) of crop was obtained under T_1 followed by T_3, T_5, T_4 and T_2 treatments. While the soil analytical results revealed that ECe and SAR decreased considerably at all the sampling depths under all five treatments the soil status changed from strongly saline (ECe >16.0 dS m^{-1}) to moderately saline (ECe 8-16 dS m^{-1}) and strongly sodic (SAR >7.0) to slightly/moderately sodic (SAR 7-12). Therefore, during the selection of crop soil properties should be examined.*

Key words: Alfalfa; Drainage water; Salinity; Water use efficiency.

INTRODUCTION

Forecasts of water withdrawal on a global scale predict sharp increases in future demand to meet the needs of the urban, industrial, and agricultural sectors. While recycle is an important as well as natural method of managing waste water. To get maximum benefit from a water supply and to facilitate disposing of drainage waters; strategies for water reuse have evolved. Drainage water must be balanced against both short and long term needs. In areas where irrigation water is limited, drainage water could use along fresh water [1]. The quality of the waste water determines which crops can be irrigated. Extremely saline drainage water cannot be used to irrigate salt sensitive crops. It could, however, be used on salt tolerant forages. Saline drainage water is being successively used for the irrigation of salt tolerant crops as well [2].

The major deprivation feature of drainage water is the high concentration of ions. Drainage water with low ionic absorption provides plants with an adequate supply of many of the essential nutrients required for growth. As salinity rises, specific ions become toxic and obstruct with uptake of other nutrients. In agriculture lands, the addition of ions increases the osmotic probability against which crops extract water [3]. It can also spoil soil structure. Deep soil leaching of salts from the root zone are important factors in the management of sodicity in crop growth. Another management factor is control of the range of salt tolerance expressed in crop species. Reuse of drainage water for crops has distinct economic incentives and many crops are known to be highly tolerant to salinity but it needs to check and manage irrigation and drainage practices and sustainability of the system.

It is possible to safely use agricultural drainage water if the quality of the water, soil, and the intended crop is known and can be economically managed. Toxic water requires selection of crops with appropriate salt tolerances, improvements in water management, and maintenance of soil structure and infiltration [4]. High care is needed during sensitive crop growth stages such as germination and early growth stages are expelled. Salt within the rooting depth integrated over the time of exposure is an effective determination of crop response. Crop responds to the weighted mean salinity within a specific growth period.

As salinity increases beyond some specific crop tolerance, yield decline is expected. It depends upon crop species and salinity level also influence the rate of plant development by increasing or decreasing the time to crop maturity [5]. In most crops there are some notable differences in root or shoot ratio, a response that would not be identifiable in the field. In some crops, salinity changes plant growth habit or increases moistness [6].

The goal of irrigated-agriculture has been to maximize yield and income, obtained by the net difference between inputs and outputs. To enhance yields, soil is to be improved by reducing salinity which is done by leaching. This goal is intervene by costs of water, drainage, applied nutrients and adjustments to soils and waters. If water quality and quantity is limited where there are restrictions on drainage, the dangerous effects of salinity on crop growth and the dangers of either insufficient or excessive leaching are serious concerns. However, agriculture can be done with saline waters if suitable irrigation and cropping strategies are used [7]. Supervision needs to be more rigorous and more precise methods should be used for water application and distribution. Water needed for crop and leaching should be precisely evaluated and provided in a timely approach. With salty water, growth and evapotranspiration are decreased. In initial stage some crop water use coefficients may apply excess water because the water un-used by the crop is needed to offset the increase in the leaching [8]. The larger the salinity of the water requires adequate irrigation and drainage. Increasing salts in the soil are dependent upon the amount and concentration of the saline water applied and the amount remaining after plant water needs have been provided. In a properly managed sustainable system, there may be a high salt content but no continuing accumulation [9, 10].

Characteristics of the drainage and canal water might influence soil properties and yield. The implementation of controlled drainage, or any other management practice, not only increases the crop productivity it will also improve soil. Judicious use of crop inputs is a guarantee of soil environment. Limited information is available about the effects of reuse of drainage water on crop as well as on soil treated with different combination of drainage and canal water for irrigation. However, reuse of drainage water is not used at large scales in developing countries due to toxic effect on crop as well as little knowledge and limited research. More information about reuse of drainage water is needed to extend to farmers for mitigating the scarcity of fresh water [11]. The study, therefore, seeks (i) the possible combination of fresh water and drainage water in reducing the effect of drainage water on soil. (ii) To explore the level of drainage water for salt tolerant crop. We hypothesized that reuse of drainage water with the combination of canal water mitigate the water scarcity by growing the salt tolerant crops.

2. MATERIALS AND METHODOS

2.1 Experimental site

The experiment was conducted during 2009-10 at Baraji canal command area, where tile drainage system was already installed. The soil of experimental site was with the characteristic of clay loam. The experimental site lies at 25˚ latitude and 68˚ longitude while the elevation of land is about 13 m above sea level. The experimental site is shown in Fig. 1.

2.2 Experimental design and treatments

The experiment was followed randomized complete block design (RCBD) arrangement. Each treatment was repeated thrice so that soil fertility error if any could be controlled. The five irrigation treatments [T_1 = Irrigation with 100% canal water (control), T_2 = Irrigation with 100% drainage effluent (D.E), T_3 = Alternate irrigation with canal water and D.E., T_4 = 85% Drainage effluent + 15% leaching fraction (L.F) with canal water, T_5 = 75% Drainage effluent + 25% L.F with canal water] were tested on alfalfa (fodder) crop. The total plot was 15 with each plot size 10.06 m × 15.24 m = 153.31 m^2 and in each replication among the main plots a buffer plot was kept to avoid moisture effects. The quality of drainage and canal water were analyzed four times (Table 2) by following the standard operating procedures for water sampling methods.

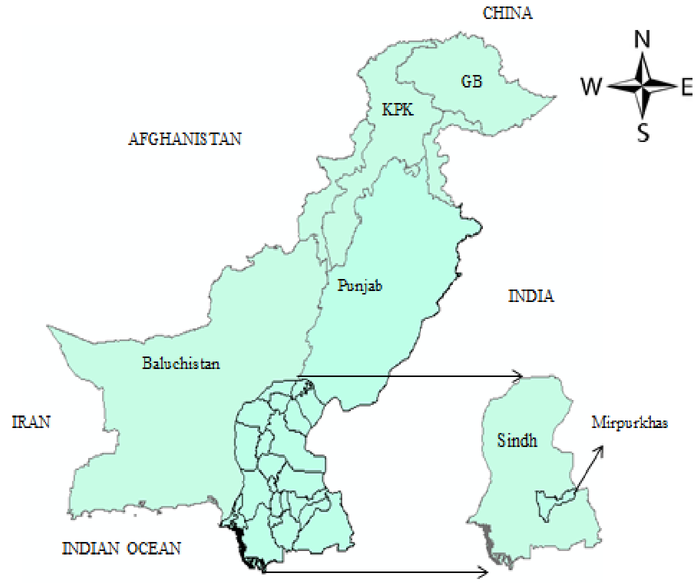

Figure 1: Experimental site, Baraji canal command area in Mirpurkhas in, Sindh (one of the provinces of Pakistan including Baluchistan, Punjab, KPK [Khyber Pakhtunkhwa], and GB [Gilgat Baltistan]) lies at 25^o latitude and 68^o longitude at an elevation of about 13 m above mean sea level taken from Indian Ocean in South of the country.

Table 1. Amount of irrigation water applied to alfalfa crop

No. of Irri.	Date of Application	Kind of Water	Water applied (m^3)				
			T_1	T_2	T_3	T_4	T_5
-	02/11/09	Canal Drainage	34.5 ---	---- 34.5	34.5 ---	5.17 (L.F) 29.33	8.6 (L.F) 25.8
1st	17/11/09	Canal Drainage	34.5 ---	---- 34.5	---- 34.5	5.17 29.33	8.63 25.87
2nd	02/12/09	Canal Drainage	34.5 ---	---- 34.5	34.5 ---	5.17 29.33	8.63 25.87
3rd	17/12/09	Canal Drainage	34.5 ---	---- 34.5	---- 34.5	5.17 29.33	8.63 25.87
4th	01/01/10	Canal Drainage	34.5 ---	---- 34.5	34.5 ---	5.17 29.33	8.63 25.87
5th	16/01/10	Canal Drainage	34.5 ---	---- 34.5	---- 34.5	5.17 29.33	8.63 25.87
6th	01/02/10	Canal Drainage	34.5 ---	---- 34.5	34.5 ---	5.17 29.33	8.63 25.87
7th	16/02/10	Canal Drainage	34.5 ---	---- 34.5	---- 34.5	5.17 29.33	8.63 25.87
8th	04/03/10	Canal Drainage	34.5 ---	---- 34.5	34.5 ---	5.17 29.33	8.63 25.87
9th	16/03/10	Canal Drainage	34.5 ---	---- 34.5	---- 34.5	5.17 29.33	8.63 25.87
Total/ Treatment		Canal Drainage	345 ---	---- 345.0	172.5 172.5	51.7 293.3	86.3 258.7

Total / ha	Canal Drainage	7500 ---	---- 7500	3750 3750	1124 (L.F) 6376	1876 5624

T_1 (control) = 100% canal water, T_2 = 100% drainage effluent, T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water

2.3 Crop irrigation

For alfalfa crops fortnightly irrigation was applied in which discharge of water was measured by a cut-throat flume (4" × 3' size), that was installed in the main water course. Thus, the discharge was observed and the quantity of water to be applied in each replication per plot was computed accordingly. The total water used under each treatment was computed by following relation [12]:

$$Q_f = C_f (H_U)^{nf} \qquad (1)$$

Where; Q_f is free flow discharge in cusecs; C_f is free flow coefficient which is 1.40 (for 4" × 3' size flume); *nf* is free flow exponent is 1.84 (for 4" × 3' size flume); H_U is upstream flow depth in ft.

b) Formula for submerged flow (if H_d / H_U is > 0.68)

$$Qs = \frac{Cs(H_U - H_d)^{nf}}{(-\log s)^{nf}} \qquad (2)$$

Where, Q_s = Submerged flow discharge in cusecs; C_s = Submerged flow co-efficient = 0.94 (for 4" × 35" size flume); H_d = Downstream flow depth in ft; *nf* = Submerged flow exponent = 1.38 (for 4" × 3' size flume); and s = H_d / H_U.

Thus, the quantity of water applied was recorded in ft^3 which was converted into m^3 (Table 1)

2.4 Yield observation

The first cutting of alfalfa was obtained after one month of sowing, whereas the last and fourth cutting was obtained in March 2010. At each time, the fodder yield was obtained weighed separately for each plot per replication and recorded. Thus, the whole fodder yield obtained from all the four cuttings was computed and yield under each treatment was converted in kg ha^{-1}.

Table 2. Analytical results of canal & drainage water samples

No.	Date of Sampling	Kind of water	Parameters: ECw (dS/m)	pH	SAR	RSC	Water Quality
1	31.10.09	Canal	0.29	7.3	1.44	Nil	Good
2	31.10.09	Drainage	2.93	7.7	4.39	Nil	Marginal (saline)
3	29.04.10	Canal	0.43	7.1	1.2	Nil	Good
4	29.04.10	Drainage	2.77	7.3	4.1	Nil	Marginal (saline)

2.5 Water use efficiency (WUE)

The water use efficiency (WUE) of alfalfa (fodder) crop for each treatment was computed by following relations [13]

$$WUE = \frac{Y}{WU} \times 100 \qquad (3)$$

Where, WUE is water use efficiency (in kg m^{-3} of water); Y is total yield (kg $Plot^{-1}$) and WU total volume of water used (m^3 ha^{-1}).

2.6 Water observation

For the observation and recording water table depths, a peizometers or observation well has been installed in the project area. Therefore, water table depths were observed and recorded periodically.

3. RESULTS AND DISCUSSION

3.1 Irrigation application

Alfalfa crop was sown in November 2, 2009 and the last (4th) cutting was completed in April 2010. Date wise application of irrigation waters (canal and drainage) applied under each treatment at an interval of 15 – 16 days, and given in Table 1.

Table 3. Influence of canal and drainage water on fodder yield of alfalfa crop.

Treatments	Fodder Yield (kg $plot^{-1}$) Cuttings: 1^{st}	2^{nd}	3^{rd}	4^{th}	Total Yield (kg $plot^{-1}$)
T_1	260 a	560 a	620 a	614 a	2054 a
T_2	101 e	102 e	105 d	65 e	343 e
T_3	240 b	365 b	570 b	605 b	1780 b
T_4	157 c	215 d	97 e	95 d	534 d
T_5	133 d	237 c	330 c	310 c	1010 c
Significance	**	**	**	**	**
LSD	7.45	7.23	6.90	0.90	16.36

T_1 (control) = 100% canal water (C), T_2 = 100% drainage effluent, T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water, LSD = Least significant difference

The results reveal that, total number of irrigations including soaking dose applied to alfalfa crop was 10 and total quantity of water in T_1, T_2 and T_3 was 7500 m^3 ha^{-1} in each treatment (100% canal water, 100% drainage effluent and 50% canal and 50% drainage effluent respectively). Whereas in T_4 and T_5, the total quantity of water applied was 7500 m^3 ha^{-1} (6376 m^3 D.E. + 1124 m^3 L.F. canal water) and 7500 m^3 ha^{-1} (5624 m^3 D.E. + 1876 m^3 L.F. canal water) respectively.

3.2 Analytical result of canal and drainage water

According to the Table 2, result regarding analytical analysis, in both the canal water samples (0.29 and 0.43 dS m^{-1} during 31-10-09 and 29-04-10, respectively) ECw was recorded which are below 1.5 dS m^{-1}, pH < 7.5, SAR < 10.0 and RSC was nil, indicating that the canal water used for irrigation was of good quality (usable). On the other hand, the ECw of both the drainage water samples (2 and 4) was in between 1.5 to 3.0 dS m^{-1}, indicating that drainage water is moderately saline / marginal quality. However, the pH and

SAR were under safe limits i.e. pH < 7.5 and SAR < 10.0 which indicated that the drainage water was non-sodic. Such quality of drainage waters can only be used for irrigation under good soil, water management and drainage conditions or blending with canal water otherwise the soils are liable to become saline within a couple of years. The results are in agreement with the finding of workers in [14] who reported that pH and SAR of water influence crop productivity.

3.3 Alfalfa (fodder) yield

Alfalfa fodder crop gave the four cutting during the one season. According to the statistical analysis each cutting yield was significantly affected by the different source of irrigation water (Fig. 2). Table 3 showed that the maximum was recorded in T_1 treatment (100% canal water). The yield obtained under each cutting in each treatment is presented in Table 4. Results indicated that the total highest yield (2054 kg plot^{-1}) was obtained under T_1 followed by T_3 (1780 kg plot^{-1}), T_5 (1010 kg plot^{-1}), T_4 (534 kg plot^{-1}) and T_2 (343 kg plot^{-1}).

Table 4. Influence of canal and drainage water on fodder yield of alfalfa crop

Treatments	Fodder Yield (kg plot^{-1}) Cuttings				Total Yield (kg plot^{-1})
	1st	2nd	3rd	4th	
T_1	260 a	560 a	620 a	614 a	2054 a
T_2	101 e	102 e	105 d	65 e	343 e
T_3	240 b	365 b	570 b	605 b	1780 b
T_4	157 c	215 d	97 e	95 d	534 d
T_5	133 d	237 c	330 c	310 c	1010 c
Significance	**	**	**	**	**
LSD	7.45	7.23	6.90	0.90	16.36

T_1 (control) = 100% canal water (C), T_2 = 100% drainage effluent, T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water, LSD = Least significant difference

The lowest yield was obtained under T_2 where 100% D.E. was applied that affected the crop yield. Further, yield indicates that 50% DE 25% CW also gives, very significant yields and reduce the application of fresh water by 50%. These results are supported by the finding of [15].

3.4 Water use efficiency (kg m^{-3})

The water use efficiency (WUE) of alfalfa (yield per unit volume of water) was computed for each treatment separately and is given in Table 5. According to the statistical analysis WUE significantly influenced under different treatments (Table 5). The result revealed that the highest WUE was achieved in T_1 i.e. 27.38 kg m^{-3} followed by T_3 (23.73 kg m^{-3}), T_5 (13.46 kg m^{-3}), T_4 (7.12 kg m^{-3}) and T_2 (4.57 kg m^{-3}). Thus under T_2, T_3, T_4, and T_5, the WUE decreased to 83.3%, 13.3%, 74.75% and 49.15% against T_1 respectively. However, T_3 (Alternate irrigation with canal and D.E.) gave a good response as only 13.33% WUE was decreased under this treatment as compare to T_1 (100% Canal water alone).

3.5 Water saving against the yield of Alfalfa

The water saving against the increase / decrease in yield of alfalfa fodder in each treatment in comparison to T_1 (Control) is given in Table 6. The result indicated that with an irrigation application of 100% drainage effluent (D.E.) under T_2, the fodder yield decreased to 83.31%. However, under T_3 when 50% canal and 50% drainage effluent (alternate irrigation) were applied, only 13.3% yield decreased against T_1 (as Bench Mark). Thus, under T_3, 50% canal water saving have been achieved. Likewise, under T_4 and T_5, although 74.00% and 50.82% water saving was achieved but, the fodder yields under these two treatments decreased to a great extent. In spite of this, T_5 (75% D.E. + 25% L.F.) was found better than T_4 (85% D.E. + 15% L.F.). Thus, it can be observed from above findings that for alfalfa production on a saline-sodic soil, T_3 and T_5 are suggested [16]. Moreover, in term of water saving the farmer can save water by recycling the drainage water with the combination of canal water for irrigation purpose [17, 18]

Table 5. Water use efficiency of alfalfa crop during the growing season

Treatment	Water used (m^3)	Yield (kg plot^{-1})	WUE (kg m^{-3})
T_1	7500 (100% C)	2054 a	27.38 a
T_2	7500 (100% D.E.)	343 e	4.57 e
T_3	7500 (50% C + 50 D.E.)	1780 b	23.73 b
T_4	7500 (85% D.E. + 15% C)	534 d	7.12 d
T_5	7500 (75% D.E. + 25% C)	1010 c	13.46 c
LSD	-	16.36	0.21

T_1 (control) = 100% canal water (C), T_2 = 100% drainage effluent (D.E), T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water, LSD = Least significant difference

3.6 Soil Salinity/ Sodicity Status

In order to know the salinity/sodicity status pre and post study composite soil samples were collected from alfalfa plots. These soil samples were analyzed for texture, ECe, pH and SAR factors. The ECe under T_1, T_2, T_3, T_4 and T_5 ranged from 18.1 to 21.8 (as bench mark data) decreased to 13.9 to18.5, indicating that ECe was decreasing slowly thereby leaching of salts or reclamation process under all the five treatments at all the five sampling depths. However the pH and SAR values averagely increased to 7.3 to 8.5 and 11.5 to 12.5 respectively, after harvest of the crop. The high pH and SAR values after crop harvest attributed to the fact that during reclamation of a salin-sodic soil with simple leaching without adding any chemical amendment, the soluble salts are leached down leaving behind the exchangeable bases which after hydrolysis result in increasing the pH and SAR of the soil. Many research studies have revealed that a saline soil which is light to medium in texture can be reclaimed within 2-3 years period through cropping under good drainage conditions [19, 20]. However, gypsum (Ca SO_4 $2H_2O$) is needed to reclaim such saline-sodic soils. On the other hand, [21] reported that the salinity in root zone area increased upto 3.0 dS m^{-1} with the application of drainage water for 5-year period.

Table 6. Water saving in Alfalfa under the treatments

Treatment	Water used (m^3)	Water saving canal (%)	Increase/ decrease in yield (%)
T_1	7500 (Canal)	---	100 (**B.M**.)
T_2	7500 (D.E)	100.0	- 83.3
T_3	3750 (Canal + (3750 D.E)	50.0	- 13.3
T_4	6376 (D.E) + 1124 (Canal)	85.0	-74.0
T_5	5624 (D.E) + 1876 (Canal)	75.0	- 50.8

T_1(control) = 100% canal water (C), T_2 = 100% drainage effluent (D.E), T_3 = alternate irrigation with canal water and drainage effluent, T_4 = 85% drainage effluent + 15% leaching fraction (L.F) with canal water, and T_5 = 75% drainage effluent + 25% L.F with canal water, B.M = Bench Mark

3.7 Ground water table depth

The water table depths from ground surface in the study area ranged from 90 cm to 147 cm. The Lowest water table was observed in the second week of March, whereas the highest was recorded in May 2010. However, it used to fluctuate from 90 to 147 cm depth during the season. The shallow water table depths occurred because of uneven electric power supply for pumping out drainage water (effluent) in drains. However, the water table was enough deep for the cultivation of ordinary crops.

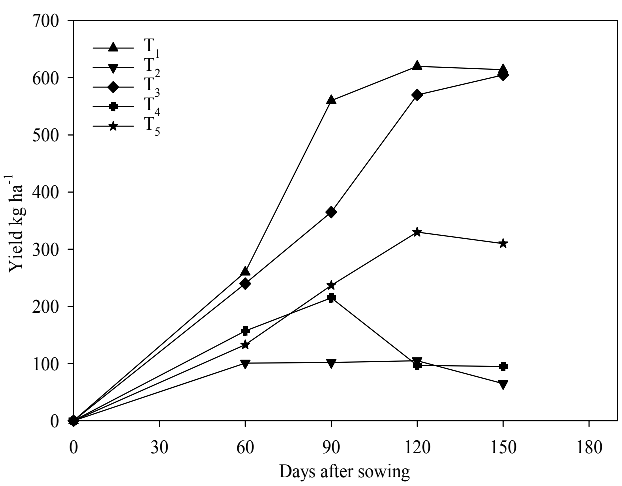

Fig. 2: Alfalfa crop response to quality of irrigation water during growing season.

4. CONCLUSIONS

i. Higher yields and WUE of alfalfa (fodder) were obtained when irrigated with canal water alone (T_1). Whereas, lowest yields and WUE was recorded when irrigated with drainage effluent (T_2). The yield in mixed water treatments T_3, T_4, and T_5 are decreased by 13.3%, 74.0% and 48.2%, respectively as compared to T_1 (control). Thus, T_3 (alternate irrigation with canal water and drainage effluent) furnished best results which was close to T_1. Although the yields of alfalfa decreased under T_2, T_3, T_4, and T_5, (83.3%, 13.3, 74.0% and 75.5%, respectively) nevertheless, the water saving under these respective treatments were recorded good that is imperative in water conservation management.

The analytical results of soil samples before sowing and after harvest of alfalfa crop indicated that soils under all the five irrigation treatments were reclaiming to a considerable level after a crop season. It is therefore, expected that if intensive salt tolerant cropping practice be continued, these soil will become normal, so that excessive salts used by crop and rest could be leached down.

5. RECOMMENDATIONS

The farmers who have saline/sodic lands and good drainage arrangements, should bring such lands under agro forestry system i.e. growing of field and forage (salt tolerant crops) and forest tree species using drainage effluent/mixing of saline water with canal water in 1:1 ratio or alternate irrigation with canal and drainage effluent. In this way not only 50% canal water saving will be obtained but good crop yields will also be achieved. Thus, poor land and water recourses could be utilized, thereby producing additional food and fiber which certainly will uplift their living standard in addition to provide better change in environment. More research in the direction of agro forestry system is needed i.e. to conduct research under different soil textures, salinity/sodicity status ,using different drainage quality waters to grow various kinds of field and forage crops and forest tree plant species under local conditions.

6. ACKNOWLEDGEMENTS

Authors thank to the World Wide Funds (WWF) for financial support during research work of this study. Authors are also grateful to Mr. Faiz Muhammad Mangrio land owner and Mr. Akbar Mangrio tenant for their kind help, cooperation and support extended to in the field during the study period.

REFERENCES

1. Qadir, M., S. Schubert, A. Ghafoor and G. Murtaza, "Amelioration strategies for sodic soils," *Land Degradation & Development*, Vol. **12**, No. 4, pp. 357−386. (December 2001).
2. Zeng, L., M.C. Shannon and S.M. Lesch, "Timing of salinity stress affects rice growth and yield components," *Agricultural Water Management*, Vol. **48**, No. 3, pp. 191−206. (2001)
3. Marcar, N. E., R. Ansari, A. N. Khanzada and M. A. Khan and D.F Crawford, "Performance of several tree species on a saline site in Southern Pakistan," *Journal-of-Tropical Forest Science*, Vol. **15**, No. 3, pp. 457−468. (2007)
4. Ahmad, R. and M.H. Chang, "Salinity control and environmental protection through halophytes," *Journal of Drainage and Water Management*, Vol. **6**, No. 2, pp. 17−25.

5. Shannon, M. C., C.M. Grieve, and L.E. Francois, "Whole-Plant Response to Salinity," In: Plant-Environment Interactions (Wilkinson, Ed.). New York: Marcel Dekker, pp. 199−244. (1994)
6. Simunek, J. S.A. Bradford, "Vadose Zone Modeling: Introduction and Importance," *Vadose Zone Journal*, Vol. 7, No**.** **2**, pp. 581−586. (February 2008)
7. Hamdy, A., P. Sfeir, U. Aksoy, D. Anac, S. Anac, J. Beltrao, J. Ben-Asher, J. Cuartero, T. J. Flowers and S. Hepaksoy, "Use of soil conditioners under saline irrigation: effect of wheat", *Proceedings of the International Symposium on Techniques to Control Salination for Horticultural Productivity, Antalya, Turkey*, pp.339−348.
8. Suarez D. R. and P. Taber, "Numerical Software Package for Estimating Changes in Solution Composition Due To Changes in Soil Water Content", United States Salinity Laboratory, USDA, http://ars.usda.gov/Services/docs.htm?docid 14567. (2007)
9. Warrence, N. J., J. W. Bauder, and K. E. Pearson, "Basics of salinity and sodicity effects on soil physical properties." Montana State Univ., Bozeman, MT, http://waterquality.montana.edu/docs/methane/basics.shtmL. (2002)
10. Singh, P. N. and W. W. Wallender, "Effects of Soil Water Salinity on Field Soil Hydraulic Functions", DOI: 10.1061/(ASCE)IR.1943-4774.0000290 *American Society of Civil Engineers*, ASCE, pp. 295−303. (2011)
11. Yadev, R. K., A. Kumar, D. Lal and L. Batra, "Yield responses of winter (Rabi) forage crops to irrigate with saline drainage water", *Experimental-Agriculture*, Vol. **40**, No. 1, pp. 65−75. (2003)
12. Manekar, V.L., P.D. Porey and R.N. Ingle, "Discharge Relation for Cutthroat Flume under Free-Flow Condition" *Journal of Irrigation and Drainage Engineering*, Vol. 133, No. 5, pp. 495:495−499. (2007)
13. Ayars, J. E., R.W. Soppe, and P. Shouse, **"**Alfalfa Production Using Saline Drainage Water" *Journal of Irrigation and Drainage Engineering*, Vol. **60**, No. 1, pp. 123−135. (2011)
14. Franzen D. and H. Kandel. Groundwater and Its Effect on Crop Production. Narth Dakota State University extension service. www.ag.ndsu.edu/northcentralrec (2013)
15. Samani, Z., R. Skaggs, and J. Longworth, "Alfalfa Water Use and Crop Coefficients across the Watershed: From Theory to Practice." *Journal of Irrigation and Drainage Engineering*, Vol. **139**, No. 5, pp. 341−348 (2013)
16. Rhoades, J. D. "Evidence of the potential to use saline water for irrigation". In: International seminar on the re-use of low quality water for irrigation Egypt: CIHEAM - Mediterranean Agronomic Institute of Bari and Water Research Centre, pp. 16−21. (1988)
17. Abbott, C. L., P. Lawrence, G. R. Pearce and S. A. Gawad, "Review of the potential for controlled drainage around the world," HR Wallingford Report, pp. 46. (2002)
18. Khalil, B. M., S. T. Abdel-Gawad and J. A. Millette, "Impact of controlled drainage on rice production, irrigation water requirement and soil salinity in Egypt," In: Cooke, R. (Ed.), Drainage VIII Proceedings of the Eighth International Symposium, Sacramento, CA, USA, *ASAE* pp. 443−452. (2004)
19**.** Levy, G. J., D. Goldstein, and A.I. Mamedov, "Saturated Hydraulic Conductivity of Semiarid Soils: Combined Effects of Salinity, Sodicity, and Rate of Wetting.", *Soil Science Society of America Journal*, Vol. **69**, No. 3, pp. 653–662. (2005)
20. Richards, L. A. "Diagnosis and Improvement of saline and alkaline soils," Handbook, US Department of Agriculture, Vol. **60**, pp. 146. ()
21. Bahceci, I., R. Cakir, A. S. Nacar, and P. Bahceci, "Estimating the effect of controlled drainage on soil salinity and irrigation efficiency in the harran plain using saltmod," *Turkish journal of agriculture and forestry*, Vol. **32**, No. 2, pp. 101–110. (2008)