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RESEARCH ARTICLE

EFFECT OF IRRIGATION WATER SALINITY ON TRANSPIRATION AND LEACHING REQUIREMENT: A CASE STUDY FOR WHEAT UNDER SEMIARID ENVIRONMENT OF PUNJAB

Zainab Noreen^a, Muhammad Mohsin Waqas^b, Syed Hamid Hussain Shah^{a,c}^a Department of Irrigation and Drainage, University of Agriculture, Faisalabad.^b Department of Agricultural Engineering, Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan^c Faculty of Science and Technology, Athabasca University, Canada*Corresponding author email: shahgee1347@hotmail.com

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ABSTRACT

Salt is a natural component of soil and water. Salinization can be produced by natural processes such as weathering or mineral phase out of an ocean. Also, it can be produced by artificial means such as irrigation. Land degradation by salinity, sodicity or combination of both is one of the major impediments to agricultural productivity throughout the world. Most salt-affected soils occur in arid and semi-arid climates. Around 800 million hectares (mha) of land (5-6% of world total land area) are salt affected. The problem of salt affected soils is not new, but its intensity has been increasing because of poor management practices and inappropriate amelioration procedures. Keeping in view the salinity problem in the soils of Pakistan, analysis was taken in order to compute the leaching requirements of the soil of lysimeter at field site of water management research center. Irrigation were applied on the basis of leaching requirement of the soil to leach down the salts. The canal water yield was high 4.99 tons/ha as compared to the tubewell water 4.33 tons/ha. The ANSWER model was used to compare the actual and modeled. The R² value for canal water yield was high (0.892) as compared to tubewell water yield (0.862). The evapotranspiration measurements were also taken from water balance equation and results were showed that the tubewell water ET was more as compared to canal water because more water was applied to leach down the salts, so more water was also evaporates as compared to the canal water. The leachate of tubewell water was more as compared to the canal water due to the reason that more salts were present in the tubewell water and applied more water to leach down the salts.

KEYWORDS

Irrigation Water Salinity, Transpiration, Leaching Requirement.

1. INTRODUCTION

Pakistan lies between Latitudes 24 to 37 North and Longitudes 61 to 76 East in northern hemisphere. Out of its total geographical area of 79.61 mha, 23.04 mha is cropped land (GOP, 2010). Hydrologically, the country is divided into three main units of (a) Indus Basin (b) the Kharan Basin, and (c) the Mekran Coastal Basin. The Indus Basin comprises of the most important agricultural area of this country with a typical feature of arid to semi-arid climate. The rest of the two Basins are dry and comprise of several small streams, which generally remain dry and, during rainstorms, often produce flash floods. The agriculture in the Indus Basin is not only a matter of food security for the country but also has established itself as an engine of economic growth. It contributes nearly 24% to GDP and 67% rural populations rely in one way or another on this sector (Sheikh, 2004).

The main sources of salts in the semi-arid regions include indigenous salts in irrigation base material, the channel and ground water, agrochemicals and precipitation. These predominantly resulted -Have three different sources of salt - affected soils of the prospective management. These types

are: saline, saline - sodic and sodic (Rengasamy and Oslon, 1993). Salinity causes reduction in crop yield is about 10 thousand ha of irrigated land worlds. The main resources of the low productivity of crops are grown under saline condition sodium who is slay toxicity. Pakistan's 6.2 to 6.67 m ha of land is allocated to different salinity levels, Goal the predominance of sodium salts with various levels of salts and mixtures (Khan, 1998).

Reclamation of salt exaggerated soils were usually initiated by the downward dislocation of surface-accumulated salts. The tiny proportion of salts removed from the top layers and the depth to which the salt peak is displaced during leaching determine the degree of reclamation which is largely governed by the quantity of water passed through the soil (Makoi and Ndakidemi, 2007). Drainage is essential at both the field and district level to put a stop to rising tables and to tolerate for leaching salts. Since amelioration of saline soils depends on the movement of water through the soil profile to remove surplus salts from the root zone, it is important that leaching and drainage for salinity control should (a) minimize flow of water through soil profile to reduce dissolution of soil minerals and (b) reduce drainage volumes.

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Land degradation by salinity, sodicity or combination of both is one of the major impediments to agricultural productivity throughout the world. Most salt-affected soils occur arid and semi-arid climates. Around 800 million hectares (mha) of land (5-6% of world total land area) are salt affected (FAO, 2008). Salinity and/or sodicity in soil profile layers are major abiotic environmental stresses to crop production (Grewal, 2010). In Pakistan, approximately 26% of total irrigated land is salt affected. The problem of salt affected soils is not new, but its intensity has been increasing because of poor management practices and inappropriate amelioration procedures.

A group researcher conducted two lysimeter experiments using automatically led rotating platform at Arava Research and development facilities in Yotvata in southern Israel Arava Valley (29°53'N, 35°04'E), and the soil is sandy loam types (Ben-Gal et al., 2008). Drop-off window nine salinity levels of irrigation and six on the amounts of water were used. To increase the levels of salinity, add 1:1 of NaCl and CaCl₂ with same ratios. Results were showed that, by increasing the water salinity, the yield was sustained without any losses.

A group researcher found that the major sources of salts in Pakistan are exposed rocks and mineral contained crust, river and ground water, seawater intrusion and sea sprays in coastal areas (Ghafoor et al., 2008). Limited rainfall, high evapotranspiration and high temperature along with poor soil and water management practices are major causes of salt-affected soils. Irrigation system of Pakistan comprise of three reservoirs, twenty-three barrages, forty-five main canals and one million water courses. Ground water in most of the areas was sufficiently deep below 33m before introduction of surface irrigation systems. But with operation of this system without adequate drainage, water table started to raise leading to water logging and salinity in many parts which were further aggravated due to flat topography, seepage from unlined channels, poor irrigation management and use of brackish water for irrigation.

A group researchers concluded that the reclamation of salt-affected soils can be done by several methods (Huertas et al., 2008). Suitability of each method depends on physical, chemical and mineralogical characteristics of the soil such as internal soil drainage, presence of pans in the subsoil, climatic conditions and types of salts, quality and quantity of water, depth of ground water, replacement of excessive exchangeable Na⁺, lime or gypsum, cost of the amendments, topographic features of the land, and the time available for reclamation. Appropriate management of soil resources constraint to economic agricultural production is the main focus in agriculture. There are different techniques for the reclamation of salt affected soils. The main ones are the chemical, biological and agronomic.

Others researcher concluded from their experiment that high saline water application in the soil will increase its salinity and sodicity (Mostafazadeh et al., 2007). These were higher in the upper depth than the lower depth. High irrigation water salinity had no effect on acidity but it decreased the water holding capacity of the soil. As the fraction of water increased, the adverse effect of water salinity was minimized but it increases acidity. Leaching efficiency of soil decreased with increase in the salinity of irrigation water respectively.

A group researchers found that In Pakistan, during early stages of planning of salinity control and reclamation project (SCARP), the only parameter considered for classification of water was the total salinity, i.e. total solute contents of water (Bauder et al., 2006). The water having EC_{iw} up to 1.5 dSm⁻¹ was marginal and those having EC_{iw} above 3.0 dSm⁻¹ were considered unsafe for irrigation. In general, on the basis of electrical conductivity water limits are, water having EC ≤ 0.25 is excellent, 0.25 to 0.75 is good, 0.76 to 2.00 is permissible, 2.01 to 3.00 is doubtful and > 3.0 dS m⁻¹ is suitable for irrigation.

Martinez and Manzur found that the presence of salt in soil profile is a major factor hampering plant growth and productivity in the world and Pakistan is no exception to this menace (Martinez-Beltran and Manzur, 2005). Roundabout 10% of the world's arable land surface (7 X 10⁹ ha) are

salt affected. The percentage of lands under irrigated agriculture, which has been affected by salts, is much greater and the area under the threat of salination/sodicitation is several folds. According to FAO/UNESCO recent reports, the total area under salinity/sodicity was 831 mha at the global level.

Some researchers evaluated that soils having soluble salts in solution and/or Na⁺ ions on exchange sites exceeding certain limits that can adversely affect soil plant health are called salt-affected soils (Ghafoor et al., 2004). Salt-affected soils are classified into three main categories namely saline, saline-sodic and sodic. The overall objectives of the study were to evaluate the effect of irrigation water application rates on transpiration, yield and leaching fraction as a function of irrigation water salinity and to compare the actual and modeled yield by using ANSWER model.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The experiment was conducted in the research area of water management research center of University of Agriculture, Faisalabad. For acquisition of the required data to investigate the effects of various treatments on wheat growth, transpiration, leaching and soil salinity, the site represents irrigated agricultural area of central Punjab of Pakistan at 31° North (longitude) and 73° East (latitude); 184m above sea level. The site area is famous for mixed cropping patterns including cotton, sugarcane, wheat, corn and almost all vegetables.

2.1.1 Sampling

Soil samples were collected from different areas with varying depth and location. Standard procedure of soil sampling was adopted. Soil were collected in different pots and labeled with location and sampling depth.

2.1.2 Soil Analysis

The sample collected from different areas was analyzed and their salts was determined at "Water Quality Lab." in the Department of Irrigation and Drainage, university of Agriculture, Faisalabad. Different parameters like soil texture, EC, PH, salts etc. were determined.

2.1.3 Water Analysis

The samples of tubewell and canal water were collected at the time of each irrigation and also in the start of experiment to check the salts in the water.

2.1.4 Leaching requirement (LR) computation

To find out the leaching requirement of different textured soils with application of irrigation water at salinity level, the following formula will be used (Food and Agriculture Organization of the United Nations (FAO) recommends computing leaching requirement LR:

$$LR = \frac{EC_{iw}}{5EC_e^* - EC_{iw}}$$

Where:

EC: electrical conductivity, Iw: Irrigation water and EC_e*: EC of the soil saturated paste extract corresponding to the soil salinity tolerated by the crop.

2.1.5 Net depth of irrigation finds out by using

$$I_N = \frac{I_G}{E_{irri}(1 - LR)}$$

Where,

I_N = Net Depth of Irrigation (mm), I_G = Gross Depth of Irrigation (mm) and E_{irri} = Efficiency of Irrigation Method

2.1.6 Evapotranspiration find out by using

$$ET = I - D_r + \Delta W$$

Where,

ET = Evapotranspiration, I = Irrigation, D_r = Drainage water and ΔW = water stored in soil

2.1.7 Answer Model

The use of flow and transport models is prevalent in the field of different environmental sciences disciplines. Typically, models are applied to predict the effectiveness of remedial or corrective actions or the fate and transport of contaminants for risk evaluating purposes. A conceptual sequential (upstream-downstream) ANSWER model of irrigation is developed that predicts crop yields and water consumption and tracks the water flow and level of salinity along a river dependent on irrigation management decisions. The ANSWER model incorporates an agro-physical model of plant response to environmental conditions including feedbacks. For a system with limited water resources, the model examines the impacts of water scarcity, salinity and technically inefficient application on yields for specific crop, soil and climate conditions. Moving beyond the formulation of a conceptual frame, the ANSWER model is applied to the irrigation of capsicum annum on Arava Sandy Loam soil. The model shows that how water application could be distributed between upstream and downstream plots or farms. Furthermore, the developed environment identifies those situations where it is beneficial to trade water from upstream to downstream farms (assuming that the upstream farm holds the water rights). The model guide that water trade will improve efficiency except when loss levels are low.

2.1.8 Input Parameters

These are the input parameters which are needed for ANSWER model.

2.1.9 Soil Parameters

These parameters were taken from the soil water characteristics model.

- K_s (mm/d)
- δ (unitless)
- β (unitless)
- θ_s (m^3/m^3)
- θ_r (m^3/m^3)
- ψ_w (mm)

2.1.10 Plant Parameters

- ψ_{root} (mm)
- ECe_{50} (dS/m)
- Tp (mm/d)

2.2 Soil Water Characteristics Model (SWC)

Soil water characteristics is the model, in which the different parameters of soil were measured. In this model, the percentages of sand and clay are given and it return gives the values of bulk density, saturated hydraulic conductivity, wilting point, soil texture and more parameters.

2.2.1 Soil Parameters

In this model I give the % sand, %clay and it gives all the values which were required for the ANSWER model as input parameters (Figure 2)

2.2.2 Tinn-R Software

It is the software which works under ANSWER model. The programmed of ANSWER model is written in Tinn-R software and then opened in R software to get the modeled yield. In this software I prepare a program and then copy in to the R software, then after run the program it gives graphs of yield, which where be compared with the actual yield and find the % error between actual and modeled yield. In Tinn-R software basically 2 functions were operated, first one was shani function, the whole model was based on this function, second one was yield function which was be run in to the R software to get the modeled yield by different graphs.

2.3 Statistical Analysis

The statistical analysis was also be made on actual yield, plant height, no. of tillers, no. of plants, no. of spikes and also on modeled yield by calculating RMSC, error % and R^2 values for modeled yield and actual yield. Analysis of variance were also be done by (CRD) completely randomized design and calculate treatment means and standard deviation on actual yield. The lowest standard deviation value indicates the best results, so the canal water yield has been given best results of yield. These formulas gave the modeled yield error, its RMSC values, R^2 value which are as follows. Root mean square error (RMSC) was calculated by this formula.

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (P_i - O_i)^2}{n}}$$

Error % was calculated by this formula.

$$Error \% = \left(\frac{P - O}{O} \right) \times 100$$

R^2 was also calculated by using excel software.

Field discription:

Lysimeter: It has six (6) blocks, each of having dimensions are 12' *8' *7'

Treatments: Two (2) treatments will be made which are:

T1: Tubewell Water T2: Canal Water

R1, R2, R3: These are three (3) replications

3. RESULTS AND DISCUSSION

3.1 Grain Yield

3.1.1 Graph b/w treatments and grain yield (tons/ha)

The bar graph between grain yield (tons/ha) and treatments (tubewell and canal water) are shown in figure 5. The graph shows that the yield obtained from canal water which was likely to be fresh water were high (4.99 tons/ha) and the yield obtained from tubewell water were slightly less than that of canal water (4.33 tons/ha) because of leaching, which were done by applying more saline water to the crop to flush down the salts which is called drainage water or leachate, to obtain maximum yield equal to the yield obtained from the canal water. Similar results were found in (Ben-Gal et al., 2008).

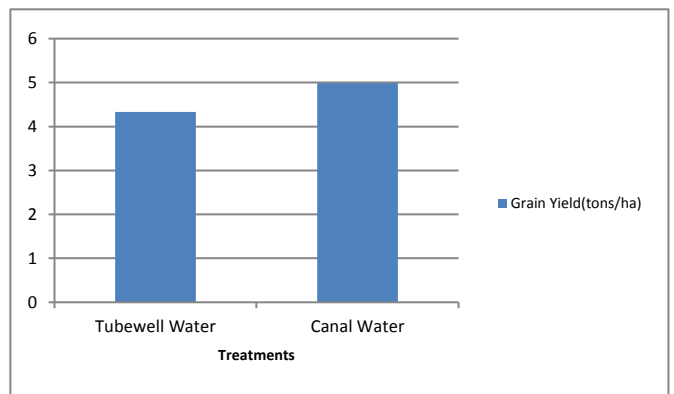


Figure 5: Graphical representation of grain yield (tons/ha) Analysis of Variance

Table 1: Statistical analysis of Grain yield (tons/ha)

S.O.V.	d.f	SS	MSS	F_{cal}	F_{tab}	P
Treatments	1	3.36	3.36	18.46*	7.71	0.05
Error	4	0.729	0.182			
Total	5	4.089	0.817			

The analysis of variance was also done by taking the probability coefficient is 5%.

Results are shown in table given below (Table 1).

ns = Non-Significant, * = Significant, ** = Highly Significant

3.2 Grain yield in relationship with water depth

This bar graph shows the combine effect of grain yield (tons/ha) and irrigation water depth (inches) of two treatments which were tubewell water and canal water. Tubewell water were applied in excess amount due to salts presents in it. To flush down the salts, more amount of water was applied to get the maximum yield as canal water gives (Ghafoor et al., 1997). Very minute difference in yield were obtained from canal water and tubewell water due to leaching of excess salts. (Figure 6) shows that the canal water was applied in less amount and get maximum yield (4.99 tons/ha) as compared to the tubewell water which were applied in large amount but get 70% yield (4.33 tons/ha).

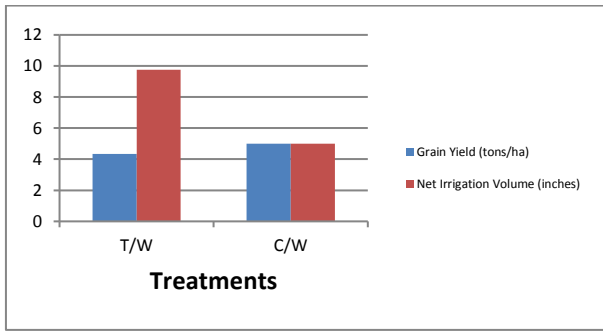


Figure 6: Graphical representation of grain yield & irrigation volume

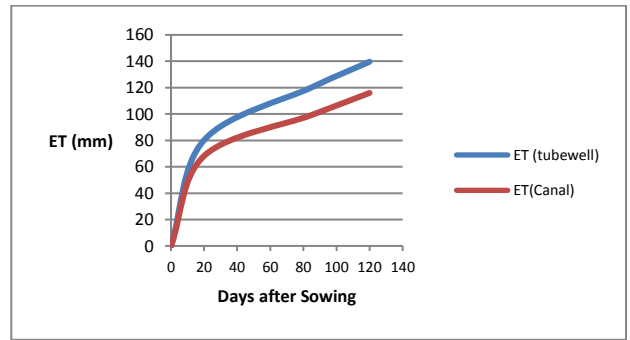


Figure 9: Comparison of ET of canal & tubewell water

3.2.1 Modeled Yield

The modeled yield of both tubewell and canal water were obtained from ANSWER model by giving all input parameters.

3.2.2 Tubewell Water Yield

It is the graph of yield for tubewell water and showed the relationship between relative irrigation and relative yield. I gave the relative irrigation to the software and it returns relative yield according to the relative irrigation (Malash et al., 2005). The results showed that the maximum yield was obtained having the relative irrigation was 0.93 for the whole growing season of wheat.

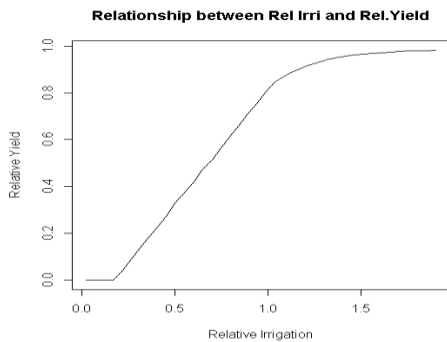


Figure 7: Modeled yield of tubewell water

3.2.3 Canal Water Yield

It is the graph of yield for tubewell water and showed the relationship between relative irrigation and relative yield. I gave the relative irrigation to the software and it returns relative yield according to the relative irrigation. The results showed that the maximum yield was obtained having the relative irrigation was 0.78 for the whole growing season of wheat.

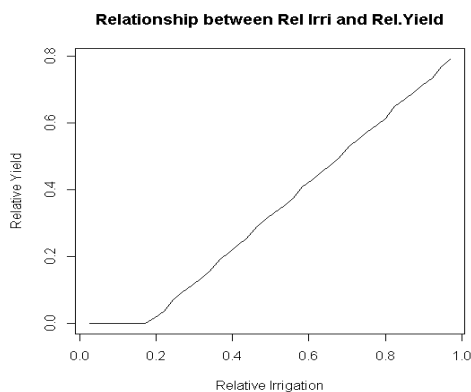


Figure 8: Modeled yield of canal water

3.3 Evapotranspiration of canal and tubewell water

It is the graph between ET of tubewell water in comparison with canal water (Figure 9). It can be seen through the graph that the ET of tubewell water was high as compared to the canal water mainly due to the more salts were present in the tubewell water as compared to the canal water.

3.4 Comparison of Leachate b/w canal & tubewell water

The leachate or drainage water was greater in tubewell water as compared to canal water because more salts were present in tubewell water, that was the reason, more tubewell water was leach down as compared to canal water. The table (table 2 and figure 10) showed the comparison between both treatments.

Table 2: Leachate in mm of tubewell and canal water		
DAS	Tubewell water leachate(mm)	Canal water leachate(mm)
0	0	0
20	207	85
85	170	80
120	171	70

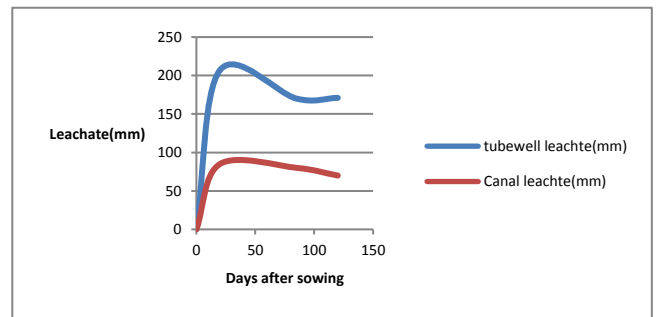


Figure 10: Comparison of Leachate

3.5 Leaching Fraction

Leaching fraction were minimum for the whole growing season of wheat. It was 0.04 for canal water and 0.06 for tubewell water. These results were similar with the results of WPF model and TETrans model. It also showed the similar results of LF.

4. CONCLUSIONS

The conclusion of this study was this, there were two treatments canal water and tubewell water, so the maximum yield was obtained by canal water and also the 70% yield was obtained by tubewell water because the tubewell water was saline and used the lysimeter to leach down the salts from tubewell water to get higher yield. Yield was also compared with ANSWER model and it was also giving the same results for both quality of water. The leachate was also more for tubewell water as compared to canal water. R² value was also high for canal water (0.892) as compared to tubewell water (0.862). Evapotranspiration was high of tubewell water because more salty water was applied, so more was the ET as compared to the canal water was the less ET, because it was just like the fresh water. The overall conclusion was that, by using even saline water, I got 70% yield as compared to the fresh water and ET was high of tubewell water because of more water was applied, due to this more water was evaporated and also leach down as compared to canal water.

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