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IMPACT OF PITCHER MATERIAL AND SALINITY OF WATER USED ON FLOW RATE, WETTING FRONT ADVANCE, SOIL MOISTURE AND SALT DISTRIBUTION IN SOIL IN PITCHER IRRIGATION: A LABORATORY STUDY†

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ABSTRACT

Three types of pitchers made of different materials were used with saline waters of varied concentrations (5, 10, 15 and 20 dS m^{-1}) separately to study the effect on flow rate, wetting front advance, moisture and salt distribution in the wetted zone of soil around pitchers. It was found that the pitcher made of clay and sand yielded the lowest flow rate, ranging from 0.42 to 0.62%, followed by the pitcher made of clay, sand and resin, 0.51–0.69% and the pitcher made of clay, sand and sawdust, 0.91–1.02% .The wetting front advance was highest for the pitcher made of clay, sand and sawdust, followed by the pitcher made of clay, sand and resin, and the pitcher made of clay and sand. The mean soil moisture content around the pitcher made of clay and sand was found to be the minimum and varied from 8.53 to 13.3%, followed by the pitcher made of clay, sand and resin, and the pitcher made of clay, sand and sawdust with 9.56–13.7% and 14.5–20.8%, respectively. In the case of the pitcher made of clay and sand, and the pitcher made of clay, sand and resin, the maximum salt concentration in the soil profile ranged between 1.09 and 3.88 dS m^{-1} and in the pitcher made of clay, sand and sawdust, it ranged from 2.30 to 6.07 dS m^{-1}. The initial salinity of water was found to be substantially reduced around the pitcher made of clay and sand, and the pitcher made of clay, sand and resin in comparison to the pitcher made of clay, sand and sawdust. In all cases, salinity levels around the pitchers were well within the safe limit of growing crops. The study reveals that pitcher irrigation may be a promising option for growing plants using highly saline waters, sustaining hardly any salinity hazard or moisture stress. Copyright © 2013 John Wiley & Sons, Ltd.

KEY WORDS: flow rate; pitcher irrigation; salinity; salt distribution; soil moisture content; wetting front advance

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RÉSUMÉ

Trois types de pichets faits de matières différentes ont été utilisés avec des eaux salines de différentes concentrations (5, 10, 15 et 20 dS m^{-1}) pour étudier l'effet sur le débit de la progression des fronts d'humectation de distribution du sel dans la zone autour des pichets d'irrigation. Il a été constaté que le pichet d'argile et de sable a donné le débit le plus faible allant (0.42 à 0.62%), suivi du pichet d'argile, de sable et de résine (0,51 à 0,69%), lui-même suivi du le pichet fait d'argile, de sable et de sciure (0.91 à 1.02%) (Note Du traducteur: le débit est donné comme un volume d'eau exfiltré du pichet, rapporté au volume total du pichet, rapporté au temps et exprimé en %.) L'avancement du front d'humectation était le plus élevé pour le pichet d'argile, de sable et de sciure, suivi par le pichet d'argile, de sable et de résine, puis, suivi du pichet fait d'argile et de sable. La teneur en eau moyenne du sol autour du pichet d'argile et de sable a été trouvée minimale (entre 8.53 et 13.3%), suivie du pichet d'argile, de sable et de résine, et du pichet d'argile, de sable et de sciure pour respectivement 9.56 à 13.7% et 14.5 à 20.8%. La concentration en sel maximale dans le profil du sol variait entre 1,09 et 3,88 dS m^{-1} pour les pichets d'argile et de sable ainsi que pour le pichet fait d'argile, de sable et de résine, alors que celle du pichet d'argile, de sable et de sciure de bois, variait de 2.30 à 6.07 dS m^{-1}. La salinité initiale de l'eau a été trouvée considérablement réduite autour du pichet d'argile

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† Impact de la matière du pichet et de la salinité de l'eau utilisée sur le débit, l'avancement du front d'humectation, l'humidité du sol et la répartition du sel dans un sol irrigué au pichet. Une étude en laboratoire.

et de sable et d'argile, de sable et de résine par rapport au pichet d'argile, de sable et de sciure. Dans tous les cas, les niveaux de salinité autour des pichets étaient bien en deçà de la limite de sécurité de cultures. Il résulte de l'étude que l'irrigation au pichet peut être une option prometteuse pour la culture de plantes avec des eaux hautement salines, car elle permet de gérer le risque de salinité et de stress hydrique. Copyright © 2013 John Wiley & Sons, Ltd.

MOTS CLÉS: MOTS CLÉS: débit; irrigation au pichet; salinité; répartition du sel; humidité du sol; avancement du front d'humectation

INTRODUCTION

Water is one of the important natural resources and it is becoming scarcer day by day owing to an ever-growing population, rising demand for food, fodder and fuel, urbanization and industrialization. There is an urgent need for its conservation, management and efficient utilization to maximize production and bring agricultural sustainability. Numerous studies have been made in irrigation management, but the scarcity of water and the problem of salinity in agriculture are becoming more serious day by day due to large-scale exploitation of non-saline soils and non-saline water. Judicious use of marginal and poor quality water resources is the only solution now to overcome this problem. Pitcher irrigation is the major innovation towards it being the cheapest localized method of irrigation. In this system of irrigation, pitchers are buried in the soil up to neck level and are filled up with water. The water comes out through the micropores of the earthen body wall and makes the surrounding soil wet, favourable for plant growth in contact with the outer surface of the pitcher. In the recent past, many investigations have been carried out to develop pitcher irrigation into a scientific irrigation technique by evaluation of flow hydraulics and various management alternatives. From the preliminary scientific investigations it is revealed that this method of irrigation is a practical alternative to drip irrigation, is most efficient in terms of water conservation and is recognized as a low-depth high-frequency irrigation method (Alemi, 1980; Dubey *et al*., 1991; Batchelor *et al*., 1996; Bainbridge, 2001). It is an ancient, but very efficient irrigation system used in many arid and semi-arid regions (Siyal *et al*., 2009).The buried clay pot irrigation maintains stable soil moisture, enables crops to grow in both basic or saline soils and is suitable for using saline waters not applicable with conventional irrigation (Mondal, 1974, 1983, 1984; Alemi, 1980; Mondal *et al*., 1992). The use of clay pitchers for irrigation is gaining considerable interest in arid and semi-arid lands due to its simplicity and auto-regulative capabilities (Abu-Zreig and Atoum, 2004). The concept of the use of saline water for irrigation has been advocated by research scientists for more than five decades, as considerable amounts of poor quality water are available in many countries of the Asian and African continents, Australia, North and South America and the dry land areas of Europe (Rhodes *et al*., 1992). Kenyan research reveals that 61% of normal crop yield was achieved using pitcher irrigation with water of 8.0 dS m^{-1}, while typical irrigation with water of 4.0 dS m^{-1}fails (Okalebo *et al*., 1995). Crops such as tomato, cauliflower, brinjal, watermelon, musk melon, bottle gourd, pumpkin, bitter gourd, radish, spinach, onion, cucumber and many other crops can be grown by using this method of irrigation.

In this system of irrigation the rate of flow of water depends on several factors, of which volume, surface area, wall thickness, construction material of the pitcher and quality of water play an important role. Scant information is available on rate of flow in the pitcher as affected by water of different levels of salinity and materials of pitcher construction. Also the literature is silent about moisture and salt distributions around the pitcher as influenced by the salinity of the water used for irrigation purposes and materials used for pitcher construction. Keeping the above facts in view, a study was undertaken using saline water of different concentrations in pitchers made of different materials to discover the effect on flow rate, wetting front advance, moisture and salt distribution in the wetted zone of the soil around the pitchers.

MATERIALS AND METHODS

The present study was conducted in the Hydraulics Laboratory of the College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, India. The laboratory set-up consisted of a metallic box of size $100 \times 100 \times 100$ cm filled with soil mounted on small wheels with one of its vertical sides made of two pieces of transparent plexiglass plates fixed at an angle of 90^o (Figure 1). The pitcher under test was centred in the box with its outer surface in contact with the vertical edge joining the two plexiglass plates for observation of the wetting front advance.

Three types of pitchers, made of different materials, were used with saline water of different concentrations. The soil used in the box was sandy loam (65% sand, 18.4% silt and 16.6% clay) with moisture content 16.7% at field capacity and wilting point 5.8% on a dry weight basis, pH 7.8 and EC 0.2 dS m^{-1}(determined from a soil water extract at a ratio of 1 : 2). The wet soil was removed from the metallic box after each experiment and replaced by fresh soil.

Preparation of pitchers

Three types of pitcher of uniform dimensions were constructed by using locally available soil with different additives (pitcher 1: local soil and sand, pitcher 2: local soil, sand and resin, pitcher 3: local soil, sand and sawdust). The proportions of

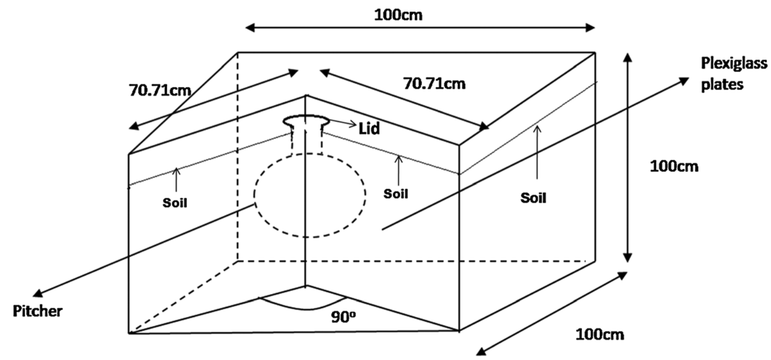

Figure 1. Schematic diagramof the laboratory set up for testing the pitchers.

additives used along with local soil for making the pitchers are given in Table I. The local soil used was determined as clay (25.2% sand, 19% silt and 55.8% clay) as per USDA soil textural classification. The detail dimensions of each pitcher used were: neck level capacity = 10×10^3 cm^3, maximum outside dia. = 27.6 cm, maximum inside dia. = 27.00 cm, thickness = 0.60 cm, depth up to neck level of pitcher = 20.5 cm, area of opening of pitcher = 50.3 cm^2.

Preparation of saline water

A suitable amount of sodium chloride (NaCl) was dissolved in normal water for preparation of saline waters of desired concentrations. The amount of sodium chloride to be dissolved in 1 l of water was determined by employing the following relationship as stated by Michael (1998):

Salt concentration, mg^{-1} or ppm = 640 × EC, in dS m^{-1}

Hence from this relationship, the amount of sodium chloride dissolved in 1 l of water was found to be 3.2, 6.4, 9.6 and 12.8 g for making saline water of concentrations 5, 10, 15 and 20 dS m^{-1} respectively. After preparation of saline waters of the above concentrations, it was again checked for accuracy with their EC reading by conductivity bridge.

Determination of flow rate from the pitcher

The flow rate through the pitcher wall was studied using the pitcher in position with saline water filled in it up to its neck level. After time period *t* hours the pitcher was again filled with the same water up to its neck level by replenishing the earlier loss. The value of flow rate was computed for the period of observations. Similarly the flow rate was studied for all the pitchers used in the experiment. The flow rate was computed with the following relation (Sahu, 1995):

$$P = (v \times 100)/(V \times t) \qquad (1)$$

where P = Flow rate of saline water per hour through the pitcher as a percentage of its neck level capacity; V = Neck level capacity of the pitcher (cm^3); v = Volume of saline water required to fill up the pitcher again to its neck level between two consecutive fillings (cm^3); t = Time elapsed between two consecutive fillings, h.

The time period *t* elapsed between two consecutive fillings in all pitchers was kept at 24 h.

Table I. Proportions of materials used in preparation of pitchers

Pitcher type	Materials used for preparation	Proportions in weight basis
1	Local soil(clay) and fine sand	5:1
2	Local soil(clay), fine sand and resin	5 : 1 : 1.25
3	Local soil(clay), fine sand and saw dust	5:1:3

Determination of wetting front advance

For determination of the wetting front advance, the pitcher was filled with the prepared saline water and movement of the wetting front was recorded through the transparent plexiglass of the laboratory set-up. The travelling distance of the wetting front in the horizontal direction was recorded with respect to time.

Determination of moisture distribution around the pitcher

The moisture distribution in the soil around the pitcher was determined after completion of the wetting front advance. From the wetted zone around the pitcher, soil samples were collected by using an auger making 10 cm grid points on a vertical plane passing through a radius originating at the pitcher neck. The moisture content in the soil around the pitcher was determined by the gravimetric method.

Determination of the salt distribution in the soil around the pitcher

Salt concentration in the soil around the pitcher was determined in terms of its electrical conductivity (EC). Therefore, soil samples were collected from the wetted zone around the pitcher. The soil samples were shade dried, properly pulverized and used for estimating the dissolved salt concentrations. The electrical conductivity of the soil was measured in a soil water extract at a ratio of 1 : 2 using a conductivity meter.

RESULTS AND DISCUSSION

As per the procedures mentioned in the materials and methods, three types of pitchers were used in the laboratory model, separately one after the other. In all three types of pitcher saline water of 5, 10, 15 and 20 dS m^{-1} concentration were used separately for observation of flow rate, wetting front advance, moisture and salt distribution in the soil at different locations around the pitcher.

Flow rate from pitchers

Using the values of replenished volume v , elapsed time t and neck level capacity V, the values of P describing the flow rate of water per hour through the pitchers as a percentage of their neck-level capacities were computed for 11consecutive days and are presented in Table II. It was observed in all three types of pitcher that the flow rate was more initially and found to gradually decrease with increasing time. From the table it is seen that the pitcher type 1 yielded the lowest flow rate in terms of its neck-level capacity, followed by pitchers 2 and 3. The little difference in flow rate between pitchers 2 and 1 shows that the quantity of resinous materials used in this study did not significantly influence the flow of water from the pitcher as compared to local soil. As pitcher type 3 yielded the highest flow rate, it shows that the quantity of sawdust used significantly influenced the flow of water as compared to local soil. In all three types of pitcher, maximum and minimum values of P were obtained when the salinity levels of water used were 5 and 20 dS m^{-1}. The maximum mean value of P obtained was 1.02% in the case of pitcher 3, when the salinity of water used was 5 dS m^{-1}. The minimum value of P obtained was 0.42% in the case of pitcher 1, when the salinity level of water used was 20 dS m^{-1}. It is observed from the flow rate data that when the salinity of water is higher, the flow rate is found to be less and it gradually decreases with time. It is due to the possibility that when the salinity of water increases, it becomes more viscous and gradually retards the flow and the pores of the pitcher wall become clogged due to salt deposition over the course of time.

Moisture distribution in soil around the pitcher

The moisture distribution pattern was determined for pitchers 1, 2 and 3 using saline waters of 5, 10, 15 and 20 dS m^{-1} separately. The moisture contents in the soil around the pitchers at different depths and distances were measured and are presented in Table III. The surface soil moisture measured was found to be a maximum at 10 cm horizontal distance just near the neck of pitcher in all three types. The mean soil moisture contents in the wetted zone in the vertical plane up to 40 cm depth were computed at 20, 30 and 40 cm horizontal distance from the pitcher. For pitcher 1, at the above three distances, when the salinity of water used was 5,10,15 and 20 dS m^{-1}, the mean moisture content in the soil varied from 13.3 to 10.8%,12.3 to 9.85%,11.7 to 9.2% and 10.9 to 8.5%. For pitcher 2,when the salinity of the water used was 5, 10, 15 and 20 dS m^{-1}, the mean moisture content in the soil varied from 13.7 to 11.7%, 13.3 to 11.1%, 12.7 to 10.2% and 12.2 to 9.56%. Similarly for

Table II. Flow rates in pitchers 1, 2 and 3 using saline waters of different concentrations

	Pitcher flow rates (%) of its neck-level capacity per hour (P)			
	Salinity level of the water used (dS m^{-1})			
Day	5	10	15	20
1	0.63 (0.70) [1.02]	0.58 (0.65) [1.00]	0.48 (0.59) [0.96]	0.45 (0.54) [0.95]
2	0.65 (0.71) [1.04]	0.58 (0.66) [1.00]	0.49 (0.59) [0.97]	0.47 (0.55) [0.96]
3	0.63 (0.71) [1.03]	0.58 (0.66) [1.00]	0.48 (0.59) [0.97]	0.46 (0.54) [0.94]
4	0.64 (0.71) [1.03]	0.58 (0.65) [1.00]	0.47 (0.58) [0.97]	0.45 (0.53) [0.94]
5	0.64 (0.70) [1.03]	0.57 (0.64) [0.99]	0.47 (0.58) [0.96]	0.43 (0.52) [0.93]
6	0.63 (0.70) [1.03]	0.57 (0.63) [0.98]	0.46 (0.56) [0.95]	0.42 (0.51) [0.92]
7	0.62 (0.69) [1.01]	0.56 (0.63) [0.98]	0.45 (0.55) [0.93]	0.40 (0.50) [0.90]
8	0.61 (0.68) [1.01]	0.55 (0.62) [0.97]	0.44 (0.54) [0.93]	0.39 (0.49) [0.90]
9	0.61 (0.68) [1.00]	0.54 (0.61) [0.97]	0.43 (0.53) [0.92]	0.38 (0.48) [0.88]
10	0.60 (0.67) [1.00]	0.53 (0.60) [0.96]	0.41 (0.52) [0.92]	0.37 (0.47) [0.88]
11	0.60 (0.67) [1.00]	0.52 (0.59) [0.95]	0.40 (0.51) [0.90]	0.36 (0.45) [0.87]
Mean P	0.62 (0.69) [1.02]	0.56 (0.63) [0.98]	0.45 (0.56) [0.94]	0.42 (0.51) [0.91]

Flow rates mentioned above 'without brackets', ( ) and [ ] indicate pitchers 1, 2 and 3 respectively.

Table III. Moisture distribution around pitchers 1, 2 and 3

Salinity level, dSm^{-1}	Depth from soil surface (cm)	Moisture content at different distances from pitchers (%)		
		20 cm	30 cm	40 cm
5	00	11.72 (12.00) [18.55]	10.52 (10.74) [16.60]	9.49 (9.99) [15.00]
	10	11.90 (12.80) [19.71]	11.26 (11.68) [17.40]	10.03 (10.52) [15.92]
	20	12.93 (13.09) [20.86]	12.12 (12.54) [18.38]	10.86 (11.59) [16.59]
	30	15.55 (16.20) [22.95]	14.40 (15.63) [21.89]	12.31 (14.00) [19.00]
	40	14.21 (14.51) [21.81]	13.25 (14.09) [20.00]	11.51 (12.43) [17.85]
Mean		13.26 (13.72) [20.78]	12.31 (12.94) [18.85]	10.84 (11.71) [16.87]
10	00	10.481 (11.77) [18.01]	9.42 (10.00) [16.00]	8.53 (9.12) [14.34]
	10	11.61 (12.25) [18.99]	10.65 (11.00) [16.82]	9.02 (9.93) [15.01]
	20	12.00 (12.80) [19.88]	11.42 (12.20) [17.99]	9.92 (10.99) [15.61]
	30	14.10 (15.69) [21.99]	13.54 (15.00) [20.20]	11.56 (13.57) [18.56]
	40	13.14 (13.86) [21.11]	12.43 (13.24) [19.29]	10.25 (11.86) [16.95]
Mean		12.27 (13.27) [19.99]	11.49 (12.29) [18.06]	9.85 (11.09) [16.09]
15	00	10.09 (11.02) [17.02]	9.00 (9.37) [15.12]	8.03 (8.52) [13.39]
	10	10.90 (11.89) [18.01]	10.26 (10.46) [16.11]	8.50 (9.03) [14.22]
	20	11.44 (12.30) [19.13]	10.91 (11.72) [17.00]	8.94 (10.00) [14.88]
	30	13.70 (14.88) [21.12]	12.50 (14.22) [19.12]	10.93 (12.60) [17.88]
	40	12.27 (13.40) [20.56]	11.99 (12.56) [18.89]	9.59 (10.94) [16.22]
Mean		11.68 (12.70) [19.17]	10.93 (11.67) [17.25]	9.20 (10.22) [15.32]
20	00	9.15 (10.68) [16.09]	8.50 (8.71) [14.09]	7.68 (7.99) [12.93]
	10	10.04 (11.30) [16.98]	9.29 (9.99) [15.01]	7.83 (8.56) [13.49]
	20	10.99 (11.88) [17.69]	10.21 (11.02) [15.99]	8.26 (9.42) [14.31]
	30	12.48 (14.00) [19.87]	11.90 (13.75) [18.57]	10.01 (11.50) [16.56]
	40	11.59 (12.95) [18.41]	11.10 (12.00) [17.59]	8.85 (10.33) [15.39]
Mean		10.85 (12.16) [17.81]	10.20 (11.09) [16.25]	8.53 (9.56) [14.54]

Moisture contents mentioned above ’without brackets’, ( ) and [ ] indicate pitchers 1, 2 and 3, respectively.

pitcher 3, when the salinity of water used was 5, 10, 15 and 20 dS m^{-1} , the mean moisture content in the soil varied from 20.8 to 16.8%, 20.0 to 16.1%, 19.2 to 15.3% and 17.8 to 14.5%. In all three types of pitcher, the moisture content in the vertical plane was found to increase with greater depth from the surface and to decrease with more horizontal distance from the pitchers. It was observed in all cases that with increasing levels of water salinity, the moisture content in the soil around the pitcher was found to decrease. It seems that when salinity is higher, the flow rate becomes less and the wetting front advance is affected and as a result the moisture content also decreases. The moisture contents found in the soil around pitchers 1 and 2 were well within the field capacity and wilting point of the soil used for the experiment. But in the case of pitcher 3, the moisture content remained well above the field capacity and wilting point of the soil used.

A paired *t*-test revealed that pitcher 3 significantly differs from pitchers 1 and 2 at $\alpha = 0.05$ when all salinity levels are compared individually.

Wetting front advance

The wetting front advance was measured horizontally with respect to time for the different pitchers. Detailed results of the wetting front advances are presented in Figure 2. The wetting front advance in the horizontal direction increased initially and finally stopped after some distance in all cases. The wetting front advance was highest for pitcher 3 followed by pitcher 2. Again, the small differences in wetting front advances between pitchers 2 and 1 revealed that the quantity of resinous material used did not greatly influence the flow of water as compared to the pitcher made of local soil. As pitcher 3 yielded the highest wetting front advance, the quantity of sawdust used substantially influenced the flow of water and wetting front advance as compared to the use of local soil. Furthermore, it was observed that increasing water salinity decreased the wetting front advance because the viscosity of the water increased with increasing salinity, thus reducing the outflow from the pitcher wall and, consequently, the wetting front advance.

Salt distribution around the pitchers

The salt distribution was minimum around pitchers 1 and 2 compared to pitcher 3 (Table IV). For pitcher 1, the maximum salinity of the soil was 1.09 dS m^{-1} at the soil surface at a distance of 40 cm from the pitcher and the lowest salinity of the soil was 1.03 dS m^{-1} at a depth of 30 cm from the soil surface and at a distance of 20 cm from the pitcher when the water salinity was 5 dS m^{-1}. A substantial decrease of salt concentration

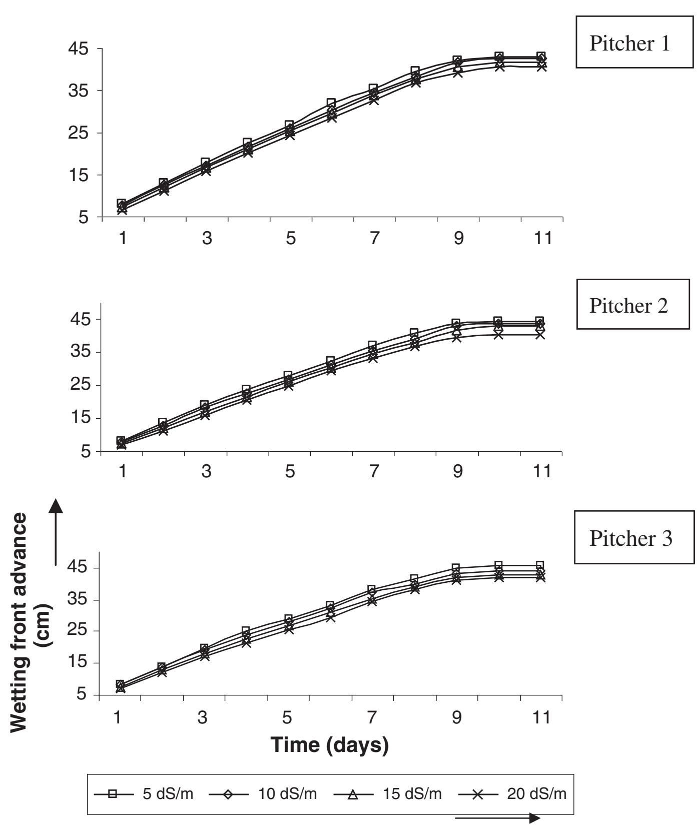

Figure 2. Wetting front advance with time.

Table IV. Salt distribution in the soil around pitchers 1, 2 and 3

Salinity level, dSm^{-1}	Depth from soil surface (cm)	Salt concentration at different distances from pitchers, dSm^{-1}		
		20 cm	30 cm	40 cm
5	00	1.08 (1.07) [2.02]	1.08 (1.08) [2.20]	1.09 (1.09) [2.30]
	10	1.05 (1.05) [1.96]	1.06 (1.06) [2.10]	1.07 (1.07) [2.13]
	20	1.05 (1.04) [1.90]	1.05 (1.05) [2.00]	1.06 (1.06) [2.10]
	30	1.03 (1.02) [1.60]	1.03 (1.03) [1.70]	1.04 (1.04) [1.85]
	40	1.04 (1.03) [1.75]	1.04 (1.04) [1.90]	1.05 (1.05) [1.91]
10	00	1.49 (1.49) [3.50]	1.50 (1.50) [3.67]	1.51 (1.51) [4.09]
	10	1.45 (1.44) [3.40]	1.49 (1.49) [3.44]	1.50 (1.50) [3.71]
	20	1.39 (1.39) [3.31]	1.46 (1.45) [3.38]	1.47 (1.47) [3.63]
	30	1.20 (1.20) [2.90]	1.29 (1.29) [2.99]	1.36(1.36) [3.20]
	40	1.29 (1.28) [3.16]	1.39 (1.39) [3.22]	1.40 (1.40) [3.60]
15	00	2.42 (2.42) [4.82]	2.49 (2.49) [4.90]	2.71 (2.71) [5.21]
	10	2.32 (2.32) [4.80]	2.40 (2.39) [4.85]	2.69 (2.67) [5.01]
	20	2.10 (2.10) [4.62]	2.16 (2.16) [4.74]	2.47 (2.47) [4.98]
	30	1.79 (1.78) [4.31]	1.84 (1.84) [4.39]	2.09 (2.09) [4.60]
	40	1.98 (1.97) [4.52]	1.99 (1.98) [4.60]	2.29 (2.28) [4.87]
20	00	3.42 (3.42) [5.98]	3.57 (3.57) [5.99]	3.88 (3.88) [6.07]
	10	3.30 (3.30) [5.95]	3.46 (3.46) [5.98]	3.70 (3.69) [6.00]
	20	3.28 (3.28) [5.93]	3.36 (3.36) [5.86]	3.53 (3.53) [5.91]
	30	2.89 (2.89) [5.68]	3.01 (3.01) [5.75]	3.27 (3.27) [5.80]
	40	3.22 (3.22) [5.83]	3.23 (3.23) [5.85]	3.50 (3.50) [5.90]

Salt concentrations mentioned above 'without brackets', ( ) and [ ] indicate pitchers 1, 2 and 3, respectively.

in the soil profile compared to that in the water was observed when higher concentrations were considered. For example, at 20 dS m^{-1}, the highest and lowest salinity levels were 3.88 and 2.89 dS m^{-1}, respectively. Similarly, the reduction in salt concentration for pitchers 2 and 3 ranged between 1.09 and 3.88 dS m^{-1} and between 2.30 and 6.07 dS m^{-1}, respectively, for water salinity of 5 and 20 dS m^{-1} at 40 cm distance.

In each case the maximum salt concentration was found at the soil surface and it gradually decreased with increasing depth. The salt concentration in the soil increased with increasing horizontal distance from the pitcher. The initial salinity level of the water was substantially reduced around pitchers 1 and 2 in comparison to pitcher 3. This might be due to the transportation of higher amounts of dissolved salts during irrigation as a result of higher flow through pitcher 3. In all cases, salinity levels around the pitchers were well within the safe limit of growing crops.

A paired *t*-test showed that pitchers 1 and 2 differed significantly from pitcher 3 at $\alpha = 0.05$, when all salinity levels were compared separately.

CONCLUSION

With the increase in salinity level of water used in the pitchers, flow rate decreases for all types of pitcher. The quantity of resinous material used in pitcher 2 did not influence significantly the flow rate of water and movement of salts as compared to local soil used in pitchers 1 and 3. The quantities of sawdust used in pitcher 3 had a greater influence on the flow rate and movement of salts from the pitcher. Crops having high evapotranspirative demand can be suitably irrigated with pitcher 3 made of clay, sand and sawdust due to its higher flow rate. The crops having low evapotranspirative demand can be suitably irrigated with the conventional pitcher made of clay and sand due to its low flow rate. The observed ranges of moisture contents in soil around pitchers 1and 2 were well within the field capacity and wilting point. In the case of pitcher 3 made of clay, sand and sawdust, the moisture distribution was found to be well above field capacity. Irrespective of pitchers, salt concentration in the soil was found to be a minimum near the pitcher and maximum at the periphery of the wetted zone around the pitcher. Salt distributions around the pitchers were observed well within the safe limit of growing crops though initial salinity levels of water used were much higher. The study shows that pitcher irrigation may be a promising option for growing plants, using highly saline waters and sustaining hardly any salinity hazard or moisture stress.

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