Pak. J. Agri. Sci., Vol. 49(4), 533-540; 2012
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

COMPOST ADMIXTURE IMPACT STUDY ON WATER INFILTRATION DEPTH, WATER FRONT ADVANCE AND RECESSION IN IRRIGATED ENVIRONMENT

Muhammad Kashif Ali[*] and S. Mahmood

Centre of Excellence in Water Resources Engineering, Uni. of Engineering and Technology Lahore, Pakistan
[*]Corresponding author's e.mail: mka2260@yahoo.com

Water is an important life supporting resource and is essential for sustainable food production. Its continued decrease has diverted the attention of researchers to find new ways of efficient irrigation management. Decomposed bio-solids (for example leaves, crop residue, animal waste, municipal solid waste) form the compost and provide friendly environment for enhancing crop production. The present study investigates the effects of compost admixture on water infiltration depth, water advance and recession phase of irrigation event in the field having loamy sand texture. Compost from two sources was used. There were nine experimental plots with 3.5 m width and 45 m length. Compost at the rate of 5 % was incorporated up to a depth of 3 cm in six plots (3 plots of each compost source) and in the remaining three plots no compost was applied. The field was irrigated twice. The results revealed that by using 5% compost admixture by weight the advance time reduced by 23.96% and 26.83 % for 1st and 2nd irrigation, respectively compared to non compost admixture plots. Results revealed that by using 5 % compost up to 3cm mixing depth the water infiltration depth decreased 42.97 % at head side of the field and 10.37 % at tail side of field during 1st irrigation, during 2nd irrigation the water infiltration depth decreased 48.67 % at upper end of the field and 11.28 % at lower end of the field. The significant decrease in water infiltration depth at head side gives uniformity in water infiltration depth along the length of field. The faster movement of the water front with the application of compost admixture reduces the difference in intake opportunity times between the head and far end of the field, thus it improves the performance of the irrigation system. Reduction in the applied water volume to the tone of 23.96% during 1st irrigation and 26.83% during 2nd irrigation, further supports this improvement in irrigation performance, considering on the advance phase.

Keywords: Compost, Border irrigation, Water advance phase, Water recession phase, Water infiltration depth, Infiltration parameters

INTRODUCTION

Optimum management of available surface and subsurface water resources is urgently needed in view of the increasing demand and limited resources of water (Flores and Holzapfel, 2009). Optimum management of water resources at the farm level is needed because of increasing water demands, limited available resources, and aquifer contamination (Kumar and Singh, 2003). Surface irrigation is the most common method to apply irrigation water to the field (Oyonarte *et al*., 2002). The traditional irrigation practices include basin, border, furrow and wild flooding irrigation systems. Pressurized irrigation systems provide labor saving but require heavy investment. Surface irrigation systems are labor intensive but require minimal investment therefore these are common in developing countries (Khan *et al*., 1997; Latif and Mahmood, 1998)

Field properties like topography, hydraulic resistance, and infiltration rate play an important role in the performance of surface irrigation systems (Strelkoff *et al.,* 2009). The quantity of water that infiltrates into and through the soil is a key parameter for water resource management (Mukheibir, 2008) and prediction of surface water runoff and soil conservation. Infiltration greatly affects the design and management of surface irrigation systems. Infiltration is the most crucial and important parameter that not only controls the water entry into soil, but also the advance rate of water flow on the land. Water front advance play a key role in efficient application of water to the soil and conservation of moisture to the desired level under surface irrigation. The water front advance in conjunction with infiltration characteristics is used to evaluate the irrigation performance. The water front advance rate can be improved by altering factors like inflow rate, field slope and infiltration characteristics (Walker and Skogerboe, 1987).

Every effort should be made to introduce irrigation methods which minimize water losses by improving system performance and give the maximum benefits from limited water resources. One way to improve the irrigation system performance is the application of soil amendments to alter the infiltration characteristics on which performance of an irrigation system depends. Different materials like compost are used for this purpose and to stabilize soil structure. The decomposed leaves, crop residue, animal waste and municipal solid waste form the compost and provide friendly environment for enhancing crop production (Sarwar *et al*., 2007). A meta-analysis of 133 scientific papers shows that yields of organic farms are equal or significantly higher than those of conventional agricultural farms under limited water conditions during crop growing season (Badgley *et al.*, 2007). The scientists have recognized the benefits of maintaining and increasing soil organic matter contents in soils (Fischer, 1989, Khaliq *et al*., 2006). Compost is farmer and environment friendly due to recycling of organic waste and possible reduction of nitrogen losses to the environment (Rizwan *et al*., 2008). Organic agriculture offers a multi-targeted and multifunctional strategy, as it provides a proven alternative option that is being implemented successfully by a number of farmers (Willer and Kilcher, 2009).

Under the present scenario of water scarcity it is essential to study the effects of compost application on water front advance on the soil in field. The present study was planned with the objective of evaluating the compost effect on water front advance of an irrigation event. Compost from two sources was used in the present experiment and has been mentioned as Compost-A and Compost-B. The uniform distribution of water in the field is one of the major advantages of applying compost in the field. It would also help the farmers to save water and to get high production of crop per unit of water consumed. This study will provide first hand information and guidance for the scope of compost mixing in the field for water conservation and for further research on the subject.

MATERIALS AND METHODS

The present experiment was conducted in a field having "loamy sand" soil texture according to the "USDA Soil Textural Triangle". Soil samples were taken to a depth of 90 cm with 30 cm increment for the soil analysis. The infiltration tests for selecting the appropriate compost admixture ratio and depth for its application in the field were performed at different locations in this field. Single ring of iron having circumference of 77 cm was used for infiltration tests. All procedure for determination of infiltration was same as of double ring infiltrometer except it was penetrated into the soil up to 45 cm to stop lateral movement of water.

The field was subdivided into nine plots, each having an area of 3.5 m × 45 m. In three plots compost from Source-A was mixed in the selected ratio while compost from Source-B was mixed in the selected ratio in the other three plots and no compost amendment was applied in the remaining three plots. The plot selection for different compost applications was done in a completely randomized manner. Proper strong dikes for partitioning the field and at the start and end sides were made by disk plough. Infiltration tests were also performed on the day of 1st and 2nd irrigation for determination of irrigation day infiltration parameters. A cut throat flume of 10 cm x 120 cm was used to measure and supply a constant discharge of water to the field. In order to measure the rate of advance of water, iron stacks were installed at an interval of 3 m along the length of borders of the field. The time was recorded regularly as the advancing water front reached at each stake. The statistical analysis was used to determine the Kostakov-Lewis infiltration unknown parameters. Kostiakov-Lewis equation (Eq.1) was fitted to infiltration curves which not only gave the verification but also the basic parameters of infiltration, i.e. a, k and f_o as shown in Fig. 2.

RESULTS AND DISCUSSION

Infiltration tests for deciding the compost admixture ratio and depth for its application in experimental fields were performed in the experimental field. The cumulative one hour infiltrated water depth without using compost was 20.1 cm. The one hour infiltrated water depth for various compost admixture ratios and depth of both the compost sources is given in Table 1.

Table 1. Infiltrated water depth for various compost admixture ratios and depth

Compost source	Compost mixing ratio by weight (%)	Compost mixing depth (cm)	Infiltration depth (cm)
Source-A	1	3	19.50 A*
Source-A	1	15	18.55 B
Source-B	1	3	19.30 A
Source-B	1	15	18.40 BC
Source-A	2	3	18.45 BC
Source-A	2	15	17.90 D
Source-B	2	3	18.25 C
Source-B	2	15	17.80 D
Source-A	4	3	14.40 EF
Source-A	4	15	14.15 G
Source-B	4	3	14.50 E
Source-B	4	15	14.25 FG
Source-A	5	3	13.10 H
Source-A	5	15	12.50 I
Source-B	5	3	13.20 H
Source-B	5	15	12.35 I

Values with different letters are significantly different at P≤0.05 according to LSD test.

On the basis of data presented in Table 1, the compost admixture of 5% by weight up to 3 cm mixing depth was applied in the field for evaluating the impact of compost on water advance and recession phases in the field. The following Kostiakov-Lewis equation was fitted to infiltration curves obtained by the infiltration tests performed on the irrigation days.

$$Z = k\tau^{a} + f_o\tau \qquad (1)$$

The basic parameters of infiltration, i.e. a, k and f_o as shown in Figure 1 and Table 2 were calculated using this equation (Eq. 1). It may be noted that the values of all the three infiltration parameters are smaller in the plots having compost admixture and greater in the plots having no compost admixture. The rate of water front advance and water infiltration depth are key parameters to improve the performance of any surface irrigation system. The data of water advance and recession phase collected from field, and infiltration depth obtained from Eq.1 (by incorporating respective values of infiltration parameters during 1st irrigation) are graphically represented in Figs. 2 & 3. For brevity the average results of three experimental plots of one type are shown.

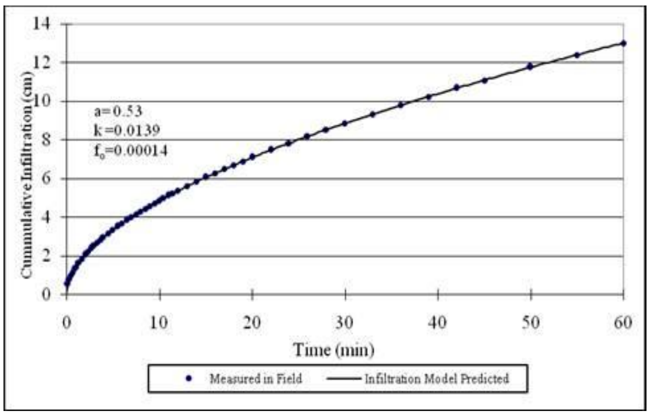

Figure 1. Curve fitting to find values of parameters a, k and f_o for experimental plot-1 with Compost-A admixture.

The comparison of water advance and recession phase (Figs. 2a, 2b & 2c) shows that the water advance time required for compost mixed experimental plots is less than the experimental plots having no compost. The comparison of water advance and recession phase (Figs. 2a & 2b) shows that initially the water moves down the field slowly then it moves rapidly to a certain distance, and finally the advance of water slows down. The initial slow water advance rate may be due to dry soil surface as most quantity of applied water was used to replenish the soil moisture during infiltration process. Subsequently the fast water advance rate may be due to consolidation of soil for few meters near the head side of the experimental plots. Samani *et al*. (1985) reported that the consolidated soil surface has greater bulk density, lower porosity and lower water holding capacity, even a thin consolidated soil surface have a significant effect in reducing infiltration on an already wet portion of soil surface. At the tail of the experimental plots, the water advance rate may be slowed down because the water has to travel more distance to reach this part of the field. The water advance phase in Fig. 2c shows that the water moves down the field rapidly to a certain distance and finally the advance of water slows down more significantly than in the compost admixture plots which may be due to greater infiltration rate of soil.

Water infiltration depth curves (Figs. 3a, 3b & 3c) show that the water infiltrates into the soil more at the head side and its depth decreases with the length of field. This difference in infiltration depth between head and tail side of experimental plots is usual because naturally the water stays more time at head side than the tail side because as long as the water does not reach at the tail it travels on the head side of experimental plot, this gives more time of infiltration at the head side of the experimental plot. The overall difference in infiltration depth between head and tail side of experimental plots in Figs. 3a and 3b is not so remarkable as in the Fig. 3c. The reason of less and more uniform infiltration in Figs. 3a,3b & 3c is the compost mixing in soil which decreases the infiltration in sandy loam soil as well as improves the irrigation performance by equalizing the water infiltration at the head and tail sides of experimental plots. The results of water infiltration depth, water advance and recession phase for 2nd irrigation is shown graphically in Figs. 4 & 5 in a pattern similar to 1st irrigation.

Table 2. Infiltration parameters during irrigation

Compost Treatment	Plot No.	Infiltration Parameters for 1st Irrigation			Infiltration Parameters for 2nd Irrigation		
		a	k	f_o	a	k	f_o
Compost-A	Plot-1	0.530	0.0139	0.00014	0.523	0.0136	0.00011
	Plot-2	0.520	0.0140	0.00015	0.510	0.0136	0.00014
	Plot-3	0.510	0.0149	0.00020	0.501	0.0145	0.00010
Compost-B	Plot-1	0.528	0.0142	0.00014	0.524	0.0133	0.00011
	Plot-2	0.520	0.0139	0.00014	0.515	0.0136	0.00012
	Plot-3	0.520	0.0140	0.00021	0.510	0.0130	0.00010
No Compost	Plot-1	0.581	0.0156	0.00043	0.571	0.0155	0.00039
	Plot-2	0.573	0.0155	0.00038	0.558	0.0154	0.00037
	Plot-3	0.600	0.0150	0.00037	0.589	0.0143	0.00034

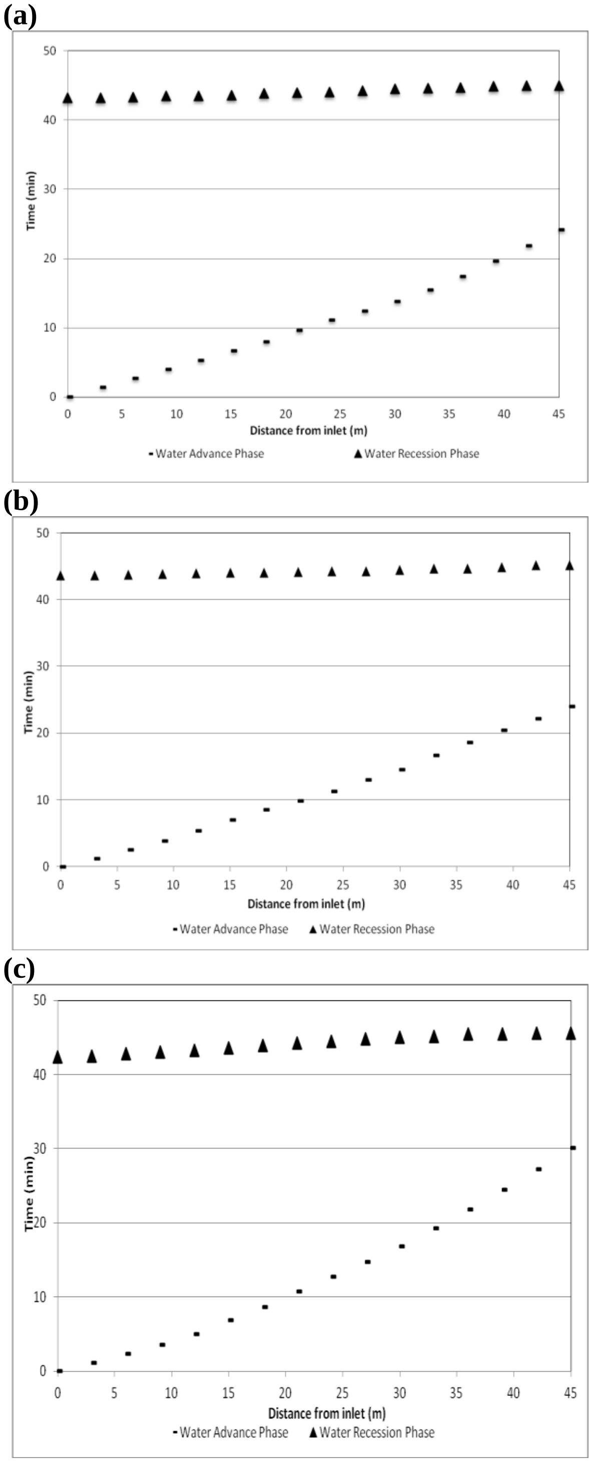

Figure 2. Water advance and recession during 1st irrigation for (a) Compost-A admixture plots (b) Compost-B admixture plots and (c) Without compost admixture plots

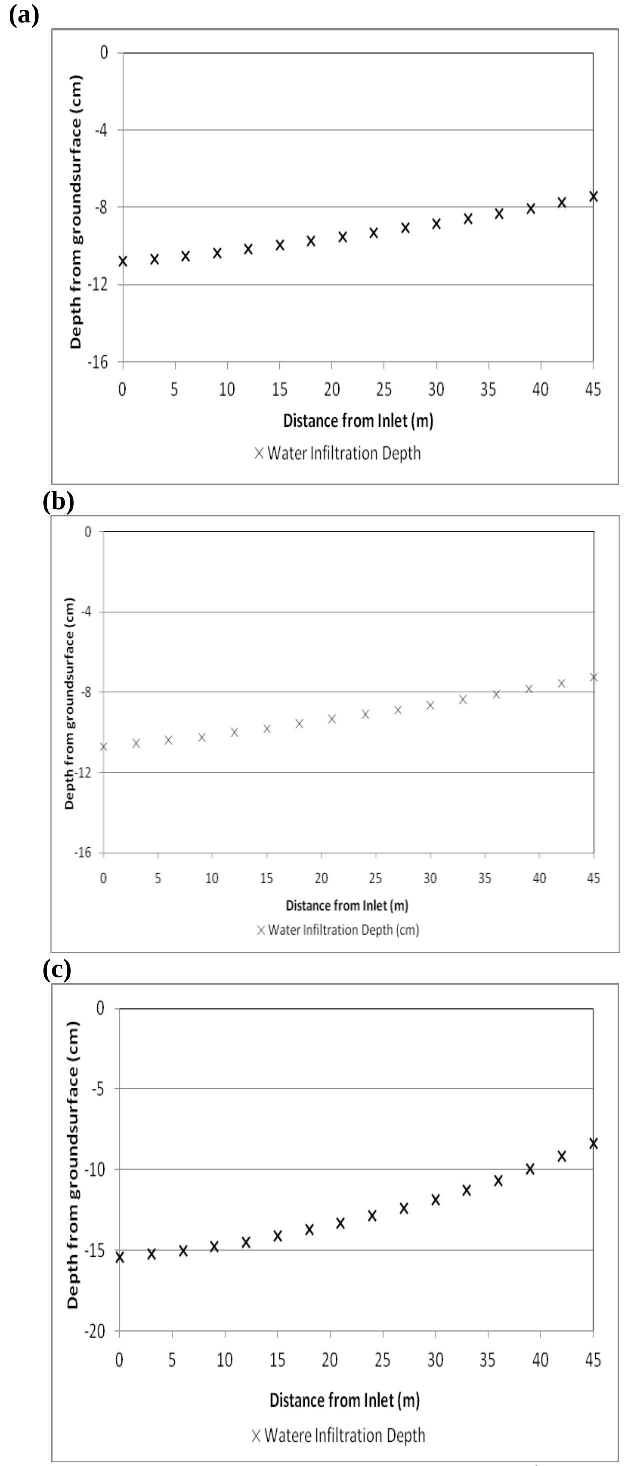

Figure 3. Water infiltration depth during 1st irrigation for (a) Compost-A admixture plots (b) Compost-B admixture plots and (c) Without compost admixture plots

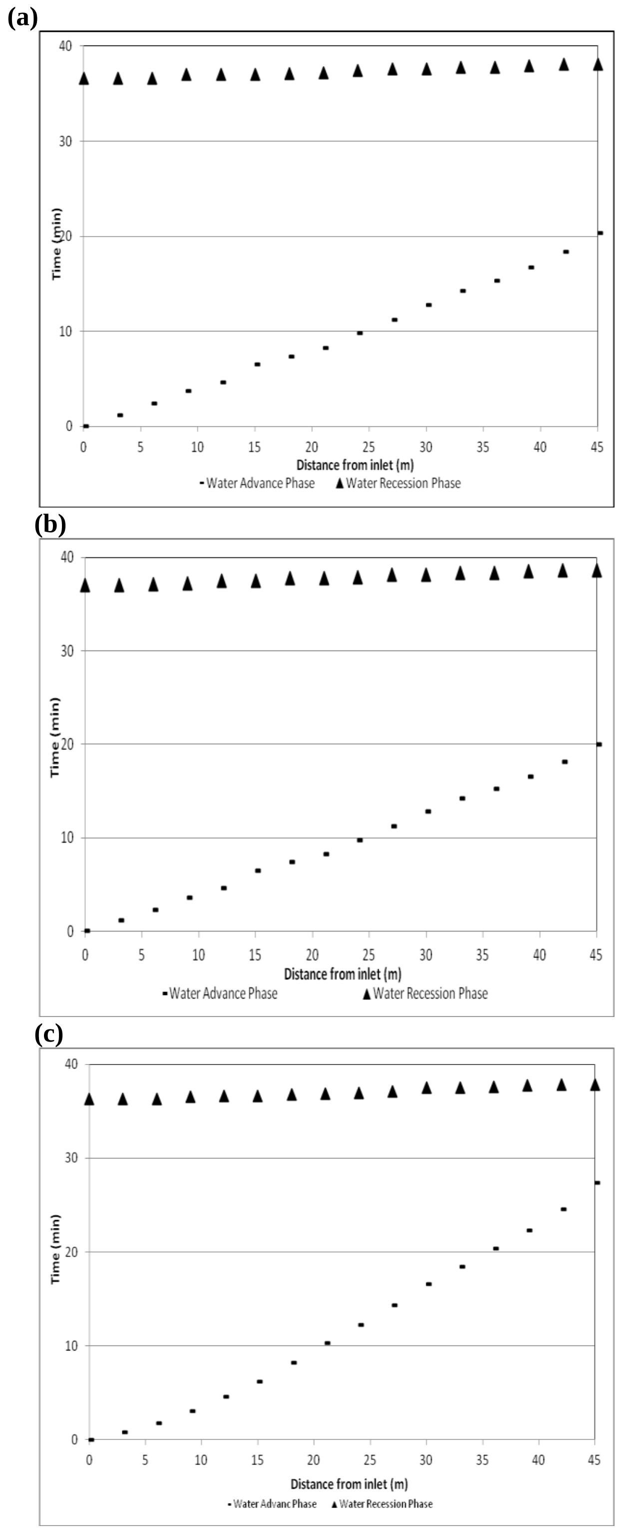

Figure 4. Water advance and recession during 2nd irrigation for (a) Compost-A admixture plots (b) Compost-B admixture plots and (c) Without compost admixture plots

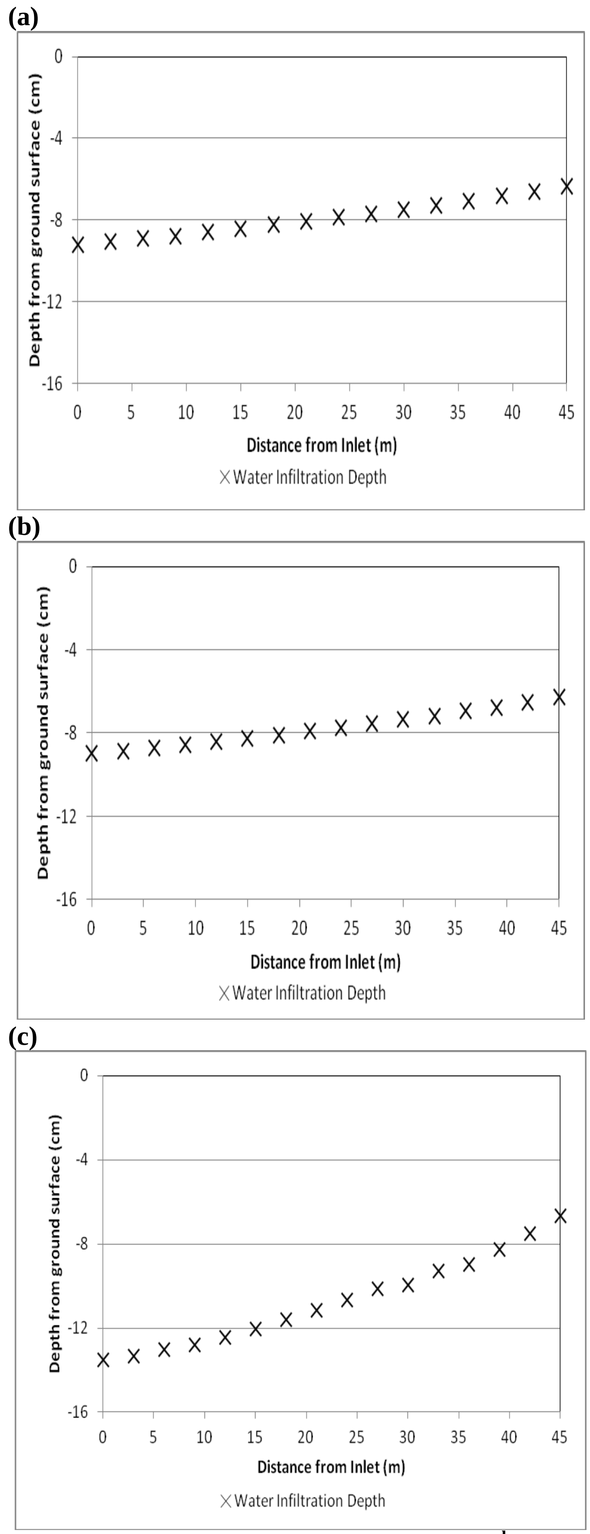

Figure 5. Water infiltration depth during 2nd irrigation for (a) Compost-A admixture plots (b) Compost-B admixture plots and (c) Without compost admixture plots

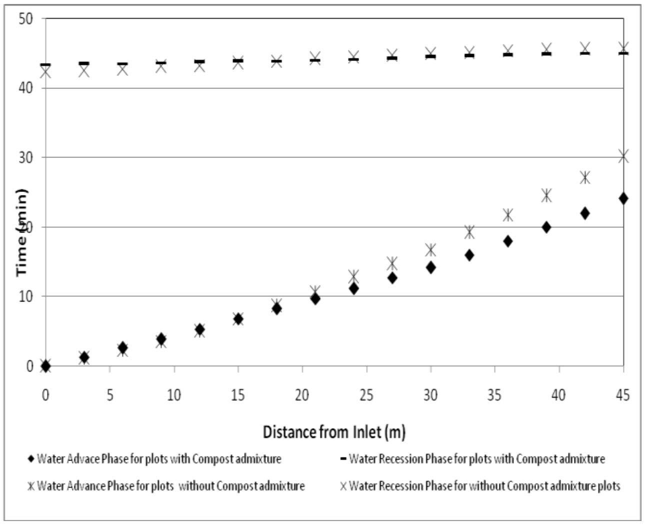

Figure 6. Comparison of advance and recession phase b/w with and without compost admixture plots for compost-A and B during 1st irrigation.

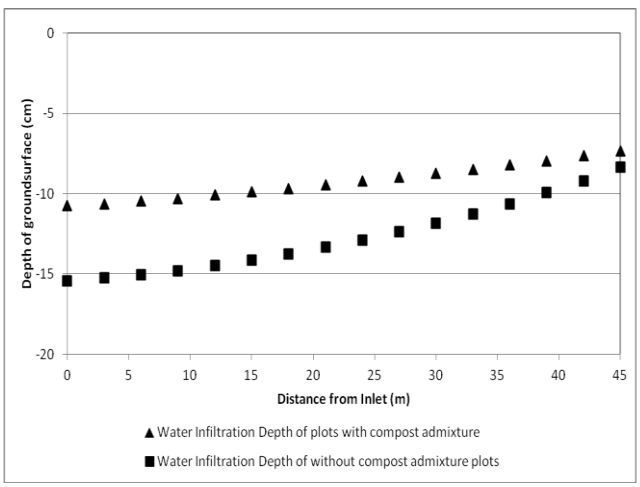

Figure 7. Comparison of water infiltration depth b/w with and without compost admixture plots for compost-A and B during 1st irrigation.

During 2nd irrigation the water advance phase (Figs.4a and 4b) was rapid initially, this may be due to consolidation of soil because of 1st irrigation which reduces the infiltration of soil, and finally the advance of water slows down gradually along the length of the experimental plots. At the tail of the experimental plots, the water advance rate may be slowed down rapidly because the water has to travel more distance to reach this part of the field. Similar results are in the case of without compost plots (Fig. 4c) where at the start water advance is fast due to soil consolidation but alone the length of experimental plot it slows down more as compared to compost admixture plots due to greater infiltration.

The infiltration depth (Figs. 5a and 5b) during 2nd irrigation shows more reduction in infiltration depth and a more uniform water infiltration between the upper and lower ends of experimental plots, this variation of results may be due to consolidation of soil because of 1st irrigation which reduces the infiltration of soil. Trout (1990) conducted an experiment to check the effect of surface seal formation on infiltration, and observed 50% reduction in infiltration on a silt loam soil because of surface seal formation. A small decrease also occurred in infiltration depth in the experimental plots without compost admixture (Fig. 5c) which may again be due to consolidation of soil because of 1st irrigation which reduces the infiltration of soil, but a considerable difference at the head and tail sides still can be noticeable. This better performance during 2nd irrigation than 1st irrigation may also be due to higher initial water content before 2nd irrigation as compared to the 1st irrigation when the initial water content was very low. This higher initial water content decreases water infiltration depth along the length of field resulting in efficient water use and homogeneous distribution along the field length.

The graphical representation (Figs. 2 to 5) of results of compost-A and B revealed that compost from both the sources show almost similar effect on water infiltration depth, water advance and recession phase during 1st and 2nd irrigation. This may conclude that compost from different sources exhibits same impacts on water infiltration depth, water advance and recession phase of an irrigation event provided that the compost used should be completely decomposed and having organic matter contents, C: N ratio, pH and EC in the acceptable limits.

For overall comparison of results from all the experimental plots, the average values of field measured results for water infiltration depth, water advance and recession rate were calculated for both compost and non compost plots. A comparison of average values of water infiltration depth, and water advance and recession rate for compost mixed plots with average values of without compost admixture plots for 1st and 2nd irrigation is shown in Figs. 6 to 9.

It is clear from the graphs that (Figs. 6 and 8) the water took less time to reach the lower end of field in plots having compost admixture and more time in plots having no compost admixture, the compost admixture improves the irrigation performance by decreasing the time of water advance. The recession time is nearly the same in both the cases but the water advance time is lower in the compost admixture plots and results in greater intake opportunity time for the plots having compost admixture. This shows that compost may also improves the water holding capacity of loamy sand soil. Younts *et al*. (1995) reported that the less difference in intake opportunity time between the upper and lower ends of the field resulted in a more uniform distribution of water intake along the length of the field.

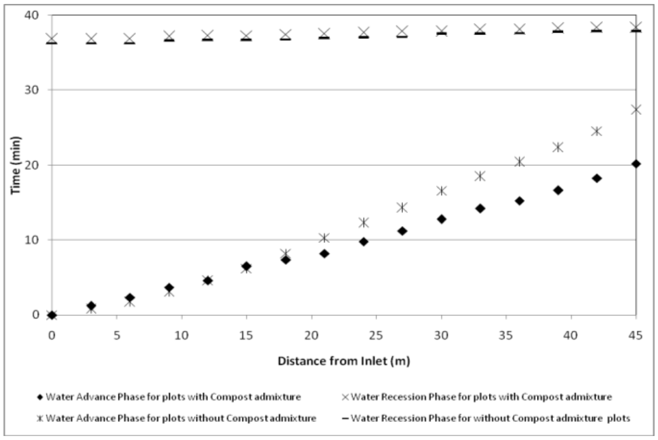

Figure 8. Comparison of advance and recession phase b/w with and without compost admixture plots for compost-A and B during 2nd irrigation.

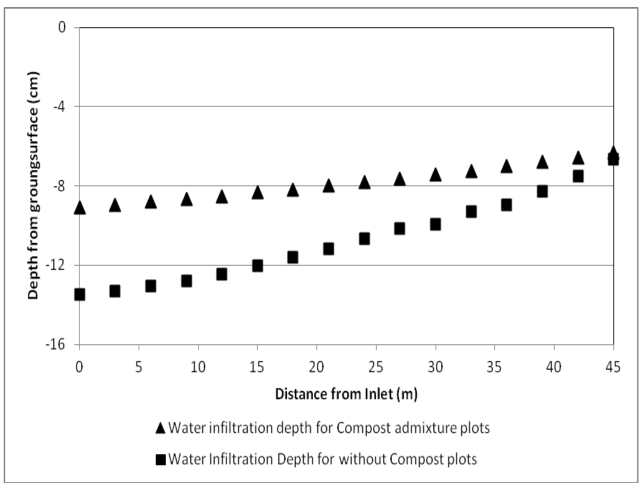

Figure 9. Comparison of water infiltration depth b/w with and without compost admixture plots for compost-A and B during 2nd irrigation.

The graphical presentation (Figs. 7 and 9) shows that the water infiltration depth is less in plots having compost admixture and more in plots having no compost admixture therefore, the compost admixture improves the irrigation performance. The roots of a plant determine the depth to which soil water can be extracted. Young plants have only shallow roots and soil water deeper than their rooting depth is of no use to the plant. Plants typically extracts about 40% of their water needs from the top quarter of the rooting zone, 30% from the next quarter, 20% from the third quarter and only 10% from the deepest quarter. Therefore, plants extract about 70% of their water from the top half of their total root penetration. Deeper portions of the root zone can supply a higher percentage of the crop's water needs if the upper portion is depleted. Reliance on utilization of deeper water will reduce the maximum plant growth (Rogers and Sothers, 1996; Ismail and Depeweg, 2005).

The time space distribution of irrigation water defines the intake opportunity time over entire field surface. Faster advance is one of the main parameters for an efficient surface irrigation system. The faster advance not only reduces the differences in the opportunity times along the length of run but also provides a more uniform distribution of water on the soil. For border irrigation, time of advance is the hydraulic parameter likely to be more important for modification. The advance time is the second after topography in terms of modification for improving hydraulic performance and water infiltration into the soil is key element affecting the advance rate (Walker and Skogerboe, 1987).

Conclusions: The present study revealed that the compost admixture decreases the infiltration rate of loamy sand soil and improves the irrigation water advance and recession phase. By using 5% compost admixture by weight the advance time reduced by 23.96% and 26.83 % for 1st and 2nd irrigations, respectively, compared to non-compost admixture plots. By using 5% compost by weight the water infiltration depth ranged from 10.75 to 7.23 cm for 1st irrigation and from 9.88 to 6.79 cm for 2nd irrigation in comparison to the non-compost admixture plots where the water infiltration depth ranged from 15.37 to 7.98 cm during 1st irrigation and 13.5 to 6.64 cm during 2nd irrigation. Consequently, this decrease in water infiltration depth improves the water advance phase and the water requirement was reduced to the tone of 23.96% during 1st irrigation and 26.83% during 2nd irrigation, compared to non-compost plots which further support this improvement in irrigation performance. The faster movement of the water front after the use of compost admixture reduces the difference in intake opportunity times between the head and far end of the field, thus it improves the performance of the irrigation system.

REFERENCES

Badgley, C., J. Moghtader, E. Quintero, E. Zakem, M.J. Chappell, K. Avilés-Vàzquez, A. Samulon, I. Perfecto. 2007. Organic agriculture and the global food supply. Renew. Agri. Food Syst. 22:86-108.

Fischer, R.A. 1989. Wheat and wheat improvements. 2nd Ed. Amer. Soc. Agron., Inc., Pub. Madison, Wisconsin, USA, pp. 249-269.

Flores, C. and E. Holzapfel. 2009. Dynamic decision system support to assist the suitable water management of an orchard under furrow irrigation. p.100. The Int. Con. Sci. and Inf. Technol. Sustainable Management of Aquatic Ecosys., 8th Int. Con. Hydro Informatics, January 12-16, 2009. Universidad de Concepción, Concepción, Chile.

Ismail, S.M., and H. Depeweg. 2005. Water productivity and crop production simulation under surge flow irrigation in short furrows in Egypt. Irrig. Drain. J. 54 :103-113.

Khaliq, A., M.K. Abbasi and T. Hussain. 2006. Effects of integrated use of organic and inorganic nutrient source with effective microorganisms on seed cotton yield in Pakistan. Bio-resources Technol. 97:967-972.

Khan, M.A., S. Mahmood, J.K. Sial and M. Iqbal. 1997. Surge irrigation- a water management tool for improving irrigation system performance. pp. 337-342. In: Proc. Int. Symp. on Water for 21st Century: Demand, Supply, Development and Socio-Environmental Issues. Center of Excellence in Water Resources Engineering, Uni. Eng. Tech., Lahore, Pakistan.

Kumar, R. and J. Singh. 2003. Regional water management modelling for decision support in irrigated agriculture. J. Irrig. Drain. Eng. ASCE, 129:432-439.

Latif, M. and S. Mahmood. 1998. Water related issues and management potential for sustainable irrigated agriculture in the Indus Basin. pp. 301-306. In: Proc. Agro-environmental Issues and Furture Strategies: Towards 21st Century, University of Agriculture, Faisalabad, Pakistan.

Mukheibir, P. 2008. Water resources management strategies for adaptation to climate-induced impacts in South Africa. Water Resour. Manag. 22:1259–1276.

Oyonarte, N.A., L. Mateos and M.J. Palomo. 2002. Infiltration variability in furrow irrigation. J. Irrig. Drain. Eng. 128:26-33.

Rizwan, A., M. Naveed, M. Aslam, Z.A. Zahir, M. Arshad and G. Jilani. 2008. Economizing the use of nitrogen fertilizer in wheat production through enriched compost. Renew. Agr. Food Syst. 23:243-249.

Rogers, D.H., W.M. Sothers. 1996. Soil, water and plant relationships. Co-operation Extension Work Acts of May, 8, Kansas State University, Kansas, USA.

Sarwar, G., N. Hussain, H. Schmeisky and S. Muhammad. 2007. Use of compost as an environment friendly technology for enhancing rice wheat production in Pakistan. Pak. J. Bot. 39:1553–1558.

Samani, Z.A., W.R. Walker, and L.S. Willardson. 1985. Infiltration under surge flow irrigation. Trans. ASAE, 28:1539–1542.

Strelkoff, T.S., A.J. Clemmens and E. Bautista. 2009. Field properties in surface irrigation management and design. J. Irrig. Drain. Eng. 135:525–536.

Trout, T.J. 1990. Furrow inflow and infiltration variability impacts on irrigation management. Trans. ASAE. 33(4): 1171-1178.

Walker, W.R. and G.V. Skogerboe. 1987. Surface irrigation, theory and practices. Prentice Hall, New York, USA.

Willer, H. and L. Kilcher (eds.). 2009. The World of Organic Agriculture. Statistics and Emerging Trends 2009. IFOAM, DE-Bonn and FiBL, CH-Frick ITC, Geneva.

Younts, C.D., E. Joel, E. Dean. 1995. Surge flow irrigation. University of Nebraska. Fact Publication, Nebraska, USA.