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EMBEDMENT OF SANDY SOIL TO INCREASE SURFACE IRRIGATION EFFICIENCY AND CROP YIELD UNDER MODELING AND EXPERIMENTAL APPROACH

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Cultivation of sandy soils is a permissible solution to overcome food security. This research was conducted at Chowk Sarwar Shaheed, District Muzaffargarh, Punjab Province, where the soil was predominately coarse, which results in higher deep percolation losses. Surface irrigation methods are normally practiced at the study area. Soil amendment such as clay soil addition was used to reduce the water infiltration rate. The objectives of the study were to control the infiltration in the sandy soil by using clay soil mixture and improve water distribution uniformity. For this SIRMOD model was used, which showed that water traveled only 34 m along the field when clay was not mixed. When 3% clay soil by volume was mixed in 5 cm depth of sandy soil, water did not reach at field end but traversed 47 m. It was found that water reached at the tail end of field with distribution uniformity of 93.17 and 96.49%, when 5 and 7% of clay was mixed, respectively. Hence, the amendment of sandy soils with clay soil is one of the good options to lower infiltration rate and increase water use efficiency. In field experiment, crop yield was also increased from 540kg/ha to 1160kg/ha in bare sand and after mixing 5% clay, respectively. There was no significant difference was observed in 5 and 7% of clay admixture. So, it was recommended that 5% clay soil mixture with sandy soil should be used to enhance water distribution efficiency.
Keywords*:* Clay-Soil-Admixture, control infiltration, water distribution efficiency, surface irrigation, SIRMOD model

INTRODUCTION

Food demand is increasing gradually in Pakistan due to population growth therefore, available marginal land increasingly brought under irrigation as Thar, Thal, Cholistan, deserts and vast arid areas of Balochistan and Punjab in Pakistan. Surface irrigation methods are practiced mostly in the Pakistan. Surface irrigation is defined as the group of application techniques where water is applied and distributed over the soil surface by gravity.

In Pakistan inefficient surface irrigation is used in majority of the irrigated agriculture lands which has some major water use efficiency issues (Shakoor *et al.,* 2012). Our fields are not designed according to the soil infiltration rate and the available flow, the application and distribution efficiencies are quite low so large volume of precious irrigation water is deep percolated (Arshad *et al.,* 2013). These losses represent considerable financial loss in term of reduced productivity. It is imperative to save surface and groundwater to achieve higher productivity per unit of water consumed (Shakoor *et al.,* 2018; Farid *et al.,* 2017). Therefore, it requires exploring new ways and means to reduce the losses. Surface irrigation is usually favored because of its lower energy, labor and cost requirements. However, the lower efficiency of surface irrigation restricts its use.

In surface irrigation methods the flow medium of water is soil so the soil type directly affects the water distribution efficiency. The infiltration characteristic of the soil is the most essential factor affecting the performance of surface irrigation (Shakoor *et al*., 2012; Lee *et al*., 2011; Udom *et al.*, 2011; Khatri and Smith, 2005). Among many models developed for monitoring the infiltration process those of Kostiakov (1932) has been studied in detail because of their simplicity and the ease of estimating their fitting parameters.

Addition of clay to the top of sandy soil has been shown to be highly effective in reducing water repellency and increasing crop yield. The most predictive factor which has the greatest effectiveness of clay soil materials in reducing water repellency in sandy soil was texture (Ismail and Ozawa, 2006). The sandy soil treated with clay deposits increased the crop yield of squash (*Cucurbita pepo*) by 12.8% compared with control treatment (Al-Omran *et al.*, 2005). Reuter (1994) reported that clay-substrate application in sandy soil significantly improved soil water regime, especially on the percolation processes. Important consequences of clay addition are reduction of plant nutrient losses and ground water contamination. The performance of a level basin designed based upon the completion of advance phase is more robust than the performance of a level basin irrigation system (Reddy, 2011). In Pakistan, ladyfinger is cooking as favorite vegetables, resulting in a steady increase in the production of ladyfinger, but the latest statistics show that five years ago there was a decreasing trend in yield per unit area and production, compared with the past 10 years. Several factors that cause a decrease in yield and production but said that limiting the availability of irrigation water were a key factor to reduce the production of ladyfinger (Siemonsma, 1982).

The present study aimed to investigate soil moisture distribution, yield improvement, and water use efficiency of ladyfinger in sandy soil treated with clay and also to figure out whether mixing of different percentages of clay by volume in 5 cm depth of sandy soil. Also determine the water use efficiency and water productivity of ladyfinger crop with and without clay mixing.

MATERIALS AND METHODS

***Site description*:** This research was conducted at Chowk Sarwar Shaheed, District Muzaffargarh, Punjab Province, where the soil was predominantly coarse, moderately coarse textured and are generally free of salinity and alkalinity. The longitude and latitude of the project area are 30°37'19.80" N and 71°13'33.26" E and elevation is 454 feet. The average rainfall in the project area is around 25.4mm per year. The earlier studies showed that the area comprised 73.72% coarser, 20.45% moderately coarser, 5.25% medium and 0.47 % fine texture soil. The remaining 0.11% was covered by marshland.

***Sieve analysis*:** Soil samples were taken from the cultivated land of CSS area and sieve analysis was initially conducted in the laboratory. It was found from the sieve analysis that the percentage of soil components of lab. Sample was 90% sand, 7% silt and 3% of clay. The results of sieve analysis of bare sand and after mixing clay are presented in Table 1.

Table 1. Sand contents after mixing clay in different percentage by volume.

Soil contents (%)	Sand before mixing (T_1)	After mixing 3% clay (T_2)	After mixing 5% clay (T_3)	After mixing 7% clay (T_4)
Sand	90	84	78	68
Silt	7	9	12	16
Clay	3	7	10	16

***Infiltration tests*:** Double ring infiltrometer was used to measure infiltration rate. Infiltrometer of 30cm diameter of inner ring and 60cm diameter of outer ring and from 10-20cm depth was used. List of experiments performed in the field are shown in Table 2. Each experiment was replicated three times and the average values were calculated. Kostiakov infiltration parameters were determined by using matching curve method and then used for further calculations in SIRMOD model. The predicted values of cumulative infiltration with calibrated Kostiakov model when plotted against observed data gave a good fit (Osman *et al*., 2003).

Table 2. List of Experiment performed in the field.

Sr.	Depth of mixing (cm)	Percentage of clay mixed (%) (by volume)	Weight of clay soil (g)
T_1	5	Nil	Nil
T_2	5	3	170.85
T_3	5	5	284.75
T_4	5	7	398.65

***SIRMOD model inputs*:** SIRMOD model was used to determine irrigation application performance without and with clay soil mixture. SIRMOD model accurately simulated the continuous and surge flow irrigation under short field conditions when the appropriate infiltration parameters are used (Saleh, 2005). Following were the constant data used in SIRMOD model:

Field length = 70 m
Field width = Half acre (33.5 m)
Discharge = 2 lps/ m of width
Roughness coefficient = 0 .04
Targeted infiltration depth = 0.08 m
Time of cut off = 25 min

***Field experiment*:** A field experiment was conducted to study the effects of mixing of clay in sandy soil on growth and yield of lady finger. The selected plot area of 64m^2 was taken and divided it into four plots of 4m x 4m. Four treatments were used as in T_1: control treatment (without mixing clay), T_2: 3% mixing, T_3: 5% clay mixing and T_4: 7% clay mixing in sandy soil. The seeds of ladyfinger were sowed directly into the soil. In each point two seeds of ladyfinger were planted and plant to plant and row to row distance was 60cm and 30 cm, respectively.

RESULTS AND DISCUSSION

***Infiltration parameters*:** Kostiakov curve fitting parameters were calculated using curve fitting method for 5cm depth and percentage of clay soil mixing with sandy soil. Kostiakov curve fitting parameters for field infiltration tests of sample (sandy soil) before mixing clay was a= 0.600, k= 0.0240 & f_o= 0.00038 (Fig. 1a). The curve fitting parameters were resulted a= 0.540, k= 0.0190 & f_o= 0.00039, when 3% by volume clay was mixed in 5 cm depth of sample (Fig. 1b). The curve fitting parameters were resulted a= 0.350, k= 0.0140 & f_o= 0.00038, when 5% by volume clay was mixed in 5 cm depth of sample (Fig. 1c). The curve fitting parameters were resulted a= 0.330, k= 0.0130 & f_o= 0.00036, when 7% by volume clay was mixed in 5 cm depth of sample (Fig. 1d).

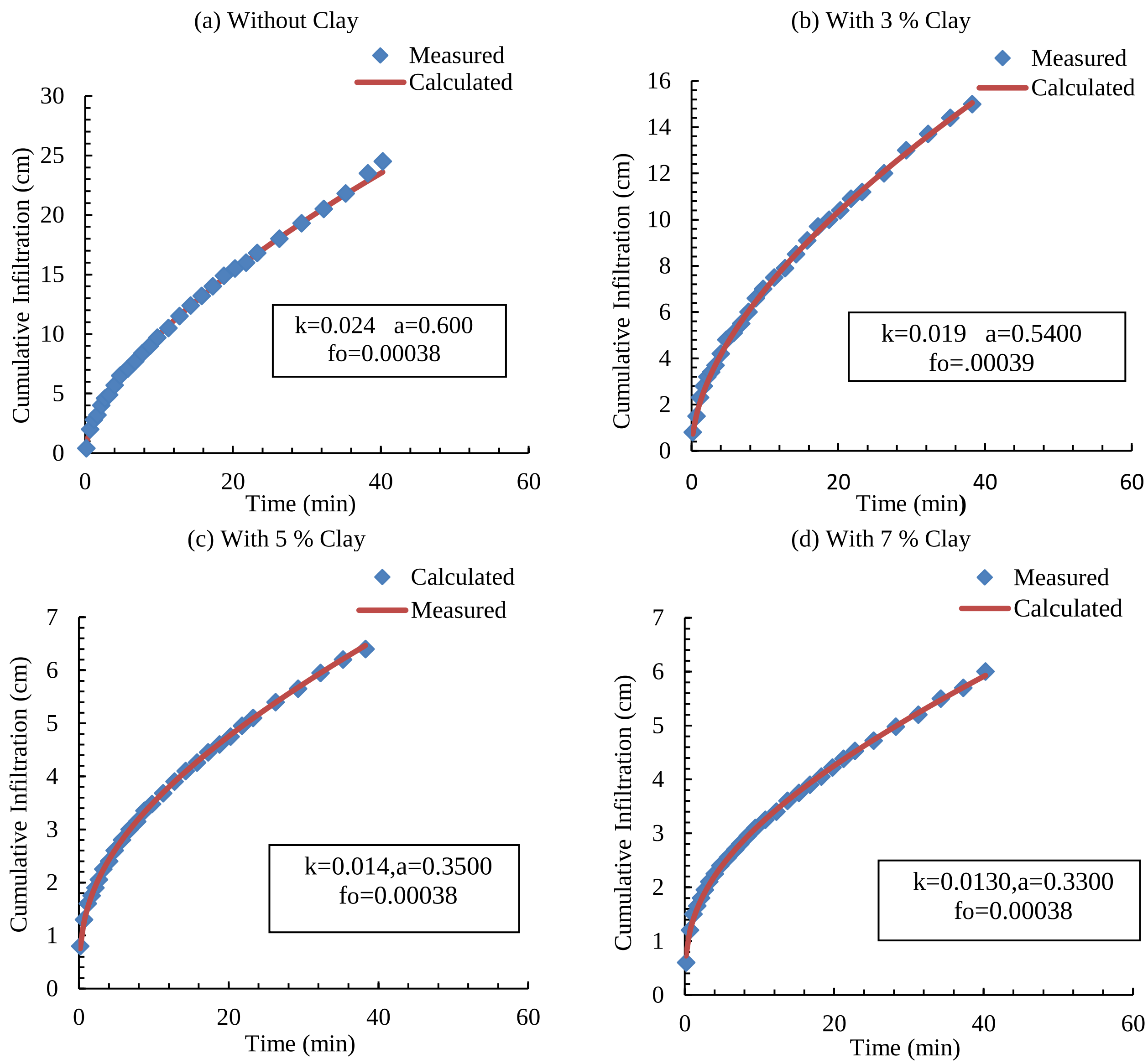

Figure 1. Determination of Kostiakov parameters.

SIRMOD results**:** It was found that before mixing of clay soil, all the water was deep percolated before reaching at the field end and water traveled only 34m along the field and water deep percolation losses was 0.20m (Fig. 2a). When 3% clay was mixed, then water deep percolation losses was reduced to 0.14m and water traversed the distance of 47 m (Fig. 2b). After mixing 5% clay more satisfactory results were found and water deep percolation losses was reduced to 0.085m. The water was reached at the end of the field (Fig. 2c) with improvement in application efficiency 97.93%, irrigation efficiency 99.60% and distribution efficiency 93.17%. When 7% clay was mixed, then water deep losses depth was reduced to 0.082m and water was reached at the end of the field (Fig. 2d) with the application efficiency 98.99%, irrigation efficiency 99.62% and distribution efficiency 99.37%.

Crop yield***:*** The results of plant height and crop yield are shown in Figure 3a, b. It was found that the plant height was 27cm and crop yield was 540kg/ha in sandy soil (before mixing clay). In the field where 3% clay was mixed in the sand the plant height was increase up to 31.5cm and crop yield was 825kg/ha. In the next two fields the results were almost same the plant height and crop yield were increased up to 39.5cm and 1160kg/ha in the mixture of 5% clay and in 7% of clay mixed the plant height and crop yield was increased up to 40cm and 1190 kg/ha. It was revealed that addition of clay up to 5% of volume of sandy soil effect on the height of plant significantly.

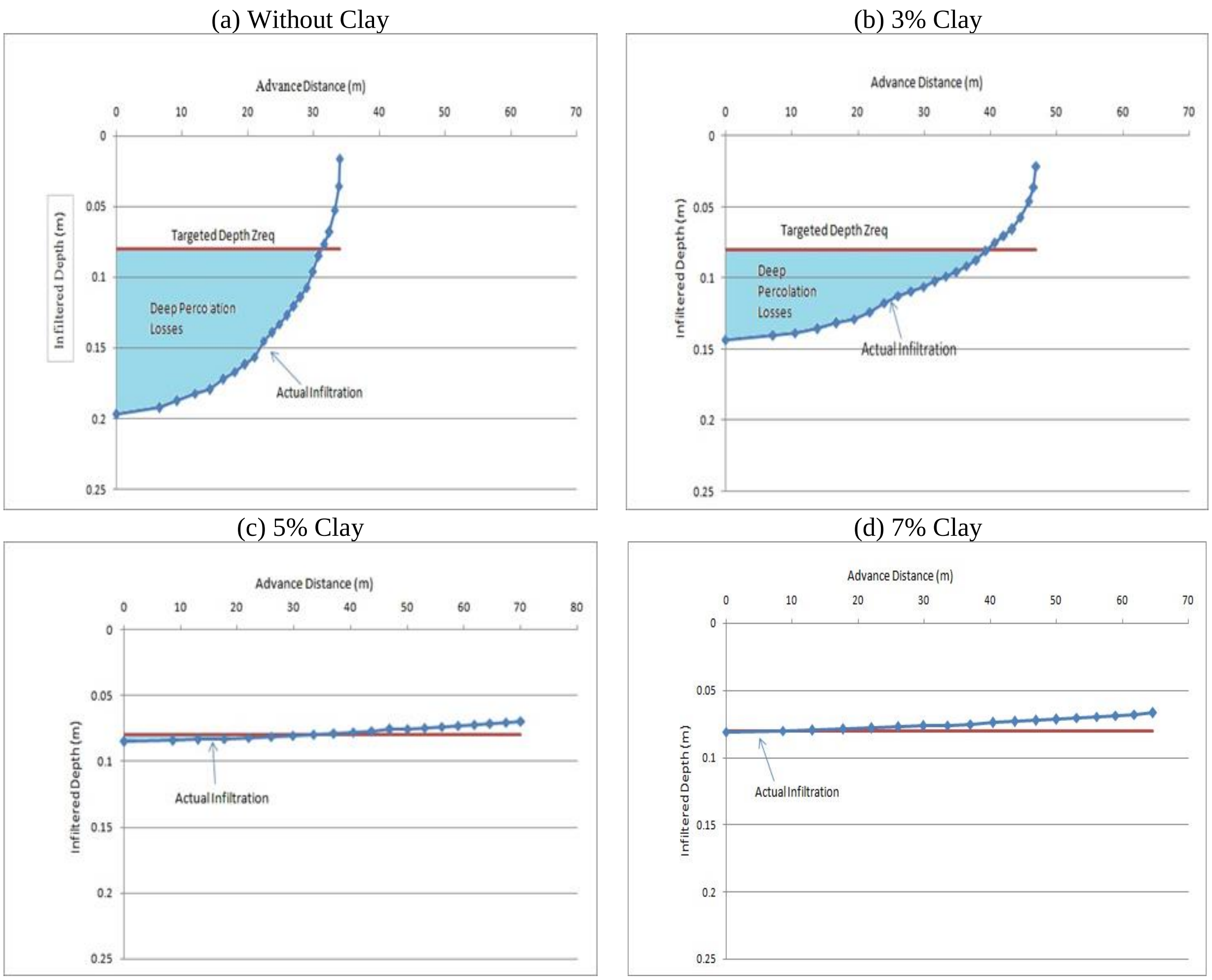

Figure 2. SIRMOD results.

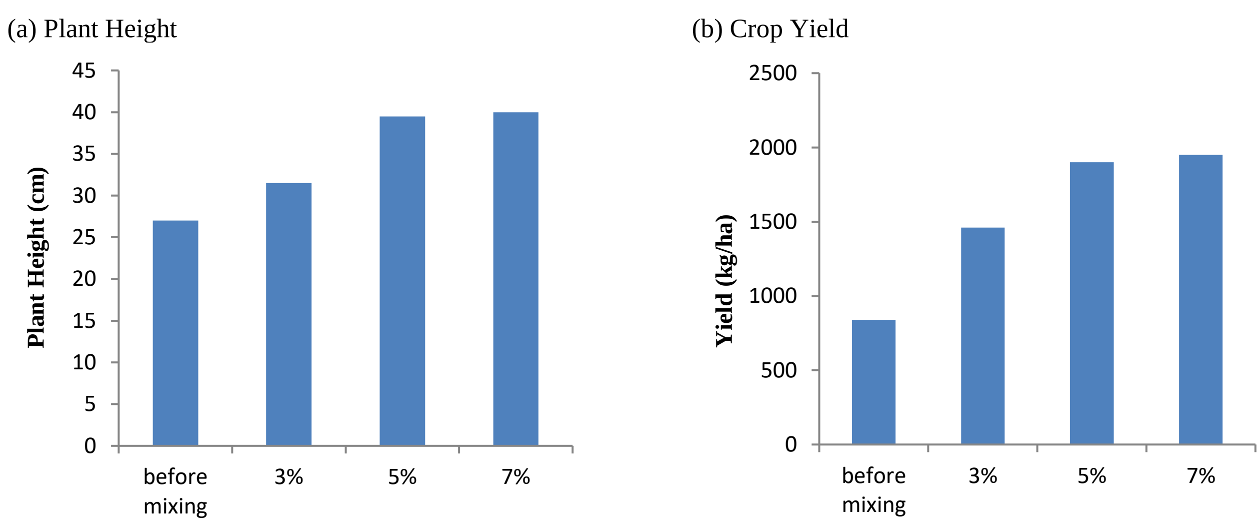

Figure 3. Field experiment results

DISCUSSION

The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the soil surface will take one hour to infiltrate. Infiltration rates of sand silt gravel etc. vary because of the differences in the size of the particles. Clay has a very small diameter, while sand has a large diameter. Clay has the slowest infiltration rate since it is the smallest particle it is able to pack tighter together thereby leaving less of a space between the particles. The infiltration rate of sand is very high due to the large size of particles and more pore spaces. As there is the water shortage, so to cultivate sandy soils it's very important to overcome this problem. There are different soil amendments can be used to control infiltration and to improve root zone water distribution efficiency of sandy soil such as addition of clay, bentonite amendment and mixing of hydrogel. Shakoor (2010) calculated parameters of Kostiakov eq. without using bentonite were; a = 0.016, b= 0.655 & f_o= 0.0004. Using 1% bentonite amendment the parameters resulted; a = 0.011, b = 0.59 & f_o = 0.0004 and for 2 % bentonite amendment it resulted a = 0.0064, b = 0.4 & f_o = 0.00038. Anjum (2013) calculated the parameters of Kostiakov equation with and without mixing hydrogel. Kostiakov's infiltration parameters found for bare soil were k = 0.012 $ft^3/ft/mn^a$, a = 0.78, f_o = 0.0004 $ft^3/ft/mn$. After mixing hydrogel with sandy soil the parameters of Kostiakov equation calculated were k = 0.0064 $ft^3/ft/mn^a$, a = 0.74, f_o = 0.00038 $ft^3/ft/mn$.

As the infiltration rate of the study area was very high, so that water was not reached at the tail end of the field because all water was deep percolated within 34m. When 3% clay by volume was mixed the SIRMOD results show that water was reached up to 47m only. This advance movement of water was not satisfactory because field length was 70m. When 5% by volume clay soil was mixed the SIRMOD results were satisfactory and water reached at the tail end with minimum advance time. 5% clay works very effectively which increased the application efficiency up to 89-100%, storage efficiency 90-97% and distribution uniformity 80-100%. When 7% by volume clay soil was mixed the SIRMOD results were also satisfactory and water reached at the tail end with minimum advance time. 7% clay was also worked very effectively which increased the application efficiency up to 89-100%, storage efficiency 90-97% and distribution uniformity 80-100%. It was found that there was no significant difference in efficiencies after mixing 5 and 7% clay.

***Conclusions*:** Adding of clay soil, decreases the infiltration rate of coarser soil and improved the irrigation water *distribution* in sandy soil. The Kostiakov infiltration equation parameters a, k and f_o decrease when percentage of clay soil increases. The percentage of clay mixed was more significant than the depth of mixing in reducing infiltration rate. For 3 % clay mixing the irrigation water was not reached end of the field and advance distance was limited to 30 to 40 m. For 5% clay mixing the water was reached to tail end of field and distribution uniformity varied as 80 to 85%. Five Percent (5%) clay soil by volume mixing in 5cm depth of soil was produced satisfactory results for lowering infiltration rate in sandy soil.

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