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WATER TRANSMISSION CHARACTERISTICS OF FLY ASH AND SULPHITATION PRESS MUD AMENDED SOILS UNDER DIFFERENT MOISTURE REGIMES IN RICE-WHEAT CROPPING SYSTEM

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ABSTRACT

Flyash (FA) and sulphitation press mud (SPM) amended soils at different moisture regime indicated that mean value of infiltration rate (IR) (cm/hr) and hydraulic conductivity (HC) (cm/hr) was found minimum in SPM + FA (1.05, 0.12) followed by SPM (1.10, 0.16), FA (1.15, 0.17), and pond soil (1.25, 0.19) over control (1.42, 0.26) whereas these were 5.6% and 1.7% lower under irrigation treatment (1.16, 0.17) over un-irrigated treatment (1.23, 0.19), respectively. The highest per cent of mean value increase in available water storage capacity has been found in SPM + FA (14.35) > SPM (10.75) > FA (6.68) > pond soil (6.15) over control at higher suction (0.33 to 15 bar). Similar trends were found at both suction *i.e.* 0.1/0.33 to 15 bar but the magnitudes were higher in 0.1 to 15 bars as compared to 0.33 to 15 bar. Thus, irrigation water cannot affect the IR and HC at significant level, whereas application of amendments like SPM + FA, SPM, FA were found to decrease the IR and HC at significant level.

KEY WORDS
Fly ash
Pond soil
SPM
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Rice-wheat cropping system

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INTRODUCTION

Presently more than 175 million tonnes of fly ash (FA) is generated in India from several thermal power plants and it is expected about 300 million tonnes of FA will be generated in the year of 2016-17(Bhattacharjee and Kandpal, 2002). According to Singh (2010), about 50-55% of total ash generated in India is being utilized in various applications such as cement, bricks, blocks, tiles, concrete, embankment, structural fill materials, etc.

The Indian Fly Ash is alkaline and as such improves soil quality. In fact, Fly Ash consists of all

elements present in soil except organic carbon and nitrogen (Kumar *et al.*, 2000). Fly ash utilization program (FAUP) has been undertaking various project/activities for safe management and gainful utilization of FA (FAUP, 2007). Soil amendments can be improved by the addition of organic materials in form of amendments like SPM, FA and along with finer particles of pond soil may be helpful in especially light texture soil (Yaduvanshi and Sharma, 2007). The availability of SPM is abundant due to presence of many sugar factories whereas presence of coal fired thermal plants produces huge amount of flyash. To convert macro pores into micro pores, organic materials like SPM, finer particles of FA and pond or chaur land soils added to the soil and ultimately affect proportion of pore size distribution.

This may be helpful to increase the retention and release capacity of soil water along with water soluble nutrients. Bulk density, porosity, specific gravity and water holding capacity of the stowing material plays a key role in hydraulic stowing (Mishra and Das, 2010). The bulk density of both the fly ashand SPM was found 0.99 g/cc and 1.25 g/cc, respectively which were less than normal soil (1.5-1.7 g/cc). Low bulk density ash samples are very much suitable for agricultural purpose. These may be used as an additive in clayey soils to reduce their plasticity (Mishra and Singh, 2007). Systemic approach to enhance moisture retention capacity and decrease in water transmission characteristics in calcareous light texture soil of North Bihar, an experiments have been conducted with SPM, FA, SPM + FA, pond soil as compared to control in irrigated and un-irrigated condition with rice-wheat cropping system.

MATERIALS AND METHODS

A field experiments was conducted in kharif and rabi season of 2010-11 and 2011-12 in Rajendra Agricultural University, Pusa situated at 25°982 N latitude and 85°672 E longitude. The soil of the experimental area was calcareous having free calcium carbonates of about 28.2 per cent. The soil of the experimental field was Entisol and sandy loam in texture with low available nitrogen (214 kh/ha), medium available phosphorus (18 kg/ha) and low available potassium (113 kg/ha). Surface soil samples were taken randomly at different places from 0-30 cm depth to determine the physico- chemical properties and fertility status by using standard procedure of the experimental plots whose values are given in Table 1. Rice *c.v.* Prabhat and wheat *c.v.* UP-262 were sown both years consecutively with recommended basal doses of fertilizers.Five treatment imposed as basal namely: control, sulphitation press mud @10 ton/ha, fly ash @ 10 ton/ ha, sulphitation press mud @10 t/ha+fly ash @ 10 t/ha, and clay @ 50 ton/ha with un-irrigated and irrigated (recommended) plots in a split plot design with three replications (Table 2). Measurement of water retention of various suctions (0.1, 0.33, 0.5, 1, 3, 5, 10 and 15 MPa) and available water storage capacity were made with the help of pressure plate apparatus (Rechards, 1948). Infiltration rate was estimated by using double ring infiltrometers (Bertrand, 1965). Saturated hydraulic conductivity (K_s) was determined directly from Darcy's equation (Klute and Dirkson, 1986)

$$Ks = \frac{VL}{At(H2 - H1)}$$

Where, A = Cross sectional area of the core; t = Time of water flow; H_2-H_1 = Hydraulic head difference; V = Volume of water flow during time t; L = length of the core. The statistical analysis has done by standard procedure followed by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Infiltration rate (IR)

The infiltration rate has been negative and significantly affected by SPM + FA, FA and SPM, whereas pond soil application has not significant effect. Mean value of IR under irrigation treatment (1.16 cm/hr) was 5.6% lower over unirrigated treatment (1.23 cm/hr) but it was not at significant level either with the application of amendments alone or in combination after harvest of first rice crop (Table 3). Similar trends were found after harvest of each succeeding crop *i.e.* little change in magnitude due to increase in total porosity.

Lower IR in light texture soil improved the soil water relations *i.e.* retention of water and nutrients ultimately improve water use efficiency and better yield. Maniram *et al.* (2004) reported favourable effects of FA and clay on physical condition of soil. An increase in total volume of pores in the upper part of alluvial horizon is due to an increase in small and medium size pore accompanied by decrease in large size pores, (Fitz Patrick, 1983., Scheffer and Schachtschabel, 1989). Similar statement were given by Osman *et al.* (1997) *i.e* amendments like fine textured soil separates, organic manures and crop residues are known to improve water transmission properties of the soil with treated plots.

Hydraulic conductivity

The maximum significant decrease in mean value of HC (cm/ hr) was found in SPM + FA (0.12) followed by SPM (0.16), FA (0.17), pond soil (0.19) and minimum in control (0.26). Although mean value of HC (0.17) under irrigation treatment has slightly reduced the hydraulic conductivity as compared to un-irrigated treatment (0.19) but it was not at significant level, after harvest of first rice crop (Table 3). The reduction in HC by the application of irrigation and amendments may be due to conversion of bigger pores into medium and smaller size pores resulted from the compaction or settlement by irrigation water along with over burden pressure on soil surface. The change in hydraulic conductivity is apparent due to addition of amendments as compared to control. Similar observation were obtained Osman *et al.* (1997) *i.e* amendments like fine textured soil separates, organic manures and crop residues are known to improve pore size distribution and ultimately differences reflect in all soil moisture characteristics curves. These curves are sensitive to changes in bulk density and disturbances in soil structure in addition the curves generally show hysteresis according to the degree of wetting and drying of soils by Kumar and Mishra (1991).

Water retention

The highest increase in water retention were found in SPM + FA treatment under both irrigated and un-irrigated condition after harvest of first rice crop. Amendments had increased the aggregation, inter and intra porosity along with proportion of pore size distribution by increasing the finer fractions in light texture soil. The addition of amendments either alone or in combination has changed the soil metric potential and ultimately soil moisture storage at various suction and soil moisture content.

This has helped in minimizing the stress under different situation *i.e* un-irrigated and irrigated condition under rice-

Table 1: Soil chemical properties of the experimental plot

S.No.	Properties	SPM	Flyash	Pond soil
1	Bulk density (Mg m^{-3})	0.9	1.1	1.31
2	Water holding capacity (%)	38.2	55.2	34.3
3	pH (1:2.5)	6.4	7.8	8
4	EC (dS m^{-1})	0.22	0.82	0.18
5	Organic carbon (%)	32.4	2.21	0.42
6	Available nitrogen (mg kg^{-1})	1520	32	81
7	Available phosphorous (mg kg^{-1})	730	97	9.5
8	Available potassium (mg kg^{-1})	880	128	42

Table 2: Treatment details

Main plot treatments (irrigation regimes)		
I_1	-	Unirrigated
I_2	-	Irrigated (recommended)
Sub plot treatments (amendments)		
A_1	-	No amendment
A_2	-	Sulphitationpressmud (SPM) @ 10 t ha^{-}
A_3	-	Flyash @ 10 t ha^{-1}
A_4	-	SPM 10 t ha^{-1} + flyash 10 t ha^{-1}
A_5	-	Clay soil @ 50 t ha^{-1}

Table 3: Effect of amendments on infiltration rate (cm/hr) and hydraulic conductivity (cm/hr) of soil under two moisture regimes after crop harvest

Amendments Level	2010-11						2011-12					
	infiltration rate (cm/hr)											
	Rice			Wheat			Rice			Wheat		
	Unirrigated	irrigated	Mean	Unirrigated	irrigated	Mean	Unirrigated	Irrigated	Mean	Unirrigated	irrigated	Mean
Control	1.45	1.4	1.42	1.4	1.36	1.38	1.45	1.4	1.42	1.4	1.4	1.4
SPM	1.1	1.1	1.1	1.2	1.1	1.15	1.1	1.1	1.1	1.2	1.1	1.15
FA	1.2	1.1	1.15	1.25	1.1	1.17	1.2	1.1	1.15	1.3	1.25	1.27
SPM + FA	1.1	1.1	1.05	1.2	1.1	1.15	1	1.1	1.05	1.13	1.1	1.11
Pond soil	1.3	1.2	1.25	1.3	1.2	1.25	1.16	1.2	1.18	1.2	1.2	1.2
Mean	1.23	1.16	1.19	1.27	1.17	1.22	1.21	1.17	1.18	1.24	1.21	1.22
			CD (0.05)		CD (0.05)				CD (0.05)		CD (0.05)	
Irrigation			0.35		0.12				0.06		0.14	
Amendments			0.13		0.15				0.18		0.20	
Amendments at same level of Irrigation			NS		NS				NS		NS	
Irrigations at same or different level of Amendment			NS		NS				NS		NS	
	Hydraulic conductivity (cm/hr)											
Control	0.27	0.25	0.26	0.21	0.19	0.2	0.27	0.25	0.26	0.23	0.21	0.22
SPM	0.17	0.16	0.16	0.14	0.13	0.13	0.16	0.15	0.15	0.14	0.13	0.13
FA	0.18	0.16	0.17	0.14	0.13	0.14	0.17	0.13	0.15	0.16	0.16	0.16
SPM + FA	0.12	0.12	0.12	0.12	0.12	0.12	0.14	0.13	0.13	0.12	0.12	0.12
Pond soil	0.2	0.19	0.19	0.18	0.18	0.18	0.25	0.22	0.23	0.2	0.19	0.2
Mean	0.19	0.17	0.18	0.16	0.15	0.15	0.2	0.17	0.19	0.17	0.16	0.16
			CD (0.05)		CD (0.05)				CD (0.05)		CD (0.05)	
Irrigation			0.11		0.05				0.04		0.04	
Amendments			0.05		0.07				0.07		0.05	
Amendments at same level of Irrigation			NS		NS				NS		NS	
Irrigations at same or different level of Amendment			NS		NS				NS		NS	

Table 4: Available water storage capacity (volumetric v/v) in between 0.1-15 and 0.33-15 bar under two moisture regimes after crop harvest

Amendments Level	2010-11						2011-12					
	Available water storage capacity (volumetric v/v) in between 0.1-15 bar											
	Rice			Wheat			Rice			Wheat		
	Unirrigated	irrigated	Mean	Unirrigated	irrigated	Mean	Unirrigated	irrigated	Mean	Unirrigated	irrigated	Mean
Control	18.56	18.56	18.56	17.69	17.69	17.69	18.41	18.41	18.41	17.2	17.54	17.37
SPM	20.68	20.73	20.7	20.3	20.4	20.35	20.68	20.73	20.71	20.01	20.01	20.01
FA	20.1	20.15	20.12	19.52	19.57	19.55	20.1	20.15	20.12	19.23	19.28	19.25
SPM + FA	21.02	21.22	21.12	20.73	20.88	20.81	21.02	21.02	21.02	20.3	20.3	20.3
Pond soil	20.01	20.01	20.01	18.85	18.85	18.85	19.72	19.86	19.79	18.56	18.56	18.56
Mean	20.7	20.13	20.1	19.41	19.47	19.44	19.98	20.03	20	19.06	19.13	19.09
			CD (0.05)			CD (0.05)			CD (0.05)			CD (0.05)
Irrigation			1.45			0.82			1.96			1.67
Amendments			2.23			2.78			2.08			2.39
Amendments at same level of Irrigation			NS			NS			NS			NS
Irrigations at same or different level of Amendment			NS			NS			NS			NS
Available water storage capacity (volumetric v/v) in between 0.33-15 bar												
Control	14.21	14.26	14.24	13.61	13.77	13.69	14.06	14.12	14.99	13.48	13.61	13.54
SPM	15.51	15.8	15.66	15.08	15.08	15.08	15.66	15.8	15.73	14.83	14.93	14.88
FA	15.08	15.28	15.18	14.64	14.79	14.71	15.08	15.18	15.13	14.64	14.7	14.67
SPM + FA	16.24	16.29	16.27	15.95	16.06	16.02	16.53	16.58	16.55	15.66	15.66	15.66
Pond soil	14.93	15.08	15.05	14.6	14.64	14.62	15.08	15.13	15.1	14.26	14.5	14.38
Mean	15.19	15.34	15.28	14.77	14.86	14.82	15.28	15.36	15.32	14.57	14.68	14.63
			CD (0.05)			CD (0.05)			CD (0.05)			CD (0.05)
Irrigation			3.17			5.20			2.45			3.44
Amendments			1.79			2.04			2.23			2.05
Amendments at same level of Irrigation			NS			NS			NS			NS
Irrigations at same or different level of Amendment			NS			NS			NS			NS

wheat cropping system but no remarkable change has been observed with passes of time. This result was supported by Bhardwaj and Bhagat (2004), addition of organic matter to soil increased water retention. Carlson and Adriano (1993) observed that application of FA in coarse texture soil improve soil water retention capacity. Similarly Osman *et al.* (1997) observed that amendment like fine textured soil enhance water retention and nutrient holding capacity in coarse textured soil. Soil physical characteristics of Kathara ash enriched in various nutrients which are very much suitable for agricultural application and land reclamation, which influence the bulk density, porosity, specific gravity, water holding capacity and liquid limit asreported by Das *et al.* (2011).

Available water storage capacity

The available water storage capacity (v/v) of soil has been found in order SPM + FA (21.42) > SPM (20.70), FA (20.12) > pond soil (20.01) and control (18.56) under 0.1 to 15 bar. For both un-irrigated and irrigated condition, there is a slight difference but not significant in available water storage capacity after harvest of first rice crop. Similar trends were observed after harvest of succeeding crops, *i.e* first wheat, second rice and second wheat crop (Table 4). Among the amendments the highest mean value have been observed in SPM + FA and lowest in control, irrespective of irrigation level. This had maintain higher available water storage capacity and help in mitigating the intermittent water stress in between two consecutive irrigation in irrigated treatment and two consecutive rain in un-irrigated treatment.

Percentage increase Available water storage capacity

The highest percentage increase in available water storage capacity has been found in SPM + FA followed by SPM, FA and pond soil over control (Fig. 1). Similar trends were found at both suction but the magnitudes were higher in 0.1 to 15 bars as compared to 0.33 to 15 bar.The higher amount of available water storage capacity facilitated to maintain better plant water status, ultimately minimized the intermittent water stress either un-irrigated or irrigated conditions. Similarly at higher suctions (0.33 to 15 bar) the magnitude of available water storage capacity pooled of four crops were lesser than the lower suction (0.1 to 15 bar) without changing the trends. The level of irrigation has not been able to create mark able

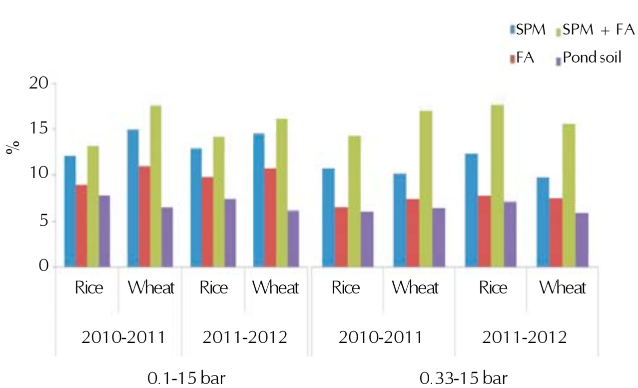

Figure 1: Percent increase of available water storage capacity (volumetric v/v) at two moisture regimes after crop

effect on per cent increase in available water storage capacity. From the highest per cent of mean value increase in available water storage capacity has been found in SPM + FA (14.35) > SPM (10.75) > FA (6.68) > pond soil (6.15) as compared to control at higher suction (0.33 to 15 bar) after harvest of first rice crop. Similarly at higher suction (0.33 to 15 bars) per cent increase in available water storage capacity were in same trend in first wheat, first rice and second wheat crop. Osman *et al.* (1997) reported that application of amendment like fine textured soil separates and organic manure increased water hold capacity as compare to un-amended soil. Similar observation were found Bhatt and Joshi (2000) also observed that FA mixing soil significant increase available water storage capacity compared to without mixing of FA soil. This statement also supported by (Saltar and Williams, 1987 and Ramani and Srivastava, 1989).

Thus, the irrigation was unable to affect the infiltration rate andhydraulic conductivity at significant level irrespective of crops and years, whereas application of amendments like SPM + FA, SPM, FA were found to decrease the infiltration rate and hydraulic conductivity at significant level.

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