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Effect of long term rice establishment methods on physical properties in Vertisol

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Abstract
The present investigation was carried out during 2016-17 at Hingnadih and Malpuri village, Dhamdha block, Durg district, Raipur. The soil of the experimental field was clay and clay loam in texture (Vertisol) localy knows as "kanhar". The experiment was laid out in Randomized block design with thirteen replications and three treatments. In this study, the effect of long term rice establishment methods on rice under rice based cropping system on physical properties were evaluated in after harvest of rice crop. In this study, three rice establishment methods (puddling, biasi and direct seeding rice) were laid in main treatment. The soil were evaluated after harvesting of rice crop under various depths viz. 0-15, 15-30, 30-45 and 45-60 cm.After harvest of rice the soil physical properties *viz*., bulk density, hydraulic conductivity, penetration resistance, water holding capacity and cracks volume were significantly affected by different rice establishment method. Puddling significantly increase the bulk density of surface soil (0-15 cm) and sub-surface layer (15-30 and 30-45 cm) but non-significant effect was found at 45-60 cm depth. The highest hydraulic conductivity was found in surface layer in direct seeding rice, when the depth increases hydraulic conductivity was decreases vice versa. Penetration resistance was found significant higher in puddled condition than biasi and direct seeding. Penetration resistance was also increased with the depth. Water holding capacity increase with the puddling and minimum was found in direct seeding. Puddling was because the crack volume, the higher crack volume was found in puddling condition.

Keywords: rice, puddling, biasi, seed drill, bulk density, hydraulic conductivity

Introduction
Rice based cropping system is most vital for food security of the Indian sub-continent. Rice is most prominent crop in India and is the staple food of the people of the eastern and southern parts of the country and provides food security and livelihood for millions of people across the globe. Oryza sativa var. indica on the Indian side and Oryza sativa var. japonica on the Chinese and Japanese side. Rice is being grown in many regions of the world, mostly by conventional flooded rice cultivation system which provides 75% of the world rice supply. Rice grown by this system consumes about 80% of total agricultural water available in Asia and 75% of total available water resources in the world (Iqbal, 2014) [1]. Rice occupies an area 153 m ha land throughout the world. In India, out of the 43 m ha area under rice cultivation (Anonymous, 2013) [2].
Soil is an essential component of crop production, but soil management operations are capable of increasing crop yield economically. Different methods of tillage can affect the physico-chemical properties of soil and hence can make differences in plant establishment, root growth, aerial cover and eventually crop yield. The soil quality is a term used to describe the health of agricultural soils. It has been suggested as an indicator for evaluating sustainability of soil and crop management practices. The deteriorating soil physical conditions have been credited to tillage for rice–wheat system (Bajpai and Tripathi, 2000; Tripathi *et al*., 2003) [3, 4].
Tillage is a practice which changes the soil properties, environment and crop production in general. It techniques are used in order to provide a good seed bed, root development, weed control and manage crop residues, levelling the surface for uniform irrigation and incorporation of manures and fertilizers. Tillage improves soil conditions by altering the mechanical impedance to root penetration, aggregate size distribution, hydraulic conductivity and water holding capacity, which in turn, affects plant growth. No till system improves organic carbon sequestration but increase bulk density compared to the conventional and reduced tillage (Arshad *et al*., 1999) [5].

As world population is increasing so the demand for food is increasing and as such the need to open more lands for crop production arises. This research delves into investigating the effects of different soil management practices on soil chemical, biological and physical properties for long term sustainable aspect. The objective of the experiments described to determine the effect of Rice establishment method on the growth and yield of rice and post-rice crop on vertisol

Materials and Methods

Farmer were selected from village- Hingnadih and malpuri, Durg District under categories marginal, medium and resourceful farmer, on the basis of survey out of 45 farmers total 39 farmers selected for research purpose and samples were collected from selected farmers field. The tillage operations studied likewise: (a) Puddling (b) Direct seeding – drilling (c) Biasi (broadcasting) with three replication in randomized block design. Durg district was considered as strata and total two villages were selected using Simple Random Sampling without Replacement (SRSWOR). From selected village 39 farmers *viz.* large (>3ha), medium (1-3 ha) and small (<1ha)} were selected for sampling and other basic information about the farmers were collected. From each selected field standard procedure of sampling was followed and sampled fields were located as latitude longitude position using GPS. The soil samples were collected from 0-15 cm soil depth within each farmer field for physico-chemical and biological properties of soil. Data obtained from all observation were statistically analyzed by applying Randomized block design (RBD).

Soil physical properties

Bulk density

Bulk density (BD) is a measure of the ratio of the mass of soil to its total volume of soil. It can give an indication of porosity or compaction. The change in BD of surface (0-15 cm) and sub-surface (15-30, 30-45 and 45-60 cm) soil in relation to rice establishment methods is presented in table 1. Noticeable differences in BD were recorded for the various rice crop establishment methods. In the surface soil layer, significantly higher BD was found under puddled condition than direct seeding and biasi rice. Puddled condition attained significantly higher BD values (1.53 Mg m^{-3}). The lowest BD (1.45 Mg m^{-3}) was obtained under direct seeding plots. Almost similar trend was observed in the second layer (15-30 cm) amongst methods of rice cultivation. BD was recorded highest 1.65 Mg m^{-3} in puddled treatment and followed by biasi 1.59 Mg m^{-3} and direct seeded rice 1.58 Mg m^{-3}. Puddled soil attained significantly higher BD values (1.65 Mg m^{-3}). The lowest BD (1.58 Mg m^{-3}) was

Table 1: Effect of long term rice establishment methods on the bulk density of soil

Rice establishment methods	Bulk density (Mg m^{-3}) Soil Depth (cm)			
	0-15	15-30	30-45	45-60
Direct seeding	1.45	1.58	1.64	1.70
Biasi	1.49	1.59	1.64	1.71
Puddling	1.53	1.65	1.68	1.72
CD at 5%	0.020	0.020	0.022	NS

Obtained under direct seeded plots. Further, down the profile (30-45 cm) layer the BD was again higher in the layer above and the highest BD (1.68 mg m^{-3}) was recorded under puddled soil which was significantly higher BD than that of direct seeding and biasi rice. Puddled soil attained significantly higher BD values (1.68 Mg m^{-3}). The lowest bulk density (1.64 Mg m^{-3}) was obtained under direct seeding plots. A similar trend was also observed in next layer (45-60 cm) but the difference in bulk density among various treatments was non-significant. Generally Puddled soil attained slightly higher bulk density values (1.72 Mg m^{-3}). Higher bulk density in the puddled condition upon drying of the soil. The lower bulk density values in unpuddled condition were therefore due to better aggregation of soil particle. The higher bulk density in the second layer can be explained by eluviation of fine soil particle from the top layer into the layer below due to puddling, Similar results were also reported by Mondal *et al.* 2016 and Aggarwal *et al.*1995 [7, 16]. In puddled condition the increment of time, the settling of suspended fine particles and shrinking of soil on drying makes the soil compact and hard. This compaction leads to the increase in bulk density (Bajpai and Tripathi, 2000) [8]. This increase in bulk density below the puddled layer may be due to the soil physical compaction caused by the heavy machinery during the puddling process (Flower and Lal, 1998) [9]. The suspended fine soil particle under puddled soil settled down slowly and gradually after puddling and formed an uniform stratification of the soil mass which would have

Increase the bulk density under transplanting while under drilling the soil was not disturbed hence the bulk density was least changed. The mechanical impedance of suspended soil particle consolidated with time and increase in the bulk density of soil was also reported by Sharma and De dutta (1991) [10].

Particle density

Data presented in table 2 revealed that particle density (PD) of the soil was non significantly influenced by different long term rice establishment methods at different depths. A comparison of rice establishment methods showed that PD of surface (0-15) soil in biasi method of rice cultivation was lower than puddled rice. Similar trend was observed in the second layer (15-30 cm) where PD was slightly higher in puddled treatment. Further down the profile (30-45 cm) layer, PD of the soil was non significantly influenced by different long term rice establishment methods. Puddled treatment attained slightly higher particle density values. A similar trend was also observed in next layer (45-60) but the difference in particle density among various treatments were non-significant. Puddled soil attained slightly higher PD values. The puddled transplanted rice registered a highest value of PD at different depth of soil. The unpuddled transplanting expressed less effect on change of PD becomes the inherent properties of soil.

Table 2: Effect of long term rice establishment methods on the particle density of soil

Rice establishment methods	Particle density (Mg m^{-3}) Soil Depth (cm)			
	0-15	15-30	30-45	45-60
Direct seeding	2.52	2.55	2.57	2.60
Biasi	2.54	2.56	2.58	2.60
Puddling	2.55	2.57	2.59	2.61
CD at 5%	NS	NS	NS	NS

Porosity

Porosity is the ratio of the volume of pores to the volume of soil due to its influence on soil water storage, air permeability, gaseous diffusion, drainage, root penetration and habitat for soil organisms. The change in porosity at surface (0-15 cm) and sub-surface (15-30cm, 30-45 cm and 45-60 cm) soil in relation to long term rice establishment methods is presented in Table 3. The pore space of soil at different depth was significantly influenced by rice establishment method. The porosity percent in 0-15 cm soil depth was highest in direct seeding which was significantly higher than puddling and biasi. Biasi treatment attained significantly higher porosity values (42.15%) whereas, the lowest porosity (40%) was obtained under puddling. Similar trend was at the second layer (15-30 cm) soil depth, Direct seeding registered significantly highest porosity than puddling and biasi methods of rice cultivation. Biasi treatment attained significantly higher porosity values (38.20%) and the lowest porosity (35.86%) was obtained under puddling. At 30-45 cm soil depth similar kind of pattern was observed in porosity. The highest porosity was recorded in direct seeding which was superior to puddling and biasi method. Direct seeding treatment attained significantly higher porosity values (36.29%) and the lowest porosity (35.06%) was obtained under puddling condition. At 45-60 cm soil depth, the porosity does not affected under different rice establishment method. No puddling with tillage and puddling with tillage could be the reason for the differences for the porosity percent. The percentage of pore space was slightly decreased with increase in depth (Bhavya *et al.* 2018) [18]. Consolidation of soil particles and decrease in macro pore space resulted in higher bulk density and decreasing the porosity of soil. This is the conformity with the finding of Ramachandran, *et al.* 2015. Shaver (2010) [12] reported that porosity is directly related to bulk density, bulk density is an important soil property because it affects soil porosity, because as bulk density decreases, porosity increases.

Table 3: Effect of long term rice establishment methods on the porosity of soil

Rice establishment methods	Porosity (%)			
	Soil Depth (cm)			
	0-15	**15-30**	**30-45**	**45-60**
Direct seeding	42.15	38.20	36.29	33.82
Biasi	41.26	37.94	36.11	34.14
Puddling	40.00	35.86	35.06	33.82
CD at 5%	1.12	1.04	0.91	NS

Penetration resistance

The change in penetration resistance of surface (0-15 cm) and sub-surface (15-30 cm, 30-45 and 45-60 cm) soil in relation to rice establishment methods is presented in table 4. In the surface layer (0-15 cm), soil penetration resistance was found significantly higher in puddling condition followed by biasi and the minimum was found in direct seeding. Puddled treatment attained significantly higher penetration resistance values (1.16 MPa). Whereas, the lowest penetration resistance (0.86 MPa) was obtained under direct seeded plots. In the second layer (15-30 cm), the penetration resistance was always higher than in the layer above. Again the highest resistance was recorded in puddled treatment. Soil penetration resistance was found significantly higher in puddling condition followed by biasi and the minimum was found in direct seeding. Penetration resistance (MPa) was observed 1.42, 1.66 and 2.33 MPa in direct seeding, biasi and puddled transplanted rice field, respectively.

At 30-45 cm soil depth similar trend was observed for penetration resistance. The highest penetration resistance was recorded in puddling which was superior to biasi and direct seeding method. Puddled treatment attained significantly higher penetration resistance values (3.51 MPa) and vice-versa the lowest penetration resistance (2.54 MPa) was obtained under direct seeding method.

A similar trend was also observed in next layer (45-60) but the difference in penetration resistance among various treatments were non-significant. The slightly higher penetration resistance was recorded in puddled condition. Soil penetration resistance showed an increasing trend with the increase in depth upto 60 cm and remain higher in puddled transplanted rice than in biasi and direct seeding systems. The higher penetration resistance in puddled condition may be breakdown of soil aggregates, which makes the soil compact and hard. A comparatively hard layer was clearly observable from penetration value in puddled soil at different depth. Creation of compaction and hardpan due to continuation and long term effect of puddling, Similar results were also reported by Mondal *et al.* 2016 [6].

Table 4: Effect of long term rice establishment methods on the penetration resistance of soil

Rice establishment methods	Penetration Resistance (MPa)			
	Soil depth (cm)			
	0-15	**15-30**	**30-45**	**45-60**
Direct seeding	0.86	1.42	2.54	3.63
Biasi	0.98	1.66	2.63	3.72
Puddling	1.16	2.33	3.51	3.74
CD at 5%	0.059	0.095	0.155	NS

Hydraulic conductivity

Data presented in table 5. Revealed that hydraulic conductivity (HC) of the soil was significantly influenced by different long term rice establishment methods at different depths. It is clear from the data that hydraulic conductivity of surface layer (0-10 cm) was significantly enhanced under direct seeding condition (1.52 cm hr^{-1}) as compared to puddled transplanted rice (1.10 cm hr^{-1}) and biasi (1.24 cm hr^{-1}). Similarly trend was also recorded in layer (10-20 cm) soil depth, The hydraulic conductivity of direct seeding plots was significantly higher than puddling and biasi methods. Highest hydraulic conductivity value was obtained under direct seeding (1.29 cm h^{-1}) and lowest under puddled transplanted rice plot (0.88 cm h^{-1}). HC at 20-30 cm layer was 1.08, 1.07 and 1.05 cm h^{-1} under direct seeding, biasi and puddling methods respectively. HC at 20-30 cm of soil significantly enhanced under direct seeding condition (1.08 cm hr^{-1}) as compared to puddled transplanted rice (1.05 cm hr-1) and biasi (1.07 cm hr^{-1}). Generally hydraulic conductivity was more in the surface layer and decreased with soil depth with minimum at 10-20 cm. HC was significantly decreased in puddling in all the layer upto 30 cm. The decrease in hydraulic conductivity by puddling was probably due to destruction and reduction of non-capillary pores, Similar results were also reported by Bajpai and Tripathi, 2000) [3]. Hobbs *et al*., (2002) [14] evaluated that puddling considerably reduced hydraulic conductivity throughout the rice season. The presence of higher volume of macro pores and transmission pores in non-puddled and partially disturbed soil under drilling and broad cast biasi, respectively registered higher HC than transplanting under puddled soil. Lowest HC under puddled soil might be due to settling of fine suspended colloidal particle of soil which formed the uniform stratification throughout the soil profile, where macropores were reduced and created impervious layer. In contrast, Tiwari (1997) found increase in hydraulic conductivity in puddled plots as compared to non-puddled plots during initial growth stage. Puddling increased bulk density of the soil and decreased hydraulic conductivity. The puddler and level of puddling had significant effect on hydraulic conductivity which decreased at a decreasing rate at higher bulk density of soil (Behera,*et al.*2009) [15].

Cracks volume

Data presented in table 5 indicate that crack volume was significantly influenced by different long term rice establishment methods. The development of cracks on soil surface at harvest of crop were greatly influenced by different rice establishment method. Puddled treatment developed significantly higher crack volume (4904 cm^3 m^{-2}). The lowest crack volume (2341 cm^3 m^{-2}) was obtained under direct seeding. Thus, clearly indicating that cracking increases with the degree or intensity of puddling. Deeper and wider cracks were recorded throughout the whole range of soil moisture potential in puddled condition. The soil physical condition was not altered under direct dry seeded plot. Hence, the crack formation was least under direct seeding method of rice establishment. A similar result was reported by Purohit (2003) [16]. Increase in the area and volume of cracks with a decrease in the soil water content. Puddling resulted in breaking down of larger aggregates into smaller aggregrates which in turn helped the crack development process (Mondal *et al.* 2016, Bandyopadhyay *et al.*2003) [6, 17]. Rice grown under puddled condition significantly enhanced different crack parameters viz., length, depth, width, surface area and volume of the cracks over non puddled direct seeded rice. Puddled soil shrank became hard and developed broad and deep cracks upon drying. Puddled soil under transplanting shrank, became harder and developed cracks as moisture stress developed. Therefore, higher volume of cracks was observed under puddled transplanting than broadcasting biasi and minimum in direct seeding condition. Thesoil physical condition not altered this condition was not altered under non puddled soil of drilled rice (Purohit, 2003) [16].

Water holding capacity

Water holding capacity (WHC) of soil is the available water holding capacity which represents the total amount of water that could be available for plant uptake. Data presented in table 5 revealed that water holding capacity of the soil was significantly influenced by different long term rice establishment methods. It is clear from the data that water holding capacity of surface layer (0-15 cm) of soil enhanced under puddled condition (39.02%) as compared to biasi (36.32%) and direct seeding (34.46%). Puddling increases the water holding capacity of soils because of compaction settling and flocculation of dispersed clay particles (Sharma, 1985) [18]. The puddled soil maintained 25% more water than the unpuddled one. Puddling markedly increases soil water retention in soils dominated by 2:1 swelling clays and the effect was less in soils dominated by kaolinitic clays (Mohanty *et al.* 2003) [19].

Table 5: Effect of long term rice establishment methods on the hydraulic conductivity and water holding capacity of soil

Rice establishment methods	Hydraulic conductivity (cm h^{-1})			Water holding capacity (%)	Volume of crack (cm^3 m^2)
	Soil depth (cm)				
	0-10	10-20	20-30	0-15 cm	
Direct seeding	1.52	1.29	1.08	34.46	2341.31
Biasi	1.24	1.05	1.07	36.32	2716.69
Puddling	1.10	0.88	1.05	39.02	4904.85
CD at 5%	0.137	0.062	0.036	1.78	394.42

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