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Long term effects of rice establishment methods on physical properties and rice productivity in *vertisols* of Chhattisgarh plain

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Abstract
The farmer field study was carried out during 2016 at village Saida, Takhatpur Tehsil in Bilaspur district of Chhattisgarh to evaluate the "Long term effects of rice establishment methods on physical properties and rice productivity in *Vertisols* of Chhattisgarh plain". The trial was laid out in Randomized block design with twelve replications and three treatments in rice based cropping system in *Vertisols*. The study on the long-term effect of rice establishment methods on soil physical, chemical, biological properties and crop productivity were evaluated after harvest of rice crop. In this study, three rice establishment methods i.e. transplanting, broadcast-biasi and direct seeded line sowing were laid in main treatment. A study was undertaken to characterize the soil resources of the investigation field. The residual effect of rice establishment methods on soil physical properties like bulk density, hydraulic conductivity, penetration resistance, water holding capacity and crack volume were significantly affected by the treatments. Transplanting method significantly increased the bulk density of surface soil (0-15 cm) and sub-surface layer i.e. (15-30 and 30-45 cm) but non-significant affect was obtained at lower (45-60 cm) depth. The hydraulic conductivity was found maximum in surface layer under direct seeded method and increases as per depth was decreased. Penetration resistance was recorded significantly increase with increase in depth. Water holding capacity was significantly increased with direct seeded (LS) method and minimum was recorded in transplanting method. Crack volume was significantly higher in transplanting method over other methods of rice cultivation.

Keywords: Long term effect of rice establishment, transplanted rice, direct seeded rice, brushing method of rice, tillage, rice

Introduction
Rice is one of the chief grains of India and every day millions of Indians find ease in it. With high carbohydrate content, it is known to provide instantaneous energy, and is a staple that is consumed by the preponderance of India's population. Our country has biggest area under rice cultivation, as it is single of the foremost food crops and provides food security and source of revenue for the peoples of country and occupies an area out of the 44.1 m ha area an annual production of 105.48 million tones and productivity of 2.39 tonnes/ ha of rice (Annual Report 2016-17). It's also the world most important cereal crop is grown over an area of 153 m ha a global level and constitutes the staple diet for over 40% of the world population including around 85% of the Asian population. Presently in Chhattisgarh, about 75 per cent area is under broadcasting, 15-17 percent under transplanting and 8-10 per cent area is covered by direct drilling method of rice seeding.

Transplanting has been the most important and common method of crop establishment under favourable rainfed and irrigated lowland in Tropical Asia. In India, 44 per cent of rice area (19.6 million ha) is under transplanting in irrigated lowland. The effect of puddled condition is destroyed soil structure as well as aggregates lose their character and soil is changed into a structurally homogenous mass of fine aggregates and textured separates. This practice provides several benefits to rice, such as weed control, ease of transplanting, decrease in deep percolation losses of water and nutrients and improved to nutrient availability. Although puddling is known to be beneficial for growing rice it can adversely affect the growth and yield of subsequent crop. The deteriorating soil physical conditions have been credited to

tillage for rice-wheat system (Bajpai and Tripathi, 2000; Tripathi *et al*., 2003) [7] and high-water requirement for crop establishment. The amount of irrigation water required for puddling varies from 100 to 544 mm (Yadav *et al*., 2011; Bhuiyan *et al*., 1995) [21, 8].

In general, under broadcast Biasi method, rice seeds are broadcast in a ploughed field immediately after the onset of monsoon. After about 30 to 45 days when sufficient water is impounded in the field, the fields are ploughed in the standing crop. This is called Biasi or bushening. The uprooted seedlings are transplanted (in situ transplanting) after Biasi, which is called Chalai in local language. In this method of rice cultivation which is generally practiced for the control of weeds in direct seeded shallow lowland rice in various forms in the different parts of Indian farmers, particularly in Chhattisgarh, Orrisa, Madhya Pradesh and Bihar, and to a smaller area in West Bengal, Assam and Utter Pradesh for optimization of stand. The intercultural practices in water stagnant paddy crop are followed in many countries and named with different terms. Like 'Gogarancah' in Indonesia, 'Kakularf' in Shri Lanka and 'Sabog, Tanim' in Phillipines. In our country and Bangladesh, it's an age old practice and known as Aus, Beausani or Biasi (Fujisaka., *et al*, 1993) [9].

Direct seeding of rice eliminates the need of nursery raising and subsequent labour-intensive transplanting thus reducing cost of cultivation and is now fast replacing traditionally transplanted rice (Balasubramanian and Hill, 2000). Direct seeding offers certain advantages like saving irrigation water, labour, energy, time, reduces emission of greenhouse-gases, better growth of succeeding crops, etc. In India direct seeded rice has grown in the area of 7.2 M ha. In Chhattisgarh, rice occupies average of 3.77 million ha with the productivity of the state ranging between 1.2 to 1.6 t/ha depending upon the rainfall and the production is 8.58 MT. The present study was focus on evaluating the long-term effects of rice establishment methods on physical properties and rice productivity in vertisols of Chhattisgarh plain.

Materials and Methods

A farmer's field experiment was conducted at village-Saida, Takhatpur, Bilaspur District during 2016-2017 on a Vertisols under categories marginal, medium and resourceful farmer, on the basis of survey out of 50 farmers total 36 farmers were selected for experimental purpose and samples were collected from selected farmer's field. The three treatment of rice establishment method studied viz.

(a) Transplanting
(b) Broadcast-Biasi
(c) Direct seeding (Line sowing) with twelve replications in randomized block design.

Bilaspur district was considered as strata and single village was selected by using Simple Random Sampling without Replacement (SRSWOR). From selected village 36 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 farmer field standard procedure of sampling was followed and sampled fields were positioned as latitude longitude by using GPS. The soil samples were collected from 0-15, 15-30, 30-45 and 45-60 cm soil depth within each farmer field for physical properties of soil. The grain and straw of the crop were kept in distinct paper bags according to the treatments. Data obtained from all observation were statistically analysed by applying Randomized block design (RBD).

Results and Discussion

Bulk Density

The changes in bulk density of surface (0-15cm) and sub-surface (15-30, 30-45 and 45-60 cm) soil in relation to rice establishment methods revealed that significantly higher BD was found under transplanting method than broadcast biasi and direct seeding rice in surface soil (Table 01). Transplanting method attained significantly higher BD values (1.47 Mg m^{-3}) and the lowest BD (1.41 Mg m^{-3}) was obtained under direct seeding plots. Almost similar trend was observed in the second layer (15-30 and 30-45 cm). BD was recorded highest 1.54 Mg m^{-3} in transplanting and followed by biasi1.52 Mg m^{-3} and lowest in direct seeded rice 1.50 Mg m^{-3} [3]. Transplanting method attained significantly higher BD values (1.54 Mg m^{-3}). The lowest BD (1.50 Mg m^{-3}) was obtained under direct seeded plots. Further, BD was again higher in sub soil (30-45 cm) and the highest BD (1.62 mg m^{-3}) was recorded under transplanting method which was significantly higher than that of broadcast-biasi and direct seeded rice. Transplanting method attained significantly higher BD values (1.62 Mg m^{-3}). However, the lowest BD (1.57 Mg m^{-3}) was obtained under direct seeding plots.

Table 1: Long term effects of rice establishment methods on bulk density.

Treatments	Bulk Density (Mg m^{-3})			
	Depth (cm)			
	0-15	15-30	30-45	45-60
Transplanting	1.47	1.54	1.62	1.69
Broadcasting-Biasi	1.44	1.52	1.59	1.68
Direct seeded (LS)	1.41	1.50	1.57	1.66
CD (P = 0.05)	0.036	0.031	0.035	NS

A similar trend was also observed in sub soil (45-60 cm) but the difference in BD among various treatments was found non-significant. Generally, puddled soil attained slightly higher BD values (1.69 Mg m^{-3}). Higher BD in the transplanting method was recorded upon drying of the soil. The lower BD in unpuddled condition due to better aggregation. The higher BD 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 [13] and Aggarwal *et al.*1995 [1]. In puddled condition the increase 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 BD (Bajpai and Tripathi, 2000) [7]. This increase in BD below the puddled layer may be due to the soil physical compaction caused by the puddling treatment during the rice cultivation (Mcdonald, 2006) [12].

Particle Density

Data presented in table 02 indicated that particle density (PD) of the soil was none significantly affected due to different long term rice establishment methods at different depths. A comparison of rice establishment methods reveals that PD of surface (0-15cm) soil in direct seeded method of rice cultivation was lower than transplanting method. Similar trend was observed in the second layer (15-30 cm) where PD was slightly higher in transplanting method. Further down the profile (30-45 cm) PD was none significantly influenced by different long term rice establishment methods. Transplanting method attained slightly higher PD.

Table 2: Long term effects of rice establishment methods on the particle density

Treatments	Particle Density (Mg m^{-3})			
	Depth (cm)			
	0-15	15-30	30-45	45-60
Transplanting	2.55	2.57	2.58	2.61
Broadcasting-Biasi	2.54	2.56	2.57	2.60
Direct seeded (LS)	2.54	2.54	2.56	2.59
CD (P = 0.05)	NS	NS	NS	NS

A similar trend was also observed in depth (45-60 cm) but the difference in PD among various treatments was non-significant. Under the transplanting method soil attained slightly higher PD. The direct seeded rice expressed less effect on change of PD due to inherent properties of soil.

Porosity

Data presented in table 03 indicated that changes in porosity at surface (0-15 cm) and sub-surface (15-30 cm, 30-45 cm and 45-60 cm) soil in relation to long term rice establishment methods. The pore space of soil at different depth was significantly influenced by rice establishment method. The porosity in 0-15 cm soil depth was highest in direct seeded rice which was significantly higher than transplanting method. Direct seeded treatment attained higher porosity (44.83%) whereas, the lowest porosity (42.49%) was obtained under transplanting method. Similar trend was recorded at the second (15-30 cm) layer, Direct seeding registered significantly highest porosity than broadcast-biasi and transplanting method of rice cultivation. Direct seeded treatment attained significantly higher porosity (39.12%) and the lowest porosity (37.58%) was obtained under transplanting method. 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 broadcast-biasi and transplanting method. Direct seeding treatment attained significantly higher porosity (37.54%) and the lowest porosity (35.90%) was obtained under transplanting method. At 45-60 cm soil depth, the porosity does not affect under different rice establishment method. Evidently, not only micropores, but, also the macropores were conducting a greater percentage of water in the minimum tillage than in the conventional tillage (Azooz *et.al.*, 1996) [4]. Porosity is directly related to BD and it is an important soil property because it affects soil porosity, and as BD decreases vice-versa porosity increases simultaneously (Salahin, *et. al.*, 2013) [15].

Table 3: Long term effects of rice establishment methods on porosity of soil.

Treatments	Porosity (%)			
	Depth (cm)			
	0-15	**15-30**	**30-45**	**45-60**
Transplanting	42.48	37.58	35.90	35.31
Broadcasting-Biasi	43.49	38.36	37.06	34.42
Direct seeded (LS)	44.83	39.12	37.54	36.18
CD (P = 0.05)	1.53	1.19	1.31	NS

Penetration Resistance

Table 04 revealed that the change in penetration resistance (PR) of surface (0-15 cm) and sub-surface (15-30 cm, 30-45 and 45-60 cm) soil in relation to rice establishment methods. In the surface layer (0-15 cm), PR was found significantly higher in transplanting method followed by broadcast-biasi and the minimum was found in direct seeded rice cultivation. Transplanting method attained significantly higher PR (1.14 MPa). Whereas, the lowest PR (0.94 MPa) was obtained under direct seeded plots. In the second layer (15-30 cm), PR was always higher than in the layer above.

Table 4: Long term effects of rice establishment methods on soil strength.

Treatments	Penetration resistance (MPa)			
	Depth (cm)			
	0-15	**15-30**	**30-45**	**45-60**
Transplanting	1.14	2.27	3.43	3.71
Broadcasting-Biasi	0.99	1.51	2.57	3.67
Direct seeded (LS)	0.94	1.44	2.48	3.62
CD (P = 0.05)	0.031	0.069	0.13	NS

Similarly, highest PR was recorded in transplanting method followed by broadcast-biasi and the minimum was found in direct seeding. PR was observed 2.27, 1.51 and 1.44 MPa in transplanting method, broadcast-biasi and direct seeded methods rice field, respectively. Similar trend was observed at 30-45 cm soil depth for penetration resistance. The maximum PR was always higher than in the layer above. Highest PR was recorded in transplanting method which was superior to broadcast-biasi and direct seeded method. Transplanting method attained significantly higher PR (3.43 MPa) and the lowest (2.48 MPa) was obtained under direct seeded method. The similar trend was also observed in the depth of (45-60 cm) but the difference in PR in all treatments were non-significant. The slightly higher PR was recorded in transplanting method. PR showed an increasing trend with the increase in depth upto 60 cm and remain higher in transplanted rice than in broadcast-biasi and direct seeded systems. The higher PR in transplanting method may be breakdown of soil aggregates, which makes the soil compact and hard. A comparatively hard layer was clearly observable from penetration value in under 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 [13] and Avtar Singh *et al.*, 2012 [3].

Hydraulic Conductivity

Hydraulic conductivity (HC) data presented in table 05 indicated that the HC was significantly influenced by different long term rice establishment methods at different depths. It is clear from the data that HC of surface layer (0-10 cm) was significantly enhanced under direct seeding condition (1.61 cm hr^{-1}) as compared to transplanting method (1.14 cm hr^{-1}) and broadcast-biasi (1.26 cm hr^{-1}). Similarly, trend was also recorded in layer (10-20 cm) soil depth. The HC of direct seeding plots was significantly higher than and broadcast-biasi methods. Highest HC was obtained under direct seeding (1.24 cm h^{-1}) and lowest under puddled transplanted rice plot (0.76 cm h^{-1}). HC at 20-30 cm layer was 0.95, 1.01 and 1.06 cm h^{-1} under transplanting method broadcast-biasi and direct seeded methods respectively. HC at 20-30 cm of soil significantly enhanced under direct seeding condition (1.06 cm hr^{-1}) as compared to transplanting method (0.95 cm hr-1) and broadcast-biasi (1.01 cm hr^{-1}).

Table 5: Long term effects of rice establishment methods on soil hydraulic parameters.

Treatments	Hydraulic Conductivity (cm h^{-1})			Volume of cracks (cm^3 m^2)	Water holding capacity (%) (0-15 cm)
	Depth (cm)				
	0-10	10-20	20-30		
Transplanting	1.14	0.76	0.95	4657	36
Broadcasting-Biasi	1.26	1.05	1.01	2942	37
Direct seeded (LS)	1.61	1.24	1.06	2551	40
CD (P = 0.05)	0.065	0.055	0.055	289.12	1.3

Generally, soil PR was found significantly higher in transplanting method followed by broadcast-biasi and the minimum was found in direct seeded rice cultivation., Similar results were also reported by Bajpai and Tripathi, 2000 [7], Tebrugge *et al*., (1999) [19] evaluated that puddling considerably reduced HC 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. Increase in HC in puddled plots as compared to non-puddled plots during initial growth stage. Puddling increased BD of the soil and decreased HC. HC in the direct seeded rice treatment was significantly higher than in the transplanted rice treatment. (Mcdonald *et al*. 2006) [12].

Cracks Volume

Data presented in table 05 indicate that crack volume (CV) was significantly influenced by different long term rice establishment methods. Transplanting method developed significantly higher CV (4657cm^3m^{-2}). The lowest CV (2551 cm^3 m^{-2}) was obtained under direct seeded. The data clearly indicating that crack increases with the degree or intensity of puddling. Deeper and wider cracks were recorded throughout the whole range of soil moisture potential in transplanting method. The soil physical condition was not altered under direct seeded plot. Hence, the crack formation was least under direct seeding method of rice establishment. A similar result was reported by Purohit (2003) [14]. 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 aggregates which in turn helped the crack development process (Mondal *et al.* 2016) [13]. A similar result was reported by Bandyopadhyay *et al.* 200 3 [6] 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.

Water Holding Capacity

The data on Water holding capacity (WHC) of soil presented in table 05 revealed that WHC of the soil was significantly influenced by different long term rice establishment methods. It is clear from the data that WHC of surface layer (0-15 cm) of soil reduced under transplanting method (36%) as compared to broadcast-biasi (37%) and direct seeding (40%). Direct seeded increases the WHC of soils because of higher loss of water through bypass flow should be taken into account while promotion substitution for conventional tillage in Vertisols of central India (Lenka Sangeeta, 2014) [11]

Table 6: Long term effects of rice establishment methods on yields.

Treatments	Yield (Kg ha^{-1})	
	Grain	Straw
Transplanting	4408	4975
Broadcasting-Biasi	3825	4370
Direct seeded (LS)	3417	3904
CD (P = 0.05)	251	231

Rice Yield

It is evident from the data (Table 06) that transplanting method rice produced significantly higher grain yield. The higher grain yield of rice was found in transplanted rice (4404 kg ha^{-1}) followed by broadcast-biasi (3825 kg ha^{-1}) and direct seeded rice (3417 kg ha^{-1}). The higher straw yield was recorded in transplanting method (4975kg $ha^{-1)}$ while the lower straw yield was recorded in direct seeded method (3904 kg ha^{-1}). The method of establishment plays an important role in growth, development and yield of rice. The proper and uniform density of plant stand under transplanting is the key to increase the grain yield of rice than direct seeding and broadcast biasi method of rice seeding. Puddling has great significance in rice establishment method because it facilitates in increasing the availability of nutrient, ensure better plant establishment and control weed (Shukla *et al*. 2016; Gathala *et al* 2011; Samra and Dhillon, 2000) [18, 10, 2].

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