Agropedology 2023, 33 (01), 68-76
doi.org/10.47114/j.agroped.2023.jun 7

Effect of tillage and land levelling practices on productivity of transplanted rice: A case study in canal command area of north western plateau agro-climatic zone

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Abstract: An on-farm study on the response of transplanted rice to land preparation methods was undertaken on a sandy clay loam soil in Pitamahal irrigation command of Sundargarh district (Odisha) for two consecutive dry seasons of 2019-20 and 2020-21. The treatments included normal ploughing with desi plough followed by levelling of 0.5 – 1 % slope (T1), deep ploughing (20 - 25 cm) with bullock drawn M.B. plough followed by levelling of 0 - 0.25 % slope (T2), and farmers' practice of ploughing with desi plough and levelling varying 1-3 % slope (T3) for puddling operation. Deep ploughing (T2) resulted in higher root length (23.88 cm) and root volume (81.75 cm^3), owing to the initial rapid growth of roots promoted by deep ploughing that cracked the hardpan. This also increased the movement of water both laterally and vertically (7.44 mm per day) compared to T1 and T3's 5.11 and 5.71 m per day, respectively. The treatment also resulted in a significantly greater grain yield (45.90 q ha^{-1}) due to a much larger effective tiller m-2 (423.40) and number of grains per panicle (71.80), as well as a higher net return per rupee spent (7.54) and benefit-cost ratio (2.01).

Keywords: *Tillage, land leveling, water movement, root growth, economics.*

Introduction

Tillage is a prime activity carried out prior to sowing of a crop with an objective to bring the soil to a favourable tilth to provide a congenial environment for crop growth and yield. Ploughing once and leaving out for a few weeks, followed by hand broadcasting of rice seeds, and then ploughing and raking together at the same time resulted in a highly substantial rice grain output (Srisa-Ard 2008). Introducing the "Sawah" system (bunded, puddled, and levelled) in Ghana's inland valleys resulting in substantial advancements in soil and water management, resulting in increased rice grain yield.

Transplanting of rice is mostly practiced in medium and low lands during wet season even the Sawah technique of agriculture, enhanced local rice yield by more than 300% due to mechanisms with inherent erosion resistance (better water control and fertiliser management) (Buri *et al.*2012). During dry season in irrigation commands under puddled condition as it provides greater support for growth and development of rice crop (Ashraf *et al.*2014).

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Puddling performs an important activity in transplanted rice that not only provides a favourable soil condition for ease of transplanting and control of weeds (Cherati *et al*. 2012) but also decreases the loss of water and nutrients through seepage and deep percolation. The reduced conditions so developed also enhance the nutrient availability (Anjum *et al*. 2019; Kalita *et al*. 2020). According to (Nwite *et al*. 2016), all of the sawah (an Indo-Malaysian word for padi refers to a levelled rice field surrounded by bunds with inlets and outlets for irrigation and drainage water management system) adopted tillage environments (Bunding-with or without puddling-levelling/ little levelling) positively improved both the soil parameters (pH, OC, Total Nitrogen and all the exchangeable bases within the study periods) and rice grain yield.

Despite these beneficial effects, necessity of puddling in rice is questioned. (Elias 1969) reported that puddling is a time-consuming and costly agricultural practice that also damages soil aggregates and changes other soil physical qualities thus reduces root growth. However, puddling has not been found favourable for rice growth and yield on Vertisols and poorly drained soils (Kumar *et al.* 2019) in Indo-Gan in Indo - Gangetic Plains (IGP) of India, reported that maximum yields, net returns and mean infiltration rate (0.10 cm hr^{-1}) and least bulk density in 15-20 cm soil depth were observed in rice-wheat system under the practice of zero-till direct-seeded rice with residue followed by zero-till wheat with residue. This findings also demonstrated that conventionally tilled (CT) rice and transplanting of rice could be successfully replaced by the profitable double ZT -RW system zero-tillage combined with residue retention reduced soil bulk density and pH, raised P and K availability to plants, and enhanced rice-wheat system efficacy in Nepal's Central Terai region (Sah 2014).

The puddling has been reported to increase the yield of rice by many authors (Obalum *et al*. 2014; Kalita *et al*. 2020; Asenso *et al*. 2022), others have opined that puddling may not be necessary as it has little effect on rice yields (Kirchhof *et al*. 2000; Evangelista *et al*. 2014; Ebrahimi *et al*. 2022). (Fujihara *et al*. 2013) reported that the practice even could not increase the duration of standing water over the field and found that pond water disappeared more quickly in puddled field than non-puddled field.

Land leveling facilitates uniform distribution of water, and has been reported to save about 50 per cent of irrigation water (Bhatt *et al.* 2021). Precision land leveling also favoured optimum flooding depth that helped in increasing nutrient availability and reduced weed menace (Khatri-Chhetri *et al.* 2016). This also helped in improving rice-wheat system profitability and water saving by 2 % over traditional land levelling (Jat *et al*. 2009) in Indo – Gangetic Plane.

Owing to the complexity of soil condition, and limited availability of water, the efficient use of irrigation water attains greater importance. Different types of agricultural instruments used in farming for early land preparation, which contribute up to 20% of crop yield among crop production elements (Amare and Endalew 2016). During the process, sub soil compaction in the form of plough pan by tillage system, especially through mechanical practices, normally occurs. In Indo-Gangetic Plains of India, maximum infiltration rate (0.10 cm hr^{-1}) and least bulk density in 15-20 cm soil depth were observed in rice-wheat system under the practice of zero-till direct-seeded rice with residue followed by zero-till wheat with residue (Kumar *et al*., 2019).Zero-tillage paired with residue retention reduced soil bulk density and pH, increased P and K availability to plants, and increased rice-wheat system productivity (Sah *et al*. 2014). Further, migration of fine soil particles along with percolating water can result in formation of clay pan in low land rice cultivation. Such altered soil environment, thus, retards functioning of rice roots which affects the overall growth and yield of crop. Such situation, developed over the years of rice cultivation, needs deep ploughing to break the clay pan to facilitate the downward entry of water.

Keeping this in view, a study was undertaken in the Pitamahal Irrigation Project of district Sundargarh, Odisha, on the impact of land preparation methods on the growth and yield of transplanted rice during the dry season.

Materials and methods

Study was carried out in farmer's fields during two consecutive dry seasons of 2019-20 and 2020-21 in Pitamahal irrigation command, North Western Plateau Agro-climatic Zone of Odisha. The experimental site is located in Lathikata block of Sundargarh district, Odisha ($22^0 05^'$ to $22^0 20^'$ N; $84^0 42^'$ to $84^0 55^'$ E). The soil of the study area was sandy clay loam having sand, silt and clay content of 56.5, 11.5 and 32.0 per cent, respectively. The treatments consisted of ploughing by bullock drawn *desi* plough with leveling of 0.50 – 1.00 % slope (T_1), deep ploughing (20 -25 cm) by bullock drawn M.B. plough followed by leveling 0 - 0.25 % slope (T_2) and farmer's practice of ploughing with *desi* plough with leveling 1.00 – 3.00 % slope (T_3) in a randomized block design with seven replications. In all the treatments, 21 days old rice (cv. Khandagiri) seedlings were transplanted at a recommended spacing of 15 cm x 15 cm. A uniform dose of 80 kg N, 40 kg P_2O_5, and 40 kg K_2O was applied to each treatment in the form of urea, single superphosphate and muriate of potash, respectively. Urea was applied in three splits *i.e.*, 25 per cent at the time of transplanting, 50 per cent at tillering and the rest 25 per cent at panicle initiation stage while all the phosphorous and potash were applied as basal. All other agro-managements were common to all the treatments.

Bulk density of soil at 0 - 15 cm and 15 - 30 cm were determined four times *i.e.*, at 1 day after puddling (initial), 15 and 30 days after puddling and at harvest of the crop by core method. Depth of puddling was measured after 24 hrs by gentle pushing a wooden scale in the mud until it hit the hard ground in all the treatments. Initially 2 cm ponding water was maintained in the field up to the time of first top dressing. Thereafter, recommended practice of application of 7 cm water one day after the disappearance of ponded water was followed. Irrigation was withheld 10 days before the harvest of crop (Anonymous 2001).

Seepage and percolation rate was estimated by monitoring the depth of water regularly at 08.00 am daily. The depth of water during irrigation and ponding period was observed by installing graduated stick at four corners of each treatment plots. The evapotranspiration (ET) for the specified period was subtracted from the total depth of water lost from the field under the specific treatment to obtain the seepage and percolation loss. The ET value of paddy crop for the period from transplanting to 10 days before harvest was obtained by multiplying the reference crop evapotranspiration with crop coefficient (Doorenbos *et al.* 1977). In the absence of the pan evaporation data in the nearby area, the data of Regional Research Technology Transfer Sub – Staion, Kirei, Sundargarh were considered for computation of reference crop evapotranspiration and the total ET value is presented in table 1.

Table 1. ET of rice crop during growth period (15.01.2020 – 19.04.2020)

Month/Number of days	Evaporation (mm)	Crop coefficient	ET (mm)
January (17 days)	57.90	1.10	63.70
February (28 days)	139.30	1.10	153.2
March (31 days)	154.30	1.25	192.90
April (19 days)	140.14	1.00	140.14
Total ((% days)	491.64		549.94

Root samples were collected from each treatment in both the years following trench method for observations on root growth. The average length and diameter of the roots were measured with the help of measuring scale and screw gauge, respectively. The volume of roots hill^{-1} was determined by water displacement method. Plant height, number of tillers per m^2 and grains per panicle were recorded at harvest. The total yield from each treatment was recorded after threshing, winnowing and drying of rice grains at 12 per cent moisture.

The additional cost involved due to imposition of treatments was recorded at the time of puddling. The data were statistically analysed following standard procedures (Panse and Sukhatame, 1985).

Results and discussion

Bulk density

Initially the bulk density at the surface layer of 0 - 15 cm as well as the sub- surface layer (15 - 30 cm) soil depth was the lowest in T_2 followed by T_1 and T_3 (Table 2) indicating various degrees of soil compaction in farmer's field. Decrease in bulk density due to puddling has also been reported by many researchers (Rezaei *et al*. 2012; Obalum *et al*. 2014; Asenso *et al*. 2022). At subsequent observations, the bulk density increased and reached to 1.71, 1.80 and 1.61 in 0 - 15 cm layer and 1.78, 1.82 and 1.66 in 15 - 30 cm soil layer in case of T_1, T_2 and T_3, an increase of 33.59, 63.63, 21.96 % and 39.06, 65.45, 25.75 % under surface and sub-surface layers, respectively. The bulk density in sub- surface was higher in all the observations than the surface layer. It might have occurred because of breakdown of the soil aggregates due to puddling and subsequent generation of open structure. In the treatments T_1 and T_3, ploughing by *desi* plough perhaps shattered the bottom layer to little.

Table 2. Effect of methods of land preparation on bulk density of soil (mgm^{-3})

Treatment / Soil depth	1 DAP		15 DAP		30 DAP		At harvest	
	0 -15 cm	15 – 30 cm	0 -15 cm	15 – 30 cm	0 -15 cm	15 – 30 cm	0 -15 cm	15 – 30 cm
T_1	1.28	1.32	1.35	1.38	1.62	1.65	1.71	1.78
T_2	1.10	1.15	1.40	1.48	1.65	1.68	1.80	1.82
T_3	1.32	1.38	1.46	1.52	1.57	1.61	1.61	1.66
C.D. (P=0.05)	0.03	0.01	0.036	0.03	0.027	0.11	0.015	0.02

DAP = Days after puddling

Depths during preparatory tillage operation resulting thereby a higher bulk density as compared to surface layer though the puddling depth was in 10 - 15 cm. The higher bulk density in surface layer under T_3 is found to be higher as compared to T_1.It may be attributed to improper leveling and uneven depth of water level over the field which might have encouraged lateral movement of water than the vertical one that make the soil more compact in surface layer as the finer particles accumulated in the pore spaces. In T_2, the puddling depth varied from 20 - 25 cm, the sub-soil layer was well shattered and pulverized. By the time of harvest, soil got compacted with finer particles settling down and finally adjusted in the pore spaces, and thus a relatively higher value of bulk density was observed.

Seepage and percolation

Puddling by M.B. / *desi* plough showed a significant effect on seepage and percolation of water in the experimental fields. The evapotranspiration (ET) for the specified period (Table 1) was subtracted from the total depth of water lost from the field under the specific treatment to obtain the seepage and percolation loss. The losses were higher in T_2 as compared to T_1 and T_3. This is possibly due to deep ploughing with M.B. plough which led to loosening of the soil (Table 3). On the other hand, in the case of T_1 and T_3, the soil was opened up to a small depth and the sub-soil layer was not much disturbed during ploughing. The average values of water loss due to seepage and percolation were estimated 5.11, 7.44 and 5.71mm per day in T_1, T_2 and T_3 respectively (Table 3). Ploughing to a greater depth in T_2, perhaps facilitated internal drainage laterally and vertically (seepage and percolation) as indicated by the presence of relatively less reddish tinge on soil surface, which is considered as a favourable sign of decline in iron concentration.

Table 3. Seepage and percolation as affected by different methods of land preparation in transplanted rice field.

Treatment	Water applied (cm)	ET crop (cm)	Seepage and percolation between transplanting to 10 days before harvest (cm)	Mean seepage and percolation (mm per day)
T_1	106.40	54.99	51.41	5.71
T_2	122.00	54.99	67.01	7.44
T_3	101.00	54.99	46.01	5.11
C.D. (P=0.05)			2.20	

Plant growth and yield

Plant height, number of effective tillers per m2, number of grains per panicle, and 1000 grain weight were recorded and are presented in table 4. Results indicated that the plant height (72.20 cm), number of effective tillers per m2 (423.40) and grains per panicle (71.80) were significantly superior in T_2 compared to other two treatments. The number of effective tillers per m^2 and grains per panicle were deciding factor for yield of rice.

Table 4. Effect of methods of land preparation on growth of rice

Treatment	Plant height (cm)	Number of effective tillers per m2	Number of grains per panicle	1000 grain weight (g)
T_1	68.14	390.30	65.90	14.80
T_2	72.20	423.40	71.80	15.10
T_3	63.57	387.7	63.90	14.40
C.D. (P=0.05)	4.98	37.18	11.70	0.30

The root growth parameters under different practices of puddling showed a significant variation (Table 5). Root length (23.88 cm) and volume (81.75 cm^3) were higher in T_2 compared to T_1 and T_3 as ploughing by M.B. plough helped to break down the sub-soil layer that provided lesser resistance for the growth of the roots because of reduced compaction. Further, uniform distribution of water over the soil helped in uniform root growth throughout the profile.

Table 5. Root growth as affected by different methods of land preparation

Treatment	Root length (cm)	Root diameter (mm)	Root volume (cm^3)
T_1	23.49	0.35	69.30
T_2	23.88	0.36	81.75
T_3	22.35	0.33	56.15
C.D.(P=0.05)	0.06	0.04	9.67

More root length (23.49 cm) and volume (69.30 cm^3) were observed in T1 than T3 might be due to uniform distribution of water as the land was properly leveled after ploughing with *desi* plough. Land leveling influenced the root length and it was more in T_1 (by 5.10 %) and T_2 (by 6.85 %) as compared to T_3 (22.35 cm). This might be due to favourable soil condition particularly at initial stage of the crop growth.

The grain yield of rice (Table 6) ranged from 35.60 in T_3 to 46.20 q ha^{-1} in T_2 across the seasons. Ploughing with *desi* plough and leveling (T_1) significantly increased the rice yield by 8.68 % and deep ploughing with M.B. plough followed by leveling (T_2) was superior by 28.21 % over farmers' practice (T_3). Straw yield in $T_1$and T_2 also followed similar trend with 7.21 and 29.58% yield enhancement over farmers' practice (T_3). The practice of land leveling after ploughing for transplanted rice helped in proper distribution of standing water in the field of T_1 and T_2. Proper land leveling might have helped to increase nutrient availability and weed suppression as observed by (Khatri-Chhetri *et al.* 2016). Deep ploughing by breaking the existing hard pan in the sub- surface layer facilitated drainage by seepage and percolation which was reflected in the crop growth and ultimately in the grain and straw yield (Table 4, 5 and 6). There was a decline in iron toxicity decrease in reddish tinge on the surface in treatment T_2 might have casted favourable influence on crop growth and yield.

Table 6. Effect of methods of land preparation on yield of rice

Treatment	Yield (q ha^{-1})					
	Grain			Straw		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean
T_1	38.40	39.20	38.80 (8.68)*	43.40	44.30	43.85(7.21)*
T_2	45.60	46.20	45.90 (28.21)*	52.50	53.50	53.00 (29.58)*
T_3	35.60	35.80	35.70	41.30	40.50	40.90
C.D. (P=0.05)	1.04	1.24		1.95	1.56	

* Values in the parenthesis indicate per cent increase over farmers practice (T_3)

Economics

Deep ploughing and levelling (T_2) showed highest net profit of Rs.45950.00 ha^{-1} in comparison with T_1 and T_3 (Table 7). Leveling alone (T_1) could increase the net profit to a tune of Rs. 5353.00 ha^{-1} over farmers' practice (T_3). In case of treatments T_1 and T_2, the mean additional cost involved ha^{-1} were Rs.712.00 and Rs.2378.00 respectively (Table 8). The additional return rupee^{-1} investments were calculated and observed to be at per *i.e.*, Rs.7.53 and Rs.7.54 in respect of T_1 and T_2, respectively. However, the mean benefit: cost ratio of 2.01 was observed in T_2 followed by 1.76 in $T_1$and 1.65 in T_3(Table 7). In the opinion of farmers, the practice of T_2 although involved extra cost, can be accepted as it can compensate the extra expenditure due to higher yield.

Table 7. Economics as affected by different land preparation methods on transplanted rice cultivation

Treatment	Mean cost of production (Rs. ha^{-1})	Mean cost of produce (Rs. ha^{-1})			Mean net profit (Rs. ha^{-1})	Benefit: cost ratio
		Grain	Straw	Total		
T_1	43642.00	70422.00	6578.00	77000.00	33358.00	1.76
T_2	45308.00	83308.00	7950.00	91258.00	45950.00	2.01
T_3	42930.00	64800.00	6135.00	70935.00	28005.00	1.65

N.B.: Cost of rice grain and straw – Rs.1815.00 and Rs.150.00 q^{-1} respectively

Table 8. Additional profit as influenced by different land preparation methods in rice cultivation

Treatment	Additional cost of treatment imposition over T_3 (Rs.)	Additional profit gained on treatment imposition over T_3 (Rs.)	Additional return per rupee investment (Rs.)
T_1	712.00	5360.00	7.53
T_2	2378.00	17945.00	7.54

Conclusion

The study indicated that in red laterite soils with restricted internal drainage and a possibility of iron toxicity, deep ploughing (20 - 25 cm) with a bullock-drawn M.B. plough followed by correct field levelling proved beneficial in terms of yield and cost-effectiveness. Thus, deep ploughing (20 - 25 cm) using an M.B. plough followed by levelling is recommended in red and laterite soils of Odisha's North Western Plateau Agroclimatic Zone.

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Received: August,2023 *Accepted: October,2023*