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Comparative Performance of Puddlers in Low Lands of Hilly Areas

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ABSTRACT

A comparative study of the quality of puddled soil and energy requirement was carried out with animal drawn traditional country plough (T_1), rectangular blade puddler (T_2), disc harrow (T_3) and power tiller operated rotavator (T_4). Weeding efficiency, puddling depth, percentage increase in bulk density, puddling index, percolation rate and energy requirement were studied for the above treatments. Puddling performance by different implements in comparison to the traditional animal drawn country plough (T_1) shows that there is a definite reduction in time requirement for field preparation. Increase in weeding efficiency, bulk density and puddling index were also observed. The highest values of weeding efficiency and puddling index were found 69.3% and 51.5, respectively, for power tiller rotavator (T_4). The total time requirement for preparation of puddled field for treatment T_4 was found to be the lowest (27.4 h/ha). Energy requirement for preparation of puddled field was found highest (2844.91MJ/ha) for power tiller operated rotavator (T_4) followed by T_1, T_3 and T_2 treatments.

1. Introduction

Rice is the most important cereal food crop of India occupying about 24 % of gross cropped area of the country. It contributes 42 % of total food grain production and 45 % of total cereal production of the country. It is also the main food grain of the North-Eastern region occupying 3.51 million hectares which accounts for more than 80% of the total cultivated area of the region and 7.8 per cent of the total rice cultivated area of the country. The common method of land preparation for wetland rice in North-East is puddling. Puddling primarily helps in water saving by decreasing percolation losses and generally refers to breaking down of soil aggregates into smaller soil particles. The quality of puddling effects the crop growth and depends mainly on type of tillage implement and intensity of puddling. The two common methods for planting of rice in the region are broadcasting and manual transplanting. In some parts of the North-East region, two crops of rice are taken annually.

During puddling operation the soil gets manipulated, soil structure is preparation for puddling starts in May-June, when soil moisture content is suitable for ploughing. The puddling operation is thoroughly disturbed and air voids are drastically reduced. Land performed with standing water in the field. Puddling is performed to reduce deep percolation of water, destroy weeds and to facilitate transplanting of rice seedling by making the soil softer. Puddling leads to compaction of soils and increases bulk density and soil penetration resistance in sub soil, which in turn reduces water losses (Rautaray et al. 1997). Farmers generally maintain standing water in the field for better growth which triggers higher percolation losses. Soil manipulation through puddling decreases infiltration, increases water holding capacity, facilitates easy transplanting and controls weed especially in heavy textured soil (Verma et al. 2006)

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Behera et al. (2009) concluded that peg type puddler with two passes produced highest depth of puddling (109.3 mm) and puddling index (30.13%) compared to rotary puddler with one pass (100.9 mm and 24.60 %) and peg type puddler with one pass (89.1 mm and 19.40 %). The bulk density of soil increased and hydraulic conductivity decreased 30 and 60 days after puddling but puddler and level of puddling had significant ($p<0.5$) effect on hydraulic conductivity only. The buried and floating hill percentage was high at 24 h sedimentation and gradually decreased with Increase in sedimentation period. Grain yield was influenced by sedimentation period rather than puddler and level of puddling. Verma and Dewangan (2006) found that puddling by different implements in comparison to the traditional animal drawn country plough had a definite reduction in time requirement for field preparation. Increase in weeding efficiency, bulk density, grain yield and puddling index were also observed. The highest values of weeding efficiency and puddling index were found 98.6 and 79.3%, respectively, for rotavator. The total time requirement for preparation of puddled field with tractor operated cultivator was found to be the lowest (9.4 h/ha) with 67% weeding efficiency and 62.7 puddling index as compared to other alternatives tested. Energy requirement for preparation of puddled field was found highest (2390 MJ/ha) for tractor operated rotavator. Mousavi et al. (2009) found that under laboratory conditions, water content of the puddled layers decreased with an increase in settling time. During drying period, no puddling condition dried faster than low, medium and high intensity puddled soil. Puddling with low intensity in laboratory and field conditions caused bulk density of 0–150 mm soil layer to decrease by 24.07 and 25.45%, respectively. Bulk density increased with time as particles settled after halting the puddling. Bulk density increased with depth as well. Under laboratory conditions, increasing puddling intensity from low to medium reduced percolation rate significantly. For all puddling intensities, soil moisture characteristic curves of both field and laboratory samples showed that puddling increased the amount of water retained over the whole range of suctions. More water was needed for high puddled field as compared to low and medium. Under the laboratory and field conditions, the high puddled field required 27.72 and 28.58% more water as compared to medium, respectively. Bulk density, soil moisture content and water percolation rate decreased faster in the puddled soil under field and laboratory conditions. Verma (1996) tested the effectiveness of puddling with different implements in relation to water use and grain yield of rice in clay loam soil.

It was observed that 100, 250 and 300 mm less water was used, respectively, after puddling by bullock-operated cultivator, angular puddler and disc harrow, compared with the local comb harrow.The tractor operated puddler reduced water was 350 mm. The major part of the region has subtropical climate.The annual rainfall received in the region comes largely from south-west monsoon and received during middle of May to end of October. The average annual minimum and maximum rainfall in the region is estimated to be 1637 mm and 6317 mm respectively. Due to the intense rainfalls, the time available for seedbed preparation is short. Puddling can be started soon after water gets accumulated in the paddy field. It involves a lot of drudgery to human and animals. Puddling is also energy intensive due to heavy churning of soil and water together. Therefore, the study was undertaken to compare the different methods of puddling with regards to effectiveness of puddling, impact on soil properties and energy used in puddling.

2. Materials and methods

The study was conducted at the research farm of ICAR Research Complex for NEH Region, Umiam, Meghalaya, during the years 2006–2010. The soils of this region are rich in organic matter and fertile. These are mostly under thick forest and where *jhum* cultivation is practiced the soils loose the organic matter and suffer from erosion hazards. Due to considerable amount of loss of bases from the soil under the influence of high rainfall the soils become acidic. The soils in the valley are mainly composed of sand, silt, clay and gravel developed due to the washing down on alluvial materials from the surrounding hills. Soil of the experimental site was sandy in texture (sand 48.2%, silt 32.8% and clay 19.0%) with a bulk density ranging from 1.2 to 1.4 mg/m^3 at 18% moisture content (db). The basic infiltration rate was found to be 0.91 and 1.4 cm/h in June and October, respectively. The experiment consisted of four puddling treatments with three replications in randomised block design having plot size of 8 m × 5 m as summarized in Table 1. Implements used for puddling were animal drawn local plough (T_1), rectangular blade puddler (T_2), disc harrow (T_3) and power tiller operated rotavator (T_4). The data collected over 4 years were statistically analysed to test the significance at 5% level for each parameters. Initially the experimental plots were ploughed once at friable moisture condition (13.5–18.3% db) with power tiller rotavator and the ploughed field was flooded to saturation (24 h). Water to a depth of 45–50 mm was maintained in the field prior to puddling operation. Figure. 1 (a-d) shows the different treatments and the sets of implements used for puddling the field.

Any standing water present in the field after 24 h of puddling operation was drained out allowing the disturbed soil to settle. Different soil physical properties such as puddling index, bulk density, permeability were measured to see the effect of puddling on soil profile.

Measurements of puddled soil conditions

The puddling performance of different implements was compared on the basis of depth of puddling, percolation rate, bulk density, puddling index and weeding efficiency. For recording the depth of puddling a flat tipped gauge was used. The percolation rate was measured with a straight edged cylinder of 100 mm diameter and 200 mm length. The cylinder was immersed in to the soil to a depth of 100 mm and a constant head of water was maintained in the cylinder. The fall in the water level was recorded daily to find out the percolation rate. The core sampler method was used for measuring the bulk density of the soil. Soil samples were collected by core sampler after segregating the area and then removing water. A mild steel tube of 63 mm inside diameter and 50 mm long having 30^0 bevelled edges at the one end was used to take out the soil samples. The tube was vertically pushed into the soil slurry at a slow rate and a uniform pressure was applied by hammering it to avoid compaction of the soil due to its contact with the surface of the sampler tube. The sample was then withdrawn from the tube. The bulk density of puddled soil at depth 50–100 mm was determined. Standard oven drying method was used to find out the moisture content of the soil. Just after final puddling operation, puddled soil sample of 200 ml was collected in a graduated glass cylinder to determine the puddling index. The volume of soil sample was noted after allowing it to settle for 48 h. Puddling index was then calculated by using the following formula (Baboo, 1976).

Puddling index (%), PI = $\frac{V_s}{V} \times 100$ ……(1)

Where, V_s = Volume of soil after settlement, ml

V = Total volume of sample before settlement, ml

Weeding efficiency was measured by quadrant of 1 m^2 size selected randomly in each plot and counting the number of weeds present before and after puddling operations. Weeding efficiency was calculated by:

Weeding efficiency (%) = $\frac{N_1 - N_2}{N_1} \times 100$ ... (2) where, N_1 = Number of weeds before the puddling operation N_2 = Number of weeds after the puddling operation The theoretical field capacity of an implement is the rate of field coverage that would be obtained if the machine were performing its function 100% of its rated width (Kepner et al., 1987).

Theoretical field capacity (ha/h) = $\frac{W \times S}{10}$ ... (3)

where, w = Actual width of the implement, m

S = Speed of operation, km/h

The theoretical field capacity, effective field capacity, field efficiency of puddling implements were calculated by recording the time consumed for actual work and the time lost for other miscellaneous activities such as turning at head land, adjustments under field operating conditions, etc. The effective field capacity, field efficiency of puddling implements was determined by the following formula (BIS 9818-Part II, 1981):

Effective field capacity (ha/h) = $\frac{\text{Actual area covered}}{\text{Time required to cover the area}}$ ...(4)

% Field-efficiency = $\frac{\text{Eeffective field capacity}}{\text{Theoretical field capacity}} \times 100$ (5)

After final puddling, each experimental plot was levelled by planking with a thick rectangular wooden plank.

Computation of energy requirement for puddling

The energy equivalence as suggested by Binning et al. (1984) was used for the calculation of energy requirement in puddling operation. It is based on the number of hours required by the different sources of power and then converting the same to energy terms with the help of energy constants as given in Table 2.The fuel input to power tiller with 12 hp engine was calculated considering the puddling operation as heavy work (load coefficient 0.6) and specific fuel consumption 330 ml/kWh (Mittal et al. 1985). The machinery mass contributing towards the activity was estimated based on total mass of the machinery, total useful hours, and the hours used to complete the activity.

Table 1. Different puddling treatments

Sl. No.	Treatment	Power source	Puddling equipment used	Tillage operation
1.	T_1	Pair of bullock	Local plough	One summer ploughing, flooding the field, two ploughing with local plough (traditional puddling), planking
2.	T_2	Pair of bullock	Rectangular blade puddler	One summer ploughing, flooding the field, two puddling with rectangular blade puddler, planking
3.	T_3	Pair of bullock	Disc harrow	One summer ploughing, flooding the field, two puddling with disc harrow, planking
4.	T_4	Power tiller 12 hp	Rotavator	One summer ploughing, flooding the field, two puddling with rotavator, planking

Table 2. Energy equivalence used for computing energy for puddling

Particulars	Unit	Equivalent energy (MJ)	Remarks
Adult man	Man-h	1.96	Normal health
Adult woman	Wman-h	1.60	Normal health
Medium size bullock	Pair-h	10.10	Weight of bullock 350-450 kg
Agricultural machinery	kg	62.70	Distributing the manufacturing energy uniformly over the life, based on weight

Source: Binning et al. (1984)

3. Results and Discussion

Time requirement and quality of puddling

The results of four puddling treatments over 4 years are given in Table 3. The effective field capacity (EFC) of the local plough was 0.0225 ha/h which was less than the theoretical field capacity (TFC) because of unploughed space left between two passes. The tilling width of the bullock drawn rectangular blade puddler and disc harrow were 630 and 720 mm respectively. The EFC of the animal drawn disc harrow was more than rectangular blade puddler because of higher width of coverage. The average working speeds for bullocks and power tiller were found to be 1.8 and 2.7 km/h respectively. Power tiller rotavator had the highest EFC of 0.173 ha/h followed by the animal drawn disc harrow (0.134 ha/h). This was because the speed of operation of power tiller (2.7 km/h) was more than that of animals (1.8 km/h). The time required for T_1 was highest (108.2 h/ha) followed by treatments T_2, T_3, and T_4. The power tiller operated rotavator required lesser time (27.4 h/ha) than other puddlers. A planking operation to level the field was required for all the treatments. The comparison of difference in treatments and total time required for puddled field (Table 3) indicates that all the treatments have significant difference at 5% level of significance. Different treatments were compared on the basis of weeding efficiency, puddling depth, increase in bulk density, percolation rate and puddling index. Results showed that the weeding efficiency of the power tiller rotavator was higher than the other methods of puddling (Table 3). The reason may be the rotary motion of the implement, which due to shear stress physically destroy weeds more effectively. Weeding efficiency was the lowest for traditional plough. The analysis of variance of weeding efficiency indicates that treatments T_2, T_3, and T_4 are significantly different. The depth of puddling with power tiller rotavator (T_4) was highest (105.2 mm) followed by T_1, T_3, and T_2.

The increase in bulk density was highest for treatment T_4 (2.08%) followed by T_3, T_1 and T_2. Puddling index was highest (51.5) for power tiller rotavator (T_4) and lowest (31.6) for animal drawn local plough (T_1). The lowest percolation rate (0.39 mm/h) was observed in case of treatment T_4 and highest (0.42 mm/h) for treatment T_2. The difference between percolation rates of non-puddled and puddled soil ranges between 0.05 to 0.08 mm/h.

Energy requirement for preparation of puddle field

Table 4 shows the energy requirement for puddling fields in different treatments. The energy requirement for preparing the puddled field for transplanting of rice seedling in four puddling treatments varied from 443.50 to 2844.91 MJ/ha. It was highest for treatment T_4 followed by T_1, T_3 and T_2. The animal drawn rectangular blade puddler of 630 mm working width (T_2) required 32.5% less energy than traditional plough. The energy required for T_3 was higher than T_2; this may be due to the higher weight (68 kg) of the disc harrow (T_3) as compared to rectangular blade puddler T_2 (33 kg). Energy requirement was highest for treatment T_4 but it has yielded better puddling quality with highest puddling index (51.5) and weeding efficiency (69.6%). Also the time required for preparing puddled field was lowest (27.4 h/ha) for treatment T_4. Energy requirement for T_2 (443.50 MJ) was less than T_3 (461.97 MJ) but the puddling quality of T_2 was poor with less weeding efficiency (50.7%) as compared with T_3 giving 53.8% weeding efficiency. The study indicates that power tiller operated implement can be adopted for timeliness of operation and better quality of puddling in hills.

Figure 1. Puddling operation by a) Traditional country plough, b) animal drawn rectangular blade puddler, c) animal drawn disc harrow and d) power tiller operated rotavator

Table 3. Comparison of four puddling operations measured over 4 years

Performance indicators	Treatments			
	T_1	T_2	T_3	T_4
Time required (h/ha)	108.2	33.1	31.7	27.4
A) Saturated non-puddled soil				
Bulk density at 100 mm depth from surface (Mg/m^3)	0.97	0.98	0.97	0.96
Moisture content (%) db	34	35	35	33
Percolation rate (mm/h)	0.46	0.48	0.45	0.47
B) Puddled soil				
Puddling depth (mm)	79.4	58.6	61.3	105.2
Bulk density at 100 mm depth from surface (Mg/m^3)	0.98	0.99	0.99	0.98
Moisture content (%) db	36	37	36	35
Percolation rate (mm/h)	0.41	0.42	0.40	0.39
Weeding efficiency (%)	47.4	50.7	53.8	69.3
Puddling index	31.6	35.2	41.9	51.5

Table 4. Energy used for preparation of puddle field

Treatment	Energy used for puddling (MJ/ha)				
	Human	Animal	Machinery/ Implement	Fuel	Total
T1	211.68	1090.80	56.87	-	1359.35
T2	64.68	333.30	45.52	-	443.50
T3	60.76	313.10	88.11	-	461.97
T4	52.92	-	145.89	2646.10	2844.91

4. Conclusion

Based on the above study following conclusions were drawn:

1. The highest increase in bulk density with highest puddling index and lowest percolation rate was observed when puddling operation was performed by the power tiller drawn rotavator.
2. Percolation rate decreased as energy input to puddling increased.
3. Lowest percolation can be achieved with puddling by a rotavator.
4. The power tiller operated rotavator has given better quality of puddling in least time of operation.

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References

Behera BK, Varshney BP and AK Goel (2009). Effect of Puddling on Puddled Soil Characteristics and Performance of Self-propelled Transplanter in Rice Crop. Agricultural Engineering International: the CIGR Ejournal. Vol. X. Manuscript PM 08 020.

Verma AK and ML Dewangan (2006). Efficiency and energy use in puddling of lowland rice grown on Vertisols in Central India. Soil & Tillage Research 90: 100–107.

Mousavi SF, Yousefi-Moghadam S, Mostafazadeh-Fard B, Hemmat A and MR Yazdani (2009). Effect of puddling intensity on physical properties of a silty clay soil under laboratory and field conditions. Paddy Water Environ 7:45–54.

Rautaray SK, Watts CW and AR Dexter (1997). Puddling effects on soil physical properties. AMA 28 (3): 37–40.

Verma VP (1996). Water use in relation to soil manipulation for wet land paddy cultivation on clay-loam. J. Indian Water Resour. Soc. 2: 62–64.

Binning AS, Pathak BS and BS Panesar (1984). Energy audit of crop production system. Research Bulletin, School of Energy Studies for Agriculture, PAU, Ludhiana

Mittal, VK, Mittal, JP and KC Dhawan, (1985). Digest on Energy Requirement in Agricultural Sector. All India Co-ordinates Research Project on Energy Requirements in Argicultural Sector, Punjab Agricultural University, Ludhiana, India.

Kepner, RA, Bainer, R and EL Barger (1987). Principles of Farm Machinery, third ed. CSB Publishers and Distributor, Delhi, India.

Ngachan SV, Mohanty AK and A Pattanayak (2012). Status Paper on Rice in North East India. Rice Knowledge Management Portal, http://www.rkmp.co.in.

Baboo B (1976). Effect of lug angle of cage wheel on traction and puddling performance of dual wheels. M. Tech. diss., Dept. of Farm Machinery and Power Engineering, G. B. Pant Univ. of Agriculture and Technology. Pantnagar, India.

BIS 9818-(Part II) (1981). Glossary of terms relating to tillage and inter cultivation equipments. Bureau of Indian Standards, Mank Bhawan, New Delhi, India.