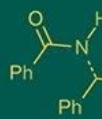


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Comparative performance studies on tractor drawn puddling equipments

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Abstract

The study “Comparative Performance Studies on Tractor Drawn Puddling Equipments” was conducted with three primary objectives: to evaluate the performance of selected puddling equipment, to assess the effect of puddling quality under field conditions, and to analyze the cost economics of different puddling implements. The study was carried out at IGKV Raipur. During summer season of 2024. The study compares the performance of three tractor-drawn puddling implements: rotavator, cultivator with cage wheel, and disc harrow. The disc harrow showed the highest speed of 3.1 km/h and an Effective Field Capacity (EFC) of 0.870 ha/h, compared to the rotavator 2.4 km/h speed and lowest EFC of 0.434 ha/h. Field efficiency was highest with the disc harrow $\times 1$ (T_6) at 80.61%, while the cultivator with cage-wheel $\times 2$ (T_2) had the lowest at 73.67%. The rotavator achieved the highest puddling index 53.84%. Fuel consumption was lowest with the disc harrow (T_6 and T_7) 4.70 l/ha and 6.73 l/ha, while the rotavator consumed the most (T_3 and T_4) 5.80 l/ha and 8.81 l/ha. Bulk density data indicated that (T_5) cultivator with cagewheel + rotavator had the lowest initial bulk density of 0.912 g/cm³, reflecting better soil loosening, while T_7 (disc harrow $\times 2$) had the highest at 0.996 g/cm³. The disc harrow demonstrated effective soil compaction reduction, with a lowest Cone Index value 127.29 kPa and better fuel efficiency. In terms of depth of puddling, the cultivator with cagewheel $\times 2$ (T_2) achieved the highest depth at 144 mm, while the disc harrow $\times 1$ (T_6) had the lowest depth at 132 mm. Cost analysis revealed the disc harrow's economic advantage, with one pass costing 891.57 Rs/ha, significantly lower than the rotavator's 2018.88 Rs/ha.

Keywords: Puddling, performance, disc harrow, capacity, efficiency

Introduction

Puddling is the mechanical manipulation of soil in the presence of water to mix fertilizer, manure and plant nutrients with soil uniformly throughout the field to reduce percolation loss of water and to facilitate the transplanting of seedlings by making the soil softer and more level. (Dash and Das, 2006) [2]. Puddling aids in weed control and reduces water loss through percolation. (Sharma and De Datta, 1985) [8].

Puddling is an important operation to minimize soil nutrient leaching and thereby increasing the availability of plant nutrients and achieving reduced soil condition. Good puddle field conditions are needed to create a favorable environment for normal growth of rice plants. However, long-term effects of puddling could lead to forms of large clods in fine textured soils, resulting in negative effect on the soil characteristics, preventing seed-soil contacts, and leading to decline in rice yield. (Asenso *et al.*, 2022) [1].

Rotavator (derived from rotary cultivator) is a tillage machine used to prepare land for seeding by breaking the soil with rotating blades (without overturning the soil). It is also used to eradicate weeds, mix manure or fertilizer into soil, break up and renovate pastures for crushing clods, and so on. Rotavator action involves the direct application of tractor engine power to soil preparation via a rotor and specially designed blades in order to create ideal growth conditions for seedlings and seeds. (Kankal *et al.*, 2016) [3].

Puddling with a cultivator involves using a cultivator implement to compact soil and create a dense, impermeable layer. Typically, this process is carried out in rice cultivation, particularly in paddy fields. The cultivator is used to repeatedly till and mix the soil while simultaneously saturating it with water. This action helps break up soil clods, improve water retention, and create an ideal seedbed for rice planting. Cultivators are versatile implements

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that can be used as both secondary and primary tillage tools in soft soil conditions and require relatively low power per meter of width in India. (Kepner *et al.*, 1987) ^[4].

A disc harrow is made up of one, two, or four groups of disc blades. Although disc blades are used in both disc harrows and disc plough, each blade in a disc plough has its own supporting bearing. As a result, disc plough blade angles can be adjusted independently, whereas disc harrow blade angles cannot. Disc harrows can be used for conventional tillage (Kheiralla *et al.*, 2004) ^[5], as well as conservation and reduced tillage (Kepner *et al.*, 1987) ^[4].

Materials and Method

The experiment was conducted in instructional farm of Swami Vivekananda College of Agricultural Engineering and Technology and Research Station, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), during summer season of 2024.

Design of experiment

An experiment was conducted to evaluate the performance of different agricultural implements, specifically a cultivator with a cage wheel, a rotavator, and a disc harrow. The study consisted of 7 treatments, with each treatment replicated 3 times to ensure the reliability of the results. The experiment was carried out on a plot of land measuring 84 × 34 meter². An experiment conducted under RBD design.

The details of experiment, dependent and independent variable are shown in table 2 and the layout plan is shown in table 1.

Table 1: Details of the experiment

Design	Randomized block design (RBD)
Number of Replication	3
Number of Treatments	7
Total Number of Plots	21
Experimental total plot area	84 × 34 m ²
Distance between replications	1m
Distance between plots	1m

Table 2: Dependent and independent variable of experimental study

(A) Independent variable			
S. No.	Treatment	Details of treatment	
1.	T ₁	Cultivator + Cagewheel × 1	
2.	T ₂	Cultivator + Cagewheel × 2	
3.	T ₃	Rotavator × 1	
4.	T ₄	Rotavator × 2	
5.	T ₅	Cultivator + Cage wheel + Rotavator	
6.	T ₆	Disc Harrow × 1	
7.	T ₇	Disc Harrow × 2	
(B) Dependent variable			
(a)	Machine parameters	(b)	Soil parameters
1.	Average travelling speed, km/h	1.	Bulk density, g/cm ³
2.	Theoretical field capacity, ha/h	2.	Moisture content, %
3.	Effective field capacity, ha/h	3.	Puddling Index, %
4.	Field efficiency, %	4.	Cone Index, kPa
5.	Fuel consumption, l/h	5.	Depth of puddling, mm

In the experiment, various parameters were calculated to assess both the machine performance and soil conditions. The machine parameters included the average travelling speed, theoretical field capacity, effective field capacity, field efficiency, and fuel consumption. Additionally, soil parameters were measured which included bulk density, moisture content, cone index, puddling index, and the depth of puddling. A cost analysis was also performed.

Machine parameters

Average travelling speed

The ratio of distance upon time is called speed of travel, used for calculating the Average travelling speed of implements this formula used.

$$\text{Speed of travel (km/h)} = \frac{\text{Distance (m)}}{\text{time (s)}} \times 3.6$$

Where,

S = Forward speed of machine, m/s

L = Distance travelled, m

t = Time taken, s

Theoretical Field Capacity

For calculating the theoretical field capacity, working width and travelling speed were taken in to consideration. It is always greater than the actual field capacity.

$$\text{TFC} = \frac{W \times S}{10}$$

Where,

T.F.C. = Theoretical Field Capacity (ha/h)

W = Working width (m)

S = speed of operation (km/h)

Effective Field Capacity

For calculating effective field capacity, the time consumed for actual work and lost for other activities such as turning and cleaning blade when clogged with weeds were taken in to consideration.

$$\text{EFC} = \frac{A}{T_t} + T$$

Where,

E.F.C. = Effective Field Capacity (ha/h)

A = Area (ha)

T_t = Productive time (h)

T = Non productive time, h (Time loss for turning and cleaning blades)

Field Efficiency

Field efficiency was calculated by taking ratio of effective field capacity to theoretical field capacity. It is always expressed in percentage.

$$\text{FE} = \frac{\text{EFC}}{\text{TFC}} \times 100$$

Where,

E.F.C. = Effective field capacity

T.F.C. = Theoretical field capacity

Fuel Consumption

The fuel consumption of the selected tractor must be measured by the top up method. Measuring fuel consumption of a tractor using the top-up method is a straightforward process that involves tracking the amount of fuel you add to the tank and recording the distance covered.

$$FC = \frac{CF}{A}$$

Where,

FC = Fuel Consumption, lit/ha
CF = Consumption of fuel, lit/h
A = Covered area, ha/h

Soil parameter

Bulk Density

Bulk density of soil is the ratio of mass of soil sample to the volume of core cutter. The bulk density of soil was calculated by following formula.

$$BD = \frac{M}{V} = \frac{M}{\pi r^2 h}$$

Where,

BD = Bulk density, g/cm³;
M = Mass of soil samples contained in the core sample, g;
V = Volume of core sample, cm³;
r = Radius of cylindrical core sample, cm; and
h = Height of cylindrical core sample, cm.

Moisture Content

For soil moisture analysis, the oven drying method was used. Soil samples are collected in an oven set to 105°C. After 24 hours, the weight of the dry soil sample was measured, and the moisture content on dry basis was calculated using following formula.

$$MC = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

MC = Moisture Content (%)
W₁ = Initial weight of soil sample, g
W₂ = Bone dry weight of soil sample, g

Cone Index

Cone index is used as the measure of soil strength in the traction equations. Cone index is the average force per unit base area required to force a cone-shaped probe into soil at a steady rate. Formula of cone index is calculated as:

$$CI = \frac{F}{A}$$

Where,

F = Force requires to penetrate into the soil (kgf); and
A = Area of cross sectional (m²)

Puddling Index

The ratio of the volume of settled soil to the total volume of soil was noted for computing the puddling index. Puddling index was determined by following formula.

$$\text{Puddling index} = \frac{V_s}{V} \times 100$$

Where,

V_s = Volume of settle soil, and
V = Total volume of sample

Depth of Puddling

The depth of puddling was recorded following the standard method suggested. A scale was inserted just after puddling to record the depth of puddling, the depth of standing water, and the depth of the puddle.

Cost analysis

The cost of puddling was calculated using the local prices of different operations and market price of various inputs. It was reported as Rs/ha. To calculate the cost of operation for puddling operation, two costs i.e., fixed cost and variable costs are calculated. Lubricants, fuel, repair and maintenance, and wages are all part of the operational cost.

Results and Discussions

An experiment was conducted to optimize the different parameters.

Machine parameter

Average travelling speed

The observed Average travelling speed during experiment was found that disc harrow treatments had the highest speed of 3.7 km/h, while cultivator-only treatments had consistent speed of 2.7 km/h. Rotavator treatments showed lower speed of 2.4 km/h, suggesting different operational efficiencies. Average travelling speed at different treatments is given in Table 3.

Theoretical field capacity

The highest theoretical field capacity (1.08 ha/h) was recorded in T₆ (disc harrow×1) and T₇ (disc harrow×2) followed by T₁ (cultivator with cagewheel ×1) 0.864, T₂ (cultivator with cagewheel ×2) 0.864, T₅ (cultivator with cagewheel + rotavator ×1) 0.711, T₃ (rotavator×1) 0.558 and T₄ (Rotavator × 2) 0.558 and they differ significantly with each other. Theoretical field capacity at different treatments is given in Table 3.

Effective field capacity

The highest effective field capacity (0.870 ha/h) was recorded in T₆ (Disc harrow×1) followed by T₇ (Disc harrow×1) 0.842, T₁ (cultivator with cagewheel ×1) 0.646, T₂ (cultivator with cagewheel ×2) 0.636, T₅ (cultivator with cagewheel + rotavator ×1) 0.546, T₃ (rotavator×1) 0.434 and T₄ (Rotavator × 2) 0.417 and they differ significantly with each other. Effective field capacity at different treatments is given in Table 3.

Field efficiency

The field efficiency was observed higher in treatment T₆ (Disc harrow × 1) 80.61%, followed by T₇ (Disc harrow × 2) 77.98%, T₃ (Rotavator×1) 77.98%, T₄ (Rotavator × 2) 76.79%, T₅ (Cultivator with cagewheel + Rotavator × 1) 74.66%, T₁ (Cultivator with cagewheel × 1) 75.59% and T₂ (Cultivator with cagewheel×2) 73.67% respectively. Field efficiency at different treatments is given in Table 3.

Fuel consumption

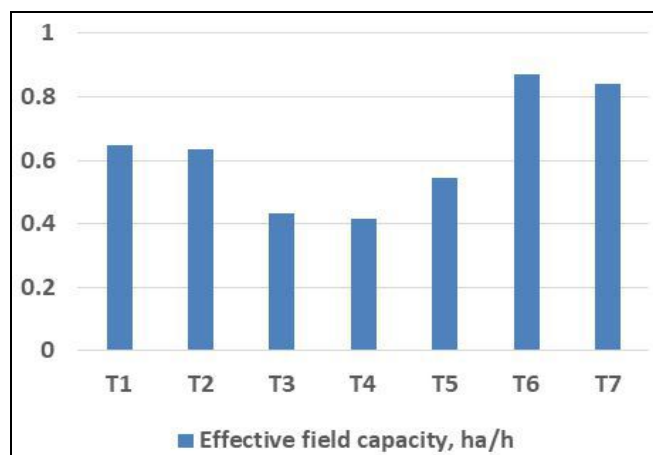
Among the treatments, treatment T₆ (Disc harrow×1) exhibited the lowest average fuel requirement of

4.70 litre per hectare, while treatment T₄ (Rotavator×2) recorded the highest at 5.810 litre per hectare. The fuel consumption was about 4.73, 5.59, 5.62, 5.73 and 5.80 litre per hectare in treatment T₇ (rotavator×2), T₁ (cultivator with

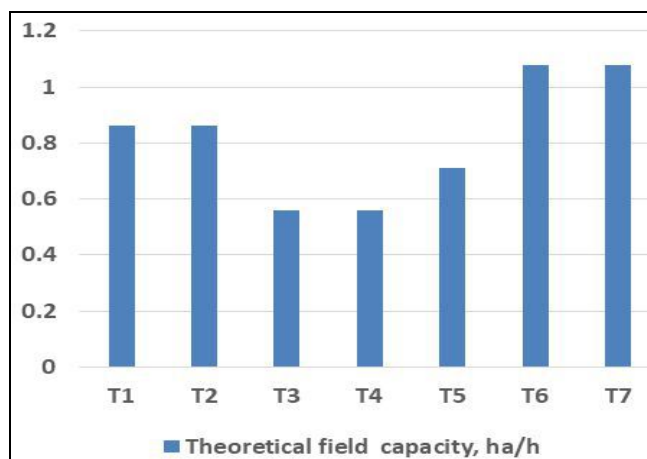
cagewheel ×1), T₂ (cultivator with cagewheel×2), T₅ (cultivator with cagewheel + rotavator ×1), T₃ (rotavator×1) respectively. Fuel consumption at different treatments is given in Table 3.

Table 3: Field performance of different implements.

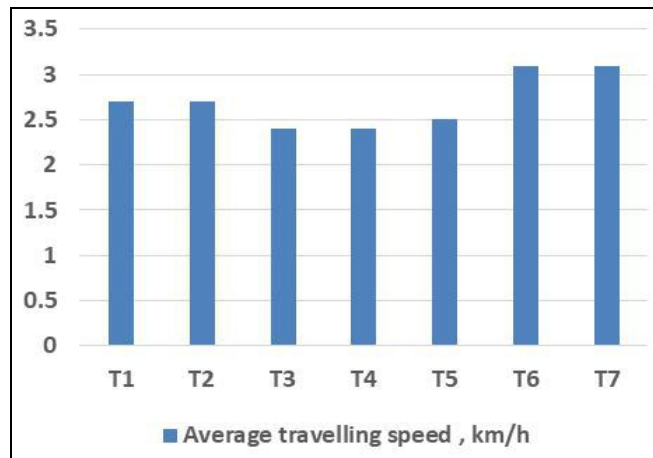
Treatment	Average travelling speed, km/h	Theoretical field capacity, ha/h	Effective field capacity, ha/h	Field efficiency, %	Fuel consumption, l/ha
T ₁	2.7	0.864	0.646	75.590	5.59
T ₂	2.7	0.864	0.636	73.677	8.62
T ₃	2.4	0.558	0.434	77.860	5.80
T ₄	2.4	0.558	0.417	74.667	8.81
T ₅	2.5	0.711	0.546	76.790	8.73
T ₆	3.1	1.08	0.870	80.610	4.70
T ₇	3.1	1.08	0.842	77.983	6.73



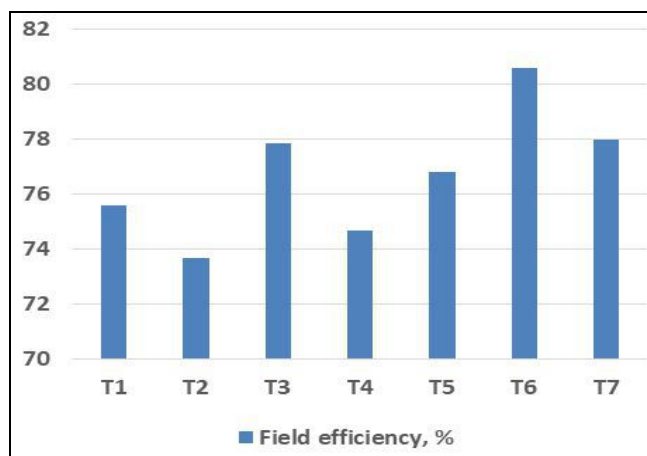
Effective field capacity



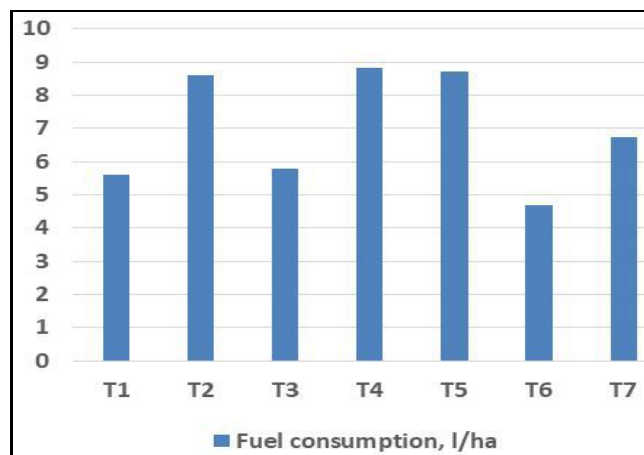
Theoretical field capacity



Average travelling speed



Field efficiency

**Fuel consumption****Soil parameter****Bulk density**

The study found that T₅ (cultivator with cage wheel + rotavator × 1) has the lowest initial bulk density at 0.912 g/cm³, suggesting effective soil loosening and reduced compaction. T₇ (disc harrow × 2) has the highest initial bulk density at 0.996 g/cm³, suggesting less effectiveness. After 15 days, T₁ remains lowest at 1.240 g/cm³, while T₇ has the highest bulk density at 1.385 g/cm³, indicating greater soil compaction. Cultivator and rotavator suggest high effective loosening and reduced compaction compared to disc harrow. Bulk density at different treatments is shown in table 4.

Moisture content

The study found that T₅ (cultivator with cage wheel + rotavator × 1) has the highest initial moisture content at 44.66%, suggesting effective moisture retention. T₇ (disc harrow × 2) has the lowest initial moisture content at 42.78%, suggesting less effectiveness. After 15 days, T₁ remains high at 41.53%, while T₇ has the lowest moisture content at 39.85%, indicating consistent moisture retention. Cultivator and rotavator suggesting high effective moisture

retention compared to disc harrow. Moisture content at different treatments is shown in table 4.

Cone index

Initial measure of cone index shows that treatment T₇ (Disc Harrow × 2) has the lowest cone index 124.84 kPa and treatment T₁ (Cultivator + Cage wheel × 1) has highest cone index 147.51 kPa. Cone index at different treatments is shown in table 4.

Puddling index

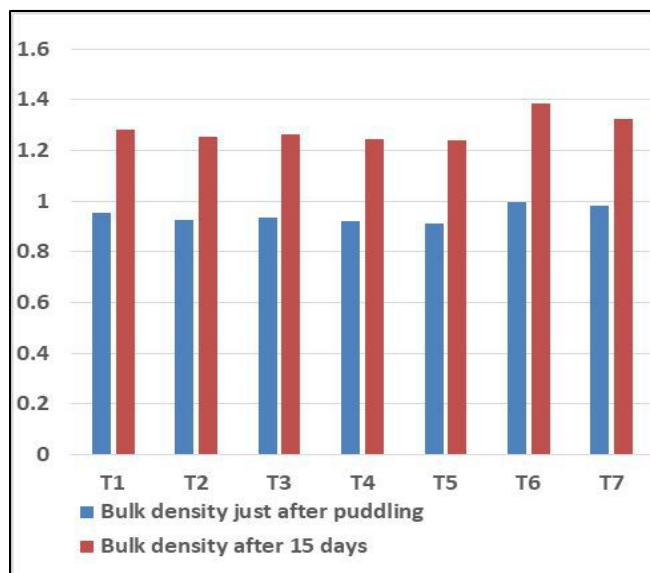
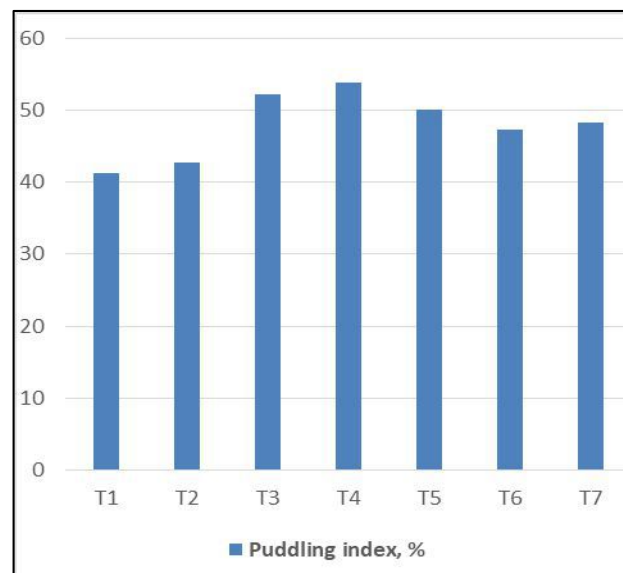
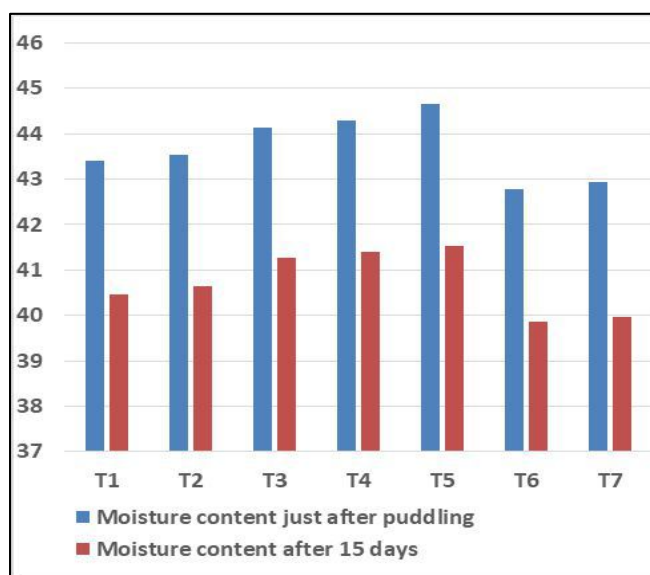
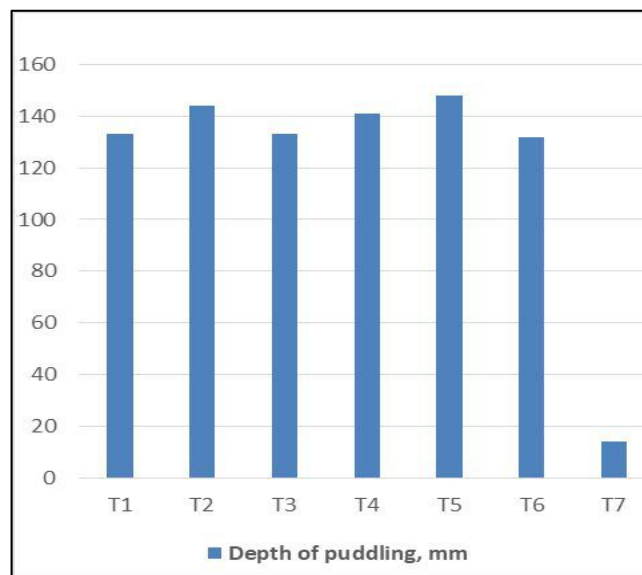
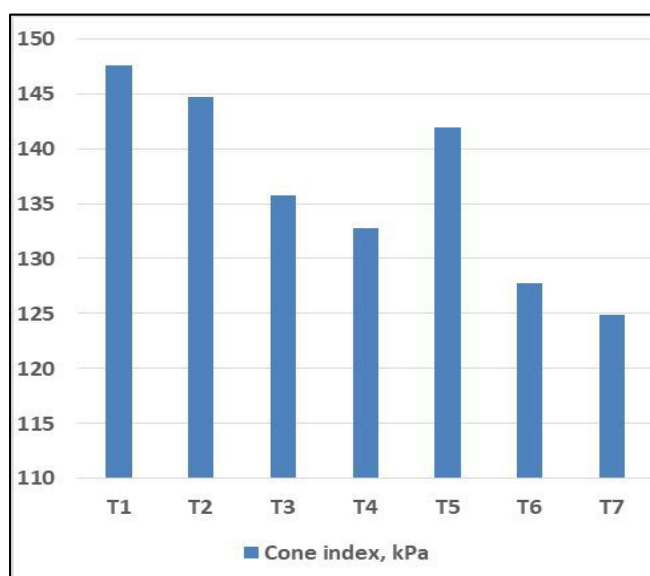
Initial measure of puddling index shows that treatment T₁ (Cultivator + Cage wheel × 1) has lowest puddling index 41.33% and treatment T₄ (Rotavator × 2) has highest puddling index 53.84%. Puddling index at different treatments is shown in table 4.

Depth of puddling

Initial measure of depth of puddling shows that treatment T₂ (Cultivator + Cage wheel × 2) 144 mm has highest depth of puddling and treatment T₆ (Disc Harrow × 1) 132 mm has lowest depth of puddling. Depth of puddling at different treatments is shown in table 4.

Table 4: Effect of Puddling Treatment on Selected Soil Physical Properties

Treatment	Bulk density,		Moisture content,		Cone index, kPa	Puddling index, %	Depth of puddling, mm
	Just after puddling	After 15 days	Just after Puddling	After 15 days			
T ₁	0.953	1.283	43.403	40.473	147.513	41.337	133
T ₂	0.926	1.256	43.543	40.653	144.720	42.707	144
T ₃	0.937	1.264	44.127	41.273	135.717	52.257	133
T ₄	0.920	1.243	44.293	41.400	132.800	53.843	141
T ₅	0.912	1.240	44.660	41.533	141.950	50.097	148
T ₆	0.996	1.386	42.780	39.853	127.797	47.373	132
T ₇	0.981	1.325	42.943	39.963	124.840	48.207	139

**Bulk density****Puddling index****Moisture content****Depth of puddling****Cone index****Cost analysis**

In this experiment, the cost of cultivator with cagewheel $\times$ 1 (T₁), cultivator with cagewheel $\times$ 2 (T₂), rotavator $\times$ 1 (T₃), rotavator $\times$ 2 (T₄), cultivator with cagewheel + rotavator (T₅), disc harrow $\times$ 1 (T₆), and disc harrow $\times$ 2 (T₇) are 1109.82 Rs/ha, 1127.26 Rs/ha, 2018.88 Rs/ha, 2101.19 Rs/ha, 3128.70 Rs/ha, 891.57 Rs/ha, and 923.33 Rs/ha, respectively.

Conclusion

Although treatment T₅ (cultivator + rotavator $\times$ 1) has reduced soil compaction (0.912 g/cm³), while T₇ (disc harrow $\times$ 2) showed the highest compaction. T₅ (cultivator + rotavator $\times$ 1) retained the most moisture (44.66%), while T₇ (disc harrow $\times$ 2) retained the least (42.78%). Disc harrow (T₆ and T₇) had lower cone index values, indicating less compacted soil suitable for planting. Rotavator treatments were most effective at reducing puddling (52.25%–53.84%, puddling index), while cultivator treatments were the least effective. T₂ (cultivator + cagewheel $\times$ 2) had the greatest depth of puddling (144 mm), while T₆ (disc harrow $\times$ 1) had the least (132 mm). The disc harrow offered a superior

balance of speed 3.1 km/h, area coverage 0.870 ha/h, fuel efficiency 4.70 l/ha, and cost-effectiveness of 891 Rs/ha. At the end, it concludes that the disc harrow has puddling parameters slightly near the rotavator. But the width of the disc harrow is greater than rotavator and cultivator with cagewheel because the disc harrow covers a larger area of the field, reduces operational time, fuel consumption, and saves cost of operation. Which gives disc harrow a slight advantage in puddling operation. It shows that disc harrow is suitable for manual transplanting.

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