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Performance evaluation of trailed type disc harrow on vertisols field condition

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Abstract
The aim of this study was to evaluate the performance parameters of tractor operated trailed type disc harrow on vertisols condition of the soil. All the tests were conducted on the research field associated with the College of agricultural Engineering, JNKVV Jabalpur (M.P.) The results of performance parameters of disc harrow were observed after five-time replication of the dependent variables 2.5 km/h forward speed and 15-17 cm depth of operation at 30x40 square meter test plot. After following all the methodology of test according to the Indian standards, the results were found as total weeding efficiency 51.25%, draft 8.10 kN, effective field capacity 0.26 ha/h, field efficiency 57.73 ha/h, fuel consumption 6.966 l/h, and wheel slippage percentage 9.028% respectively. These findings can guide future optimization strategies for agricultural practices using similar machinery in vertisol field conditions.

Keywords: Disc harrow, vertisol, weeding efficiency, draft, and field efficiency

1. Introduction
To enhance agricultural productivity, efficient seedbed preparation is crucial in addition to employing high-yielding varieties, fertilizers, irrigation, and plant protection measures. Typically, rice harvesting spans from mid-October to mid-November, leaving a limited window of 15-20 days for timely wheat sowing. Unfortunately, the delayed preparation of rice-harvested fields often leads to a postponement in wheat sowing, resulting in reduced yields. Notably, approximately 16-25 percent of the total energy dedicated to the rural sector is allocated to agricultural production, with seedbed preparation alone accounting for around 20 percent of this energy expenditure (Kumar *et al*. 2018a, and Kumar *et al*. 2018b) [18-19]. Efficient implements offer a solution to minimize the time and energy required for seedbed preparation in puddled rice fields.

Expansive soil is another name for the black cotton soil known as Vertisol with a significant soil order in the soil taxonomy. Vertisol is a type of churned clay soil with a lot of swelling clays (Dudal, 1963) [9]. These soils are deep to shallow, dark in colour, and they are dominated by clay mineralogy and have a distinctive profile structure (Kankal *et al*. 2016) [16]. They are defined as mineral soils that have 30% or more clay, or structural aggregates in the shape of a wedge that are angled from the horizontal (Fouda, 2016) [10]. When these soils dry out, which happens most years, they form deep, wide cracks from the surface down, making it extremely challenging to work with and manage. Traditionally, these soils were believed to be exclusive to the peninsular region. The state-wise distribution of black soils, as presented in Table 1.2 (Mandal *et al*. 2012, and Cheng *et al*. 2021) [20, 7], reveals that Maharashtra encompasses 27% of the total area covered by black soils, followed by Madhya Pradesh (21.3%), Gujarat (11.5%), Karnataka (9.2%), Andhra Pradesh (7.1%), and Chhattisgarh (5.6%). Additionally, black soils extend into portions of the lower Gangetic plain in Bihar (3.1%) and West Bengal (3.0%) (Murthy *et al*. 1982) [21].

Tillage operations are closely tied to soil characteristics, with soil type and condition serving as critical indicators that influence the performance of tractors and implements in the field. The traction efficiency of the tractor and the implement it powers are notably impacted by these soil-related factors (Belel and Dahab, 1997) [5].

Smith (1993) [23] emphasized the significant variability in plough performance, attributing these differences to factors such as soil type, moisture content, weed growth, crop residues, and the overall shape or pattern of the field.
The study by John *et al.* (1987) [15] underscored the importance of soil type and condition as major determinants affecting the operational effectiveness of field machinery. Belel and Dahab (1997) [5] further argued that implements operating in firm soil conditions demonstrate superior efficiency compared to those in loose soil. Observations by Bukhari and Baloch (1982) [6] indicated a higher incidence of wheel slip in clay loam soil, particularly with increased ploughing speeds, compared to other soil types.
Highlighting the relationship between energy consumption and soil characteristics, Kepner *et al*. (1982) [17] identified soil type and condition, operational speed, and tillage quality as primary factors influencing energy requirements. They specifically noted that clay soil demands a higher energy input for breakup compared to sandy soils. Additionally, Shebi *et al*. (1988) [22] maintained that, for a given soil type, the energy requirements of farm machinery increase with the bulk density of the soil. The aim of this study to evaluate the performance of tractor operated trailed type disc harrow in vertisols condition and also study the factor which affected by the operation of tractor operated disc harrow.

2. Materials and Methods

2.1 Description of selected study area and type of soil

This research was conducted at the research farm of the College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh. The farm is located at a latitude of approximately 23.90° N and a longitude of about 79.58° E, with an elevation of 411.78 m above mean sea level. Jabalpur experiences a humid subtropical climate characteristic of north-central India, encompassing parts of Madhya Pradesh and southern Uttar Pradesh (Kumar *et al*. 2018a) [18]. The summer season extends from late March to June, with May being the hottest month, often recording temperatures exceeding 40 °C (104 °F). The soil in Jabalpur belongs to the vertisol type, as classified by the US soil classification system. It exhibits a dark black colour, ranging from mild to deep (Kumar *et al*. 2018b) [19]. During the summer months, the soil, rich in clay content, develops extensive and wide cracks due to increased dryness. The soil's performance is suboptimal, regardless of whether conditions are excessively dry or wet. The soil of the test field were identified as vertisols, characterized by a composition of 13.6% sand, 32.8% silt, and 53.6% clay.

2.2 Selection of tractor for experiment

A 50hp at 2200 rpm tractor was used during the experiment. The tractor Model was Farm Tech 60 EPI. The power take-off shaft was 540 rpm. The tractor's weight was 2035 kg. Tires front 7.5 X 16 and rear 14.9 X 28 in size. The tractors have 12 forward speeds and 2 reverse speeds. Wheelbase, overall length, width, and ground clearance of the tractor were 2110, 3355, 1735, and 370mm respectively. The lifting capacity of the tractor was 1800 kg.

2.3 Moisture content of the soil

A rapid soil moisture meter and oven dry method were used to measure moisture content before conducting each test of treatments (ASAE, 1999) [4]. The moisture meter was calibrated by comparing it with the oven drying method by collecting the sample from the same spot of measurement. All the experiments were conducted at 14-16% range of the soil moisture content.

2.4 Weeding efficiency

Weeding efficiency was measured by a quadrant of square meter size selected randomly in each plot and counting the volume of weeds present before and after tillage operations depicted in plates 1 and 2. The weeding efficiency can be calculated by the following equation 1.

$$\text{Weeding efficiency (\%)} = \frac{W1-W2}{W1} \times 100 \quad (1)$$

Where
W_1= Volume or of weeds before tillage, g;
W_2 = Volume of weeds after tillage, g.

Plate 1: Weeds before operation Plate 2: Weeds after operation

2.5 Measurement of draft force
The draft was measured in the field with the use of a load cell by the dummy tractor method. Two tractors were used in the dummy tractor method. The front tractor was used to pull the rear tractor, which was always set in neutral gear. A tensile-type load cell was placed between these two tractors using suitable chain linkage as shown in plate 3. The implement was mounted at the rear of the tractor, and draft force on the load cell was observed and recorded during the field operation. Values of tensile force were observed and recorded by a data logger system. The average value of these forces gave the rolling resistance required of the rear tractor.

Plate 3: Draft force measurement (Dummy tractor method) by using tensile load cell

2.6 Theoretical field capacity
The theoretical field capacity of the machine may be defined as the field coverage by a machine that is obtained from (Equation 2) if the machine were performing its function 100% of the time with respect to the rated forward speed of the machine and always covering 100% of its rated width (IS11531, 1985; Kepner *et al.* 1978) [14, 24].

$$\text{Theortical field capacity } \left(\frac{ha}{h}\right) = \frac{W \times S}{10} \qquad (2)$$

Where,
S = Forward speed of operation km/h; and
W = Rated width of implement, m.

2.7 Effective field capacity
It is the actual field capacity defined as an actual average rate of coverage by the machine from the equation 3. The total time required to complete the function was determined and effective field capacity was recorded as follows. It is also taken as the total time required to carry out functional operation including the time lost during the field turning, idle travel, operator's skill, etc. (IS11531, 1985; Kepner *et al.*, 1978) [14, 24].

$$\text{Effective field capcity } \left(\frac{\text{ha}}{\text{h}}\right) = \frac{\text{A}}{\text{T}} \qquad (3)$$

Where,
A = Actual field area covered by the machine, ha; and
T = Effective time consumed, h.

2.8 Field efficiency
The field efficiency was determined as the ratio of effective field capacity to the theoretical field capacity and expressed in percent as equation 4:

$$\text{Field efficency (\%)} = \frac{\text{Effective field capacity (EFC)}}{\text{Theortical field capacity(TFC)}} \qquad (4)$$

2.9 Fuel consumption
The tank was full of fuel before conducting the test and operated on the specific area. After completion of the operation remaining amount of fuel was measured by the filling method. Fuel consumption was taken five times and calculated as fuel consumed per unit area (l/ha) or time taken to cover that area (l/h) by the following expression as equation 5:

$$\text{Fuel consumption} = \frac{\text{Fuel consumed in (ml)}\times 10}{\text{Area covered in (m2)}} \qquad (5)$$

2.10 Slippage percentage of tractor
The slippage percentage of a tractor during operation is a measure of the difference between the theoretical distance the tractor should cover and the actual distance it covers due to wheel slippage. It is expressed as a percentage and can be calculated using the following formula (equation 6):

$$S = \frac{V_t - V_a}{V_t} \times 100 \qquad (6)$$

Where,
S = Slip, %;
V_t = Theoretical velocity; and
V_a = Actual velocity.

3. Results and Discussions
Details on the performance evaluation of a tractor operated trailed type disc harrow on vertisol field conditions are presented here, along with the ensuing findings and discussions. In this results and discussions section, analysis were carried out of the findings of different parameters of trailed type disc harrow.

3.1 Weeding efficiency (%)
The effect of operational parameters; 2.5 km/h forward speed and 15-17 cm average depth of operation. The volume of weed collected from five randomly selected locations of the field with the help of square meter. The average value of weed before the trial of machine was found 1036g and after completing single pass of the machine the average volume of weeds was found 794g over the tilled field, and the weeding efficiency was found as 23.36% during first pass of the machine (Illustrated in table 1). During the second pass of the machine the average volume of weed was found 805g over the soil bed before double pass of the machine and after passing the machine the volume of weed was remain as 505g over the soil bed and weeding efficiency was observed 37.27%. The total weeding efficiency before passing the machine and after second pass of the machine was observed as 51.25% shown in Fig 1.

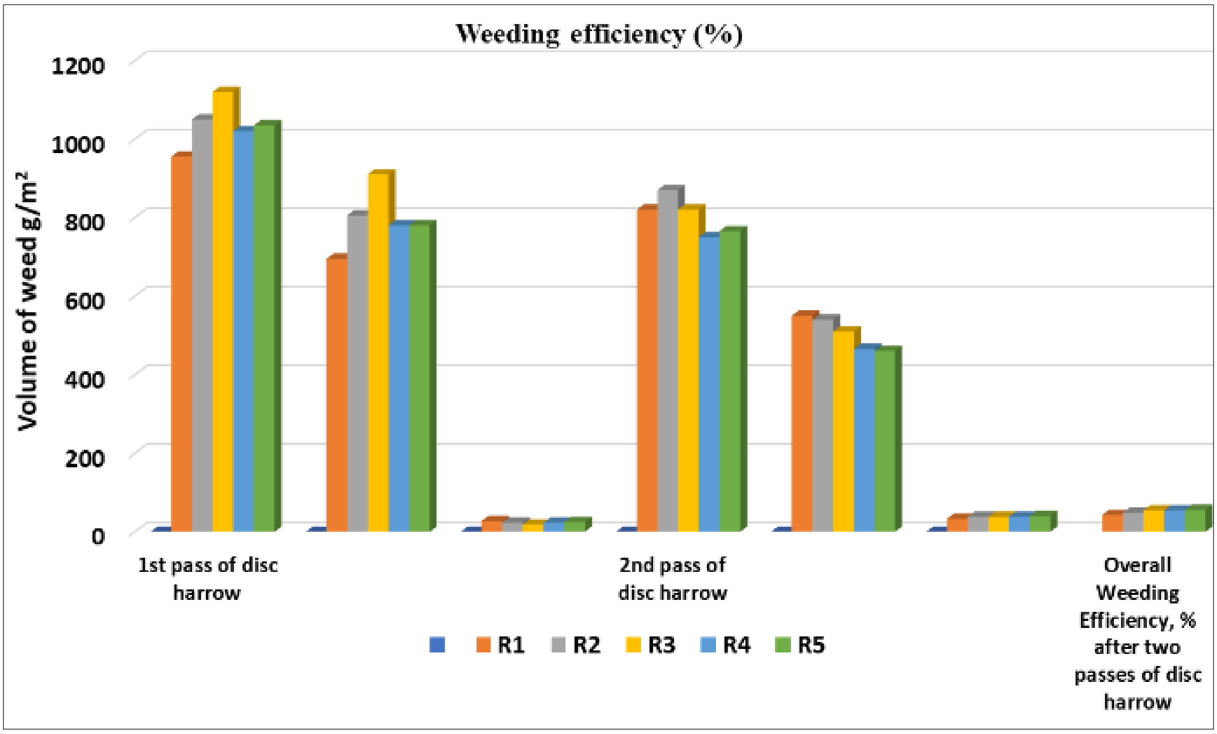

Fig 1: Weed population and weeding efficiency during the trial of machine

Table 1: Weed population and weeding efficiency by the operation of tractor operated trailed type disc harrow

Replications	1st pass of disc harrow			2nd pass of disc harrow			Overall Weeding Efficiency (%) after two passes of disc harrow
	Before	After	Weeding Efficiency (%)	Before	After	Weeding Efficiency (%)	
R1	955	695	27.23	820	550	32.93	42.41
R2	1050	805	23.33	870	540	37.93	48.57
R3	1120	910	18.75	820	510	37.80	54.46
R4	1020	780	23.53	750	465	38.00	54.41
R5	1035	780	24.64	765	460	39.87	55.56
Average	1036	794	23.36	805	505	37.27	51.25

3.2 Draft force (kN)
The variations of the draft of disc harrow with forward speed of 2.5 km/h at different operating depths for both the passes of tillage. In general, the draft requirement of disc harrow was found to increase with an increase in forward speed and operating depth during both the passes of tillage. The average draft of disc harrow at the first and second passes of tillage were found 10.02 kN and 8.10 kN (shown in table 2).

3.3 Theoretical field capacity (ha/h)
The actual working width of the machine was found during its first or second pass was 180cm. The calculated theoretical field capacity at the forward speed of 2.5 km/h was found as 0.45 ha/h, shown in table 2.

3.4 Actual field capacity (ha/h) and field efficiency (%)
From the table 2, observed the average field capacity of the disc harrow at the forward speed of 2.5 km/h, depth of operation 15-17 cm. After the first pass of the disc harrow, the average actual of field capacity was found 0.24 ha/h, and after the second pass of the machine the actual field capacity was found as 0.26 ha/h. The average field efficiency of disc harrow after five time replicate the treatment and found the value of field efficiency as 53.16% during first pass and 57.73% during the second pass of the disc harrow in vertisol field condition.

3.5 Fuel consumption
The fuel consumption of 55 hp tractor in l/h at all test conditions. The average fuel consumption of the machine was measured by using the fuel measurement method. After completing five replications of the selected variables 15-17 cm depth of operation, and 2.5km/h forward speed. The average fuel consumption during single and double pass of the machine was found 6.478 l/h and 5.966 l/h respectively (Illsustrated in table 2).

3.6 Wheel slippage (%)
The average wheel slippage of the tractor after first pass of the disc harrow was found as 8.42% and after second pass of the tractor wheel slippage was found as 9.028% at the forward speed of 2.5 km/h, and 15-17 cm depth of operation (illustrated in table 2). The higher wheel slippage was observed for disc harrow while second pass of the machine could be due to the sinkage of tractor tires in pulverized soil due to the first pass of tillage operation which decreased the tractability of tractor and increased the wheel slip despite the lesser draft requirement during the second pass of tillage.

Table 2: Responses of the performance of trailed type disc harrow in vertisol field condition

Pass	Replications	Draft force (kN)	TFC (ha/h)	AFC (ha/h)	Field efficiency (%)	Fuel consumption (l/ha)	Wheel slippage (%)
Single pass of trailed type disc	1	10.05	0.45	0.25	55.33	6.3	8.5

harrow	2	9.85	0.45	0.23	52.00	6.25	7.8
	3	10.45	0.45	0.24	53.56	6.39	9
	4	10.00	0.45	0.22	48.89	6.7	8.7
	5	9.76	0.45	0.25	56.00	6.75	8.1
	Average	10.02	0.45	0.24	53.16	6.478	8.42
Double pass of trailed type disc harrow	1	8.50	0.45	0.26	58.00	5.95	8.9
	2	7.90	0.45	0.27	59.56	5.92	9.2
	3	7.89	0.45	0.27	60.00	6.05	9.15
	4	8.00	0.45	0.25	55.56	5.89	8.89
	5	8.20	0.45	0.25	55.56	6.02	9
	Average	8.10	0.45	0.26	57.73	5.966	9.028

Conclusions

In summary, the study investigated the impact of operational parameters, specifically a forward speed of 2.5 km/h and an average depth of operation between 15-17 cm, on the performance of a disc harrow in weed removal. In conclusion, the study provides valuable insights into the operational parameters' effects on weed removal efficiency, draft force, field capacity, fuel consumption, and wheel slippage. These findings can guide future optimization strategies for agricultural practices using similar machinery in vertisol field conditions.

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