

# Performance Evaluation of MB Plough With Combination of Different Tillage Implements

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## Abstract

*This study evaluates the performance of tractor-drawn tillage implements in various combinations on clay loamy soil. The research aimed to assess performance parameters such as field capacity, efficiency, depth and width of cut, and energy requirements during seedbed preparation. The experiments were conducted on a 40 × 30 m<sup>2</sup> plot using multiple tillage combinations, including moldboard (MB) ploughing, MB ploughing combined with cultivating, MB ploughing followed by rotavating, single-pass rotavating, and double-pass rotavating. The findings revealed that the double-pass operation of the rotavator achieved the highest performance index of 86.86%, demonstrating superior efficiency in seedbed preparation. Moreover, this combination exhibited the lowest energy consumption at 616 MJ/ha, signifying cost-effectiveness and environmental sustainability. These results underscore the importance of optimizing tillage combinations to enhance agricultural productivity and energy efficiency in clay loamy soil conditions. This study provides valuable insights for farmers and agricultural practitioners seeking to maximize efficiency in seedbed preparation while minimizing energy input.*

**Keywords:** Tillage implements, rotavator performance, field capacity, energy efficiency, seedbed preparation

## INTRODUCTION

Timeliness is a critical factor in agricultural operations, as delays in key activities can result in reduced yields, lower quality crops, and inefficient use of resources. Agricultural mechanization plays a central role in enhancing the efficiency and effectiveness of these operations.

Farm equipment and the techniques for its optimal use fall under the umbrella of agricultural mechanization. This field covers a wide range of machinery and tools used in various stages of crop production, from land preparation to harvesting. The introduction of mechanized equipment has drastically transformed farming practices by reducing labor requirements, increasing speed and precision, and enabling larger areas of land to be cultivated more efficiently (Oduma et al., 2015). Agricultural mechanization, when appropriately matched with the needs of specific crops and regions, significantly enhances farm productivity and economic sustainability. Furthermore, the continued development of technologies like precision agriculture, automation, and digital tools promises to further revolutionize the field by improving the accuracy, efficiency, and environmental sustainability of agricultural practices.

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Upadhyaya et al. (1984) emphasize the critical role of energy in agricultural operations, particularly in tillage, seeding, planting, and harvesting processes. As per Larson and Clyma, (1995) tillage stands out as a fundamental operation within agricultural systems, with its energy demands accounting for a significant share of the total energy used in crop production. This highlights the importance of optimizing energy efficiency in tillage to enhance overall sustainability and productivity in agriculture. Sale et al. (2013) highlight the critical time sensitivity of agricultural operations, which are strongly influenced by weather conditions. Considering the significant investments in this sector, they emphasize the necessity of assessing the capacitive performance of agricultural machinery. This evaluation plays a vital role in selecting appropriate machinery, optimizing operational efficiency, and establishing effective farm schedules to maximize productivity. Yohannah and Ifem (2003) propose two approaches for evaluating agricultural machines. The first involves short-term assessments during productive work, akin to speed trials, focusing on performance under ideal conditions. The second approach involves long-term monitoring, which accounts for associated delays, providing a comprehensive evaluation of machine efficiency and reliability over time. Whitney (1988) emphasizes that efficient machinery management relies on accurate performance data for individual machines. Such data is essential for ensuring that machines can meet specific work schedules and for creating balanced mechanization systems by aligning the performance of different equipment components. This approach optimizes operational efficiency and enhances overall productivity. Adopting enhanced tillage techniques rather than traditional ones can save a significant amount of energy used in the land preparation process. Presently, rotavators, or horizontal rotational tillage systems, are being used by farmers more frequently because of their high pulverization and low or negative draft needs (Kepner et al., 1972). Because the soil failure for pulled or passive tools primarily occurs under compression, these tools require a comparatively larger power consumption (Yatsuk, 1981). In heavy soils, a tractor-drawn rotavator saves 32–35% of time and energy, making it an energy-efficient piece of equipment (Sahay, 2004). According to Bukhari et al. (1996), rotavators are becoming more and more popular because of their ability to do high-quality tillage, puddling, mulching, and leveling tasks with ease. In Punjab, there are roughly 6720 rotavators in use, and both their quantity and popularity are rising daily throughout all northern India (Prakash et al., 2012). Selecting the most energy-efficient tillage system necessitates field performance data of different tillage implements under varying local conditions. This study focuses on evaluating the field performance of tractor-drawn tillage implements, specifically a 2-bottom mouldboard plough, a spring-loaded 7-tynes cultivator, and a Rotavator. The findings aim to identify the most energy-efficient options suited to specific agricultural conditions and needs.

## Material and Methods

A field experiment was conducted during the 2023–24 growing season at the College of Agriculture and Research Station, Kurud Dhamtari, to evaluate the performance of a mouldboard (MB) plough and other tractor-drawn tillage implements. The study tested four tillage operation combinations: T1: Ploughing with an MB plough only, T2: MB ploughing followed by cultivating, T3: MB ploughing followed by a single pass of a rotavator and T4: MB ploughing followed by a double pass of a rotavator. Each treatment was replicated three times to ensure result accuracy. Trials were conducted on rectangular field plots measuring 40 m × 30 m, as this layout supports optimal performance of tractor-drawn implements.

Key factors influencing the performance included soil type, soil moisture content, weed presence, crop residues, and the traveling speed of the tractor. Before testing, soil moisture content was measured on a dry basis, and all experiments adhered to the RNAM test code, ensuring standardized and reliable evaluations.

During the field trials, for each operation, the following parameters were recorded: speed of operation in km/h, depth of penetration in cm, area covered in unit time (ha/hr), moisture content of the soil to the operational depth in percent, sieve analysis for clod size after operation in mm, and draft required for pulling the implement (kg). These observations were used to calculate the fuel consumption, implement combination, depth of cut, field performance index, cost of operation, and energy requirement. A

pulverization test was carried out in the field, where aggregates were considered as the pulverization index and expressed in mm. The experimental procedure to measure these data during the field operation of the tillage implements was also included.

### Observation Recorded

Moisture content on dry basis- The moisture content of the soil on a dry basis was determined using core samples collected randomly from the field. The core sampler used had a diameter of 10 cm and a height of 13 cm. The procedure involved the following steps:

1. *Collection*: Soil samples were extracted from the field using the core sampler.
2. *Drying*: The collected samples were dried in an oven at 105°C for 24 hours to remove moisture completely.
3. *Weighing*: The dried samples were re-weighed, and their weights were recorded.

(Mari *et al.* 2011).

$$\text{Moisture content (db)\%} = \frac{\text{Weight of moist soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

*Bulk density*: To determine bulk density, undisturbed soil cores were collected by driving a 10 cm diameter metal cylinder into the soil to the desired depth in the plot using an iron hammer. The core samples were carefully extracted and processed to calculate bulk density based on the volume and dry weights of the soil. A core penetrometer of 10 cm diameter and 13 cm height was used for this purpose (Mari *et al.* 2011).

$$\text{Bulk density (gm / cc)} = \frac{\text{Weight of soil (gm)}}{\text{Volume of soil (CC)}}$$

*Puddling index*: To determine the puddling index, soil-water suspension samples of 500 ml were collected from different spots behind the puddling equipment using a 1.25 cm diameter steel pipe. The procedure was as follows:

1. *Collection*: Soil-water suspension samples were collected during puddling.
2. *Settling*: The collected samples were allowed to settle for 48 hours, giving time for the soil particles to separate from the water.
3. *Recording*: The volume of the soil that settled at the bottom of the container was recorded.

(Baboo 1976).

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

Where,

$V_s$  = Volume of settled soil, ml

$V$  = Total volume of the sample, ml

*Weeding efficiency*: Number of weeds per unit area was counted before and after the experiment and the weeding index was calculated as follows-

$$\text{Weeding efficiency (\%)} = \frac{\text{Number of weeds per unit area before operation}}{\text{Number of weeds per unit area after operation}}$$

*Field capacity and field efficiency*: It was calculated as

$$\begin{aligned} \text{Theoretical field capacity (ha/h)} &= (\text{Speed (km/h)} \times \text{Width of implement (m)})/10 \\ \text{Actual field capacity (ha / h)} &= \frac{\text{Total area covered (ha)}}{\text{Total time taken (h)}} \end{aligned}$$

$$\text{Field efficiency \%} = \frac{\text{Actual field capacity}}{\text{Theoretical field capacity}} \times 100$$

### Fuel Consumption

The fuel consumption was measured by toping method, in this method tractor was place in horizontal position was tank field completely before use in the field for testing of tillage implement after the test place the tractor on the same level horizontal position and field the tank on the same level with the help of measuring cylinder. After ploughing a specific area, the fuel tank of the tractor was refilled to the same level as it was before the operation. The procedure to measure fuel consumption was as follows: Once the ploughing operation was completed, the fuel tank was refilled to its original fuel level. The total volume of fuel needed to refill the tank to the initial level was measured and recorded. This volume represents the amount of fuel consumed during the ploughing process. The total duration required to plough the test plot was recorded. The amount of fuel added to return the tank to its starting fuel level indicates the fuel consumption during the ploughing operation. This measurement is crucial for calculating fuel efficiency and evaluating the tractor's performance in terms of energy use during tillage

### Operational Energy

The sufficient availability of appropriate energy sources, along with their effective and efficient utilization, is crucial for enhancing agricultural production. Utilizing farm machines and implements can boost productivity and reduce operational costs. Strategies such as reducing, eliminating, or combining machinery operations can lead to lower fuel (energy) input, as well as potential savings in labor and time (Karale et al., 2008) Energy sources involved in wetland and dryland preparation include human effort, machinery, and petroleum energy. The energy coefficients relevant to this context are presented in Table No. 1. The energy calculations were performed using the formulas provided by Singh and Mittal (1992).

$$\text{Human Energy (MJ/ha)} = \text{no of labor} \times \text{energy coefficient} \times \text{time (h)}$$

$$\text{Rotavator (machinery energy) (MJ/ha)} = [\text{wt. (kg) of machine} \times \text{coefficient} \times \text{time (h)}] \div [\text{life (Y)} \times \text{annual use (h)}].$$

$$\text{Diesel energy (MJ/ha)} = \text{consumption} \times \text{coefficient} \times \text{time (h)}$$

**Table 1.** Energy co-efficient

Particulars	Units	Equivalent energy, MJ
Human	Man-hour	1.96
Diesel	Litre	56.31
Farm machinery excluding self-propelled machine	Kg	62.70

Source: Mittal et al. (1985). Research digest on energy requirement in Agriculture Sector (1971 – 1982), PAU, Ludhiana.

## RESULT AND DISCUSSION

This chapter presents and discusses the findings of a field experiment conducted on sandy loam soil using various combinations of primary and secondary tillage tools. The indices used to assess the effectiveness of implementation. The mean weight diameter, field performance index, moisture content, fuel consumption, and energy demand are the indicators used to assess the effectiveness of an implement combination on clay loam soil. Each combination of independent variables was computed to examine the variation. Every plot's moisture content was measured throughout the field experiment. The moisture content at a depth ranging from 5 to 10 cm was recorded between 6- 8% on a dry basis. At a depth of 15 cm, the soil moisture content was observed to increase to between 9-10% on a dry basis. Further down at 30 cm, the moisture content was found to range from 12-14% on a dry basis. The bulk density of the clay loamy soil was measured and determined to be 1.32 g/cc. The plot used for all the trials measured 40 meters in length and 30 meters in width, covering a total area of 0.012 hectares.

### Field Time, Productive Time, Delay Time and Fuel Consumption

Among the implements tested, the double pass rotavator (S4) had the lowest fuel consumption, at 9.13 l/ha (4.02 l/h), followed by the single pass rotavator (S3) at 10.85 l/ha, and the combination of ploughing with cultivator (S2) at 19.95 l/ha. The highest fuel consumption was recorded for the mouldboard plough (S1), which consumed 26.34 l/ha, as shown in Table 2.

The high fuel consumption of the mouldboard plough can be attributed to its significant tractive effort, its capacity to handle a large volume of soil per unit time, and its heavy self-weight. These factors increased the energy input required during operation. The total field time, which encompasses productive (effective) time and any delay time experienced during the operation, was also highest for the mouldboard plough, followed by the spring-loaded tine cultivator. The findings indicate that maximum fuel consumption was observed in clay loam soil, attributed to the high draft force needed by the implements and the substantial resistance offered by the soil. In contrast, the lowest fuel consumption was seen in implements with lower draft requirements, which reduced the load on the tractor and minimized fuel usage.

### Field Efficiency and Effective Field Capacity

The double pass rotavator demonstrated the highest average field capacity at 0.44 ha/h and achieved the highest field efficiency of 86.27%, as shown in Table 2. In comparison, the mouldboard plough recorded the lowest field efficiency at 83.75%, followed by the disk plough at 78.75%.

The average effective field capacities for the mouldboard plough and the disk plough were 0.168 ha/h and 0.16 ha/h, respectively, as detailed in Tables 3 and 4. For the disk plough, the field time per hectare was 6.26 hours, with a delay time of 1.16 hours (Table 1). For the mouldboard plough and the spring-loaded tine cultivator, the field times per hectare were 5.98 hours and 4.51 hours, respectively, with delay times of 1.28 hours and 1.63 hours (Table 6). The spring-loaded tine cultivator showed the maximum delay time per hectare at 1.63 hours, followed by the mouldboard plough at 1.28 hours and the disk plough at 1.16 hours. The higher delay time for the spring-loaded tine cultivator was primarily due to its wider operating width, which increased the time spent maneuvering at headlands. Additionally, it was observed that operators often had to dismount to clear the tines of clogs caused by trash and weeds. Wider equipment results in longer turning times at headlands, especially when implements are raised and not in use, and headland areas are typically larger, contributing to the delay.

**Table 2.** Field performance of different tillage implement.

S N.	Particular	T1	T2	T3	T4
1.	Length of plot covered (m)	40	40	40	40
2.	Width of plot covered (m)	30	30	30	30
3.	Area of plot covered (ha)	0.12	0.12	0.12	0.12
4.	Depth of cut (cm)	31.56	14.62	10.24	11.43
5.	Width of cut (cm)	60	210	145	145
6.	Average speed of implement (km/h)	2.92	3.45	3.62	3.86
7.	Actual field capacity (ha/h)	0.17	0.22	0.39	0.44
8.	Theoretical field capacity (ha/h)	0.21	0.27	0.46	0.51
9.	Field efficiency (%)	80.95	81.48	84.78	86.27
10.	Fuel consumption (l/h)	4.48	4.39	4.23	4.02
11.	Fuel consumption (l/ha)	26.34	19.95	10.85	9.13

### Energy Expenditure

The energy requirement was 616.06 MJ/ ha with implement S1 (mould board plough). Energy requirement was 770.59 MJ/ha with implement combination S2 (ploughing + cultivator). Energy requirement was 809.21 MJ/ha with implement combination S3 (rotavator single pass). Energy requirement was 799.68 MJ/ha with implement combination S4 (rotavator double pass) in mean weight diameter. The energy requirement is also affected by fuel consumption and different properties for each implement. Mean weight diameter after the operation was found to be 5.2 mm with implement S4 (rotavator double pass) mean weight diameter was found to be 5.6 mm with implement S3 (Rotavator sing pass) in sandy loam soil. mean weight diameter was found 12.65 mm with implement combination S2 (ploughing + cultivator) and mean weight diameter 13.45 mm with implement S1 (mould board plough) Table 3.

**Table 3.** Energy analysis of tillage implement during field experiment.

Name of implement	Energy for machinery (MJ/ha)	Energy for diesel (MJ/ha)	Energy for human (MJ/ha)	Energy for trail (MJ/ha)
Ploughing	86.86	520.04	6.006	616.06
Ploughing + cultivator	20.12	132.52	1.89	770.59
Rotavator single pass	39.08	151.31	2.75	809.21
Rotavator double pass	12.09	168.10	3.41	799.68

## CONCLUSION

In this study, the double pass rotavator demonstrated superior efficiency compared to the single pass rotavator, mould board ploughing, and the 7-tyne cultivator during field preparation. The rotating blades of the double pass rotavator facilitated more effective soil pulverization after the tillage operation. This improvement in performance was evident in both higher effective field capacity and reduced energy expenditure during field preparation. In mould board plough observed maximum fuel consumption for clay loam of soil that's because high draft offered by implement for deep ploughing and high resistance surface. This indicates that the rotavator created smaller soil clods, which is better for seed bed preparation and secondary tillage.

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