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Fuel Consumption Pattern for Disc Plough and Cultivator Tillage Implement

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the effects of different (Disc plough and Cultivator) tillage implements on soil physical properties and operational cost under loam soil. Different (Disc plough and Cultivator) tillage implements were used in a field under separate plots. The fuel consumed by the tractor during the Disc plough and Cultivator tillage operations was measured by the field to determine the cost of both tillage operations. Results showed that the soil moisture content (MC) was 25.31%, while soil bulk density (BD) 1.3 under the plot (field) tilled with cultivator followed by disc plough

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compared to that tilled with cultivator only. The fuel consumed by the tractor during different tillage operations was 16.08 and 7.53 lit/ha for Disc plough and cultivator respectively. It is concluded that Cultivator can prepare better seedbed under loam soil as compared to Disc Plough only at almost same operational cost.

Keywords: Disc plough; cultivator; fuel consumption; tillage operations.

1. INTRODUCTION

"Tillage is a mechanical action on the soil to prepare for agricultural cultivation purpose with different tillage implements to produce favourable environment for plant growth. Tillage has both direct and indirect effects on crop stand establishment and residue decomposition. Tillage directly affects residues fragmentation and distribution as well as facilitates seed placement within the seedbed" [1]. "Tractors are the basic need of Indian agriculture. In 2023, India produced 9,86,000 tractors accounting for 47.98% of world's output. It is the world's largest producer and market for tractors" [2]. "Reducing fuel consumption in cropland agriculture is a complex and multifactorial process, where farm management plays a key role. Conventional tillage with plough is one of the most energy-consuming processes in plant production" [3]. "Physical properties play an important role in determining soil's suitability for agricultural, environmental and engineering uses. The supporting capability; movement, retention and availability of water and nutrients to plants; ease in penetration of roots, and flow of heat and air are directly associated with physical properties of the soil. Physical properties also influence the chemical and biological properties" [4]. "Mouldboard plough, tined implements and disc implements are the main implement types for primary tillage. The fuel consumption of soil tillage operations varies widely and can be reduced through proper matching of tractor size, operating parameters, tillage implement. Disc harrow operating performance in clay soil when using 220 rad s^{-1} (2100 rpm) engine rotation speed aided reduction in fuel consumption and higher effective field capacity" [5]. "Soil Tillage Conservation (STC) are considered major components of agricultural technology for soil conservation strategies and part of Sustainable Agriculture (SA). STC involves reducing the number of tillage operation to direct sowing and plant remains at the soil surface in the ratio of at least 30%. STC aims to ensure an appropriate aero hydric regim for the biological activity and balance in nutrient solubilisation. Plant debris left on the soil surface or superficial incorporated contributes to increased biological activity and is an important source of CO_2" [6]. The main objective of this work is Fuel consumption pattern for Disc plough and Cultivator & determination of cost of operation [7-10].

2. MATERIALS AND METHODS

This chapter deals with various materials and techniques employed for conducting experiments to determine fuel consumption pattern for different tillage implement at varying implements with tractor and soil conditions.

The experiment conducted on the agricultural field of SVPUA&T, Meerut. The selected area is near the Central library of Sardar Vallabhbhai Patel University of agriculture and technology and the location (Longitude and latitude) of selected area is 29.084070, 77.698715.

The equipment required for the measuring of area such as measuring tape of engineering chain the total area we measured by measuring tape and engineering chain also thus the length was 49.35 meters and the width was 41 meters and according to this area was 2023.35 square meters or 0.499 Acre or 0.202 ha., after area measuring, we mark a straight line by white powder.

2.1 Soil Properties

Collection of soil Sample.

2.2 Material Required for Collect the Soil Sample

- Spade or auger (screw or tube or post hole type)
- Khurpi
- Core Sampler
- Sampling bags
- Plastic tray or bucket

2.3 Procedure at Collection Soil Samples

- Divide the field into different homogenous units based on the visual observation and farmer's experience.

- Remove the surface litter at the sampling spot.
- Drive the auger or Khurpi to a plough depth of 15 cm and draw the soil sample.
- Collect at least 10 to 15 samples from each sampling unit and place in a bucket or tray.
- If auger is not available make a 'V' shaped cut to a depth of 15 cm in the sampling spot using spade.
- Remove thick slices of soil from top to bottom to exposed face of the 'V' shaped cut and place in a clean container.

2.4 Soil Testing in Lab

- **Particle Density**

The particle density (ρs) of a soil is the oven-dried mass of soil (M_s) per unit volume of soil solids (V_s) [11].

$$\rho s = \frac{\mathrm{Ms}}{\mathrm{Vs}}$$

- **Bulk Density**

Bulk density (ρb) of a soil is the oven-dried mass (Ms) per unit volume (Vt) of soil as a whole including pore space [12].

$$\rho b = \frac{\mathrm{Ms}}{\mathrm{Vt}}$$

- **Total Porosity**

The total porosity (f) is the volume occupied by pores (V_f) per unit volume of soil (V_t). it is an index of relative pore volume in soil and is generally expressed as percentage [13].

$$\mathrm{f} = \frac{\mathrm{Vf}}{\mathrm{Vf}} \times 100$$

- **Soil Moisture**

Calculate the moisture content on a wet-weight basis using the following formula [11]:

$$\text{Moisture Content (\%)} = \frac{\mathrm{W2-W3}}{\mathrm{W2-W1}} \times 100$$

where,

W_1= weight of container with lid
W_2 = weight of container with lid and sample before drying
W_3= weight of container with lid and sample after drying

2.5 Selection of Machine

Selection of Machine on the basis of general required conditions:

- Land holding
- Soil conditions
- Climatic Conditions
- Repairing facilities

2.6 Selection of Tractor

Tractor selection on the basis of Power requirements:

- Medium Power Tractor (25-45 Hp)
- High Power Tractor (More than 45 Hp)

2.7 Selection of Implement

Disc Plough: The Sonalika 3 Bottom is an excellent disc plough equipment. Sonalika 3 Bottom is selected for performing the experiment in field is an excellent disc plough equipment for farming. The device works with a tractor, ranging from 50 to 65 Hp. Also, the functions of disc plough are suitable for making farming work easy. It has a Seamless Tubular Frame (OD 168, ID 146) and Spindle axle, which is fitted with 3 plain discs at a space of 570 mm. moreover, the disc diameter is 660 mm, making deep tillage.

Cultivator: The Sonalika 9 Tyne is an excellent cultivator equipment with Sonalika 9 TYNE cultivator; It is selected as second equipment for experiment Sonalika 9 Tyne cultivator for farming. It comes under the Cultivator category. And, it has 40-45 HP implement power that provides fuel efficient work. It is an implement that comes from the Sonalika brand house known for its superb quality niches.

2.8 Cost Calculation for Fuel Consumption

Brake specific fuel consumption: BSFC is the quantity, which expressing how much fuel uses the engine on perform useful work 1 Joule.

$$\boldsymbol{BSFC} = \frac{\mathrm{Mp}}{Pe} \times 1000$$

BSFS= Break specific fuel consumption
Mp = Fuel consumption in kg/hr
Pe= effective engine power (kW)

Cost calculation:

Total cost = Total fuel consumed × fuel price

2.9 Calculation for Specific Fuel Consumption

Fuel consumption (lit./hr):

$$SFC\ (\frac{g}{bhp} - h) = \frac{\text{fuel consumption(CC)} \times \text{Specific Gravity of HSD}}{\text{Rated BHP of Tractor}}$$

where:

SFC= Specific fuel consumption
g= gram
Bhp= Break Horse Power
h= Hours
cc= cubic cm
HSD= High speed diesel

3. RESULTS AND DISCUSSION

This chapter deals with result of physical property of soil sample, fuel consumption pattern of disc plough and cultivator, compression between fuel consumption with implement and cost calculation of fuel consumption.

3.1 Soil Property

The physicochemical characteristics of the soils from different land use systems are summarized in Table 1 The major goals of soil tillage are fundamental working, preparing the germinal layer, and field maintenance. These goals lead to a number of immediate effects, some of which are good. However, the consequences of soil tillage over this one can frequently have long-lasting (good or negative) effects in addition to immediate unfavorable effects. The cultivation of soil is a drying process; therefore, effects of tillage always need to be evaluated in terms of soil moisture availability in soil. Data on soil moisture obtained from a field show 25.31%.

The bulk density increases with depth and significantly varies with tillage treatment. The analysis of variance revealed that bulk density of soil for top layer (10-15cm) was not different for all before tillage treatment and we found the bulk density of our filed is 1.3 g/cm-3 and the particle density is 2.41 g/cm^{-3}.

3.2 Fuel Property

The properties of the produced emulsion are listed in Table 2. The agent-in-oil method was used to manufacture water-in-diesel (W/D) emulsions. Slowly, water was added to the mixture of diesel and emulsifying agent, which had been dissolved in the continuous phase. At room temperature (25–30), the emulsions were aggressively stirred with a typical three-blade propeller. To check for w/o or o/w emulsions, the prepared emulsions were utilized. Every emulsion that was studied belonged to the class of water-in-oil emulsions (oil continuous phase).

3.3 Fuel Consumption in Disc Plough and Cultivator

The result's shown in Table 3 that the tractor of 50 hp consumed maximum fuel on hourly basis at all the three load settings, because it was expected as this tractor had higher horsepower. Specific average fuel consumption in unploughed condition were 3.296 lit/hr and 16.08 lit/ha for disc plough and 3.416 lit/hr and 7.53 lit/ha for cultivator respectively. The results on fuel consumption are given in Table 3.

Table 1. Physical properties of the soil

Soil type	BD	PD	Porosity	pH	Moisture Content
Loam Soil	1.3 g/cm3	2.41 g/cm3	45.87%	7.37	25.31%

Table 2. Physical properties of the diesel fuel

Density at 20^{0}C, (Kg/m^3)	819.4
Dynamic viscosity at 20^{0}C, mPas	6.5
Surface tension at 20^{0}C (mN/m)	29.4
Flash point, ^{0}C	78
Initial boiling point, ^{0}C	174.5
Final boiling point, ^{0}C	380.3

Table 3. Fuel consumed by disk plough and cultivator

Replication	Disc plough			Cultivator		
	Fuel Consumption			Fuel Consumption		
	lit./0.5 acre	Lit/hr	Lit/ha	lit./0.5 acre	Lit/hr.	Lit/ha
1	3.2	3.245	15.84	1.5	3.383	7.42
2	3.25	3.362	16.08	1.55	3.446	7.67
3	3.3	3.281	16.33	1.52	3.42	7.52
Average	3.25	3.296	16.08	1.523	3.416	7.53

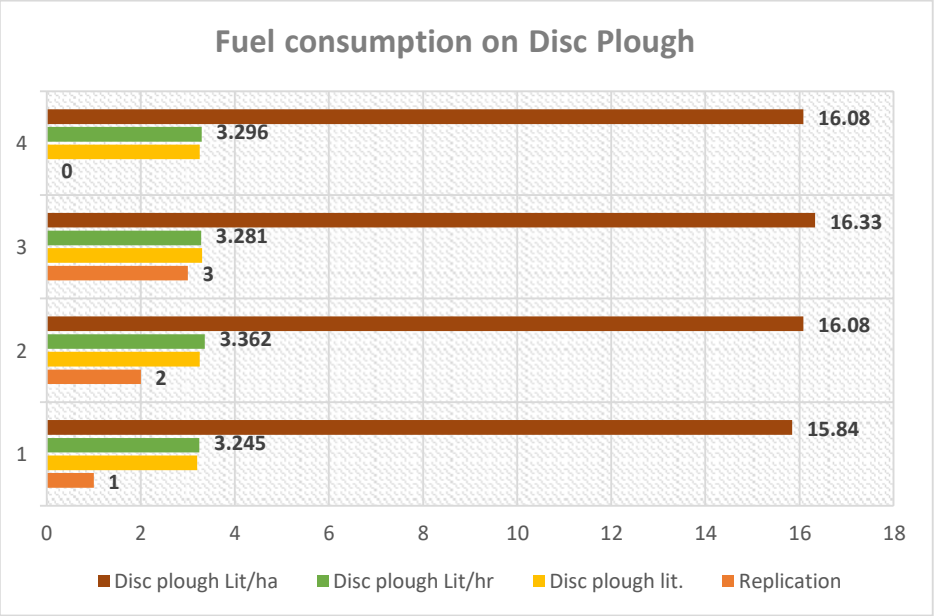

Fig. 1. Fuel consumption on Disc plough

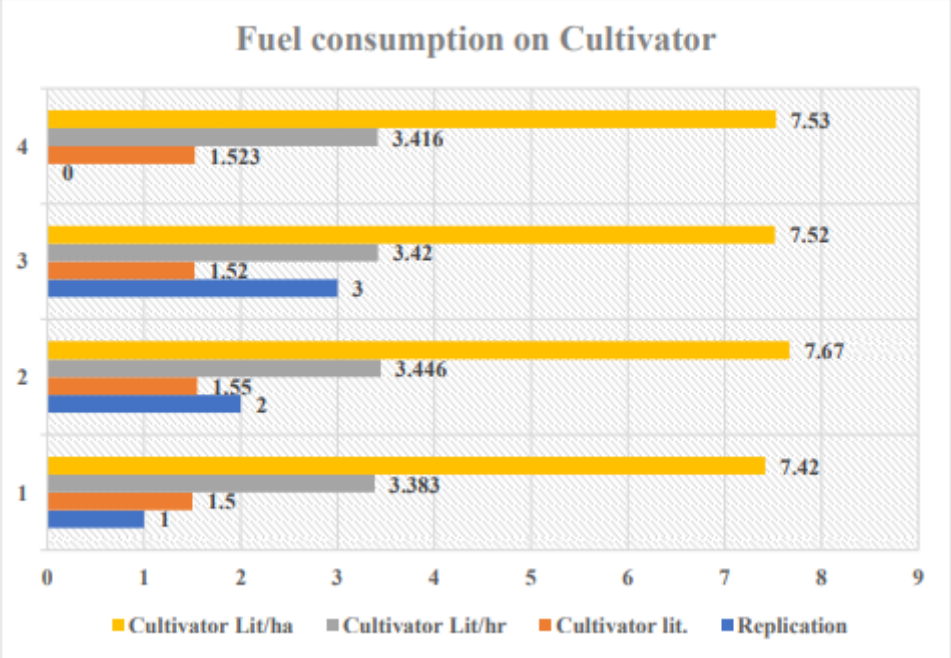

Fig. 2. Fuel consumption on Cultivator

3.4 Cost Calculation in Disc Plough and Cultivator

The results on cost of operation are given in Table 4. The cost of operation by each implement per hour and per hectare, total area of 0.0202-hectare area were tilled. The total cost were Rs. 1413.77/ha and Rs. 662.72/ha for disc plough cultivator respectively. The overall cost of operation was found less by cultivator as compare to disc plough.

3.5 Fuel Consumption Comparison between Disc Plough and Cultivator

In this Fig. 5 shown the results of fuel consumption, in liters/0.5 acre, liters/hours and liters/hectares were (3.25, 3.29 and 16.08) and (1.53, 3.41 and 7.53) for disk plough and cultivator respectively. The fuel consumption was found less by cultivator as compare to disc plough.

Table 4. Cost of operation by each implement per hour and per hectare

Implement	Area tilled (ha)	Cost of fuel/lit. Rs.	Fuel consumed lit/hr	Total cost Rs. /hr	Fuel consumed lit/ha	Total cost Rs. /ha
Disc plough	0.202	89.40	3.24	290.10	15.814	1413.77
Cultivator	0.202	89.40	3.38	302.44	7.413	662.72

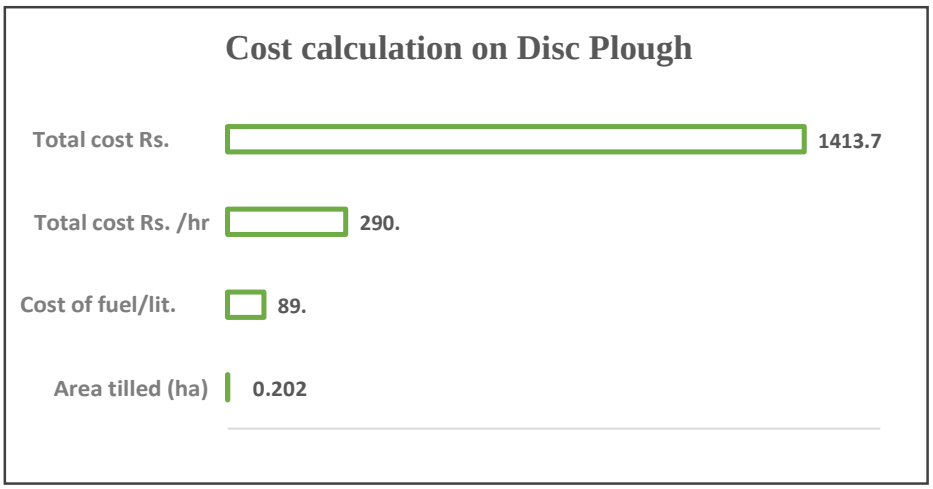

Fig. 3. Cost calculation on disc plough

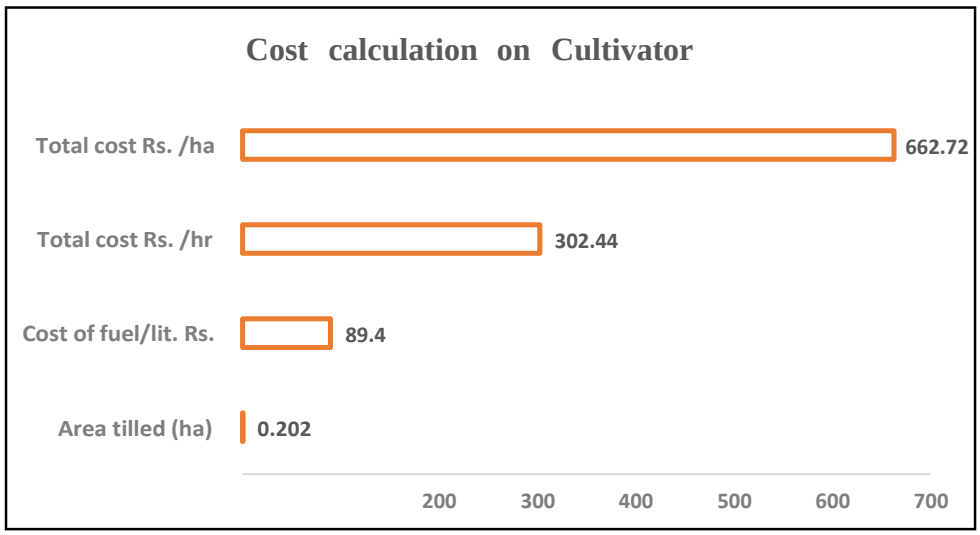

Fig. 4. Cost calculation on Cultivator

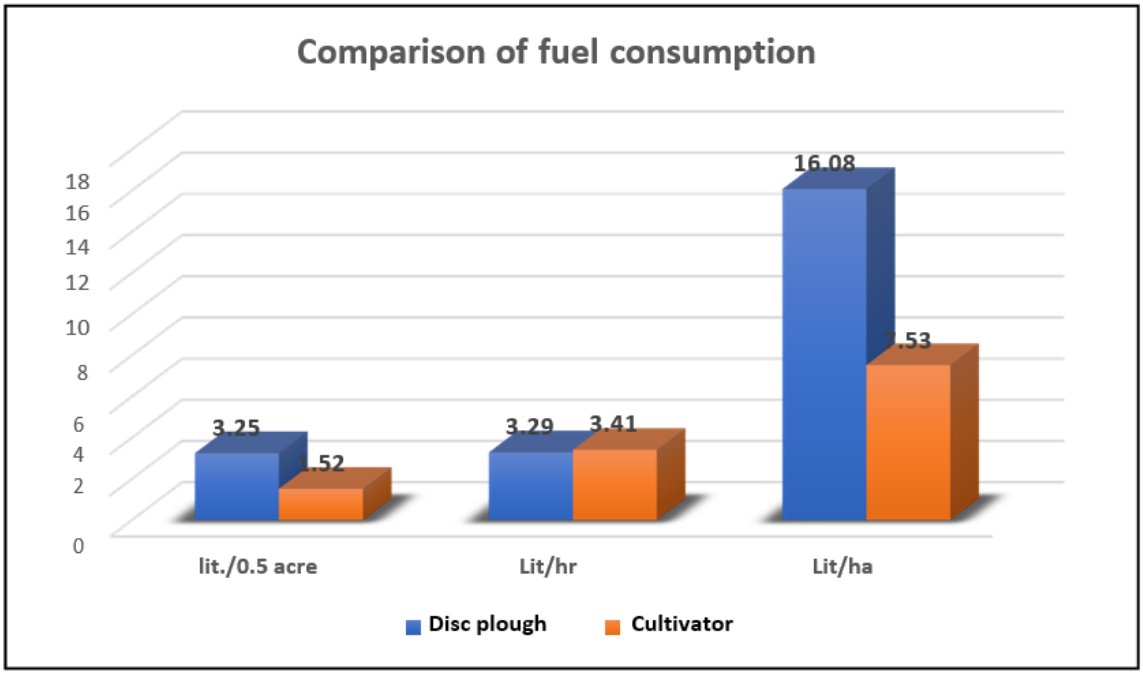

Fig. 5. Comparison of fuel consumption between disc plough and cultivator

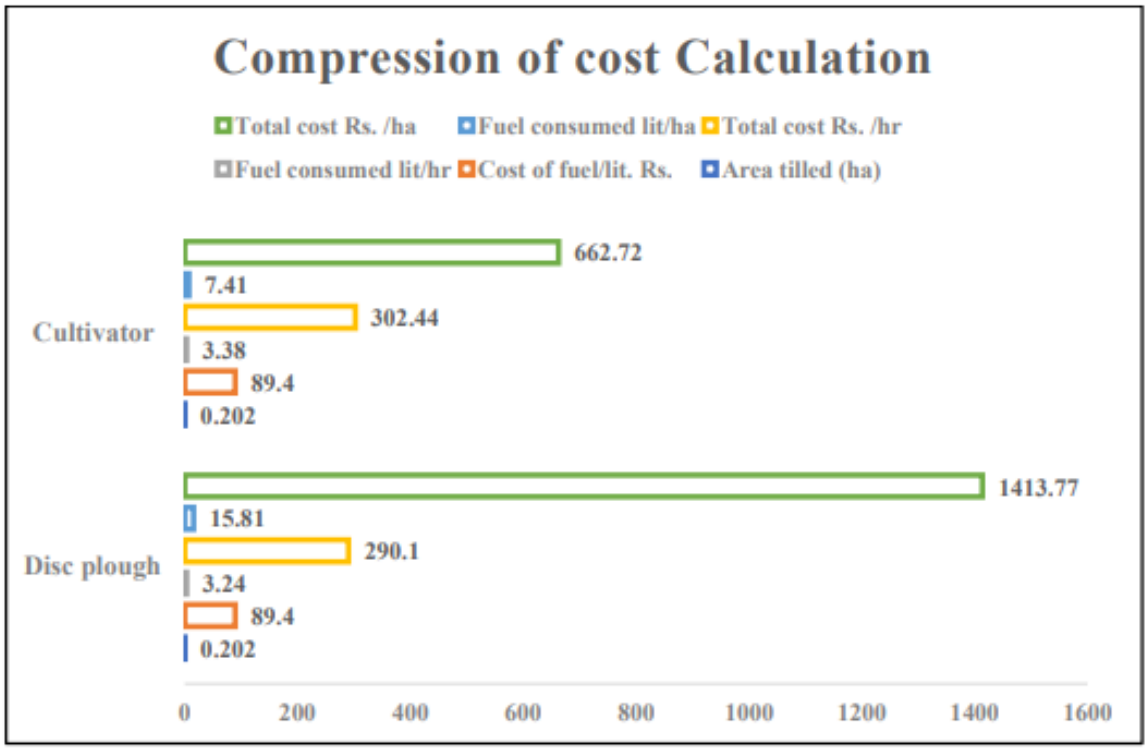

Fig. 6. Cost calculation consumption between disc plough and cultivator

3.6 Cost Calculation Comparison between Disc Plough and Cultivator

In this Fig. 6 shown the results on cost of operation are given in Table 4. The cost of operation by each implement per hour and per hectare, total area of 0.0202-hectare area were tilled. The total cost were Rs. 1413.77/ha and Rs. 662.72/ha for disc plough cultivator respectively. The overall cost of operation was found less by Cultivator as compare to disc plough.

4. CONCLUSION

The main objective of the experiment was to evaluate the fuel consumption and work performance of two different implement for determine the better performance and fuel economy with same brake horse power (41 hp) such implement are disc plough and cultivator. The performance was evaluated on tilled soil for secondary tillage implement.

The operation was evaluated at 8 kmph for cultivator and 9 kmph for disc plough speed and throttle position for cultivator was 1800 and disc plough was 2000, thus the cultivator was found most economical to be operated with 50 hp tractor for secondary tillage operation maximum fuel consumption with cultivator was 7.53 lit/ha and 16.08 lit/ha and cost of operation to operate 0.0202 ha land was 89.4 Rs/lit fuel with 12 cm and 15 cm depth of ploughing respectively cultivator and disc plough.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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