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Performance evaluation of tractor drawn standard disc plough for Indian farms

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Abstract
The tillage operations are the most important for a good crop production. In India most of the farmers using a most popular implement of standard disc plough. A study was conducted by accessing the evaluation of standard disc plough at three different engine speeds, such as 1500, 2000 and 2500 rpm with the following parameter, such as theoretical field capacity, effective field capacity, field efficiency, fuel consumption, draft and wheel slip was considered for evaluation of the implement. The obtained results shows that a lower speed of 3.2 km/h at 1500 rpm to 5.2 km/h at 2500 rpm as high speed. The theoretical field capacity was increased form 0.18 ha/h to 0.32 ha/h, however effective field capacity observed as lowest 0.13 ha/h and being highest as 0.24 ha/h, based on this field capacities a higher field efficiency of 76.9% was reported at 2000 rpm. The fuel consumption also reported as the engine speed rises, which leads to high fuel consumption, lower as 3.5 L/h at 1500 rpm and higher as 6.8 L/h at 2500 rpm. The draft at 1500 rpm reported as 10.5 kN and at 2500 rpm as 13.7 kN, the draft not only depends on the speed, but it largely depends on depth of ploughing and soil conditions. Based on the study the engine speeds shows a significant effect on performance of tractor drawn standard disc plough. A speed of 2000 rpm suggested for best speed for field efficiency, fuel consumption and economy.

Keywords: Tractor, standard disc plough, actual field capacity, field efficiency and fuel consumption

Introduction
Tillage is classified as one of the simplest and extremely important ploughing operation among entire agricultural field operations. To prepare a good quality seedbed a precise and advanced equipment and machinery are required, during the process of seedbed preparation the braking of upper layer of soil horizon, few farmers are added granular fertilizers during the field preparation to mix thoroughly, this process makes soil to fertile, weed control can also be achieved simultaneously. The process of tillage greatly enhances the porosity and voids space in soil, which supports the crop growth and development by proper aeration and water holding capacity (Hendrick and Gill, 1971a; Hendrick and Gill, 1971b; Du *et al*., 2021). The disc plough is one of the very important primary tillage equipment, it will cut, lift the soil, invert the soil and makes little pulverizing and mix the soil.
The labour availability during the peak season is very difficult and the agricultural operation by labour and draft animals are time consuming and leads to more expensive, the mould board plough is important mechanized agricultural equipment it can perform tasks which will helps significantly reduce them labour shortage and save time. They are some estimations that a 70% of farm power was consumed by tillage operation. Right selection, matching and use of machinery or equipment reduces the overall operating cost, if mould board plough are used properly, it will increase the field efficiency and reduces the operating cost their by a little increasing profit of farmers by reducing overall production cost.
Farm power availability by human was only 0.091 kW/ha in 2016-17 and for draught animal it was decreased from 0.221 kW/ha in 1971-72 to 0.130 kW/ha (Mehta *et al*., 2019) [9]. Over the decades the farm equipment and machinery usage was increased as result the average farm power availability has significantly raised from 0.30 kW/ha in 1960-61 to 2.02 kW/ha in 2013-14 (Surendra Singh *et al.*, 2014). (Kanth *et al*., 2024) [13, 27] was analyzed the trends and patterns of farm mechanization in India. (Rahaman *et al*., 2025) [29] Addressed various factors which are affecting mechanization index and farm power availability. The maintenance cost for draught animals and as well as the daily paying amount for agricultural workers has increased, identifying the need of further mechanization, it includes two main benefits of mechanization need to follow, firstly intime field operations are essential for coordinating with crop calendars and secondly high quality work, which leads to improved soil structure for better plant growth.
Indian agriculture fields are small and scatter land holdings, which have boundaries to economic feasibility of advanced machinery adaption or usage for mechanization increment. A tractor drawn mould board plough is the viable option under these circumstances. It is most appropriate and feasible for small and medium holding farmers because simple design and easy to use it, high functional efficiency. (Rahaman *et al*., 2024) [30] Studied economic analysis and feasibility of self-propelled rotor power weeder. (Kanth *et al*., 2024) [27] Was studied various precision agriculture techniques and technologies.
However, operation of standard disc plough somewhat difficult in Vertisols, because it is heavy black soils with clay percentage of various moisture conditions. An advanced and specialized equipment or machinery are needed for active tillage in diversified soil conditions (Kepner *et al*., 1978 [5]; Kumar *et al*., 2023a; Kumar *et al*., 2023b; Du *et al*., 2021; Kankal *et al*., 2016) [4, 15]. A performance of a tractor drawn Standard Disc Plough was evaluated at the Aditya University, Agricultural Field Laboratory, Surampalem, aiming to assess field performance parameters such as field capacity, field efficiency and fuel consumption in the view of suitability to small and medium farms with efficient conditions.

Materials and Methods

1. Working principle of tractor standard disc plough

The working principle of tractor drawn standard disc plough takes place in 4 stages such as cutting, lifting, turning and inversion, soil pulverization and covering. The disc of the concave cuts the soil due to its suction and penetrates into soil, next stage soil lift along the length of concave surface, there after the soil turned aside and inverted due to its disc angle and in the last stage the soil broken and pulverized partially.

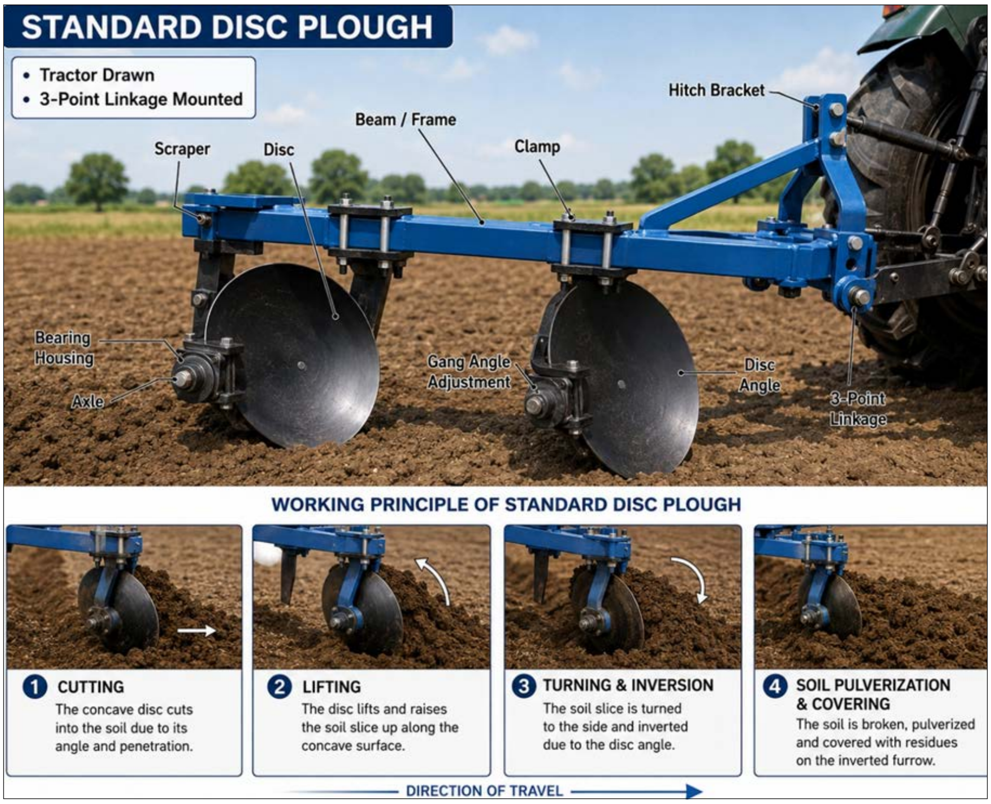

Fig 1: Working Principle and components of Standard Disc Plough

Table 1: Particulars of Tractor Drawn Standard Disc Plough

S. No	Component and Material	Specifications
1.	Number of Discs	2 – 3
2.	Type of Plough	Tractor drawn standard disc plough
3.	Overall Working Width	600 – 900 mm
4.	Disc Diameter	600 – 750 mm
5.	Number of Furrows	2 – 3 furrows
6.	Furrow Width per Disc	300 – 450 mm
7.	Furrow Depth	150 – 300 mm
8.	Disc Spacing	450 – 600 mm
9.	Frame Type	Heavy duty tubular / box frame
10.	Frame Material	Mild steel (MS)
11.	Disc Type	Concave standard disc
12.	Disc Material	High carbon steel / boron steel
13.	Disc Thickness	6 – 8 mm
14.	Bearing Type	Taper roller / anti-friction bearings
15.	Scraper Type	Adjustable scraper
16.	Scraper Material	Mild steel / wear-resistant steel
17.	Standard of Hitching	3-point linkage (Category II)
18.	Hitching System	Tractor mounted / tractor drawn
19.	Clearance (Under Frame)	600 – 700 mm
20.	Weight (approx.)	450 – 650 kg
21.	Power Requirement	45 – 65 hp
22.	Field Capacity (approx.)	0.25 – 0.50 ha/h
23.	Field Efficiency	70 – 85 %
24.	Soil Suitability	Hard, dry, sticky and stony soils
25.	Working Speed	4 – 6 km/h
26.	Draft Requirement	10 – 16 kN (approx.)
27.	Disc Angle	40° – 45°
28.	Tilt Angle	15° – 25°
29.	Application	Primary tillage, deep ploughing, soil pulverization, trash burial and land preparation

2. Performance evaluation of tractor drawn standard disc plough

The performance evaluation of tractor drawn standard disc plough is important to know the theoretical field capacity, effective field capacity, field efficiency and fuel consumption with respect to the varied engine speeds such as 1500, 2000 and 2500 rpm and data was replicated three times. This assessment was necessary for every implement, equipment and machinery for suitability to type of soil, crop and size of farm for best use of resources which leads to save crop production cost for farmers. The numerical formulas for the evaluation of standard disc plough were presented in the following sub-sections.

2.1 Field efficiency

Field efficiency (F_e) defined as ratio of Actual to theoretical field capacity and expressed as a percentage. It was calculated using Eq.1**.** (Nagesh *et al.*, 2014) [10].

$$\text{Field efficiency (\%)} = \frac{\text{A.F.C}}{\text{T.F.C}} \times 100 \qquad \text{... (1)}$$

Where, A.F.C = Actual field capacity, ha/h and T.F.C = Theoretical field capacity, ha/h.

2.2 Theoretical Field Capacity

Theoretical field capacity is calculated by using Eq.2. (Patange *et al*., 2015) [11]. The standard disc plough width was considered as 1 m.

$$\text{TFC (ha/h)} = \frac{S \times W}{10} \qquad \text{... (2)}$$

Where, S = Forward speed, km/h and W = Width of the implement, m

2.3 Actual Field Capacity

Actual field capacity is usually expressed as hectare per hour. It is calculated by using Eq.3. (Manjunatha *et al.*, 2014) [8].

$$\text{AFC (ha/h)} = \frac{A}{T_P + T_{NP}} \qquad \text{... (3)}$$

Where, A = Area of coverage, ha T_P = Productive time, h and T_{NP} = Non-productive time, h.

2.4 Fuel consumption

Fuel consumption (F_t) measured by top-fill method. Firstly, fuel tank is filled to its full capacity before testing on levelled surface. After the test, amount of fuel required to re-fill the tank gives amount fuel consumption for given test run and it is expressed in litre per hour. Fuel consumption is calculated by using Eq.4. (Raghavendra *et al.*, 2013) [12].

$$\text{Fuel consumption (L/h)} = \frac{V}{t} \qquad \text{...(4)}$$

Where, V = Volume of fuel consumed, L and t = Total operating time, h

2.5 Draft

The draft of Standard Disc Plough was calculated by amount of pull required to run the implement to the area required to cover by the implement. The draft is calculated by using the Eq.5.

$$\text{Draft} = \frac{\text{Pull}}{\text{Area}} \qquad \text{...(5)}$$

2.6 Wheel slip

Wheel Slip is important parameter, it occurs when the drive wheel rotates faster than the tractor forward speed, it results in the lowering the performance of the implement. The wheel sleep is calculated by using the Eq.6.

$$\text{Wheel slip} = \frac{N_1 - N_2}{N_1} \times 100 \qquad \text{...(6)}$$

Where

N_1 = Speed at no load condition

N_2 = Speed at load condition

Results and Discussion

1. Performance evaluation of tractor drawn standard disc plough

After the experimental data collected for three different engine speeds such as 1500, 2000 and 2500 rpm, it was calculated by using standard formulas, analyzed and presented with graphical representation. Table 2 displays the results of calculations for important operational characteristics, including field efficiency, theoretical field capacity (TFC), actual field capacity (AFC), fuel consumption, draft and wheel sleep.

Table 2: The calculated performance parameters of the tractor drawn standard disc plough

Engine Speed: 1500 rpm								
Observation Number	**Speed (km/h)**	**TFC (ha/h)**	**AFC (ha/h)**	**Efficiency (%)**	**Fuel (L/h)**	**Draft (kN)**	**Slip (%)**	**Depth (cm)**
1	3.0	0.18	0.13	72.2	3.5	10.2	11	20
2	3.1	0.19	0.14	73.7	3.6	10.4	10	21
3	3.2	0.20	0.15	75.0	3.7	10.5	9	21
Engine Speed: 2000 rpm								
1	4.0	0.24	0.18	75.0	4.8	11.5	12	22
2	4.2	0.25	0.19	76.0	5.0	11.8	11	23
3	4.3	0.26	0.20	76.9	5.1	12.0	10	23
Engine Speed: 2500 rpm								
1	5.0	0.30	0.22	73.3	6.5	13.2	15	24
2	5.2	0.31	0.23	74.2	6.7	13.5	14	24
3	5.3	0.32	0.24	75.0	6.8	13.7	13	25

1.1 Effect of engine speed on field capacity

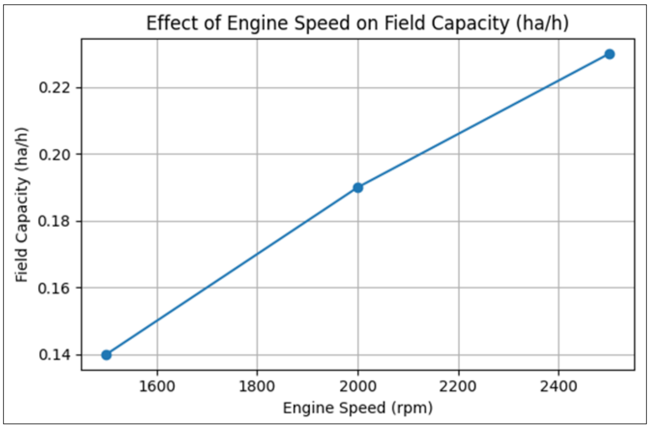

Fig 2: Effect of engine speed on field capacity

The graphical representation (Figure 2) clearly shows that a parallel in increasing of field capacity with increasing engine speeds. If was observed that at 1500 rpm field capacity are low due to reduced forward speed, it was reached to 2000 rpm, a significant improvement was observed for both parameters and at engine speed 2500 rpm, a very high field capacities noticed. The forward speed and field capacities showcased the functional relationship with liner increasing trend. Operating at higher speeds resulted in more coverage area. The theoretical field capacity increases with increasing speed, however effective field capacity showcased slower rate of increment when compared to theoretical field capacity, this is because of turning losses, overlaps and time lost during field for adjustments etc. the similar find of results were reported by Abbaspour Gilandeh *et al*. (2022) [31].

1.2 Effect of engine speed on field efficiency

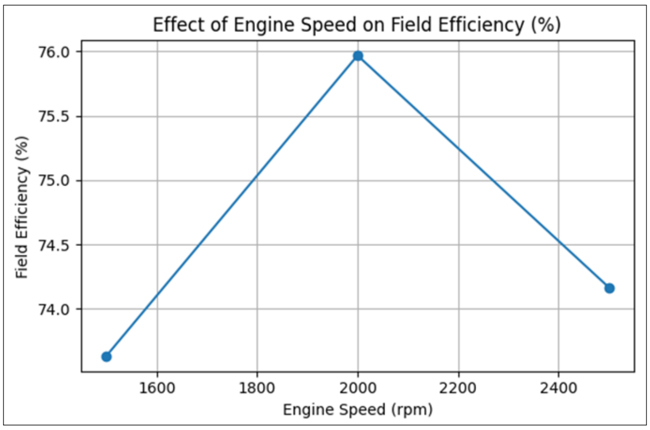

Fig 3: Effect of engine speed on field efficiency

The field efficiency is a important parameter to represent the field performance of the implement, From the above figure 2 it was shown that a increased field efficiency was observed if the engine rpm increasing from 1500 to 2000 rpm, however it was noticed at declining trend at engine rpm of 2500. At a engine 2000 rpm indicated as recommended speed as the higher field efficiency noticed. The higher efficiency reported due to the more engine performance due to the reduced ideal time which leads to more efficiency at engine speed of 1500 to 2000 rpm, on the other hand higher speed 2500 rpm, the efficiency declined due to increased wheel slip, turning losses and overlaps in the field condition, all this factors leads to drop the field efficiency. The similar kind of findings were reported by Kim *et al*. (2020) [32].

1.3 Effect of engine speed on fuel consumption

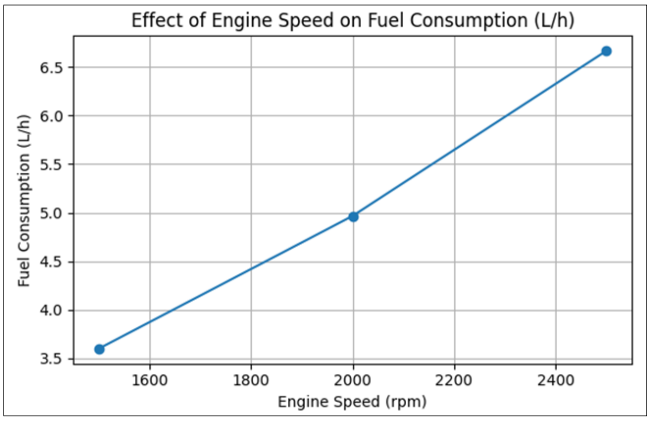

Fig 4: Effect of engine speed on fuel consumption

The below graphical representation (Figure 4) depicts the three different engine speeds with respect to fuel consumption for the operation. The fuel consumption is the important parameter for most of the field implements in the economic point of view. The results showcased the extremely positive linear relationship between engine speed and fuel consumption. The increase in fuel consumption with rpm is expected due to higher combustion frequency and increased load on the engine. When the tool interacts with soil, resistance increases slightly at higher speeds which results in more fuel consumption. Field capacity goes up a lot when speed increases, which means it takes time to cover one hectare. Because of this fuel consumption per hectare does not go up much as you might think and might still make sense for farmers at somewhat higher speeds. This is really important for farmers who want to keep their costs down. They can use this information to make choices about how to run their operations. It is all, about finding that spot where speed and fuel use balance out. A significant and constant increase of fuel consumption with increase of engine speed, however the lowest and highest fuel consumption reported at 1500 and 2500 rpm respectively. The similar findings were reported by Damanauskas and Janulevičius (2023) [33].

1.4 Effect of engine speed on draft

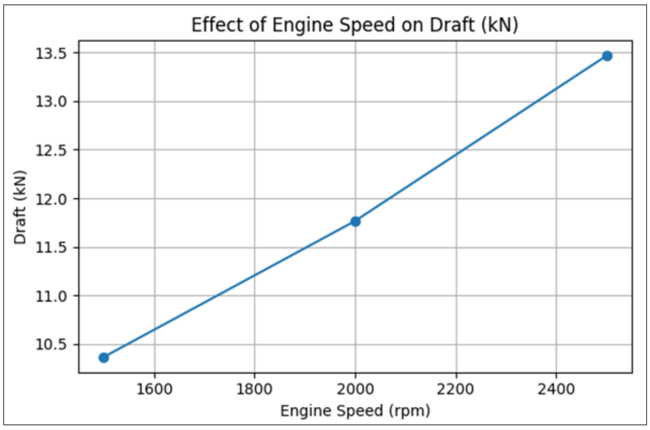

Fig 5: Effect of engine speed on draft

Draft is the most important factor for tillage implements, it is directly related to resistance of soil offered to implement. The above figure 3.4 represents the draft increases as the engine rpm rises, lowest reported at 1500 rpm and highest being reported at 2500 rpm. At the higher speeds develops a more draft Which enable implement to penetrate more deeply, makes the soil to brake and little pulverized. Wang *et al* (2026) [35] working on soil-tool interaction and reported the draft increases with speed.

1.5 Effect of engine speed on wheel slip

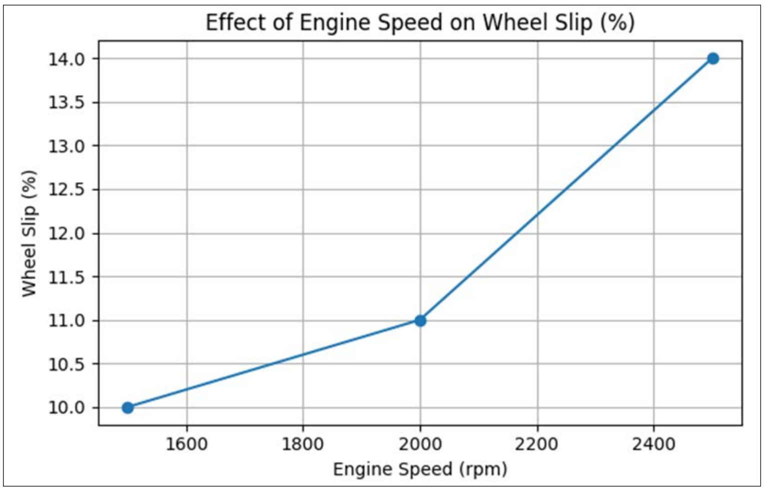

Fig 6: Effect of engine speed on wheel slip

The wheel slip is very critical parameter, indirectly if effect the all the performance parameters. The above graphical representation (Figure 6) depicts the as the engine speed increases the wheel slip also increases. A very high wheel slip was observed at 2500 rpm and at lower speed 1500 rpm a acceptable range of wheel slip reported with traction between soil and tool, as which will enable the sufficient power utilization, on the other hand a greater slippage was observed at maximum speed of 2500 rpm, which results in the loss of power and inefficient usage. A similar results were reported by Kim *et al*. (2020) [32].

Table 2: ANOVA for significance of engine speed vs field efficiency and fuel consumption

Field parameter	Field Efficiency				Fuel Consumption		
Source of Variation	**df**	**SS**	**MS**	**F-value**	**SS**	**MS**	**F-value**
Treatments (RPM)	2	8.969	4.484	3.747	14.162	7.081	374.882
Error	6	7.180	1.197		0.113	0.019	
Total	8	16.149			14.276		

Table 3: ANOVA for significance of engine speed vs draft and wheel slip

Field parameter	Draft				wheel slip		
Source of Variation	**df**	**SS**	**MS**	**F-value**	**SS**	**MS**	**F-value**
Treatments (RPM)	2	14.460	7.230	144.60	26.000	13.000	13.00
Error	6	0.300	0.050		6.000	1.000	
Total	8	14.760			32.000		

Table 4: ANOVA Table of Significance

Parameter	F-value	Significance (5%)	Critical F-value (α = 0.05, df = 2,6) = 5.14
Field Efficiency	3.747	NS	F > 5.14 → Significant F < 5.14 → Not Significant (NS)
Fuel Consumption	374.882	Significant	
Draft	144.600	Significant	
Wheel Slip	13.000	Significant	

The results obtained from ANOVA test shows the significant effect of different engines speeds with respect to all the performance parameters of tractor drawn standard disc plough. The field efficiency, fuel consumption, draft and wheel slip shows the significant effect. The maximum field efficiency was noted at 2000 rpm, it indicates that operating a implement at medium speeds gives the best results. A higher fuel consumption reported at 2500 rpm, but it will increase the operating cost, running at lower will results in the inefficient power transfer to carry out the ploughing operation, so it advised to run on medium recommended speed for fuel and economical bases. A wheel slip also reported the significant effect with increasing of engine speed, however a reduced speed makes less wheel slip percentage, which is recommended to carry out the best results with implements in the field conditions. The draft reported the higher speed generates the more soil resistance for the field operations. The interpretation of the results was drawn from the statistical analysis of ANOVA test was given in the following. The F-calculated value of field efficiency was 3.747. The effect of speed on field efficiency was not significant at 5% level, F0.05(2,6) = 5.14. However the remaining parameters such as fuel consumption, draft and wheel sleep shows the highly significant at 5% level of F-values 374.88, 144.60 and 13.00 respectively.

Conclusion

The performance assessment of tractor drawn standard disc plough was significantly influenced by different engine speeds. The theoretical field capacity was increased form 0.18 ha/h to 0.32 ha/h, however effective field capacity observed as lowest 0.13 ha/h and being highest as 0.24 ha/h, based on this field capacities a higher field efficiency of 76.9% was reported at 2000 rpm. The fuel consumption also reported as the engine speed rises, which leads to high fuel consumption, lower as 3.5 L/h at 1500 rpm and higher as 6.8 L/h at 2500 rpm. The draft at 1500 rpm reported as 10.5 kN and at 2500 rpm as 13.7 kN, the draft not only depends on the speed, but it largely depends on depth of ploughing and soil conditions. Based on the study the engine speeds shows a significant effect on performance of tractor drawn standard disc plough. A speed of 2000 rpm suggested for best speed for field efficiency, fuel consumption and economy.

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Competing Interests

The author have declared no conflict of interests exist.

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