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# Performance evaluation of tractor drawn 2-Bottom mould board plough for field crops

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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 2-botom mould board plough (2-Bottom MB plough). A study was conducted by accessing the evaluation of 2-botom mould board plough at three different engine speeds, such as 1500, 2000 and 2500 rpm, 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 0.9 ha/h to 0.31 ha/h, however aeffective field capacity observed as lowest 0.14 ha/h and being highest as 0.23 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 3.2 L/h at 1500 rpm and higher as 6.3 L/h at 2500 rpm. The draft at 1500 rpm reported as 8.5 kN and at 2500 rpm as 10.6 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 2-bottom mould board plough. A speed of 2000 rpm suggested for best speed for field efficiency, fuel consumption and economy.

**Keywords:** Tractor, 2-bottom mould board 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 mould board plough is one of the very important primary tillage equipment, it will make horizontal 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 an 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). 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) was analyzed the trends and patterns of farm mechanization in India. (Rahaman *et al*., 2025) 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) studied economic analysis and feasibility of self-propelled rotor power weeder. (Kanth *et al*., 2024) was studied various precision agriculture techniques and technologies.

However, operation of mould board 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; Kumar *et al*., 2023a; Kumar *et al*., 2023b; Du *et al*., 2021; Kankal *et al*., 2016). A performance of a tractor drawn 2-bottom mould board 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 mould board plough**

The working principle of tractor drawn MB Plough takes place in 4 stages such as cutting, lifting and pulverizing the soil to obtain the seedbed. In the first step share inserted into the soil and makes a horizontal cut, a vertical cut generated by the coulter ahead of the share. The mould board lifts the soil and moves along the length of curvature of mould board and makes the inversion of the soil, a minor pulverization takes place during the inversion process.

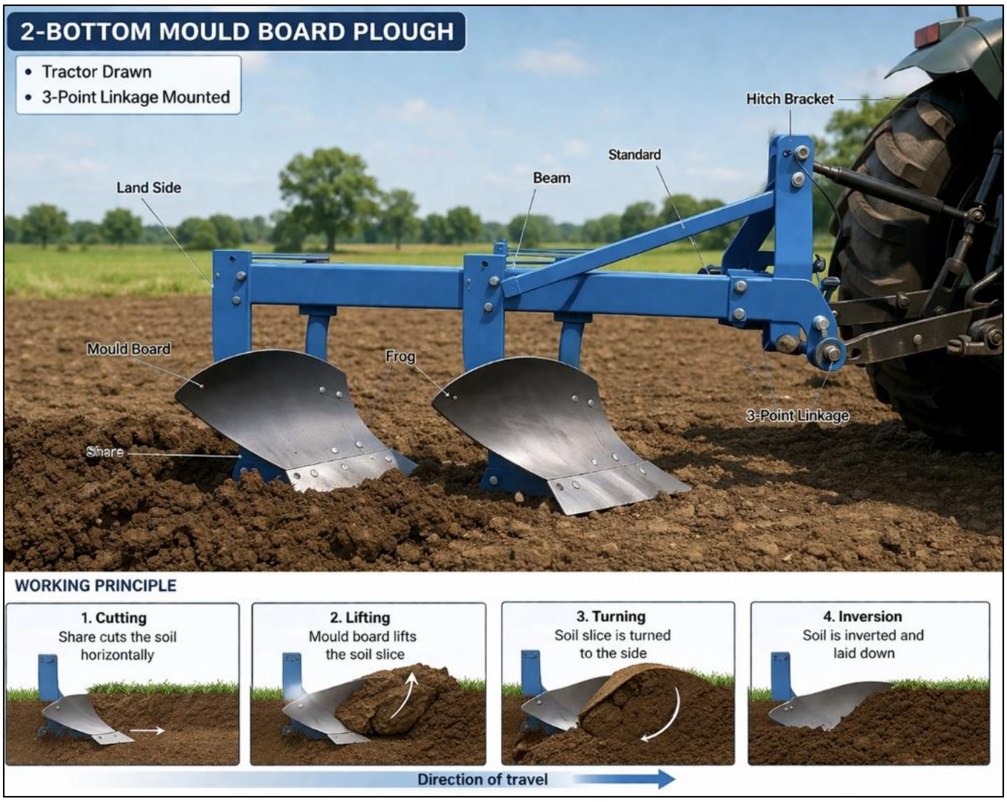


**Fig 1:** Working Principle of 2-Bottom Mould Board Plough

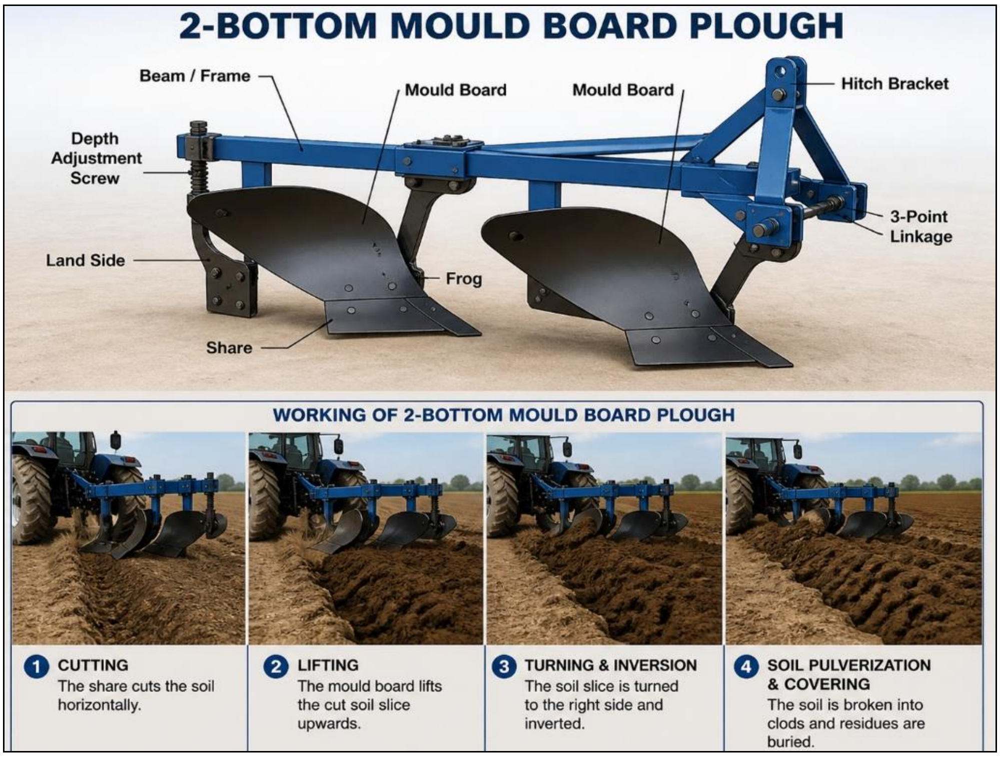


**Fig 2:** Components of 2-Bottom Mould Board Plough

**Table 1:** Particulars of Tractor Drawn 2-Bottom Mould Board Plough

| S. No | Component and Material | Specifications |
|---|---|---|
| 1. | Number of Bottoms | 2 |
| 2. | Type of Plough | Mounted mould board plough |
| 3. | Overall Working Width | 600 – 750 mm |
| 4. | Furrow Width per Bottom | 300 – 350 mm |
| 5. | Furrow Depth | 150 – 250 mm |
| 6. | Bottom Spacing (Inter-body) | 300 – 400 mm |
| 7. | Frame Type | Heavy duty box / tubular frame |
| 8. | Frame Material | Mild steel (MS) |
| 9. | Mould Board Type | General purpose / semi-digger |
| 10. | Mould Board Material | High carbon steel / alloy steel |
| 11. | Share Type | Replaceable share (bar point / slip share) |
| 12. | Share Material | High carbon steel |
| 13. | Landside Material | Wear-resistant steel |
| 14. | Coulter Type | Disc / knife type (optional) |
| 15. | Standard of Hitching | 3-point linkage (Category II) |
| 16. | Hitching System | Tractor mounted |
| 17. | Clearance (Under Frame) | 500 – 600 mm |
| 18. | Weight (approx.) | 400 – 500 kg |
| 19. | Power Requirement | 35 – 50 hp |
| 20. | Field Capacity (approx.) | 0.20 – 0.40 ha/h |
| 21. | Field Efficiency | 70 – 85 % |
| 22. | Soil Suitability | Medium to heavy soils |
| 23. | Working Speed | 3 – 5 km/h |
| 24. | Draft Requirement | 8 – 12 kN (approx.) |
| 25. | Application | Primary tillage, soil inversion, weed burial |

## 2. Performance evaluation of tractor drawn mould board plough

The performance evaluation of tractor drawn mould board 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 mould board 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).

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

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). The mould board 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).

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

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).

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

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

### 2.5 Draft

The draft of 2-Bottom Mould Board 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 2-Bottom Mould Board 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 2-bottom mould board plough

| Observation Number | Speed (km/h) | TFC (ha/h) | AFC (ha/h) | Efficiency (%) | Fuel (L/h) | Draft (kN) | Slip (%) | Depth (cm) |
|---|---|---|---|---|---|---|---|---|
| **Engine Speed: 1500 rpm** | | | | | | | | |
| 1 | 3.2 | 0.19 | 0.14 | 73.7 | 3.2 | 8.5 | 10 | 18 |
| 2 | 3.1 | 0.18 | 0.13 | 72.2 | 3.1 | 8.3 | 11 | 17 |
| 3 | 3.3 | 0.20 | 0.15 | 75.0 | 3.3 | 8.6 | 9 | 18 |
| Engine Speed: 2000 rpm | | | | | | | | |
| 1 | 4.2 | 0.25 | 0.19 | 76.0 | 4.5 | 9.2 | 12 | 19 |
| 2 | 4.0 | 0.24 | 0.18 | 75.0 | 4.3 | 9.0 | 13 | 18 |
| 3 | 4.3 | 0.26 | 0.20 | 76.9 | 4.6 | 9.3 | 11 | 19 |
| Engine Speed: 2500 rpm | | | | | | | | |
| 1 | 5.2 | 0.31 | 0.23 | 74.2 | 6.2 | 10.5 | 15 | 20 |
| 2 | 5.0 | 0.30 | 0.22 | 73.3 | 6.0 | 10.2 | 16 | 19 |
| 3 | 5.3 | 0.32 | 0.24 | 75.0 | 6.3 | 10.6 | 14 | 20 |

## 1.1 Effect of engine speed on field capacity

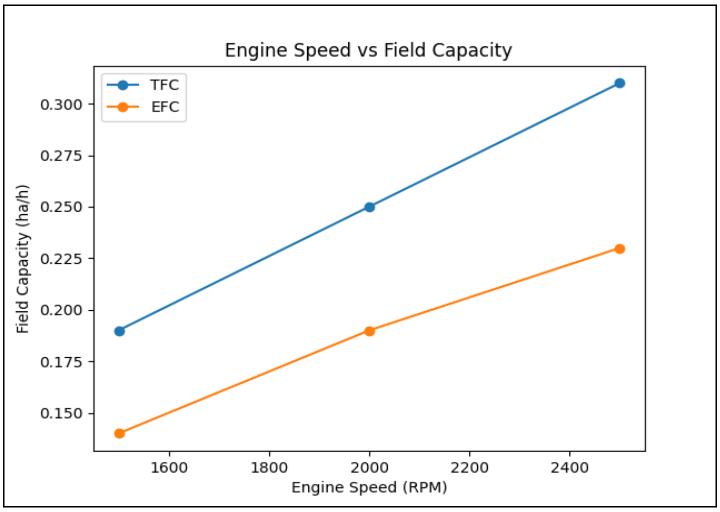


**Fig 1:** Effect of engine speed on field capacity

The graphical representation (Fig 1) clearly shows that a parallel in increasing of both the theoretical and effective field capacity with increasing engine speeds. If was observed that at 1500 rpm both theoretical and effective 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).

## 1.2 Effect of engine speed on field efficiency

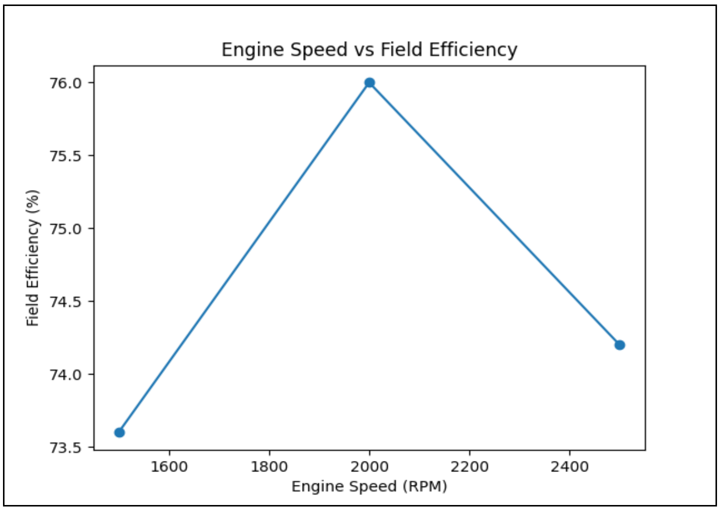


**Fig 2:** Effect of engine speed on field efficiency

The field efficiency is a important parameter to represent the field performance of the implement, From the above Fig 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).

### 1.3 Effect of engine speed on fuel consumption

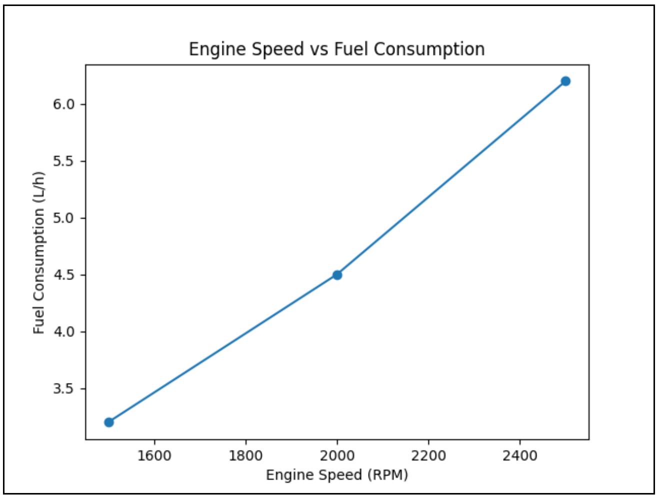


**Fig 3:** Effect of engine speed on fuel consumption

The below graphical representation (Fig 3) depicts the three different engine speeds with respect to fuel consumption for the operation. The fuel consumption is the important parameter for the 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).

### 1.4 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 Fig 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) working on soil-tool interaction and reported the draft increases with speed.

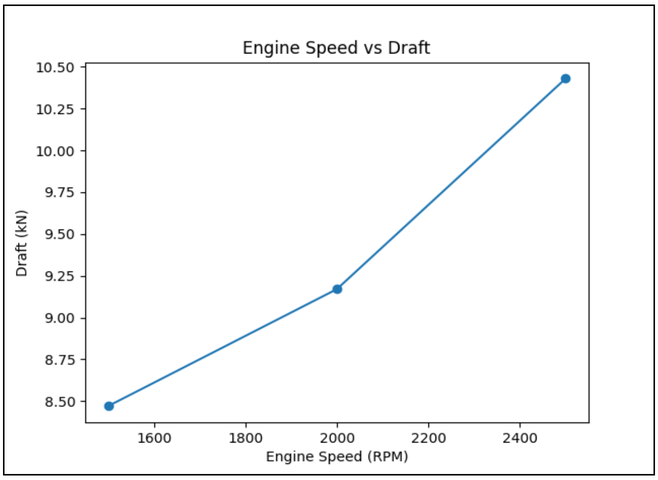


**Fig 4:** Effect of engine speed on draft

### 1.5 Effect of engine speed on wheel slip

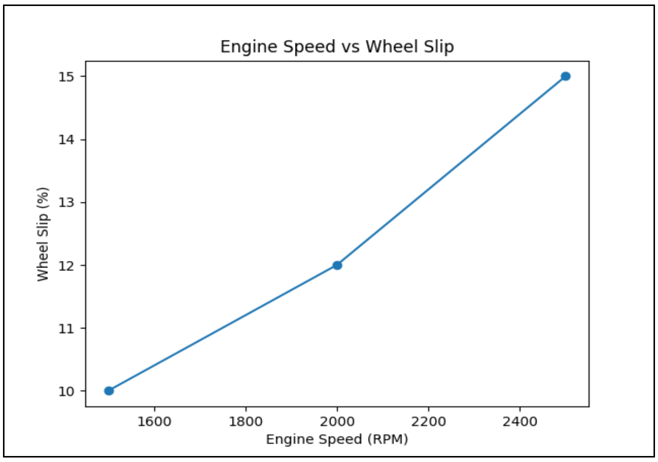


**Fig 5:** Effect of engine speed on wheel slip

The wheel slip is very critical parameter, indirectly if effect the all the performance parameters. The above graphical representation (Fig 5) 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).

**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** | **SS** | **MS** | **F** |
| Treatments (RPM) | 2 | 18.24 | 9.12 | 12.67 | 9.86 | 4.93 | 48.12 |
| Error | 6 | 4.32 | 0.72 | - | 0.61 | 0.10 | - |
| Total | 8 | 22.56 | - | - | 10.47 | - | - |

**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** | **SS** | **MS** | **F** |
| Treatments (RPM) | 2 | 6.74 | 3.37 | 21.45 | 38.0 | 19.0 | 31.67 |
| Error | 6 | 0.94 | 0.16 | - | 3.6 | 0.60 | - |
| Total | 8 | 7.68 | - | - | 41.6 | - | - |

The results obtained from ANOVA test shows the significant effect of different engines speeds with respect to all the performance parameters of tractor drawn 2-bottom mould board 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.

## Conclusion

The performance assessment of tractor drawn 2-bottom mould board plough was significantly influenced by different engine speeds. The theoretical field capacity was increased form 0.9 ha/h to 0.31 ha/h, however a effective field capacity observed as lowest 0.14 ha/h and being highest as 0.23 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 3.2 L/h at 1500 rpm and higher as 6.3 L/h at 2500 rpm. The draft at 1500 rpm reported as 8.5 kN and at 2500 rpm as 10.6 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 2-bottom mould board plough. A speed of 2000 rpm suggested for best speed for field efficiency, fuel consumption and economy. The maximum field capacity was reported at 2500 rpm, at this corresponding speed resulted in a high fuel consumption and also high wheel sleep. However running a tractor at 2000 rpm was noted to be best performance with recommended fuel economy and field efficiency.

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## Competing Interests

The author have declared no conflict of interests exist.

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