5.1 Introduction

The comparative performance assessment of different lugs through soil bin test is presented in the previous Chapter. The better performance of larger size split lugs could be seen from the soil bin test. As discussed earlier, the soil-bin test was conducted simulating the operation of longitudinal half of power tiller using soil compacted in bin. However, to examine the validity of soil bin test results, appropriate field testing was planned and procedure and results are discussed in this Chapter as below.

The cage wheel fitted with six different newly designed lugs (S8, S12, S16, NS8, NS12 and NS16) were tested in the field using a commercially available power tiller. The field testing of two lugs (S27 and NS27) could not be performed due to certain unavoidable technical issues arose during testing. Due to larger size of lugs (S27 and NS27), it was obstructed while fitting on the cage wheel used for field test. The spokes and lug mounting bars of the cage wheel required to be rearranged. For this fabrication of another cage wheel was required, which could not be done due to time limit. This may be considered as one limitation of this work. However, the field testing of two different designed lugs (split and non-split) having three different surface areas were evaluated in the field to know the trend of performance.

Power tiller is a single axle walking type small tractor primarily used as a source of power to prepare seed bed with rotary tillers. Power tillers are mainly used by the small farmers for land preparation in dry as well as wetland cultivation. Power tiller produces a low draft because of the small wheel size and low machine weight. The weight of the machine to power ratio in agricultural tractors also affects the pulling ability at a particular condition [1]. A commercial power tiller (KAMCO- KMB 200) is used for field testing.
Specifications of power tiller used for field testing are given in Appendix 5.1. The field test is conducted with the following objectives.

iii. To assess the wheel slip and field capacity of developed lugs at two different levels of soil moisture.

iv. To assess the effect on time rate and area rate of fuel consumption of power tiller fitted with newly developed lugged cage wheel.

5.2 Materials and Methods

For testing the modified lugs, the conventional cage wheel having diameter 700 mm is slightly modified by welding square bar of 12 mm size in between the spokes to enable the fixing of modified lugs. Holes are drilled in the welded square bar and lugs are mounted with the help of bolts. The orientation of lugs on the cage wheel is such that the split portion of lug is in the direction of forward movement of cage wheel. Total 8 numbers of lugs on each cage wheel are fitted for each test. View of the modified cage wheel and power tiller fitted with modified cage wheel for field test is shown in Fig. 5.1 (a) and (b).

Fig. 5.1 View of the (a) cage wheel fitted with modified lugs and (b) power tiller fitted with modified cage wheel for field test.

5.2.1 Parameters considered for describing the test field

In wet condition due to poor stability of the soil aggregate, the soil becomes very soft and unable to bear the applied load. In this situation the sinkage may increase resulting in poor tractive performance [2]. Therefore, information on soil type, soil moisture content, cone penetration resistance, proportion of different soil aggregates and bulk density are assessed and presented in Appendix 4.1 and Appendix 5.2, detail of which are given below.
5.2.2 Field testing procedure

The field was initially ploughed twice with power tiller operated rotavator under dry condition. After that the field was flooded with water and allowed to saturate for 24 hrs [3]. The cone penetrometer was used to determine the cone index before testing the cage wheel. The dial pressure reading was recorded for inserting cone of known area to a particular depth at uniform rate. Detail of the cone index measured is given in Appendix 5.2. Soil samples were also collected for estimation of soil moisture content, bulk density and other soil parameters in the field condition as given in Appendix 4.1. For testing the modified lugs, the cage wheel is mounted with modified lugs as shown in Fig. 5.1 (a). Power tiller is fitted with a graduated measuring cylinder by the side of fuel pump for holding the fuel. The fuel (diesel) is supplied from the cylinder to the power tiller engine. The initial and final level of the fuel in the cylinder is recorded for a particular period of operation to know the fuel consumed. For measuring the level of fuel power tiller is stopped in level position. To estimation the slip of cage wheel the power tiller was operated for a fixed number of rotations by counting the marking on the cage wheel [4]. The time taken to complete the fixed number of rotation was recorded with stop watch. The linear distance covered in fixed number of rotations was also measured with measuring tape and recorded. For estimation of fuel consumption, field capacity the power tiller was operated for half an hour and area covered and fuel consumed for this period was recorded. Each test in the field was replicated three times at two field conditions viz., (I) moisture content of 23.5% and (II) moisture content of 36% with each lugged cage wheel. Details of the dependent and independent variables are given below.

Independent and dependent variables

a) Independent variables

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Variable</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Split lug (S)</td>
<td>3</td>
<td>8000, 12000 and 16000 mm²</td>
</tr>
<tr>
<td>2.</td>
<td>Non-split lug (NS)</td>
<td>3</td>
<td>8000, 12000 and 16000 mm²</td>
</tr>
<tr>
<td>3.</td>
<td>Conventional lug (CC)</td>
<td>1</td>
<td>27300 mm²</td>
</tr>
</tbody>
</table>

b) Dependent variables (measured/assessed)

1. Field capacity
2. Wheel slip
5.2.3 Observation and data analysis

The cage wheels with 6 different lugs (S8, S12, S16, NS8, NS12 and NS16) are used for field testing using a commercially available power tiller (as discussed earlier). The field performance in terms of (i) travel speed, kmph, (ii) field capacity, ha h\(^{-1}\) (iii) wheel slip, %, (iv) fuel consumption, l h\(^{-1}\), and (v) fuel consumption, l ha\(^{-1}\) are assessed for all the tests at two different field conditions (23.5% and 36% moisture content). The soil of the test field is sandy loam. The different soil properties of the field are given in Appendix 5.2. The percent changes of performance parameters of split lugs in relation to non-split lugs are also determined for both the field conditions for all 3 types of lugs (S8, S12 and S16). Results of the test are given in Appendix 5.4. Performance parameters of field tests are plotted and discussed as given below. To compare the effects of different design parameters on field performance, the observed field test data are statistically analysed using Duncan’s Multi Range Test (DMRT).

5.3 Results and Discussion

The improvement of traction performances (drawbar power developed and tractive efficiency) with the increase in lug area of cage wheel was reported by earlier researches [7, 8, 9]. Further, the similar findings of better tractive performance with higher contact area are also obtained during the soil bin test in the present investigation. However, the reflection of better tractive performance on field performance has also been an important matter of consideration which has been attempted through field investigation.

The test soil is sandy loam with (i) 23.5% moisture content and (ii) 36% moisture content. Average specific weight of soil is about 17.73 kN m\(^{-3}\). The cone index of field soil vary with depth and ranges between (a) 80 kPa to 1180 kPa and (b) 0 kPa to 1080 kPa corresponding to depths of 50 mm and 250 mm for (a) low and (b) high moisture conditions, respectively. The effects of lug split, lug area on field performances for these two different soil conditions are presented in the following sections.
5.3.1 Effect of lug split on rate of field coverage at different field conditions

The test result of field capacity (ha h\(^{-1}\)) of 6 different lugs in two different field conditions (with 23.5% and 36% soil moisture) is presented in Fig. 5.2. The field capacity is increasing with the increase in surface area of both split and non-split lugs. This is due to the decrease in slip with increasing lug area (Appendix 5.4).

The split lug has positive effect on field capacity at 36% soil moisture content and is higher than the non-split lugs of same contact area for all sizes. At lower soil moisture content (mc) (23.5%), S8 (split lug of 8000 mm\(^2\)) and S12 (split lug of 12000 mm\(^2\)) yielded higher field capacity than non-split lugs but at lower moisture condition, there is no difference between the field capacity of S16 (split lug with 16000 mm\(^2\)) and NS16 (non-split lug with 16000 mm\(^2\)). However, field capacity of split lug is higher than non-split lug while operating under more moisture condition (36% moisture) by about 16%. Thus the benefit of split is realized with higher moisture field for which this lug is intended.

![Fig. 5.2 Field capacity of six different lugs at two different field conditions](image-url)
While operating at moist field (36%), S16 lug mounted operation resulted 0.0523 ha h\(^{-1}\) of field capacity (maximum amongst the treatments) and NS8 resulted only 0.0369 ha h\(^{-1}\) (minimum). Thus, a wide variation of field capacity is noticed amongst the treatments (42% difference between the highest and lowest). Thus, the reflection of varying level of traction performance could be seen as varying level of field capacity which is attributed by design parameters. Comparing the field capacity results, the split lug with higher area is expected to provide more benefits in high moisture soils.

Table 5.1 Effect of different lug design on field capacity

<table>
<thead>
<tr>
<th>Lugs</th>
<th>Field Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>S8</td>
<td>0.043(^{cd})</td>
</tr>
<tr>
<td>S12</td>
<td>0.043(^{cd})</td>
</tr>
<tr>
<td>S16</td>
<td>0.053(^{b})</td>
</tr>
<tr>
<td>NS8</td>
<td>0.036(^{d})</td>
</tr>
<tr>
<td>NS12</td>
<td>0.048(^{bc})</td>
</tr>
<tr>
<td>NS16</td>
<td>0.051(^{b})</td>
</tr>
<tr>
<td>CC</td>
<td>0.083(^{a})</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different (CV: 10.25%, LSD: 0.01)

Table 5.1 shows the pooled effect of lug design on field capacity as there was marginal difference between two soil moisture contents. There is significant difference in field capacity of split and non-split lugs except for larger size lug. The larger size lug (S16) has also shown gain in field capacity as compared to NS16, but statistically non significant.

5.3.2 Effect of lug split on wheel slip

Wheel slip of six different types of lugs at two levels of soil moisture condition is shown in Fig. 5.3. The slip has decreased with increase in surface area of both split and non-split lugs. The split lugs exhibited less slip as compared with non-split lugs of same area thus the splitting has shown positive effect on slip. The slip is minimum for lug S16 (14.89%) and maximum for lug NS8 (64.90%) at 23.5% soil moisture and it has increased by 34.6% and 3% at 36% soil moisture for lugs S16 and NS8 respectively.

The maximum reduction of wheel slip in respect of non-split lug was 27.3% for S16 at 36% moisture content, whereas minimum reduction was 0.41% for S16 at moisture content 23.5%.
A study on comparison of two models of power tiller indicated that the significant difference exist for field efficiency, fuel consumption and slippage. At 0-7 cm depth, significant differences exist for soil moisture content. For depth 7-14 cm depth significant differences exist for all the physical properties of soils covered in the experiment [10].

Fig. 5.3 Cage wheel slip at two different soil moisture conditions (23.5% and 36%)

Similar to the results of field capacity, the improvement of wheel slip through split is more prominent under higher moisture field than relatively dry field. Thus, larger size split lug is expected to reduce the energy losses for field operation.

Table 5.2 Effect of lug design on wheel slip in two different field conditions

<table>
<thead>
<tr>
<th>Lugs</th>
<th>Field Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I (23.5% moisture content)</td>
</tr>
<tr>
<td>S8</td>
<td>60.97&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>S12</td>
<td>38.25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S16</td>
<td>14.89&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>NS8</td>
<td>64.90&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>NS12</td>
<td>39.69&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NS16</td>
<td>15.24&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>CC</td>
<td>9.78&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different
Statistically there is no significant difference in wheel slip of split and non-split lugs in field condition. However marginal difference in primary field data can be seen showing the positive effect of split lugs (Appendix 5.3).

**5.3.3 Effect of lug split on fuel consumption**

The time rate of fuel consumption \( (1 \text{ h}^{-1}) \) and area rate of fuel consumption \( (1 \text{ ha}^{-1}) \) of power tiller fitted with six different lugs in two field conditions are presented in Fig. 5.4 and Fig. 5.5, respectively. The fuel consumption per unit time has shown a mixed trend with marginal variation as the power tiller throttle was put to almost same position during test condition. Small variation shown might be due to throttle setting variation and auto adjustment due to load change especially in more wet condition.

Time rate of fuel consumption is not sufficient to indicate the performance attributed by design parameters, due to variations in the amount of intended work (i.e. rate of field coverage) during the same time interval. Therefore, the fuel consumptions per unit area coverage are also assessed and presented below.

![Fuel consumption (l h\(^{-1}\)) of power tiller with different cage wheels](image)

Fig. 5.4 Fuel consumption \( (1 \text{ h}^{-1}) \) of power tiller with different cage wheels

The fuel consumption \( (1 \text{ ha}^{-1}) \) is decreasing with increase in surface area of both split and non-split lugs. Fuel consumption \( (1 \text{ ha}^{-1}) \) at higher moisture content (36%) has decreased for split lugs as compared with non-split lugs of same area for all the three lugs. Thus, positive effect of split lugs is also reflected in terms of fuel saving compared to identical
size non-split lug. Further, higher benefits of fuel saving is realised with increase in moisture. In higher soil moisture, maximum reduction of 16% in fuel consumption was observed in S8 compared to dry condition. At lower soil moisture content, the difference in fuel consumption per unit area of split and non-split lug was marginal. Earlier research has also concluded that the fuel consumption per unit area has increased with the increase in soil moisture content of the field [11].

![Graph showing fuel consumption (l ha\(^{-1}\)) of power tiller with different cage wheels](image)

Fig. 5.5 Fuel consumption (l ha\(^{-1}\)) of power tiller with different cage wheels

### 5.3.4 Comparison of split and non-split lugs and its feasibility

The above investigation and the investigation conducted in the laboratory (as discussed in Chapter 4) clearly indicate that the split lugs are performing better than non-split lugs at higher soil moisture content. Among the split lugs the lugs of higher surface area are giving positive result. The split lug has shown better results at higher soil moisture (36%) in terms of field capacity and fuel consumption. The biggest split lug fitted power tiller operation resulted 0.0523 ha h\(^{-1}\) of field capacity which is about 17% higher than the identical non-split lug fitted operation. Similarly, the operation of S16 fitted power tiller resulted about 27% less wheel slip associated with about 14% saving of fuel (l ha\(^{-1}\)) in comparison of NS16 in moist field.

The introduction of bigger size split lug in the cage wheel of power tiller is expected to improve the traction performance and hence result energy conservation. It is expected
that the results will also be applicable to riding tractor. However, some additional tests including the ergonomic tests on a range of field conditions would be required to transfer the technology for adoption.

It is also observed that increasing the lug size from 8000 mm$^2$ to 16000 mm$^2$ about 3 liters of diesel saving is possible while operating the power tiller in one ha field using split lugs. Similarly, though there is only marginal difference in fuel consumption between split and non-split lugs in relatively dry condition, but substantial benefits of split is observed under moist condition (~3 l ha$^{-1}$). The relative changes of field performance results of split lugs in comparison to non-split lugs are presented in Table 5.3 for two field conditions.

Table 5.3 Percent changes of split lug (S) over non split lug (NS) in field condition I & II

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Field Condition I (23.5% mc)</th>
<th>Field Condition II (36% mc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linear Speed</td>
<td>FC</td>
</tr>
<tr>
<td>S8</td>
<td>25.53</td>
<td>25.53</td>
</tr>
<tr>
<td>S12</td>
<td>-8.13</td>
<td>-8.13</td>
</tr>
<tr>
<td>S16</td>
<td>-0.41</td>
<td>-0.41</td>
</tr>
</tbody>
</table>

From Table 5.3 it could be summarized that larger lugs with split provide more benefits in relatively moist soil condition. About 17%, 27% and 14% benefits in terms of rate of field coverage, reduction of wheel slip, and reduction of fuel consumption are achieved by S16 mounted power tiller operation compared to operation of power tiller with NS16 lug in field having 36% moisture content.

Overall it is observed that the field performance results are in line with the soil bin tests performed in the laboratory, as both tests indicated the benefits of split lug with higher area of contact surface.

5.4 Conclusions

The following conclusions are drawn from the field experiments.
- The split lug has positive effect on field capacity at 36% soil moisture content and is higher than the non-split lugs of same contact area for all sizes.

- The split lug with higher surface area is expected to provide more benefits of field coverage in high moisture soils.

- The split lugs exhibited less slip as compared with non-split lugs of same area thus the splitting has shown positive effect on slip.
References


