PERFORMANCE EVALUATION OF TRACTOR OPERATED SPADING MACHINE

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PROJECT REPORT

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Acknowledgement

Dedicated to

Our beloved parents

&

Teachers

Introduction

Chapter 1

INTRODUCTION

Tillage is the basic operation in farming. It is the mechanical manipulation of soil with tools and implements which are used to maintain, modify or promote changes in soil structure in an effort to produce more desirable soil environment for plant growth, for obtaining conditions ideal for seed germination, seedling establishment and growth of crops. It includes ploughing, harrowing and mechanical destruction of weeds and soil crust. A certain amount of tillage is required on most soils to promote growth of plants. Tillage helps to obtain seed bed of good tilth, add humus and fertility to soil, destroy the weeds and prevent their growth and finally leaves the soil in a condition to retain moisture from rain. About 20% of the total energy is utilized in tillage operations. So tillage being a significant step in cultivation, tillage equipments also has an important role.

Agricultural productivity cannot hope to increase unless adequate inputs such as power, improved seeds, fertilizers and irrigation water are available in a timely manner and are applied judiciously. With the current increase in world population, energy consumption needs effective planning. Crop yields and food supplies to consumers are directly linked to energy, which means sufficient energy is needed in the right form at the right time for adequate crop production (Gevao *et al*., 2004). There are many implements invented for making tillage more efficient and easier including primary and secondary. Most of the traditional tools are being mechanised and powered and are used for cultivation. Considerable development has taken place in the improvement of tillage tools. Spading machine is such a mechanized tillage implement which is now being used widely.

Spading machines are agricultural machines designed for loosening and breaking up the soil. The principle is the same as that of digging by hand with a spade. The machine is made up of several spade shovels that are connected to a crankshaft. Blades are driven alternately into the soil, clods are lifted and thrown backwards. Each spade enters the soil through a slicing motion and breaks the soil off at the bottom of the spade’s stroke. Spading machines are hitched to a tractor using the standard three point linkage and P.T.O driven. The spading machine work is such that it causes less compaction to the soil and does not form a hard pan. The motions of the spades are such that they do not cause compactness in a single pass, one blade will be touching the ground at a time and thus requires less power.

Spading machines incorporate residues, straw, compost, green manure etc during the tilling operation. This enhances the soil fertility, porosity etc. It has a uniform working, which leads to a uniform and homogenous soil tilth along the working width. It can invert the clods which were broken in the pass and this provides high aeration, mixing and tilth to the soil. The machine can be adjusted to both deep and shallow depths and can penetrate deeper than ordinary tillage implements. The tilled land will be flat and the clods will be of regular size. It also helps in erosion control and leaching process. (Dhiman 2016) The spading enables the root system of crops to access the most fertile surface layer of soil.

The purpose of this study is to evaluate the potential of the tractor operated spading machine in soils typical to Kerala. This study aims at evaluating the effect of varying soil conditions and operational conditions such as depth of operation and forward speed of the tractor operated spading machine, on its performance with reference to parameters such as soil bulk density, soil strength (cone index), pulverization index, soil moisture content, field capacity, and fuel consumption.

Review of literature

Chapter 2

REVIEW OF LITERATURE

The information about various studies related to spading machine carried out by various researchers in India and other countries has been briefly reviewed and combined in this chapter.

2.1 Spading machine and tillage operations

The primary tillage deals with the breaking up of clogged soil in the field and its complete inversion (top soil layer). The plough was most frequently used for this purpose in past. But minimum tillage or zero tillage introduced as a part of reducing the negative impacts in economical and environmental impacts of tillage, as well as to maximize the crop production involved the use of alternative machinery instead of plough (Hoffman (1993) and Borin *et al.,* (1997)). One of the alternatives is the development of spading machines.

Tillage is an important farm operation for seed bed preparation. Farm machines involve a major portion of the cost of the crop production (Al-Suhaibani, 2010). The proper selection of farm machine is very important in reducing the crop production cost. The energy input in soil manipulation is only next to that in irrigation (Singh, 1983). Tillage tools direct energy into the soil so as to make some desirable effects like cutting, breaking, inversion, or movement of soil.

Spading machine is an implement coupled with the three point hitch of the hydraulic lift and operated through the tractor PTO. A strong frame is supporting the spade and the working tool has a trapezoidal shape, which is located at the end of the connecting rods. These rods are connected to a central gearbox of the machine with the help of a rotor. Notwithstanding the development in the past of rotating machines (Pellizzi (1965) and Gasparetto (1970)), the models that now available in market is based on the connecting rod-crank mechanism, also called articulated quadrilateral mechanism.

The digging action of the spading machine produces same effect as that of hand spading. Rather than slicing the spading machine detaches, there by leaving a porous, permeable bed allowing the soil to breathe and absorb water. Recent research shows that nutrient availability is improved when top soil is buried by spading machine or mould board ploughing because nutrients become concentrated in the root zone and become less susceptible to soil drying from evaporation, especially when majority of the nutrients are on the soil surface (Davies *et al.,* 2012).

2.2 Performance of spading machine

Gasparetto (1966a) studied various types of spading machines, both for the movement paths and for the speed and acceleration produced, precisely under the kinematic point of view. In 1980s, there was increased increase in spading machine, mainly in Italy. In fact, the most important manufacturers are Italian (Pezzy *et al.,* 1987). Moreover, many research papers concerning the spading machines were written more than 40 years ago by Italian authors (Gasparetto 1966b, 1968). At that time the plough were restricted to a limited working width, a factor reducing their performance.

More recent analyses were carried out at the end of 1990s (Peruzzi *et al., (*1997) and Pezzi *et al., (*1997)), regarded only the performance analysis of the spading machine, without comparing it directly with any other equipment. The spading machine have only recently been introduced to the Australian market from Europe where these are used for deep tillage and incorporating large amount of biological residues into the biologically active top soil (30-45cm top soil) (Palmer, 2002). The depth available for a spading machine is clear advantage over traditional method of clay incorporation using offset disc and smudge bars.

Brozozko and Murawski (2007) studied the effect of loosening depth on power requirement for driving a spading machine on cultivated land and felling site at three tractor engine speed and two gears. It was reported that increase in soil loosening depth result in increased power requirement, which also depended on the type of soil and tractor engine speed.

According to Kumar *et al.,* (2012), soil bulk density varied from 1.05 to 1.52 Mg/m^3 for no-tillage and 1.08 to 1.72 Mg/m^3 for conventional tillage Soil bulk density measured at harvest of rice was reported to vary with zones, soil texture, and depth, but the interactions were non-significant (Singh *et al.,* 2009).

The resistance to penetration highlights a very compact layer at a depth ranging from 30 to 40 cm, due to the previous repeated passages of the plough (Giordano *et al.*, 2015). For many crops this is a problem, but in the paddy field this is considered a favorable condition, as it reduces the water consumption necessary to maintain the submersion of the surface. The real working depth, compared to the untilled soil and obtained through several measurement repetitions was 24±2 cm, for both implements. One of the main aims of conservation tillage is to reduce soil erosion (Holland, 2004).

For ploughing 87% of the maximum engine power was engaged, while for the spading operation an amount of 64-72 % was necessary (Giordano *et al.*, 2015).

Sumer studied the fuel consumption and power distribution between tractor and PTO driven machines. The draft and energy requirement of different tillage implements have been reported (Hunt, 2001). The rotary tillers consumed more energy than any other implement, however, the degree of pulverization varied considerably (Saimbhi, 2009).

Materials and method

Chapter 3

MATERIALS AND METHODS

The tests were carried out from the Department of Agricultural Engineering, College of Horticulture, KAU, Vellanikkara campus, in different fields of the College, where different types of crops were grown in rotation. Three different fields were selected for the study. The tractor operated spading machine used for the study has the following specifications:

Table 3.1: Specifications of the tractor operated spading machine

Model	SPD 1606
Manufacturer	Gomadhi Engineering Works, Kunnatur, Tirupur district, Tamil Nadu, 638103
Type	Tractor PTO operated
Dimension (mm)	1615×1320×1150
Working width (mm)	1600
Tractor power required (hp)	35-45
Number of blades	6
PTO input speed (rpm)	540
Rotor shaft speed (rpm)	167
Maximum working depth (mm)	250-300

The travel speed and depth of operation are set as the independent parameters and their effects on the variables such as soil bulk density, pulverization, field capacity and fuel consumption is studied.

Table 3.2 Experimental design

Variables	**Levels**
Independent variables	
Forward speed (kmh^{-1})	2.5, 3.5
Depth of operation (cm)	10, 15, 20, 25
Dependent variables	
	Soil bulk density (kgm^{-3}) Pulverization index (mm) Field capacity ($hahr^{-1}$) Fuel consumption (lhr^{-1})

3.2 Study of soil properties

3.2.1 Bulk density

The field bulk density of the soil is determined by core cutter method (IS-27270-PART 29). The equipment consists of core cutter, dolly and rammer. Site for collecting soil samples was cleaned and leveled. The core cutter with the dolly at the top of it was placed at the level surface and driven into the soil to its full depth with the help of a steel rammer. The soil around the surface of the core cutter was excavated without disturbing the core cutter and it was gently lifted out. The top and the bottom surfaces of the samples were trimmed and the outside surface of the cutter cleaned. Weight of the core cutter, with soil, was noted. The weight of the empty core cutter was also noted after removing the soil from the core cutter, using a sample ejector. The soil cores (samples) were collected for further analysis. After the core samples were collected, they were placed in labeled poly bags, sealed tightly. These samples were then taken to the Agricultural Engineering Laboratory and the bulk density was determined as per standard procedure.

The bulk density is calculated using the following formula.

$$\text{Ywet} = (W_2 - W_1) / V$$

where,

Ywet = Bulk density, (kgm^{-3})

W_1 = Empty weight of core cutter, (kg)

W_2 = Weight of core cutter + soil, (kg)

V = volume of core cutter, $((\pi d^2/4) \times H)$, (m^{-3})

d = Inner diameter of core cutter, (m)

H = Height of core cutter, (m)

3.2.2 Soil moisture content

The soil moisture content was determined on wet basis. Six soil samples were collected randomly from different plots. The soil samples were dried in oven for 24 hours at 105°C. Dried samples were re-weighed and the weight recorded, and moisture content calculated by the formula

$$\text{M.C} = \left(\frac{\text{Wd}}{\text{Ww}}\right) \times 100$$

Plate 3.1 Measuring bulk density

Plate 3.2 Core cutter method

3.2.3 Pulverization Index

The degree of pulverization was determined by calculating the MMD (Mean Mass Diameter) using the sieve analysis technique. For this, sieves of appropriate sizes were selected. The set contained eight sets of sieves, ranging in size from 75µ to 2mm. The various sizes include 75µ, 150 µ, 212 µ, 300 µ, 425 µ, 600 µ, 1mm, and 2mm. The soil was shade dried for 24 hours before carrying out the sieve analysis using a column of sieves with gradual decrease in mesh size top downwards. The weighted mass of soil retained in each sieve is taken for calculation of the MMD in every treatment.

$$\mathrm{MMD} = \left\{\Sigma \mathrm{M(I)} \times \mathrm{D(I-1)} + \frac{\mathrm{D(I)}}{2}\right\} / \sum \mathrm{M(I)}$$

where,

I = 1, 2, 3….

M (I) = Mass of soil retained on I^{th} sieve from top, (kg)

D (I) = size of the I^{th} sieve, (mm)

Plate 3.3 Soil samples for sieve analysis

Plate 3.4 Sieve analysis

3.2.4 Strength of soil (Cone Index)

The strength of the soil is measured by cone index. A cone penetrometer with digital indicator, load cell and battery was used to measure the soil resistance to vertical penetration of the cone. The penetration resistance was taken before and after the treatments. The cone is mounted with on a frame with a lever by which the rod is moved up and down. The hand lever was operated in such a way that the cone penetrometer penetrated the soil at a uniform rate during the treatment. Penetrometer was positioned in the field and slightly pressed on the handle. The solid stem penetrated into the soil and force was measured and indicated on the indicator. The penetrometer resistance was measured for each increment of 2.5 cm and recorded manually.

Plate 3.5 Measurement of penetration resistance using cone penetrometer

3.3 Machine parameters

3.3.1 Field capacity

The time lost in every event such as turning, adjustments and change gears are recorded. For calculating field capacity, the time consumed and time lost for real work were used. The field capacity was calculated by using the formula:

$$C = A/(Tp + Tt)$$

where,

C = Effective field capacity, (ha/hr)

A = Area tilled, (ha)

T_p = Non-productive time, (hr)

T_t = productive time, (hr)

3.3.2 Fuel consumption

For the fuel consumption measurement a fuel measuring jar developed from K.C.A.E.T, Tavanur is used. It was connected to the tractor fuel tank. The measuring jar was filled with diesel up to top level that is to 1000ml before the treatment. The operation was done for a fixed distance. After each treatment, the final level of fuel in the jar and the total time taken for the operation was noted. From the values obtained the fuel consumption was calculated as

$$\text{Fuel consumption (l/hr)} = \frac{\text{Initial fuel level} - \text{final fuel level}}{\text{Time consumed}}$$

Plate 3.6 Installing fuel jar for measuring fuel consumption

3.3.3 Slip

Slip is the measure of relative motion between the device and soil. For the slip measurement number of revolutions taken was six. A mark on the tractor drive wheel was created. The distance covered by the wheel for the six revolutions on no load and on load was measured. From these values using the following equation, the slip was calculated as.

$$\text{Wheel slip}(\%) = \{[\text{Lo} - \text{L1}]/\text{L0}\} \times 100$$

where,

L_o = Length on no load, (m)

L_1 = Length on load, (m)

Plate 3.7 Measurement of slip

3.3.4 Draft

The draft of the tractor attached with spading machine was measured using two-tractor method. There was one driving tractor and one driven tractor. The tractor attached with the spading machine was pulled by the driving tractor. In between the two tractors a load cell was chained to the draw bar of the driving tractor and to the front of the driven tractor. The load cell was connected to an indicator which directly gave the draft values. The power was taken from the driving tractor’s battery. The driving tractor was operated in the required speeds and the driven tractor is kept at neutral gear. The tractors were operated for all treatments and the draft values were obtained.

Plate 3.8 Two tractor method for draft measurement

Plate 3.9 Draft measurement

3.4 Statistical analysis

A statistical analysis was done to determine the effects of independent parameters on dependent parameters. Depth of operation and speed of operation were taken as independent parameters and two way analysis of variance (ANOVA) was performed to test the significance of independent variables and their interactions on the dependent variables at 5 percent level of significance.

Table 3.3 List of parameters and levels

<table>
<tr><th>Sl no.</th><th>Parameter</th><th colspan="2">Levels</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Speed</td><td rowspan="2">2</td><td>L-1</td></tr>
<tr><td>L-3</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">Depth</td><td rowspan="4">4</td><td>10 cm</td></tr>
<tr><td>15 cm</td></tr>
<tr><td>20 cm</td></tr>
<tr><td>25 cm</td></tr>
</table>

Number of treatments = 2×3 = 6

Number of replications = 3

Number of experiments = 6×3 = 18

Table 3.4 Dependent parameters of experiment

Sl No.	Dependent parameters
1	Bulk density
2	Pulverization Index
3	Field Capacity
4	Fuel consumption
5	Slip
6	Cone Index

The analysis of variance (ANOVA) was performed to test the significance of independent variables and their interactions on the dependent variables at 5 percent level of significance.

Results and discussion

Chapter 4

RESULTS AND DISCUSSION

This chapter deals with the results of various experiments conducted in the field for the performance evaluation of the tractor operated spading machine at different operating speeds and depths.

Initial field trials, for the performance evaluation of the tractor drawn spading machine was conducted in two plots under the Central Nursery, KAU Headquarters, Vellanikkara. The machine was operated using the New Holland 3630, 55 hp tractors (4 wheel drive). The field was covered with crop residues from the previous season, and was unploughed.

Before ploughing the field using the tractor operated spading machine, the parameters such as soil moisture content, bulk density, area of the field, pulverization index (MMD) etc were noted. Samples were collected as per the procedures described in the earlier chapter to determine these values. The spading machine was hitched to the tractor through the three point linkage and was operated in the field (in 1st gear, medium). Observations were recorded for the time of operation, fuel consumption. Samples were again collected from the ploughed area to determine the bulk density and particle size post ploughing.

Further studies on the performance evaluation of tractor operated spading machine was conducted at the Department of seed science, Department of Plantation Crops, College of Horticulture, KAU, and the fields of KVK, Vellanikkara, Thrissur. The operating procedures were same as that explained above. The machine was attached to the PTO of the New Holland 3630, 55hp tractor and operated at different speeds (in 1st gear low, 3rd gear low) and depth of operations (10 cm, 15 cm, 20 cm, 25 cm respectively). The observations of slip, penetration resistance values (using cone penetrometer), weed count were also noted along with the time of operation and fuel consumption. The soil samples from the fields were collected for sieve analysis and moisture content determination (before ploughing). The procedure was repeated in each of the selected fields location 1 (P1), location 2 (P2) and location 3 (P3).

4.1 Effect on pulverization index

The soil pulverization index was expressed in terms of MMD (Mean Mass Diameter). The samples of soil collected from the fields were subjected to sieve analysis and based upon the clod size the MMD can be calculated. Lesser the average MMD value, more will be the pulverization.

Table 4.1: Effect of forward speed and depth of cut on pulverization index (MMD)

Treatments	Mean mass diameter (mm)			Mean MMD (mm)
	P1	P2	P3	
D10L1	1.679	_	0.185	0.932
D10L3	1.709	_	0.203	0.956
D15L1	1.828	_	0.224	1.026
D15L3	1.821	_	0.217	1.019
D20L1	_	1.155	0.187	0.671
D20L3	_	1.675	0.174	0.924
D25L1	_	1.589	0.232	0.9105
D25L3	_	1.4513	_	1.4513

The effect of depth of cut and operating speed on pulverization index obtained by the operation of the spading machine at different depth is shown in Fig 4.1.

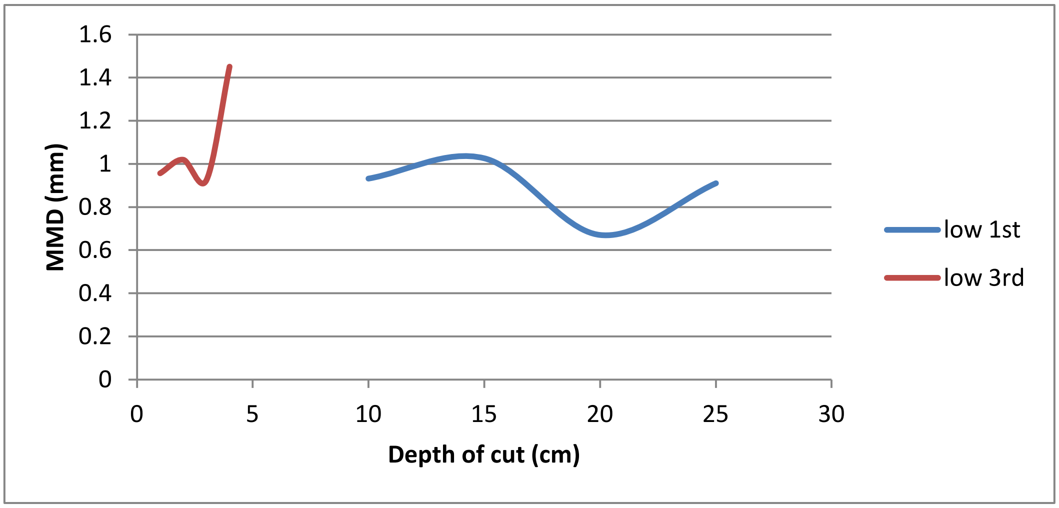

Fig 4.1 Effect of depth of cut and operating speed on pulverization index (MMD)

A comparative study on rotavator and spading machine shows a variation in MMD in the range 0.187 mm for spading machine and 0.223 mm for the rotavator. Hence the results on the comparison show that spading machine has less MMD value and the pulverization is more compared to the rotavator at the same operating speed (Fig 4.2).

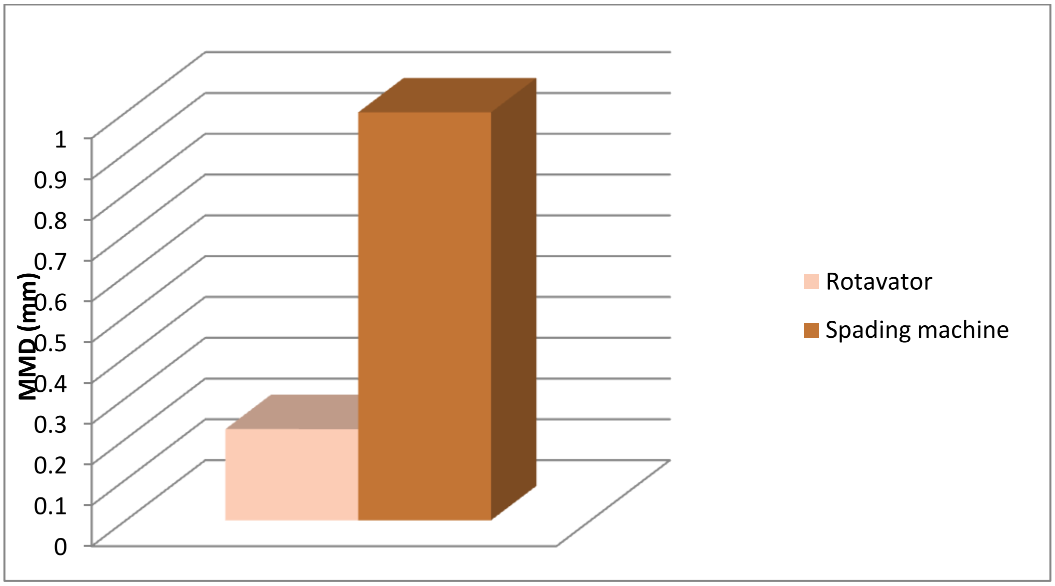

Fig 4.2 Comparison of MMD values for Rotavator and Spading machine at same operating speed.

Table 4.2: Result of analysis of variance on MMD

Source	df	Sum of squares	Mean square	Significance
Depth	3	0.153	0.051	0.356
Speed	1	0.082	0.082	0.208
Error	3	0.096	0.032	

From the Analysis of variance (ANOVA) was performed to test the significance of independent variables and their interactions on the dependent variables at 5 % level of significance. The ANOVA results are given in table 4.2. It was observed that the level of significance of the independent variables depth and operating speed was 0.356 and 0.208 respectively. The results show that there is no significant difference of the variable.

4.2 Effect on bulk density

The bulk densities of the experimental plots were computed before ploughing and the variation in bulk density after ploughing was compared with these values. The average bulk density of the plots before ploughing was recorded as 1.344 gcm^{-3} (P1), 1.288 gcm^{-3}(P2) and 1.540 gcm^{-3} (P3) respectively. The variations in bulk density after ploughing in different treatments are discussed in Table 4.3.

Table 4.3: Effect of forward speed and depth of cut on bulk density

Treatment	Soil bulk density (gcm^{-3})			Mean
	P1	P2	P3	Bulk density (gcm^{-3})
D10L1	1.029	_	1.418	1.223
D10L3	1.235	_	1.475	1.355
D15L1	1.287	_	1.434	1.3605
D15L3	1.336	_	1.460	1.398
D20L1	1.338	1.184	1.158	1.227
D20L3	_	1.280	1.264	1.272
D25L1	1.029	1.215	1.099	1.114
D25L3	_	2.880	_	2.88

Table 4.4: Result of analysis of variance

Source	df	Sum of squares	Mean square	Significance
Depth	3	0.734	0.245	0.621
Speed	1	0.490	0.490	0.327
Error	3	1.080	0.360	

From the Analysis of variance (ANOVA) was performed to test the significance of independent variables and their interactions on the dependent variables at 5 percent level of significance. The ANOVA results are given in table 4.4. It was observed that depth of cut and operating speed did not significantly inference with bulk density.

From the data given in the Table 4.3, the minimum bulk density was observed as 1.114 gcm^{-3} for the treatment D25L1 (D25: the depth of operation is 25 cm and L1: operating gear low 1^{st}), while the maximum bulk density was noted as 2.88 gcm^{-3} for the treatment of D25L3 (D25: depth of operation is 25 cm and L3: the operating gear low 3^{rd}).

The graphical representation of effects of depth of cut and operating speed on bulk density are shown in Fig 4.4.

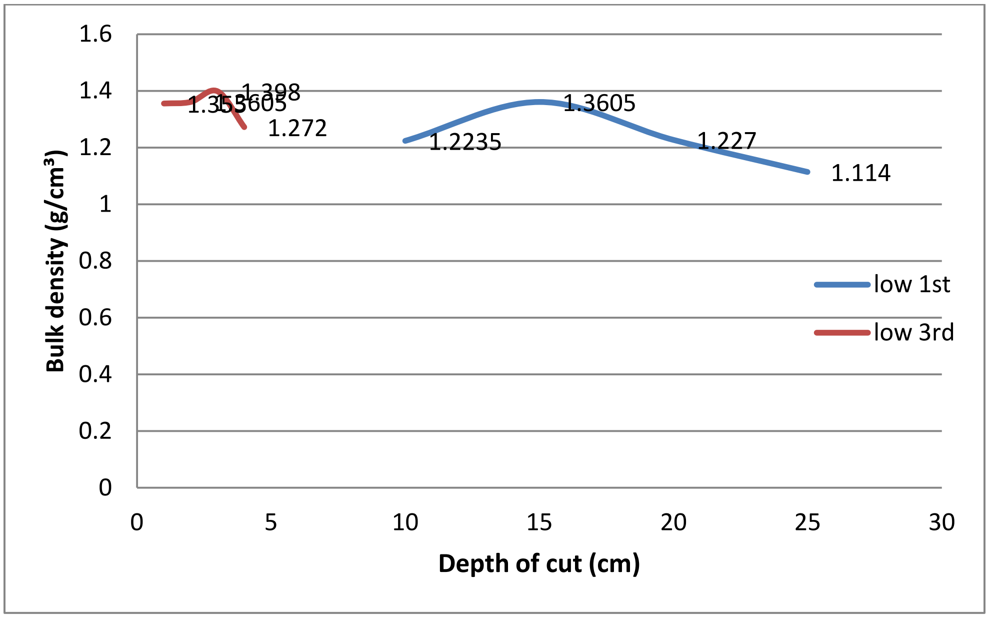

Fig 4.3 Effect of depth of cut and operating speed on bulk density

A comparative analysis was done with rotavator and spading machine for comparing their tillage properties. The bulk densities observed for rotavator was slightly less (1.302 g/cm³) compared to spading machine (1.325 gcm^{-3}). The effect of rotavator and spading machine in soil bulk density is represented in the graph shown below (fig.4.4)

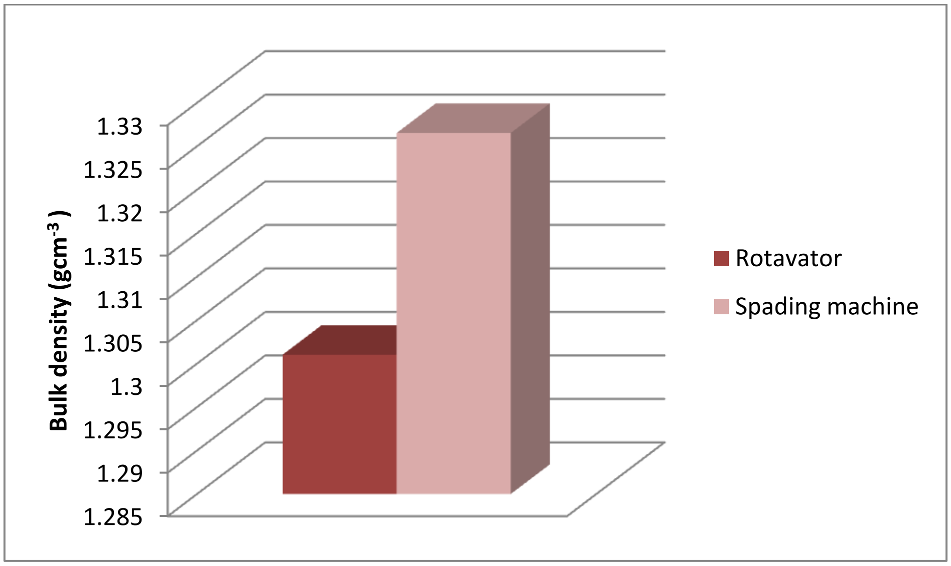

Fig 4.4 Effect of use of rotavator and spading machine on soil bulk density

The above discussed results show that the bulk densities at same depth of cut vary with the operating speed of the spading machine. The maximum bulk density is observed for depth of cut of 25 cm when operated at low 3rd gear. Also, when the operating speed is high, the bulk density showed an increased value. Higher the bulk density value, lesser the pulverization of the soil. An operating depth between 10 to 15 cm and operating speed of low 1st showed good pulverization and less bulk density. Hence low gear can be selected for operating the spading machine, to get a better pulverization index.

4.3 Effect on fuel consumption

The effect of depth of cut and operating speed of the tractor on fuel consumption was studied in the experimental plots. The amount of fuel consumed for operating the spading machine for one hour was calculated and is explained in detail in Table 4.5.

Table 4.5: Effect of depth of cut and operating speed on fuel consumption

Treatments	Fuel consumption(lhr^{-1})			Mean fuel consumption (lhr^{-1})
	P1	P2	P3	
D1OL1	3.123	3.442	4.48	3.682
D1OL3	2.459	_	3.956	3.207
D15L1	2.691	_	4.635	3.663
D15L3	3.16	_	4.733	3.946
D20L1	2.504	3.5635	6.00	4.022
D20L3	_	3.7010	4.075	3.888
D25L1	_	5.561	7.11	6.334
D25L3	_	6.083	_	6.083

From Table 4.5 it is clear that the maximum amount of fuel consumed is 6.334 lhr^{-1} for the treatment D25L1 (D25: depth of cut 25cm and low 1st gear). And the minimum value of fuel consumption 3.2 lhr^{-1} for the treatment D10L3 (D10: depth of cut 10cm and the operating condition low 3rd gear). As the depth of cut increases, the fuel consumption also increases and when operating gear is low 3rd, the amount of fuel consumed decreases.

The graphical representation of effect of depth of cut and operating speed on fuel consumption is given in Fig 4.5

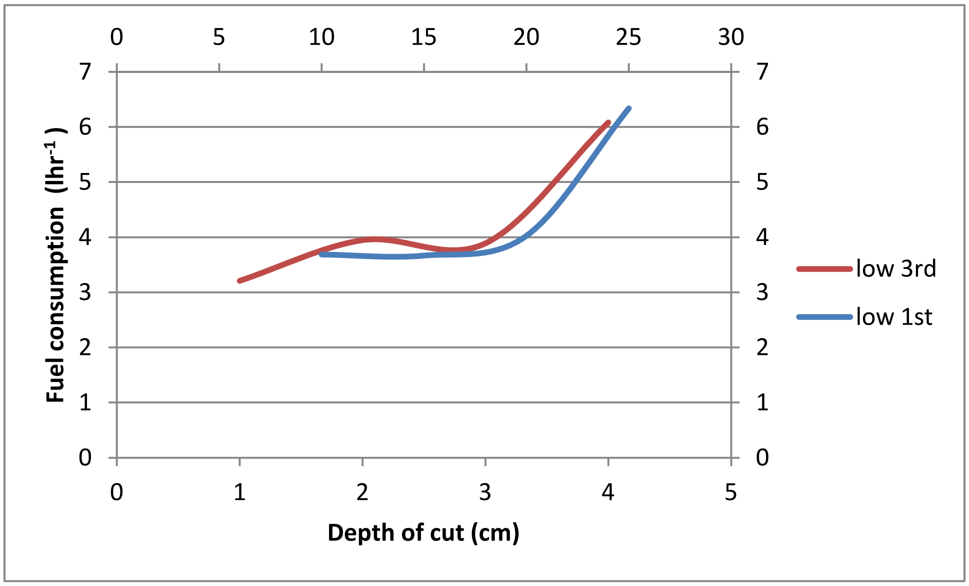

Fig 4.5 Effect of depth of cut and operating speed on fuel consumption

From the Fig 4.5 we can conclude that the value of fuel consumption at same depth varies with the operating speed of the tractor. The low gear at a depth of 10 cm will be suitable for operating the spading machine in normal field conditions.

For studying the effect of use of spading machine and rotavator on fuel consumption, a comparative analysis was conducted. The machines were operated in same operating speed and maximum available depth (depth of 10 cm for rotavator and 20 cm for spading machine. The hourly fuel consumption of rotavator was noted as 7.04 litre where as spading machine shows an amount of 5.7 litre. (Fig 4.6)

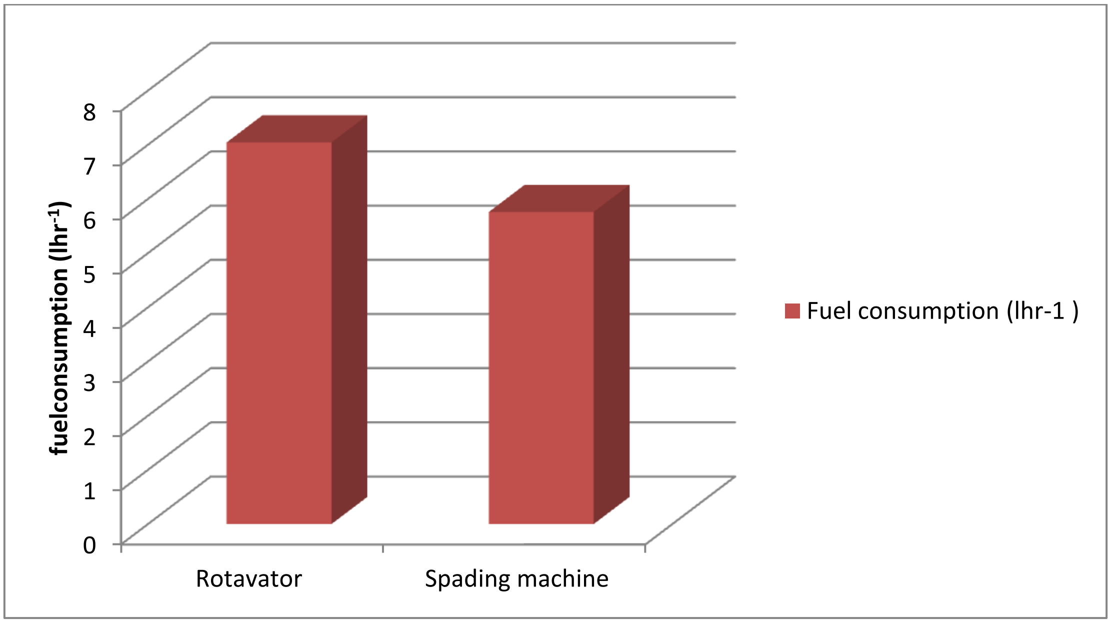

Fig 4.6 Effect of spading machine and rotavator on fuel consumption (a comparative study)

Table 4.6: Result of analysis of variance on fuel consumption

Source	df	Sum of squares	Mean square	Significance
Depth	3	9.455	3.152	0.003
Speed	1	0.042	0.042	0.431
Error	3	0.152	0.051	

From the Analysis of variance (ANOVA) was performed to test the significance of depth of speed ad operating speed and their interactions on the fuel consumption at 5 % level of significance. The ANOVA results are shown in table 4.6

It was observed that the level of significance of the independent variables depth and operating speed was 0.003 and 0.431 respectively. It was seen that there is a significant difference in fuel consumption with respect to depth of operation, and the confidence level of the significance observed from the ANOVA is 0.963 (96.3%). However the inference of operating speed was non- significant

4.4 Effect on field capacity

The machine was operated in the field for two different operating speeds (low 1st and low 3rd gear). The field capacity in terms of hectare per hour was calculated by taking necessary data from the field (as explained in the Chapter 3). The observations are noted in the Table 4.7

Table 4.7: Effect of operating speed and depth of cut on field capacity (hahr^{-1})

Treatments	Effective field capacity (hahr^{-1})			Mean Field capacity (hahr^{-1})
	P1	P2	P3	
D10L1	0.22	0.255	0.228	0.234
D10L3	0.371	_	0.490	0.431
D15L1	0.519	_	0.228	0.3735
D15L3	0.139	_	0.551	0.345
D20L1	0.445	0.260	0.234	0.313
D20L3	_	0.341	0.515	0.428
D25L1	_	0.206	0.203	0.205
D25L3	_	0.371	_	0.371

The maximum value of effective field capacity was noted as 0.431 hahr^{-1} for the treatment D10L3 (D1O: depth of cut is 10cm and low 3rd gear) and the minimum value observed was 0.205 hahr^{-1} for the treatment D25L1 (D25: depth of cut 25cm and low 1st gear). For the same depth of operation, the higher field capacity is most frequently observed for low 3rd gear operations.

The fig.4.7 shows a graphical illustration of effect of depth of cut and operating speed on field capacity (hahr^{-1})

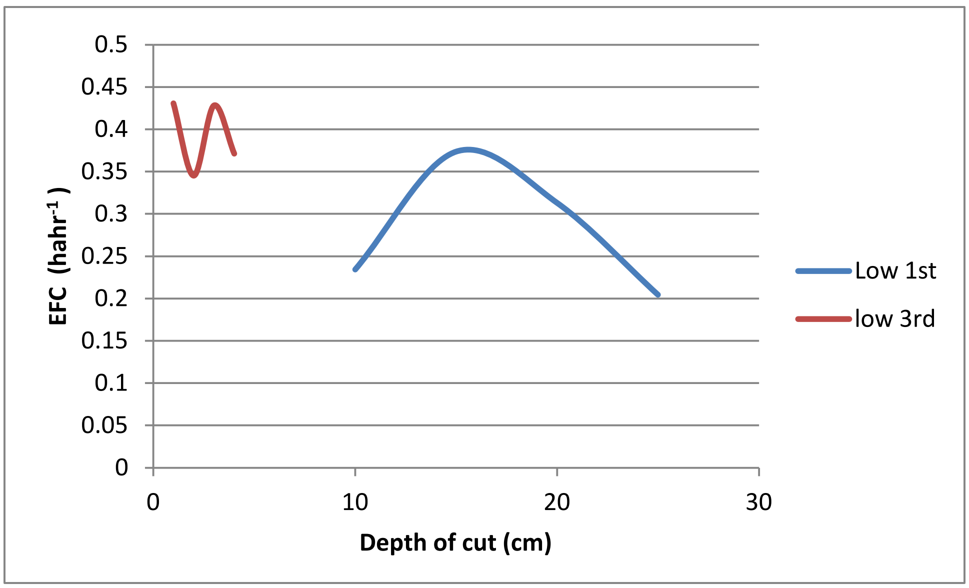

Fig.4.7 Effect of depth of cut and operating speed on field capacity (hahr^{-1})

The comparative study with rotavator and spading machine shows the following variation in effective field capacity (Fig 4.8)

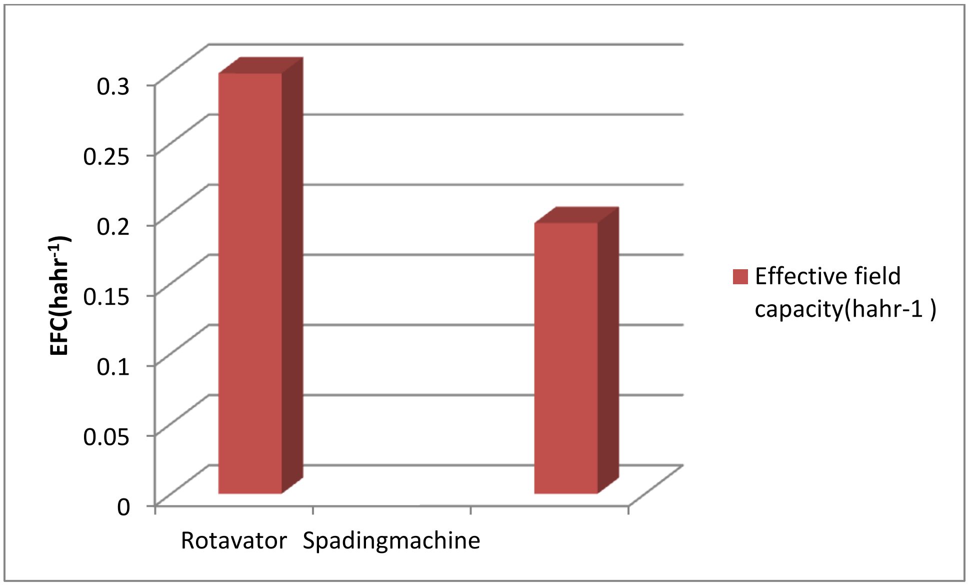

Fig 4.8 Comparison of effective field capacity (hahr^{-1}) using rotavator and spading machine

The rotavator shows higher effective field capacity (ha/hr) value of 0.2997 ha/hr compared to spading machine, 0.193 ha/hr at same operative speed (low 1st gear).

Table 4.8: Analysis of variance on effective field capacity

Source	df	Sum of squares	Mean square	Significance
Depth	3	0.008	0.003	0.687
Speed	1	0.025	0.025	0.110
Error	3	0.015	0.005	

From the Analysis of variance (ANOVA) was performed to test the significance of depth of cut and operating speed and their interactions on the dependent variables at 5 % level of significance. The ANOVA tables are given in Appendix. And results on ANOVA show that there is no significant difference in field capacity with respect to independent variables

4.5 Effect on wheel slip

The wheel slip of tractor when it is attached with the tractor operated spading machine is calculated using the observation taken from the field. The distance travelled by the tractor when it was operated in no load as well as loaded condition was noted down. The results of wheel slip in various depth of operations and operating speed is given in Table 4.9

Table 4.9: Effect of depth of cut and operating speed on wheel slip

Treatments	Wheel slip (%)			Mean slip (%)
	P1	P2	P3	
D10L1	-0.6689	-0.671	-0.99	-0.7766
D10L3	-2.3809	-1.532	-0.778	-1.5636
D15L1	-1.00	_	-1.386	-1.193
D15L3	-1.19	_	-0.389	-0.789
D20L1	_	-1.190	-3.366	-2.278
D20L3	_	-1.809	-0.5836	-1.196
D25L1	_	-1.754	-3.168	-2.461
D25L3	_	-1.8656	_	-1.865

Table 4.10: Analysis of variance on wheel slip

Source	df	Sum of squares	Mean square	Significance
Depth	3	1.725	0.575	0.317
Speed	1	0.210	0.210	0.474
Error	3	0.945	0.315	

From the Analysis of variance (ANOVA) was performed to test the significance of independent variables and their interactions on the dependent variables. The ANOVA at 5% level of significance showed that there was no significant difference on operating speed and depth of operation on draft.The confidence level of the significance observed from the ANOVA is 0.235 (23.5%), which is not taken in to consideration since it is below 50%.

The spading machine shows a negative slip at different depths of cut and operating speeds. The wheel slip observed range from 0.77% to 2.46% for depth from 10 cm to 25 cm and tractor operating speed at low 1st gear. The effect of depth of cut and operating speed on wheel slip of tractor is graphically represented in Fig 4.9

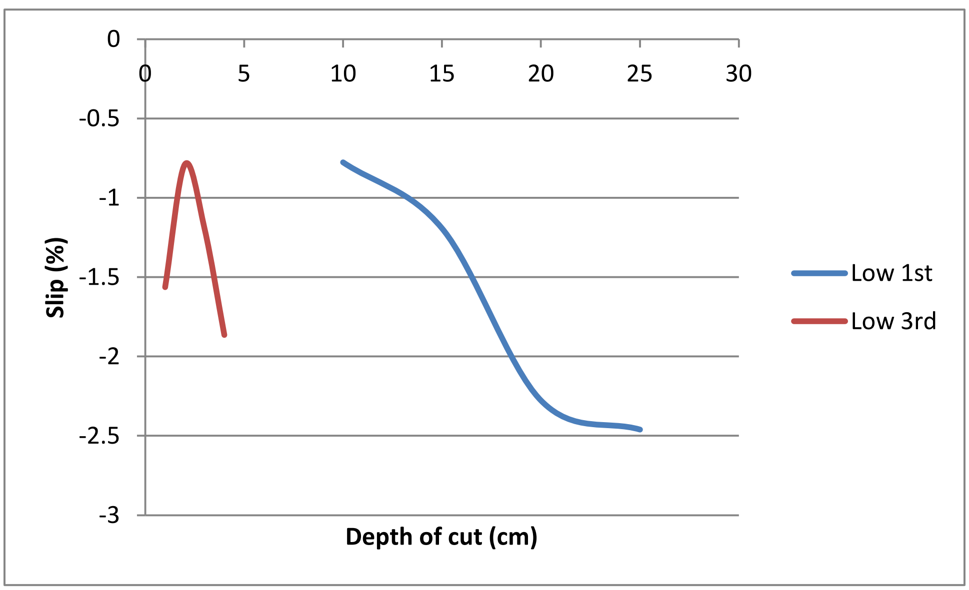

Fig 4.9 Effect of depth of cut and operating speed on wheel slip (%)

4.6 Effect on soil strength

The soil strength was measured in terms of cone index using a standard cone penetrometer. The penetrometer connected with a digital indicator box gives the penetration resistance of the soil. As the depth of operation increases, the penetration resistance value also increases. The results are explained in table 4.11 below.

Table 4.11: Effect of depth of cut and operating speed on soil strength

Treatment	Cone Index (MPa)		Mean cone index (MPa)
	P2	P3	
D10-L1	_	0.01547	0.01547
D10-L3	_	0.06656	0.06656
D15-L1	_	0.03992	0.03992
D15-L3	_	0.04434	0.04434
D20-L1	0.0007	0.02519	0.01295
D20-L3	0.00352	0.02787	0.01569
D25-L1	0.00336	0.02424	0.01392
D25-L3	0.0024	_	0.0024

The penetration index values are explained in detail in the table 4.11. The maximum cone index value of 0.06656 MPa for cone index was observed on D25L3 (D25: depth of cut 25 cm and operating speed low 3rd) and the minimum value of

0.024 MPa was obtained in D10L3 (D10: depth of cut 10 cm and operating speed of low 3rd)

The graphical representation of effect of depth of cut and operating speed on soil strength is given in fig 4.10

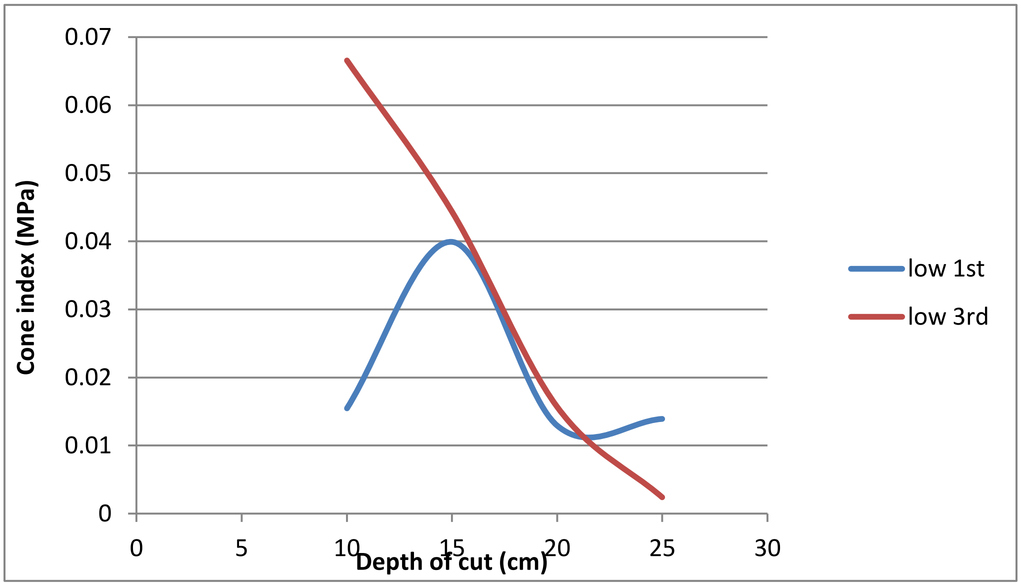

Fig 4.10 Effect of depth of cut and operating speed on soil strength

Table 4.12: Analysis of variance on soil strength

Source	df	Sum of squares	Mean square	Significance
Depth	3	0.002	0.001	0.338
Speed	1	0	0	0.454
Error	3	0.001	0.00	

From table 4.12, it is clear that depth of cut and operating speed have only a non significant influence on the soil strength.

4.7 Effect on draft

The draft of the tractor, when it attached with the spading machine was obtained using two tractor method explained in chapter 3. The load cell which was connected in between the driving and driven tractors gives the direct value of draft in terms of kgf in the indicator box. The measurements were done at various depth of cut by adjusting the position control of the tractor, and the operating gear of driving tractor was set to various operating gears (low 1^{st} and low 3^{rd}). The driven tractor was set in neutral position.

The observations were obtained at various depths (10 cm, 15 cm, 20 cm, and 25 cm). The observed value for depth of 10-15 cm cut ranges from 250-380 kgf where as 300-500 kgf was observed when depth of cut was adjusted to 20-25 cm.

Summary and conclusion

Chapter 5

SUMMARY AND CONCLUSION

- Spading machine is an agricultural machine designed for loosening and breaking up the soil. The spading machines are commercially available in other parts of the world but are only finding an entry in India. Information on tillage characteristics of the spading machines under Indian conditions is not available and because of many advantages of Spading machine over conventional tillage machines.
- The study was done to evaluate its performance and to suggest a suitable parameters for its operation. The study involved various depth of cut (4 levels: D1: 10 cm, D15: 15 cm, D20: 20 cm and D25: 25 cm) and operating gear (2 levels: L1: Low 1^{st} and Low 3^{rd}) as independent parameters. Their effects were studied on dependent parameters like soil bulk density, pulverization index (MMD), soil strength (cone index), fuel consumption, field capacity, wheel slip and draft.
- The field experiments were conducted at various fields near KAU, Head quarters Vellanikkara and KVK, Vellanikkara. The effects of independent parameters on seven dependent parameters were studied.
- The following conclusions were drawn from the results of the study;

1. The minimum value of bulk density was observed for the treatment D25L1 (25 cm depth of cut and operating gear low 1^{st}) was 2.88 gcm^{-3}. However the independent variable had a non-significant influence on bulk density.
2. The pulverization index (MMD) was observed higher for 25 cm depth of cut and low 3^{rd} while minimum value was obtained for 20 cm depth of cut and low 1^{st} gear.

3. The fuel consumed by the tractor while operating the spading machine was found higher for a depth of 25 cm at 1st gear (low) and it was observed that depth of cut significantly influence the fuel consumption.
4. The spading machine shows a negative slip while operating at various depth of cut and operating speed.
5. The soil strength was represented in terms of cone index. The resistance to penetrate into the soil shows the presence of hard soil strata in the zone. The 25 cm depth of cut shows low cone index value compared to 10 cm depth of cut. Statistically there is no significant effect of the independent parameters on slip.
6. The spading machine developed by the Gomadhi engineering works, Tamilnadu was manufactured for the soil conditions in the state. The machine blades brocke during accurate depth of operations (25 cm). The hardness tested for the blade shows less brittle hardness compared to standard IS: 6690-1981 (Rotavator). This indicates that for the soils of our state, the blade should be made of stronger material.

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Appendices

APPENDICES

LABORATORY TEST

The hardness of blades was determined at edge and shank portion. The results of hardness test are tabulated in **Table-I.**

Sl. No	Hardness				Remarks	
	As per IS: 6690-1981		As observed (HB)		Shank portion	Edge portion
	Shank portion	Edge portion	Shank Portion	Edge portion		
1	(37 – 45 HRC) 344 – 411	(56 ±3 HRC) 512 – 634	**25-27**	**30-32**	Conforms/ Does not conform	Conforms/ Does not conform

(IS as per Rotavator

Chemical composition

The material of rotor blade was got analyzed from this institute itself by using SPECTRA PLUS Multi CCD Spectrometer-2110 **(IS as per Rotavator)**

Constituents	As per IS: 6690-1981		Composition As observed (% of weight)	Remarks
	Carbon Steel	Silicon Manganese Steel		
Carbon (C)	0.70 -0.85	0.50-0.60	**0.795**	Conforms/ Does not conform
Silicon (Si)	0.10 -0.40	1.50-2.00	**0.265**	Conforms/ Does not conform
Manganese (Mn)	0.50 -1.0	0.50-1.00	**1.04**	Conforms/ Does not conform
Sulphur (S)	0.05(max)	0.05(max)	**0.052**	Conforms/ Does not conform
Phosphorous (P)	0.05(max)	0.05(max)	**0.08**	Conforms/ Does not conform

Sample calculation:

1. Bulk density

Treatment = D10L

Weight of core cutter + soil sample (W_2) = 1.325 kg

Empty weight of core cutter ($W_{1)}$ = 0.775 kg

Weight of soil = 0.55 kg

Volume of core cutter (V) = 0.00485 m^3

Bulk density = Ywet

$= (W_2 – W_1) / V$

= 0.55/.00485

= 1132.34 kgm^{-3}

= 1.132 gcm^{-3}

2. MMD

Treatment = D10L1

Total weight = 833 g

Mass of soil retained (M (I)) = 356.5g

Sieve size (D (I)) = 2 mm

MMD $= \text{MMD} = \left\{\Sigma \text{M}(\text{I}) \times \text{D}(\text{I}-1) + \frac{\text{D}(\text{I})}{2}\right\} /$

$\sum \text{M}(\text{I})$

$= \frac{356.5 \times 2}{833}$

= 0.855 mm

3. Fuel consumption

Treatment =D10L1

Initial fuel level = 2000 ml

= 2 l

Final fuel level = 1100 ml

= 1.1 l

Fuel consumed = 900 ml

= 0.9 l

Fuel consumption $= \frac{\text{Initial level} - \text{final level}}{\text{Time consumed}}$

$= \frac{2-1.1}{0.288}$

= 0.9 lhr^{-1}

4. Field capacity

Treatment = D10L1

Area covered = 141.31 m^2

= 0.014ha

Time taken = 223s

= 0.062hrs

EFC $= \left(\frac{Area\ covered}{time\ taken}\right)$

$= \frac{0.014}{0.062}$

= 0.228 $hahr^{-1}$

5. Wheel slip (%)

Treatment =D10L1

No of revolutions = 6

Length on no load (L_0) = 29.8 m

Length on load (L_1) = 30 m

Slip (%) $=\{[\text{Lo} - \text{L1}]/\text{L0}\} \times 100$

$=(29.8 - 30) \times \frac{100}{29.8}$

= -0.67 %

6. Cone index

Treatment = D10L1

Force = 4.9 N

Cone area = 0.0041 m^2

Cone index = Force / area of cone

$= \left(\frac{4.9}{0.0041}\right)$

= 1200.98 Nm^{-2}

= 0.0012 MPa

Analysis of variance (ANOVA):

1. Effect on bulk density:

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	1.224[a]	4	0.306	0.851	0.576
Intercept	17.492	1	17.492	48.611	0.006
DEPTH	0.734	3	0.245	0.680	0.621
SPEED	0.490	1	0.490	1.363	0.327
Error	1.080	3	0.360		
Total	19.796	8			
Corrected Total	2.304	7			

Adjusted R squared = -0.093

2. Effect on MMD

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	0.235[a]	4	0.059	1.832	0.323
Intercept	7.781	1	7.781	242.214	0.001
DEPTH	0.153	3	0.051	1.590	0.356
SPEED	0.82	1	0.082	2.558	0.208
Error	0.096	3	0.032		
Total	8.113	8			
Corrected Total	0.332	7			

Adjusted R squared = 0.322

3. Effect on field capacity

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	0.033[a]	4	0.008	1.673	0.351
Intercept	0.912	1	0.912	182.990	0.001
DEPTH	0.008	3	0.003	0.540	0.087
SPEED	0.025	1	0.025	5.070	0.110
Error	0.015	3	0.005		
Total	0.960	8			
Corrected Total	0.048	7			

Adjusted R squared = 0.278

4. Effect on fuel consumption

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	9.497[a]	4	2.374	46.945	0.005
Intercept	151.598	1	151.598	2.998E3	0.000
DEPTH	9.455	3	3.152	62.319	0.003
SPEED	0.042	1	0.042	0.823	0.431
Error	0.152	3	0.051		
Total	161.246	8			
Corrected Total	9.648	7			

Adjusted R squared =0.963

5. Effect on slip

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	1.935[a]	4	0.484	1.536	0.377
Intercept	18.368	1	18.368	58.335	0.005
DEPTH	1.725	3	0.575	1.827	0.317
SPEED	0.210	1	0.210	0.666	0.474
Error	0.945	3	0.315		
Total	21.248	8			
Corrected Total	2.880	7			

Adjusted R squared = 0.235

6. Effect on soil strength

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	0.002[a]	4	0.001	1.454	0.395
Intercept	0.006	1	0.006	15.088	0.030
DEPTH	0.002	3	0.001	1.693	0.338
SPEED	0.000	1	0.000	0.736	0.454
Error	0.001	3	0.000		
Total	0.009	8			
Corrected Total	0.003	7			

Adjusted R squared = 0.206

Abstract

PERFORMANCE EVALUATION OF TRACTOR OPERATED SPADING MACHINE

By

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Meera T (2014-02-029)

ABSTRACT OF THE REPORT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology
In
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Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

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2018

ABSTRACT

Spading machines are agricultural machines designed for loosening and breaking up the soil. . The machine is made up of several spade shovels that are connected to a crankshaft. Spading machines are hitched to a tractor using the standard three point linkage and P.T.O driven. Spading machines incorporate residues, straw, compost, green manure etc during the tilling operation. This enhances the soil fertility, porosity etc. The purpose of this study is to evaluate the potential of the tractor operated spading machine and the specific objective of the proposed study is to evaluate the performance of tractor operated spading machine for the soil typical in Kerala. This study aims at evaluating the effect of varying soil conditions and operational conditions such as depth of operation and forward speed of the tractor operated spading machine on its performance with reference to parameters such as soil bulk density, soil strength (cone index), pulverization index (MMD), wheel slip, field capacity, fuel consumption and draft. A comparative analysis between the performance of rotavator and spading machine was also done as a part of this study. The travel speed and depth of operation were taken as the independent parameters and their effects on the variables such as soil bulk density, soil strength, pulverization index, field capacity, fuel consumption, wheel slip and draft were studied.