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Development and laboratory evaluation of spading machine

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Abstract
Spading machine is a tillage implement which loosen and break up the soil. The principle of spading machine is similar to digging of soil by spade. Spading machine is designed to approximate the effect of proven smaller-scale hand digging tool for the purpose of deeper aeration and effective integration of organic matter. The machine was developed in research workshop, Department of Farm Machinery and Power Engineering, KCAET Tavanur, KAU Thrissur. The evaluation of machine was conducted in soil bin which, is containing laterite soil with 13.87% moisture content and 1.73 gcc^{-1} bulk density. The minimum and maximum field capacity of spading machine were 0.03 and 0.064 ha h^{-1} with forward speed 1 and 3 km h^{-1} respectively. The efficiency of spading machine was varied from 75 to 80% at 1 and 3 km h^{-1} respectively. The depth of operation 13 cm obtained at low crank speed 165 rpm.

Keywords: Spading machine, forward speed, crank speed, field capacity and digging efficiency

1. Introduction

Tillage, as a fundamental mechanical soil preparation phase, is an important operation in agriculture for crop production. It is a major farming operation for seedbed preparation. It is the most energy consuming operation in crop production. The energy demand for tillage is influenced by the tool design and configuration, soil properties and operating conditions. The tractors have their own limitations for use small fields and their costs are also beyond the reach of small and marginal farmers (Tiwari *et al.*, 2004) [9].

Spading machines are agricultural machines which loosen and break up the soil. The working principle spading machine is similar to digging of soil by spade. Spading machine is designed to approximate the effect of proven smaller-scale hand digging tool for the purpose of deeper aeration, and effective integration of organic matter. It is either rotary or reciprocating, and the spades of both types move more slowly than rotary tiller. This action works in the soil more effectively without compaction. Spading machine is an alternative to using a rotary tiller or a plough (Hoffman, 1993) [4]. As a result, the roots of the plants develop in better manner and increases the water holding capacity (Giordano *et al.*, 2015) [3]. Spading machine incorporates a large amount of organic material such as crop residue, straw and compost. Operation of this machine requires less draft force, power requirement and fuel consumption as compared to the conventional soil engaging machines. Spading machines can operate at more depth as compared to conventional tillage. These machines are breaking up the soil up to 20 cm to 30 cm depth and it creates the good seedbed in a single pass (Knight and Sahai, 2013) [7]. Removal of subsoil compaction by deep operation results, 45% yield increases with spading machine (Davies *et al.*, 2013) [2]. The spading machine comprises of a horizontal crankshaft with spades on the connecting rods plunging rotationally, sequentially, downwards into the soil **(**Manfred *et al.*, 2009) [89].

The spading machine is equipped to help of gears or chain and sprocket according to requirements. It has been claimed that their action subtly aerated/fractured the subsoil twice the depth of the stroke of the spades (Manfred *et al.*, 2009) [8]. Recent research shows that using rotary spaders can considerably improve biomass and grain yields from underperforming sandy soils by incorporating manure or organic matter, burying non-wetting top soil, removing compaction in shallow layers and breaking up and mixing in delved or spread clay. The functional components of the spading machine are to be designed using standard test procedures.

The laboratory evaluation of the spading machine conducted in laterite soil which, is having 44-47, 29-30 and 23-25% sand, silt and clay respectively.

The effect independent parameters on dependent parameters will be studied. Each trial is to be studied in detail and modifications are incorporated accordingly. The data and readings recorded at various levels of observation will be analyzed statistically to optimize the dependent parameters and for final modification of the prototype. Soil samples will be collected from different locations at different depths of soil bin by using a cylindrical core cutter and properties of soil will be studied following standard test procedures. The moisture content will be measured by oven dry method. Cone penetrometer will be used to measure the penetration resistance of the soil. The clod mean weight diameter of soil will be measured by sieve analysis method. The performance evaluation of the developed spading machine will be carried out at 3 levels of forward speed.

2. Materials and Methods

The spading machine was developed and fabricated in the workshop of department of Farm Machinery and Power Engineering, Kelappaji college of Agricultural Engineering and Technology, Tavanur, KAU Thrissur.

2.1 Construction details of spading machine

The lab model of spading machine consists of crankshaft, connecting rod, rocker arm, and spade. The crankshaft having four crank where, connecting rod is attached. The rocker arm and blades are attached to the connecting rod. The crank is having circular motion which is cover 360^0 in one revolution. The connecting rod is having oscillatory motion. The spade is having trapezoidal shape 100 mm diameter of holes for attachment to the connecting rod with the nut, bolts and washer. In this experiment the 3 hp motor is used. The rpm of crankshaft is controlled by using variable frequency drive.

Table 1: Specification of Motor

Sl. No	Specification	Value
1	Hp	3
2	Rpm	1440
3	Phase	3
4	Amps	4.5
5	Cycle	60

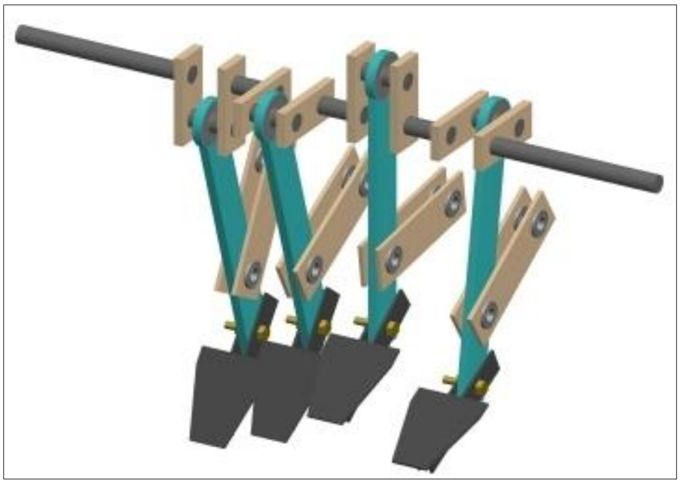

Fig 1: Spading machine (Lab model)

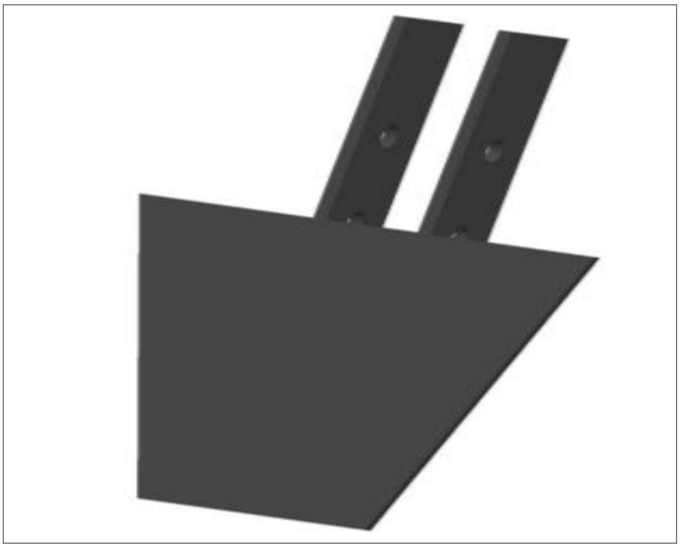

Fig 2: Trapezoidal shape Blade

2.2 Bulk density of soil

The bulk density of soil was determined by using core cutter method. For determining the bulk density of the soil, the soil samples were taken from the soil bin with the help of core sampler having 12.7 and 9.7 cm height and diameter respectively. The bulk density was determined according to procedure mentioned in IS: 2720 (P: 29): 1975.

2.3 Moisture content of soil

The soil moisture content was determined by hot air oven method. Soil samples were collected from experimental soil bin and the known weight of soil sample was kept in the hot air oven at a temperature of 105 °C for 24 hours. The water content of soil sample was calculated according to procedure mention in IS: 2720 (P 2): 1973.

2.4 Cone index

Soil cone penetrometer was used to measure the penetration resistance of the soil. The cone penetrometer was positioned in the soil bin and slightly pressed on the handle. Cone index provides an indication of soil resistance and it is expressed as force per square centimetre required for a cone of standard base area to penetrate into soil to different depths. The solid stem penetrated into the soil and force was measured from the deflection of the needle proving ring corresponding to the insertion of 30° cone (Venkatareddy, 2018) [10].

2.5 Clod mean weight diameter

To determine soil clod mean weight diameter, the soil sample was allowed to permit through a set of sieves which is collected from the field. Weighed soil retained on the main aperture sieve, passed through individually sieve and retained on the next sieve and passed through the smallest aperture sieve. Clod mean weight diameters (CMWD) were determined as:

$$\mathrm{CMWD} = \sum_{i=1}^{n} \frac{Xi \times Wi}{W} \quad \ldots (3.34)$$

Where,
CMWD = Clod mean weight diameter (mm)
X_i = Mean diameter of each size class (mm)
W_i = Proportion of each size class to the total sample (g)
W = Total weight of sample (g)

2.6 Theoretical field capacity
It is the amount of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width. The theoretical field capacity was determined by following equation (Bainer *et al.*, 1956) [1].

Table 2: Specification of spading machine

S. No	Specification	Value
1	Working width	400 mm
2	No. of spades	4
3	Depth of ploughing	10 cm
4	Crank speed	150-200 rpm
5	Power transmission	Chain and sprocket
6	Material of spade	High carbon steel

3. Results and Discussion
The developed implement was tested in laboratory condition at Department of Farm Machinery and Power Engineering, KCAET, Tavanur. The spading machine was tested with laterite soil, which is having cone index 1.53 kg/cm^2. The maximum bulk density was 1.73 g/cc obtained before conducting the tillage operation in lab. Performance evaluation of spading machine was done at moisture content 13.87%, with 3 forward speed 1.0, 2.0 and 3.0 km h^{-1} and constant crank speed 165 rpm respectively. Bulk density, cone index, actual field capacity, field efficiency, clod mean and weight diameter were estimated.

3.1 Bulk Density
The bulk density of soil was varies from 1.42 to 1.73 g cc^{-1}. The minimum bulk density of soil after operation 1.42 g cc^{-1} was obtained at 13.87% moisture content while maximum bulk density of soil before operation 1.73 g cc^{-1} was obtained at 13.87% moisture content respectively.

3.2 Cone index
The cone index of soil varied from 0.82 to 1.53 kg cm^{-2}. The highest value of the cone index was 1.53 kg cm^{-2} with 13.87% moisture content at before the operation. The minimum cone index was 0.82 kg cm^{-2} at 13.87% moisture content at after the operation

3.3 Clod mean weight diameter
The clod mean weight diameter of soil was varied from 5 to 8 mm at 13.87% moisture content and 165 rpm of crank speed. The maximum clod mean weight diameter of soil 8 mm was at a forward speed of 1 km h^{-1} with crank speed 165 rpm at 13.87% moisture content while minimum clod mean weight diameter of soil 5 mm was at a forward speed 3 km h^{-1} with crank speed 165 rpm at 13.87% moisture respectively.

3.4 Actual field capacity
The actual field capacity of the spading machine was varied from 0.03 to 0.064 ha h^{-1} with different forward speeds at constant crank speed was 165 rpm and 13.87% moisture content. The maximum actual field capacity 0.064 ha h^{-1} was recorded at a forward speed 3 km h^{-1} with crank speed 165 rpm at 13.87% moisture content while minimum actual field capacity 0.03 ha h^{-1} was at a forward speed 1 km h^{-1} with constant crank speed 165 rpm and 13.87% moisture content respectively.

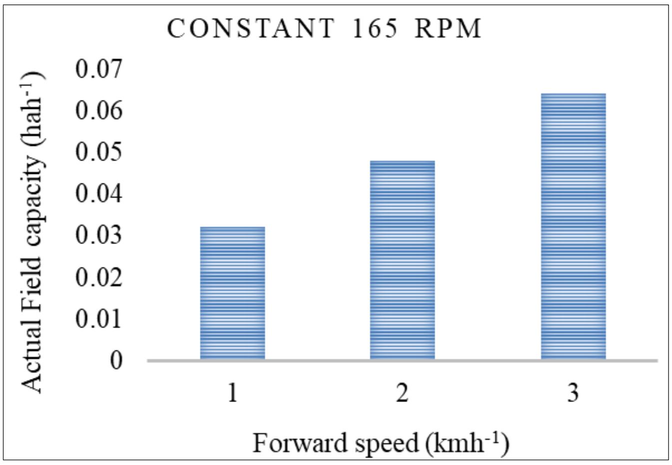

Fig 3: Actual field capacity of spading machine

3.5 Field efficiency
The field efficiency of spading machine was varied from 75 to 80% with different forward speed and constant crank speed. The maximum field efficiency of spading machine 80% was at forward speed 3 km h^{-1} with 165 rpm of crank speed and 13.87% moisture content, while minimum field efficiency 75% was at forward speed 1 km h^{-1} with constant crank speed 165 rpm and 13.87% moisture content respectively.

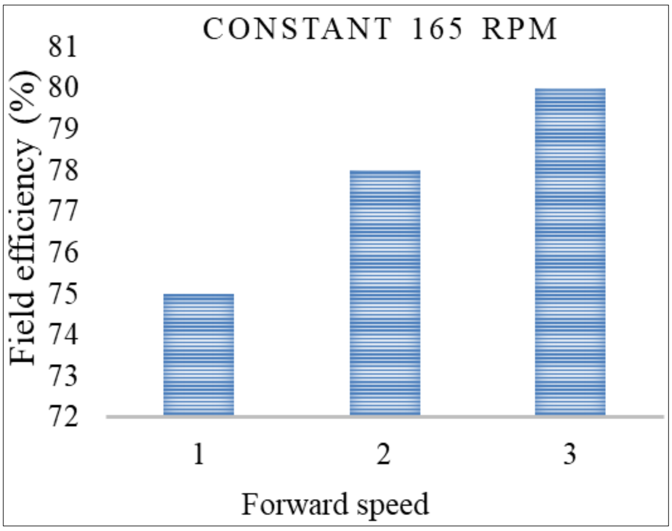

Fig 4: Field efficiency of spading machine

4. Conclusion
In all trials, as the forward speed increases, the field capacity and field efficiency increases. The quality of work was obtained at low crank speed of spading machine.

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