Grenze International Journal of Engineering and Technology, June Issue

Field Evaluation of Power Tiller Operated Spading Machine

Chandrashekar[1], Chethan B. J[2], Vikas L[3], Bini Sam[4] and Basavaraj Patil[5]
[1-3]Assistant Professor, Department of Agricultural Engineering, Akshaya Institute of Technology, Tumkur, Karnataka.
[4]Professor and Head, ICAR-KVK, Kollam, Kerala.
[5]Associate Professor, Department of Agricultural Engineering, Tontadarya College of Engineering, Gadag, Karnataka.

***Abstract*— Manual spading needs more labour, takes more time, high energy and cost per cultivable area. The depth of cut is also less in manual spading operation. Tractor operated spading machines have their own set of limitations in small fields, and their cost was also out of reach for small and marginal farmers. These factors lead to the development of a spading machine as an attachment to power tiller. Overall, the maximum field efficiency 87 per cent was achieved at the forward speed of 2.1 km h^{-1}, when the depth of cut was 10 cm at 30° spade angle and 200 rpm crankshaft speed. The minimum fuel consumption 0.87 l h^{-1} was noticed at 1.5 km h^{-1} forward speed, 10 cm depth of operation and 100 rpm crankshaft speed respectively.**

***Index Terms*— Tillage, Spading machine, Field capacity, Field efficiency, Fuel consumption**

I. INTRODUCTION

Tillage involves the mechanical manipulation of soil to create a favorable environment for plant development. Tillage activities account for 16-25 per cent of overall energy use (Shukla and Gupta, 2017). Tillage tools use energy to induce desired effects in the soil, such as cutting, breaking and inversion or movement. The tool design and configuration, soil parameters, and operating conditions all impact the energy consumption for tillage. Spading machines are farm implements that loosen and break up the soil. The goal of the spading machine is to simulate the effect of a proven smaller-scale spade for deeper aeration and organic matter integration. It consists of a horizontal crankshaft with spades on connecting rods that plunge into the soil in a rotating, consecutive manner (Manfred *et al.*, 2009). It has been stated that their action aerated/fractured the subsoil twice as deep as the spade stroke (Manfred *et al.,* 2009). A spading machine can be used instead of a rotary tiller or a plough (Hoffman *et al.,* 1993). As a result, the roots of the plants develop more quickly and the water-holding capacity of the plants rises (Giordano *et al.,* 2015). Using a spading machine to remove subsurface compaction leads in a 45 per cent improvement in yield (Davies *et al.*, 2013).

There are limitations in manual spading and tractor operated spading in small and marginal land cultivation. Manual spading needs more labour, takes longer time, more energy and high cost per cultivable area. The depth of cut is also low when using a manual spade. Tractor operated spading machines have their own set of limitations when it comes to using in small fields, and their costs are also out of reach for small and marginal farmers. The power tillers might potentially be employed for seedbed preparation and inter-culture operations in hilly regions. Currently, most of power tillers mass-produced in the nation are in the 6-7.46 kW range (Kadu *et al.*, 2015). The power tiller is a multi-purpose hand tractor that is mostly used for rotary tillage, puddling, and other farm tasks.

Grenze ID: 01.GIJET.10.2.748

Power tillers are the most ideal for agricultural activities for small and marginal farmers in most parts of the country, due to their small size, lightweight, and high maneuverability. Power tillers' adaptability is limited by the lack of matching equipment for various farm operations. Development of suitable power tiller operated spading machine is to be the most appropriate mechanical tillage equipment for small and marginal farmers.

II. Materials And Methods

The experimental method for evaluating machine performance as a function of soil, machine and operational characteristics. The machine was designed and developed using Pro-e software and empirical design. The spading machine was developed at the Department of FMPE's research workshop in KCAET, and the field trials were conducted in KCAET, Tavanur.

Bulk density of soil

Using the core cutter method, the bulk density of the soil was calculated. Soil samples were collected at random from the experimental plot using a core sampler with a height and diameter of 12.7 and 9.7 cm, respectively, to determine the bulk density of the soil. The bulk density was estimated before and after spading operation using the method described in IS: 2720 (P: 29): 1975.

$$\text{Bulk density} = \frac{\text{Dry weight of soil}}{\text{Volume of core sampler}}$$

$$\rho = \frac{M}{V}$$

where,
ρ = Bulk density (g cm^{-3})
M = Dry weight of the soil (g)
V = Volume of core sampler (cm^3)

Moisture content of soil

The moisture content of the soil was determined using hot air oven method. To determine the moisture content of the soil, soil samples were randomly chosen from the experimental plot, and the known weight of the soil sample was kept in a hot air oven for 24 hours at a temperature of 105^0 C. The moisture content of a soil sample was determined using the method described in IS: 2720 (P 2) 1973.

$$\text{Moisture content, } W = \frac{Ww - Wd}{Wd} \text{ X } 100$$

Where,
W = Moisture content (per cent)
W_w = Wet mass of soil (g)
W_d = Dry mass of soil (g)

Shear strength

The shear strength of soil refers to its maximum resistance against shearing stresses (Venkatareddy, 2018). To measure the in-situ shear strength of the soil, a vane shear test apparatus was used. Bore holes were excavated at depths of 30, 45 and 60 cm. The torque applicator was fixed on a stand using spikes, while a vane with a diameter of 37.5 mm was connected to a vane rod with a matching thread. The vane was then lowered to the desired depths.

Cone index

The cone index is a measure of soil strength that is stated as the force required to probe into the soil per square centimeter. The cone index was determined using a cone penetrometer at various depths. The following equation was used to calculate the cone index.

$$CI = 0.025Y + 0.099$$

where,
CI = Cone index (N mm^{-2})
Y = Gauge deflection (divisions)

Theoretical field capacity

It is the amount of field coverage that would be increased if the machine performed its task at the rated forward speed of 100 per cent of the time and always covered 100 per cent of its rated width. The theoretical field capacity was calculated using the equation below.

$$TFC = \frac{S \times W}{10}$$

where,
TFC = Theoretical field capacity (ha h^{-1})
W = Width of cut (m)
S = Speed of operation (km h^{-1})

Actual field capacity

It is the machine's real average rate of coverage based on field operation time. The actual field capacity is determined by the proportion of the machine's rated width, operating speed, and field time lost during operation. The unit of field capacity is ha h^{-1}, which is a common way of expressing effective field capacity.

$$AFC = \frac{A}{Tp + T_i}$$

where,
AFC = Actual field capacity (ha h^{-1})
A = Actual area covered (ha)
T_p = Productive time (h)
T_i = Non-productive time (h)

Efficiency

It is the ratio of actual field capacity to the theoretical field capacity, expressed as percentage.

$$\eta = \frac{AFC}{TFC} \times 100$$

where,
η = Efficiency (per cent)
AFC = Actual field capacity (ha h^{-1})
TFC = Theoretical field capacity (ha h^{-1})

Fuel consumption

The fuel consumption is the amount of fuel required per unit time of operation for the machine and was calculated using the top fill method. Before the testing on a levelled surface, the diesel tank was filled full to its capacity. The actual fuel usage was recorded when the field operation was completed. The fuel usage was measured in liters per hour.

TABLE I SPECIFICATION OF POWER TILLER SELECTED FOR THE STUDY

S. No	Specification	Value
1	Make	KAMCO
2	Engine Model	ER-90
3	Engine Type	4 Stroke, DI, Single cylinder
4	Power	9 hp
5	Engine rpm	2000
6	Numbers of Gears	6+2
7	Fuel tank capacity	10.7 L
8	Total weight	450 kg

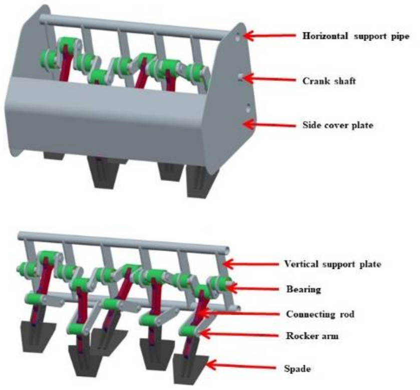

Plate. 1. Different components of spading machine

Plate. 2 Power tiller operated spading machine

III. Results And Discussion

This chapter explained the performance evaluation of power tiller operated spading machine. The results of soil and machine parameters was also presented. Experimental trials were conducted to determine optimum levels of field performance of spading machine under different operating conditions and the results of the data are statistically analyzed and discussed in the following sections.

Soil type

The soil samples taken separately from the cultivated fields and analyzed for finding its textural composition. The field trials were carried out in laterite soil. The percentage of different textures ranged between 44-47, 29-30 and 23-25 per cent sand, silt and clay in the field respectively.

Soil moisture content

The soil moisture content was measured at different places of the experimentalplot. The moisture content of laterite soil varied from 14 to 17 per cent with mean of 15.5 per cent. A favorable moisture level was chosen where the required draft and the soil penetration resistance were moderate and within the working limits for obtaining maximum tillage efficiency.

Soil bulk density

The bulk density of the soil ranged from 1570 to 1810 kg m^{-3} with an average mean of 1690 kg m^{-3}. It shows the variations in soil bulk density at respective soil moisture. It was observed that bulk density of soil increased with increase in soil moisture content and had a linear relationship.

Cone index

The cone index varied from 0.8 to 1.72 kg cm^{-2} with mean of 1.26 kg cm^{-2}. The highest value of the cone index was 1.72 kg cm^{-2} at the soil moisture of 14 per cent. As the depth increased from surface, penetration resistance also increased.

Shear strength

The shear strength of soil was determined by using vane shear apparatus. The shear strength of soil varied from 0.0118 to 0.0132 kg cm^{-2} with mean of 0.0125 kg cm^{-2}.

Actual Field capacity

The minimum actual field capacity was 0.0658 ha h^{-1} at 1.5 km h^{-1} of forward speed, 20 cm depth of cut, 30° spade angle and 100 rpm of crankshaft speed and the maximum actual field capacity 0.1132 ha h^{-1} was noted at 2.1 km h^{-1} of forward speed, 10 cm depth of cut, 30° spade angle and 200 rpm of crankshaft speed configuration. It was found that the actual field capacity of power tiller operated spading machine was 0.1132 ha h^{-1} which is higher than traditional method of 0.008 ha h^{-1} and less than tractor operated spading machine (0.4 ha h^{-1}). It was observed that the actual field capacity of spading machine increased with increase in forward speed.

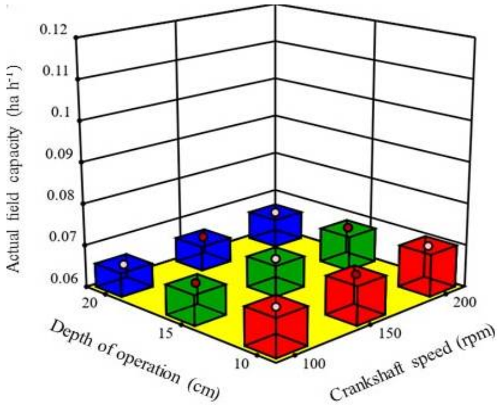

Fig. 1. Effect of depth of operation and crankshaft speed on actual field capacity at forward speed of 1.5 km h^{-1}

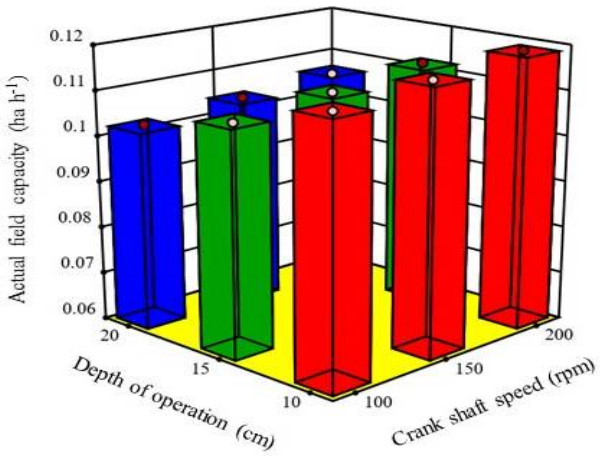

Fig. 2. Effect of depth of operation and crankshaft speed on actual field capacity at forward speed of 2.1 km h^{-1}

Field Efficiency

The field efficiency of spading machine varied from 67 to 87 per cent. Overall, the maximum efficiency 87 per cent was achieved at the forward speed of 2.1 km h^{-1}, when the depth of cut was 10 cm at 30° spade angle and 200 rpm of crankshaft speed. On the other hand, the lowest efficiency 67 per cent was observed, where the forward speed was 1.5 km h^{-1}, the depth of cut was 20 cm, 30° spade angle and the crankshaft speed of 100 rpm. It was observed that the field efficiency of spading machine increased with increase in forward speed.

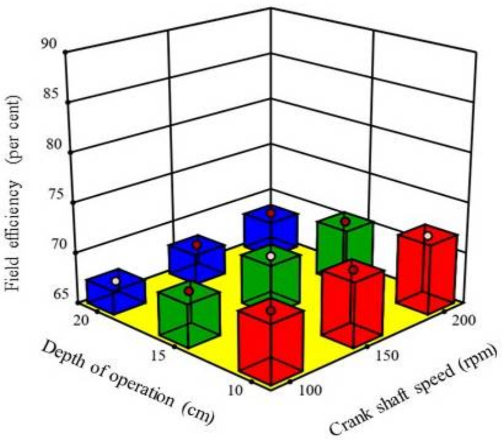

Fig. 3. Effect of depth of operation and crankshaft speed on field efficiency at forward speed of 1.5 km h^{-1}

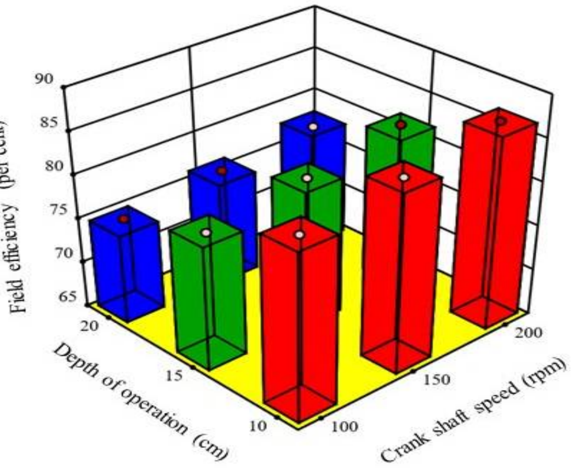

Fig. 4. Effect of depth of operation and crankshaft speed on field efficiency at forward speed of 2.1 km h^{-1}

Fuel Consumption

The recorded fuel consumption ranging from 0.87 to 1.34 l h^{-1}. The minimum fuel consumption 0.87 l h^{-1} was noticed at 1.5 km h^{-1} forward speed, 10 cm depth of operation and 100 rpm crankshaft speed respectively. The maximum fuel consumption 1.34 l h^{-1} was obtained at 2.1 km h^{-1} forward speed, 20 cm depth of cut, and 200 rpm of crankshaft speed respectively. The above data were relatively low when compare to Bist (2017) when evaluated the vertical rotary plough for hill with fuel consumption 1.56 l h^{-1} at 2.1 km h^{-1} forward speed. It was indicated that the fuel consumption of spading machine increased with increase in forward speed from 1.5 to 2.1 km h^{-1}.

IV. CONCLUSIONS

The actual field capacity of power tiller operated spading machine was 0.1132 ha h^{-1} which is higher than traditional method 0.008 ha h^{-1} and less than tractor operated spading machine 0.4 ha h^{-1} respectively. It was observed that the field efficiency of spading machine increased with increase in forward speed and decreases with increases in depth of operation. The field efficiency varied from 67-87 per cent. It was observed that the efficiency of the machine was increases with increase in rpm crankshaft and forward speed of operation. The fuel consumption of the machine varies from 0.87-1.34 l h^{-1} with different forward speeds and rotational speeds. The fuel consumption of the machine was increase with increase in both forward speeds and rotational speeds.

REFERENCES

[1] Bist. V.S., 2017. Design and Development of Rotary Plough for Hills, M.Tech (FMPE) thesis, G. B. Pant University of Agriculture and Technology, Pantnagar, 66p.
[2] Davies, S.L., Bakker, D.M., Scanlan, C.A., Gazey, C., Hall, D.J., Riethmuller, G.P., Abrecht, D.G., Newman, P.D., Harding, A., Hayes, D.W., and Smart, S.D. 2013. Deep soil cultivation to create improved soil profiles for dryland crop production. Int. Soc. Eng. Agric. 3(2): 410-420.
[3] Giordano, D.M., Facchinetti, D., and Pessina, D. 2015. The spading machine as an alternative to the plough for the primary tillage. J. Agric. Eng. 46: 36-40.
[4] Hoffman, K.D., Kelley, S.W., and Davis, M.A. 1993. A typology of retail failures and recoveries. J. Ret. 69(4): 429-436.
[5] IS: 2720 [P: 2]: 1973. Methods of test for soil. Determination of water content, Bureau of Indian Standards, New Delhi. pp. 1-5.
[6] IS: 2720 [P: 29]: 1975. Methods of test for soil. Determination of dry density of soils in-place by the core-cutter, Bureau of Indian Standards, New Delhi. pp. 1-10.
[7] Kadu, L.S., Kadam, G.B., Jadhav, K.P., Gawade, V.S., Garje, A., and Gosavi, A. 2015. Design, Development and Operation of 3.5 HP Power Tiller. Int. J. Res. Civil. Mech. Eng. 2(1):149-154.
[8] Manfred, K., Tobias, S., and Schulin, R. 2009. Development of the mechanical stability of a restored soil during the first 3 years of re-cultivation. Soil Tillage Res. 103(1):127-136.
[9] Shukla, K. and Gupta, P. 2017. Design and development of mini tractor operated wavy disc type PTO powered tillage implement. Pharma Innovation J. 6(11): 621-627.
[10] Venkatareddy, H. K. and Jayan, P. R. 2018. Design analysis of KAU pokkali paddy harvester towards the development of its scale down prototype. Ph.D. (Ag. Engg) thesis, Kerala Agricultural University, Thrissure. 321p.