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Performance Evaluation of Vertical Rotary Plough

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A rotary plough is an agricultural implement, popularly used to reduce the amount of time and labour spent in soil preparation. The objective of this study was to evaluate the performance evaluation of vertical rotary plough on fallow and cultivated land. The observed experimental are: moisture content of soil, bulk density of soil, cone index, soil mean weight diameter, wheel sleep, theoretical field capacity, effective field capacity, field efficiency, fuel consumption and weeding efficiency. Result were: soil moisture content 8.19% and 11.74%, bulk density of soil 1.99 gm/cm³ and 1.90 gm/cm³, cone index 0.236 kg/cm² and 0.144 kg/cm², soil mean weight diameters 4.17 mm and 3.86 mm, fuel consumption 6.30 l/hr and 5.76 l/hr, field capacities 0.17 ha/hr and 0.23 ha/hr and field efficiency 71.53% and 82.14% in case of fallow land and cultivated land respectively. It shows that the time required for rotary plough operation in fallow land was more than the time required for the cultivated land.

Keywords: Vertical rotary plough; tillage; tillage parameter; field efficiency; fuel consumption.

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1. INTRODUCTION

In India mostly traditional tillage implements are used for seed bed preparation because of low level of mechanization, farmers have less capital as well as land. The higher cost of other tillage implement like rotavator, rotary plough, disc plough etc. are limited in use. Most of the farmers are illiterate and they do not know the advantages of rotary and vibrating tillage over traditional tillage. Traditional tillage equipment's require higher amount of power, because it has sliding action while in case of rotary plough, there is rotary action. Also, frictional resistance in traditional tillage is high, whereas, in rotary tillage it is low. But rotary tillage also has some disadvantages since it cannot work properly in hard soil.

Rotary plough mainly cause three operations: ploughing, cutting and mixing in soil and thereby it replaces the plough and harrows. It is also used for deep cultivation. Many farm operations done in monsoon by tractor or other heavy implements cause formation of hard pan in soil. Rotary plough breaks these hard pans and mixes them throughout. So, it is the best primary tillage implement that develops the favorable farming condition for plant and there by save lot of time and energy.

Researchers studied that tillage is an operation performed to obtain a desirable soil structure for a seedbed or root bed [1]. The research works carried out by many researchers that tillage is most costly operation in the budget of a farmer because amongst all the agricultural operation like drilling, spraying, harvesting etc., tillage machinery requires maximum amount of power for seedbed preparation [2-4]. The main three things are involved in soil tillage which includes; physical properties of soil, power source and the matching implement suitable to the available power source. The draft and power requirements under different soil condition is important to decide the size of the tractor that could be used for a specific implement. References suggested that the draft required for a given implement is directly depends on the soil conditions and the geometry of the tillage implement [5,6].

In tillage, the performance of tools is determined by their specific draft, energy requirements and the quality of works [7]. Vertical rotary plough gave better quality of soil than horizontal rotary plough. Soil resistance in vertical axis rotary plough is less than horizontal axis rotary plough and soil disturbed in vertical axis rotary plough is much more than horizontal one [8].

According to reference rotary plough saved 30-35% of time and 20-25% in the operation cost compared to tillage by cultivator. It gave higher quality of work 25-30% then tillage by cultivator. The rotary plough is the most efficient means of transmitting engine power directly to the soil with no wheel slip and a major reduction in transmission power loss [9].

Considering the present practice of seed bed preparation among the farmers and implements used to performed different operations, there is need to study the best alternative, either operation wise or equipment wise, by which we can reduce the cost of operation and improves the efficiency of the system. Hence, the object of this study was to evaluate the performance of vertical rotary plough.

2. MATERIALS AND METHODS

A vertical rotary plough (Fig. 1) was operated in the fallow land with help of 55 HP tractor at the experimental farm of the Department of Farm Machinery and Technology, Junagadh Agriculture University (JAU), Junagadh, India. Straight knife type blade was used in a rotary plough and specifications of rotary plough are given in Table 1.

The soil was medium black and covered partly with roots and trashes of last crop grown. Soil parameter was studied for both laboratory and field test.

2.1 Soil Moisture Content

Samples of soil were taken randomly from three different locations of test plot to measure soil moisture. Weight of each soil sample was measured immediately after collection. The samples were put in a hot air oven maintained at 105℃ for 8 hrs. After oven drying samples were weighted [10]. The soil moisture (Dry bulb %) was calculated by using the formula;

$$\text{Soil moisture content (Dry bulb \%)} = \frac{W1 - W2}{W2} \times 100$$

Where,

W_1=Weight of wet soil sample
W_2= Weight of oven dry sample

Table 1. Specification of existing rotary plough

Particulars	Specification
Make	Shaktiman
Model	SRP-100
Length of machine (cm)	105 cm
Width of machine (cm)	79 cm
Height of machine (cm)	122 cm
Type of transmission system	gear drive
Length of shaft (cm)	75 cm
Diameter of shaft (cm)	26 cm
No. of flange	4
Type of blade	straight knife type blade
No. of blade on flange	2
Total no. of blade	8
Length of blade (cm)	28.5 cm
Cutting width of blade (cm)	4 cm
Cutting angle of blade (degree)	95°
Thickness of blade (mm)	12 mm
Diameter of rotar (cm)	24 cm
Type of linkage system	3 point linkage
Weight of machine (kg)	460 kg
Type of the gear system	Bevel pinion type

2.2 Bulk Density

Measurement of bulk density of soil was taken with a cylindrical core sample. The core sample was kept in hot air oven maintained at 105℃ for 8 hr [11]. Bulk density was determined using the formula:

$$\text{Bulk density of the soil} = \frac{M}{V} = \frac{4M}{\pi D^2 L}$$

Where,

M= Mass contained in the core sample of oven dry soil (gm)
V= Volume of cylindrical core sample (cm³)
D= Diameter of cylindrical core sample (cm)
L= Length of cylindrical core sample (cm)

2.3 Cone Index

Cone index is an indication of soil hardness and is expressed as force per square cm required for penetrating the cone into the soil. Cone index was measured by using a penetrometer for a different depth of 3 to 10 cm range. The average reading was taken as the cone index [12].

2.4 Mean Weight Diameters (MWD)

To determine Soil Mean Weight Diameter (SMWD) soil sample was allowed to pass through a set of sieves. Weighed soil retained on the largest aperture sieve, passed through each sieve and retained on the next sieve and passed through the smallest aperture sieve. Mean weight diameters (MWD) were determined as [13]:

$$MWD = \sum_{i=1}^{n} \text{XiWi}$$

Where,

Xi = Mean diameter of each size class (2, 2-1, 1-0.25 and 0.25-0.053 mm)
Wi = Proportion of each size class to the total sample.

(A) **(B)**

Fig. 1. (A) Vertical rotary plough (B) Operating condition of vertical rotary plough

2.5 Wheel Slip

Tractor drive wheel slips in all operations. Percentage of wheel slip is called travel reduction ratio. However, the travelled distance of the tractor in given number of revolutions increases due to the soil frictional force in case of rotary plough [14].

$$\text{Wheel slip (percentage)} = \frac{(A-B)}{A} \times 100$$

Where,

A= Distance covered at every 10 revolution of the tractor drive wheel at no load (m),
B= Distance covered at every 10 revolution of the tractor drive wheel with load (m).

2.6 Theoretical Field Capacity

According to reference [15], the theoretical field capacity is measured by the given formula:

$$\text{Theoretical field capacity} = \frac{W \times S}{10}$$

Where,

W= Working width of implement (m)
S= Travel speed of Tractor (km/hr)

2.7 Effective Field Capacity

In the data sheet, time lost for event such as turning was recorded. Thus in calculating field capacity, the time consumed for the work and also time lost for other activities such as turning and adjustment were also used [15]. The effective field capacity was calculated by given formula:

$$\text{Effective field capacity (S)} = \frac{A}{(Tp + Ti)}$$

Where,

S= Effective field capacity (ha/hr)
A= Area covered (ha)
T_p= productive time (hr)
T_i= Nonproductive time (hr)

2.8 Field Efficiency

The field efficiency was calculated as follows [16]:

$$\text{Field efficiency (Er)} = \frac{Effective\ field\ capacity\ (ha/hr)}{Theoretical\ field\ capacity\ (ha/hr)}$$

2.9 Fuel Consumption

The fuel consumption was calculated through physical measurements i.e. the fuel consumed during the operation and to that the power requirement is calculated. The fuel tank was filled up to the full level and the time for rotary plough operation was noted down. At the end of the operation the total time consumed for operation was noted down and the level of fuel in the fuel tank was checked again. This way the fuel consumption for rotary plough operation was determined [17].

2.10 Weeding Efficiency

Weeding efficiency is quantitatively expressed as ratio of number of weeds or stubbles of last crop left on soil surface after operation to that before it [18]. It was determined using the formula:

$$F = \frac{Wp - We}{Wp} \times 100$$

Where,

F = indicator for soil inversion; ratio of weed or crop stubble being filled up.
W_p = No. of weed or crop stubble before operation per unit area.
W_e = No. of weed or stubble exposed on the surface after operation.

A square frame having sides 50 cm or 100 cm is convenient for counting weed or the stubble.

3. RESULTS AND DISCUSSION

Average value of soil parameters are given in Table 2 while different field capacities are compared in Table 3.

3.1 Soil Moisture Content

The moisture content of soil for fallow land as well as cultivated land was measured for three different locations within the field. This was determined by oven drying method, The results of moisture content for fallow land were 8.56, 7.61, 8.40% and its average was 8.19%.The moisture content for cultivated land was measured to be 11.12, 11.90, 12.20% and its average moisture content was taken as 11.74%. So moisture content in cultivated land was higher than the fallow land.

3.2 Bulk Density of Soil

Bulk density was measured for two fields for fallow land and cultivated land. In the fallow land reading of bulk density were taken, it gave 1.99 gm/cm^3 and 1.90 gm/cm^3 bulk density before and after rotary plough operation respectively. This indicated the increase of pore space due to the loosening of soil and the bulk density of soil was reduced to about 4.52% by rotary tiller operation.

3.3 Cone Index

The value of the cone index for fallow land at 3-10 cm depth before ploughing was measured as 0.115, 0.206, 0.388 kg/cm^2 respectively and its average value was 0.236 kg/cm^2 and cone index value after ploughing for depth of 3-10 cm was 0.055, 0.117, 0.260 kg/cm^2 respectively and its average value was 0.144 kg/cm^2 for cultivated land, It shows that the cone index was more in the fallow land where as it was less in the cultivated land because there was more moisture in the soil in the cultivated land, which resulted in less cone index for cultivated field. The difference between the cone index after and before the ploughing operation was due to the loosening of soil after ploughing operation and this operation gave good crumbling of soil.

Table 2. Soil parameters during field operation

Soil parameter	Fallow land	Cultivated land
Soil moisture content (%)	8.19	11.74
Bulk density (gm/cm^3)	1.99	1.90
Cone index (kg/cm^2)	0.236	0.144

3.4 Mean Weight Diameters (MWD)

The main function of rotavator is tilling and pulverising the soil. The quality of pulverising is measured in terms of soil mean weight diameter (SMWD). The SMWD was determined by standard procedure. After the rotary plough operation, the values of soil mean weight diameters were 4.17 mm and 3.86 mm for fallow land and cultivated land respectively.

3.5 Percentage Wheel Slip

The percentage of tractor wheel slip, in the fallow land the wheel slip was measured to be 12.05, 14.7 and 12.7%, the average was 13.18%. Similarly observations for cultivated land were also taken, in cultivated land the wheel slip was measured to be 6.57, 5.99 and 7.69%, the average was 6.75%.

3.6 Theoretical Field Capacity

The average theoretical field capacity, for fallow land was measured as 0.237 ha/hr, and the average field capacity for the cultivated land was determined to be as 0.280 ha/hr. Theoretical field capacity of cultivated land was more than that in the fallow land it was due to that the operating speed of rotary plough was more in cultivated land as compared to fallow land.

3.7 Effective Field Capacity

The average effective field capacity for fallow land was calculated as 0.170 ha/hr. similarly the average effective field capacity for cultivated land was calculated as 0.232 ha/hr. it was found to be better than other tillage practices for seedbed preparation.

3.8 Field Efficiency

The average field efficiency, for fallow land was calculated as 71.72%. Similarly, for cultivated land the field efficiency was calculated as 82.14%. It gives a clear indication that, during operation in fallow land the full working width of the machine could not be utilized thus its field efficiency was less than that of the cultivated land.

Table 3. Field observation of Rotary plough

Particulars	Fallow land	Cultivated land
Percentage wheel slip (%)	13.18	6.75
Theoretical field capacity (ha/hr)	0.23	0.28
Effective field capacity (ha/hr)	0.17	0.23
Field efficiency (%)	71.53	82.14

3.9 Fuel consumption

The fuel consumption of rotary plough for fallow land and cultivated land was measured, It was found that the fuel requirement for fallow land was 6.3 l/hr and for cultivated land it was 5.76 l/hr (Fig. 2).

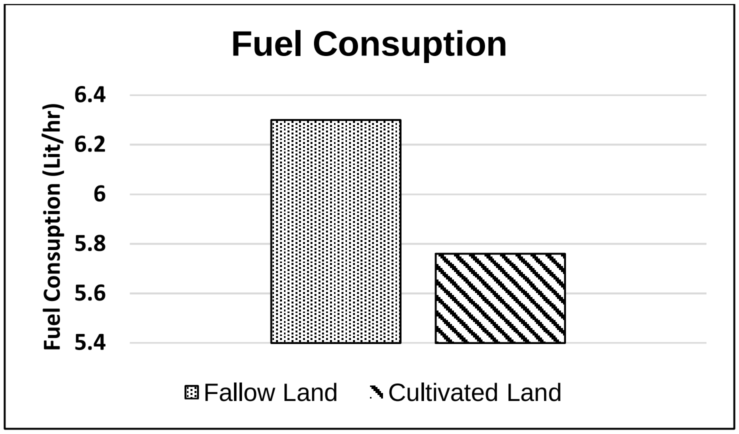

Fig. 2. Fuel consumption of vertical rotary plough in fallow and cultivated land

3.10 Weeding Efficiency

The weeding efficiency of this implement is measured by calculating the No. of weed plants from the two or three random places before and after tillage operation in both fallow and cultivated land. The reading shows that, the weeding efficiency was found to be 100% in both the case. So, this implement is very suitable for weeding.

4. CONCLUSION

The soil moisture content obtained from rotary plough was higher in cultivated land; bulk density reduced about 4.52% and Cone index 0.236 kg/cm² to 0.144 kg/cm² from fallow land to cultivated land respectively. This shows that tillage operation by rotary plough improves the plant growth conditions. The field capacities of rotary plough were measured as 0.17 ha/hr and 0.23 ha/hr with the field efficiency 71.53% and 82.14% in case of fallow land and cultivated land respectively. It shows that the time required for rotary plough operation in fallow land was more than the time required for the cultivated land.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mahal JS, Manes GS, Prakash A, Singh M, Dixit A. Study on blade characteristics of commercially available rotavators in Punjab. Agric. Engg. Today. 2012;36(3):8-11.
2. Ahmed MH, Haffar I. Comparison of five tillage systems for cotton production in Rahad scheme, Sudan. Agricultural Mechanization Asia, Africa & Latin America. 1993;24(2):17-29.
3. Iqbal M, Sabir MS, Younis MD, Azhar AA. Draught requirements of selected tillage implements. Agricultural Mechanization Asia, Africa & Latin America. 1994; 25(1):13-15.
4. Finner MF, Straub RJ. Farm machinery fundamentals. Madison: American Pub. Co; 1978.
5. Taniguchi T, Makanga JT, Ohtomo K, Kishimoto T. Draught and soil manipulation by a moldboard plough under different forward speed and body attachments. Trans. ASAE. 1999;42(6):1517–1521.
6. Naderloo L, Alimadani R, Akram A, Javadikia P, Khanghah HZ. Tillage depth and forward speed effects on draft of three primary tillage implements in clay loam soil. Journal: Food Agriculture and Environment. 2009;7:382-385.
7. Shrivastava AK, Goering CE, Rohrbach RP. Engineering principal of agricultural material machines. ASAE Textbook No. 6. St Joseph: American Society of Agricultural Engineers; 1993.
8. Azadbakht M, Azadbakht B, Janzadegalogah R, Kiapei A, Jafari H. Soil properties after plowing with vertical and horizontal axis rotavator. International Journal of Environmental, Ecological, Geological and Mining Engineering. 2014;8(1):61-65.

9. Shinde GU, Potekar JM, Shinde RV, Kajale SR. Design analysis of rotary tillage tool components by CAD-tool: Rotavator. International Conference on Environment and Agriculture Engineering. 2011;15:1-6.
10. Mohsenin NN. Physical properties of plant and animal materials. New York: Gorden and Breach Science Publisher; 1979.
11. Makange NR, Tiwari VK. Effect of horizontal and vertical axis rotavator on soil physical properties and energy requirement. Trends in Biosciences. 2015;8(12):3225-3234.
12. ASAE S313.1. Soil cone penetrometer. ASAE Standard; 1984.
13. Shepherd TG, Saggar S, Newman RH, Ross CW, Dando JL. Tillage-induced changes to soil structural and organic carbon fractions in New Zealand soils. Australian Journal of Soil Research. 2001;39:465-489.
14. Dabhi KL, Godhani RS, Swarnkar R. Comparative performance of mini tractor drawn tillage implements for seed bed preparation under sandy loam conditions of middle Gujarat. International Journal of Agricultural Engineering. 2016;9(1):53-61.
15. Mehta ML, Verma SR, Mishra SR. Sharma VK. Testing and evaluation of agricultural machinery. Delhi: Daya Publishing House; 2005.
16. Dabhi KL, Godhani RS, Swarnkar R. Performance evaluation of selected tractor drawn rotavators for seed bed preparation under sandy loam soil condition. Green Farming. 2016;7(6):1436-1440.
17. Kankal US, Karale DS, Thakare SH, Khanballkar VP. Performance evaluation of tractor operated rotavator in dry land and wet land field condition. International Journal of Agricultural Science and Research. 2016; 6(1):137-146.
18. Ramesh P, Sachin C, Ritesh M, Sunny B, Ankur S. Performance evaluation of rotavator based on different soil moisture content. International Journal of Engineering Science and Research Technology. 2016;5(8):808-816.

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