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# Investigation on the Effect of Vertical Axis Rotary Tiller (Rotavator) for Tillage System

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## ABSTRACT

**In this research, the effect of horizontal and vertical axis rotary tillers in different forward speed, depth and rotor rpm on mean weight diameter and cone index have been analyzed. Soil mean weight diameter is measured by standard sieve analysis method and cone penetrometer was used to measure soil cone index. Factorial experiments based on a randomized complete block with 72 treatments, four different forward speeds of 2.0, 2.5, 3.0 and 3.5 Kmph; three different depths of 150, 200 and 250 mm; three different rotor rpm of 220, 270 and 310 and with two rotary tillers with three replications were used. Result showed that in the optimum speed of 3.0 Kmph and 200mm of depth with a rotor rpm of 270 were 34.8mm and 1mm of the maximum and minimum mean weight diameter for vertical axis rotary tiller respectively; the maximum and minimum MWD in 3.0 kmph and 150 mm of depth (maximum depth) with a rotor rpm of 270 were 45 mm and 1mm for horizontal axis rotary tiller. The values of cone index 2970 kPa and 3480 kPa for vertical axis and horizontal axis rotary tiller were obtained.**

**Key words** *rotavator, vertical axis, tillage, rotary tiller, power harrow, implement.*

The Indian agriculture tillage system is in the stage that Moldboard plough, disc plough are replaced with horizontal axis rotary tillers. Rotavator became popular among the farming community because of its time and energy saving. Potekar *et al.,* reported that rotavator tillage system energy consumption was less compared to other tillage implements. This resulted in fine seedbed preparation with less effort and within short time as compared to other tillage systems. Prasad *J* compared the performance of conventional plows with horizontal axis rotavator and reported that soil specific weight and mean weight diameter were much less for rotavator. Destan *et al.,* reported that by using rotavator soil which had been tillage before will be soft and mixed so the clods size will have a good distribution. In compare with active implement rotavator needs less pass in farm to reach the same soil quality. Azadbakht *et al.,* compared and evaluated the performance of rotavator with horizontal rotary axis and vertical rotary axis. The mean weight diameter, cross sectional area disturbed and cone index of soil investigated. In India vertical axis rotary tiller has been introduced in recent years by some farm equipment manufacturers. Farmers claim difference between horizontal and vertical axis rotary action but there are no scientific work compare them. Some research has been done on comparison between rotavator and conventional tillage implements. In this research single row vertical axis rotavator has been developed and evaluated. Therefore the mean weight diameter, and cone index of soil investigated.

The axis of ratavator may rotate in vertical axle of rotor shaft (Fig.1)

## MATERIALS AND METHODS

### Soil type

The experiments were done in farm machinery workshop soil bin, Tamil Nadu Agricultural University, India. The soil bin has two compartments one side is filled with clay soil and the other side is filled with sand. The clay soil is taken for the experiment Fig.2.

### Soil moisture content and bulk density measurements

Soil moisture content was determined using the standard oven drying procedure. The soil sample for the determination of the moisture content collected immediately upon the completion of test run. At least 12 soil samples were collected in metallic containers had a specified volume for each test run from different located strata of the soil whose moisture content was to be determined. The mass of the collected moist samples was determined using a scale balance with an accuracy of 0.01g, and placed in a constant temperature oven for drying at a temperature of about $105^0$ C for a minimum drying period of 24 hours as described by ASAE standards. Also soil moisture meter were used, it directly digit the moisture content of soil (Fig.3). Finally found that moisture content and bulk density was 16.2% and 1.72g/$cm^3$ respectively.

### Experimental layout

Factorial experiments based on a complete block with 72 treatments four different forward speeds of 2.0, 2.5, 3.0 and 3.5 Kmph; three different depths of 150, 200 and 250 mm; three different rotor rpm of 220, 270 and 310 and with two rotary tillers were used. All experiments have been done in three replications. Yuvraj 215 tractor was used in all the experiments.

For each experiment rotavator were mounted on tractor and their power was provided through PTO shaft of the tractor. Determining mean weight diameter and cone index of soil was done after ploughing.

### Soil cone index measurements

The cone penetrometer was used to measure soil cone index in different depths. This device consists of four main parts an aluminium rod with detachable cone, load cell, digital display and sensor. The sensor measures the depth and shown in the display. Data were collected in the soil bin and then transferred to computer Fig.4.

**Table 1. Comparison tests of different levels of depth and plough type on MWD**

| Depth (mm) | Ploughs | |
|---|---|---|
| | Vertical | Horizontal |
| 150 | 35.0$^{Ba}$ | 45.0$^{Aa}$ |
| 200 | 34.8$^{Ba}$ | - |
| 250 | 34.5$^{Ba}$ | - |

*same capital letters in each row and same small letters in each column show not significant different (LSD 1%).

**Table 2. Comparison tests of different levels of forward speed and type of plough on MWD**

| Forward speed (Kmph) | Ploughs | |
|---|---|---|
| | Vertical | Horizontal |
| 2.0 | 33.8$^{Ba}$ | 45.0$^{Aa}$ |
| 2.5 | 34.3$^{Ba}$ | 46.7$^{Ab}$ |
| 3.0 | 34.8$^{Ba}$ | 48.2$^{Ab}$ |
| 3.5 | 35.3$^{Ba}$ | 52.3$^{Aa}$ |

*same capital letters in each row and same small letters in each column show not significant different (LSD 1%).

**Table 3. Comparison tests of different levels of rotary rpm and type of plough on MWD**

| Rotary rpm | Ploughs | | Soil dust, % |
|---|---|---|---|
| | Vertical | Horizontal | |
| 220 | 36.2$^{Ba}$ | 49.0$^{Aa}$ | 15 |
| 270 | 34.3$^{Ba}$ | 46.7$^{Ab}$ | 18 |
| 310 | 33.8$^{Ba}$ | 43.2$^{Ab}$ | 25 |

*same capital letters in each row and same small letters in each column show not significant different (LSD 1%).

**Table 4. Cone index measurement**

| S. No | Vertical axis plough | | Horizontal axis plough | |
|---|---|---|---|---|
| | Depth, mm | Force, kPa | Depth, mm | Force, kPa |
| 1 | 100 | 1950 | 100 | 2120 |
| 2 | 150 | 2320 | 150 | 2760 |
| 3 | 200 | 2560 | 200 | 3050 |
| 4 | 250 | 2970 | 250 | 3480 |

### Mean weight diameter measurements

To measure soil fragmentation in different depth and velocity with two ploughs, rectangular sieve was used. The soil was collected in different depths like 100, 150, 200 and 250mm and sieve analysis were done for each depth. Sieves taken for the experiment were in the sizes of 2, 3, 4, 5, 10, 20, 25, 35 and 45 mm (Fig. 5)

To calculate the proportion of the total sample that is in each aggregate size class (P*awi*).

$$P_{awi} = \frac{\left[W_A - \left[\frac{W_c}{W_o}\right] \times W_A\right]}{W_T}$$

Where,

$P_{awi}$ = proportion of aggregate weight for each size class *i*;

$W_A$ = weight of total material in each size class *i*;

$W_c$ = weight of coarse material in size *i* as measured after weight sieving;

$W_o$ = weight of aggregates placed on the sieve prior to wet sieving size *i*;

$W_T$ = total sample weight.

## RESULTS AND DISCUSSION

### Soil mean weight diameter determination

The effects of two different rotavator with vertical and horizontal axis in different forward speed, rotor rpm and depths on MWD have been analysed in this experiment.

According to table I in each depth level the effects of plough type is significant but type of plough on different

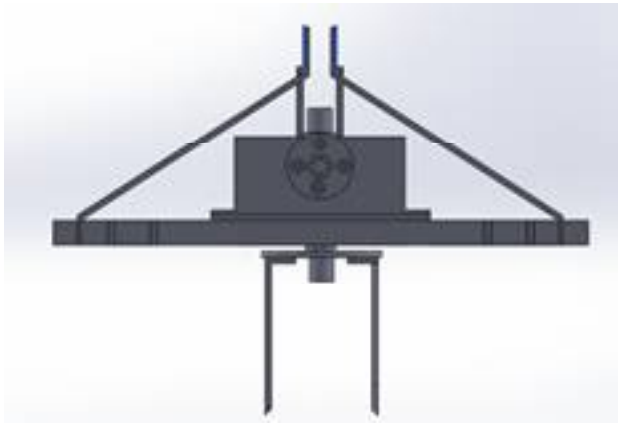

Fig.1 Single row vertical axis rotary tiller

Fig. 2. Soil bin


Fig.4.a Cone penetrometer


Fig. 3. Soil moisture meter

Fig. 4b. Soil cone index measurement

depth levels have no effect on MWD. It means that in same depth vertical axis rotavator cut down soil more than horizontal one but in both of them the amount of soil pulverization in different depth is same because in horizontal axis soil picks up as a whole a piece and create hunk and these hunks are thrown back during axis rotation and on impact with the back plate may not shatter, but in vertical axis rotavator soil is mixed and uniformly cut down. Also it was absorbed that maximum MWD in 150mm and horizontal axis rotavator was 45.0mm. Minimum MWD in 150mm and vertical axis rotavator was 35.0mm.

Fig. 5. Soil MWD determination by sieve analysis - horizontal plough (left), vertical plough (center) and sieve.

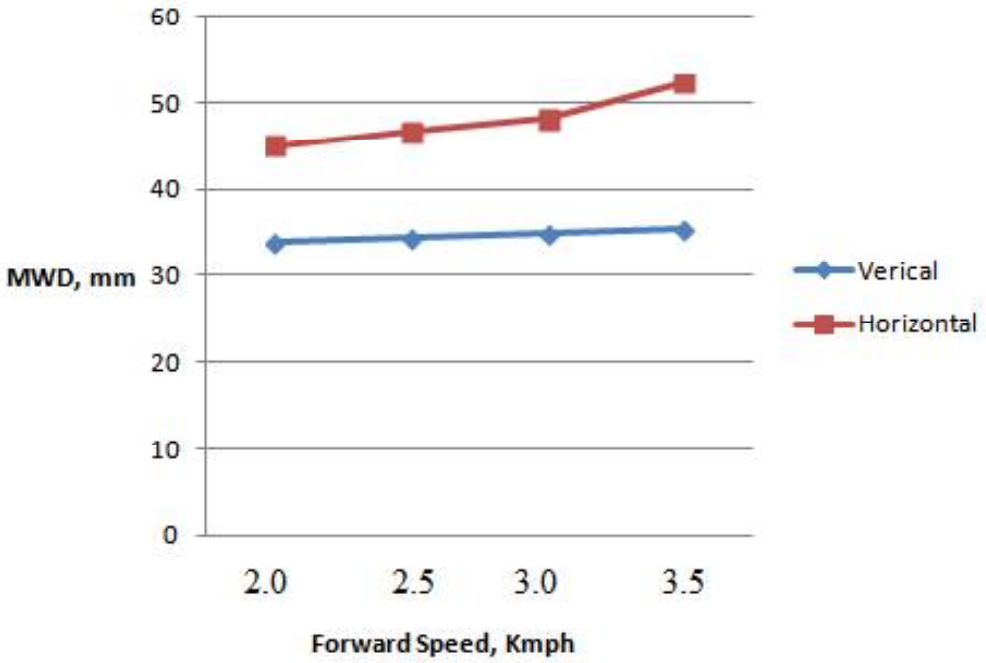


Fig.6. Comparison of MWD with two different rotavator (horizontal and vertical) in different forward speed

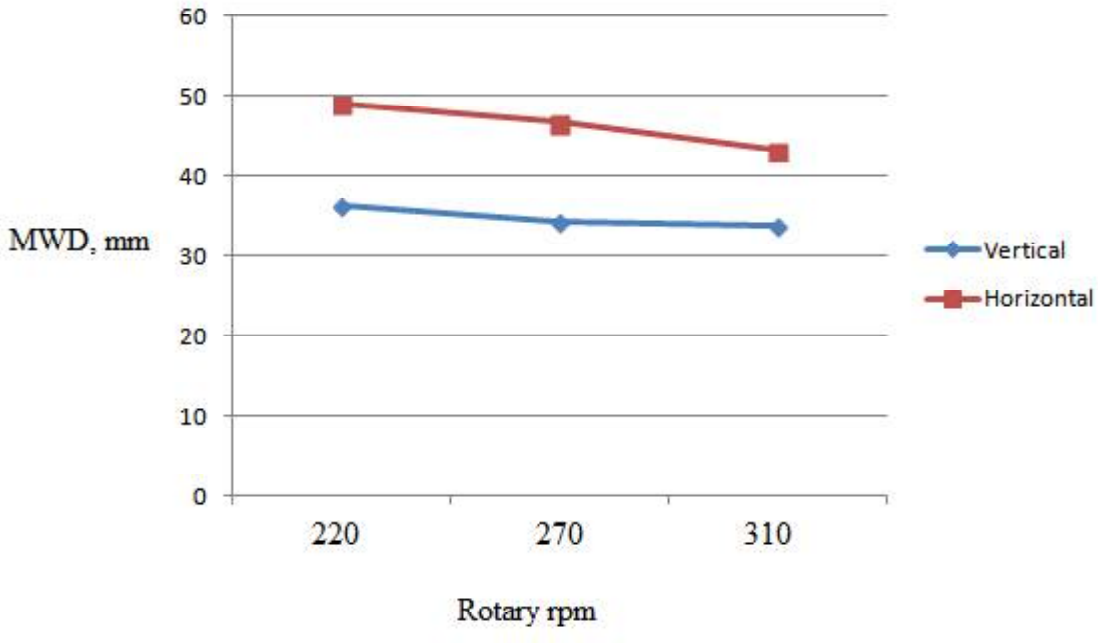


Fig. 7. Comparison of MWD with two different rotavator (horizontal and vertical) in different rotary rpm

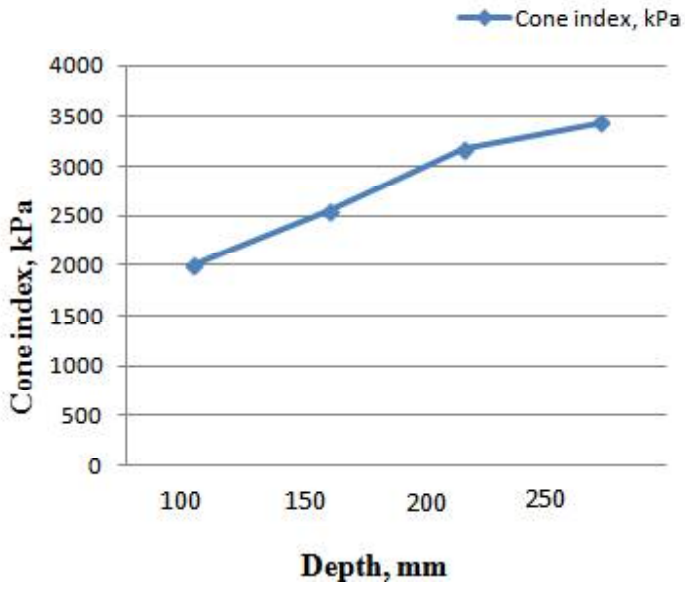


Fig.8.a.Soil cone index for vertical axis rotavator

According to table II in each forward speed the effects of plough type is meaningful but in vertical axis rotavator different levels of forward speed have no effect on MWD but in horizontal axis rotavator different levels of forward speed have a effect on MWD. This is because soil is picked up as a whole piece and create hunk in horizontal axis rotavator. This kind of rotavator in lower forward speed has much time to cut down the hunks. Vertical axis rotavator never creates hunks and mixes soil, therefore forward speed has no effects on it. Also it was absorbed that maximum MWD in 3.5Kmph and horizontal axis rotavator was 52.3mm. Minimum MWD in 2.0 Kmph and vertical axis rotavator was 33.8mm (Fig. 6).

According to table III in each rotary rpm the effects of plough type is meaningful but in both vertical and horizontal rotavator the levels of effect have on MWD. This is because lower rpm creates soil cut down as a whole piece and create hunk in both the rotavator and higher rpm causes the soil in powdery form. The amount of dust soil was high in higher rpm which is result in soil erosion. So the optimum rpm of 270 was used in vertical axis rotavator. Also it was absorbed that maximum MWD in 310rpm and horizontal axis rotavator was 43.2 mm. Minimum MWD in 220 rpm and vertical axis rotavator was 36.8.8mm (Fig. 7). The soil dust was measured in three rotary rpm and 270rpm was considered as the optimum rpm.

**Cone index measurement**

In this test the effects of two different type rotavator in different forward speed, rotor rpm and depth on soil cone index were statically analysed.

As it clear in Fig.8.a.cone index increases with increase in depth. This is because that, according to table I MWD increases with increase in depth in both ploughs so in deeper depth more force is needed. Values of 1950, 2320, 2560 and 2970 kPa for 100, 150, 200 and 250mm are shown respectively. According to Fig 8.b soil resistance in vertical axis rotavator is less than horizontal axis rotavator. This is because that, according to Fig 6 and 7 the result is that MWD of horizontal axis rotavator is much more than vertical one. So tillage with this plough creates more resistant soil. Values of 2970 and 3480 kPa for vertical axis rotavator and horizontal axis rotavator are shown in Fig. 8.b.

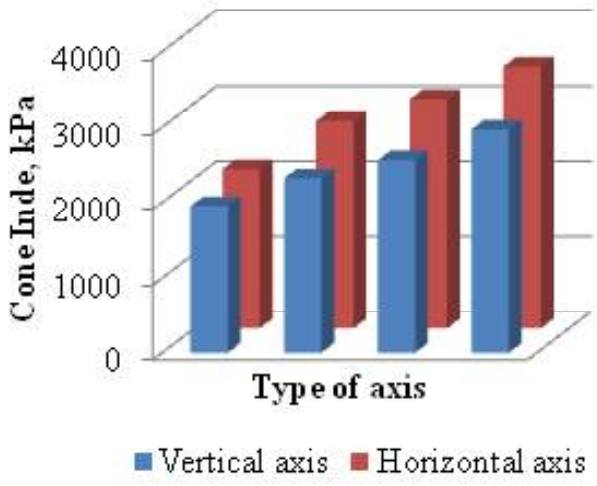


Fig.8.b. Soil cone index

**CONCLUSION**

Considering the speed increase will lead to increased farm efficiency, in rotavator with vertical axis increasing farm efficiency and more pulverization are simultaneously. While in rotavator with horizontal axis increasing farm efficiency leads to less pulverization. Both the horizontal and vertical rotavators have different ploughing depth, while in rotavator with vertical axis most hunks are crushed at different depths. Higher rotary rpm creates the soil more powdery form also the lower rpm causes soil larger in size. Also, soil resistance in vertical axis rotavator is less than

horizontal axis rotavator. Thus, regardless of other factors and according to the results, use of rotavator with vertical blade more appropriate than rotavator with horizontal blades.

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