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# Comparative performance of mini tractor drawn tillage implements for seed bed preparation under sandy loam conditions of middle Gujarat

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**ABSTRACT :** Tillage is an operation performed to obtain a desirable soil structure for a seedbed or rootbed. Reducing tillage operations is a way of saving money and labour, but there are other factors which need to be considered before adopting a particular technique. Field tests were conducted to evaluate the performance of three types of mini tractor drawn tillage implements for seedbed preparation at College of Agricultural Engineering and Technology, Anand Agricultural University Godhra, district: Panchmahal. The mini tractor, Mahindra-Yuvraj (15 hp) and the matching tillage impalements *i.e.* cultivator, M.B. plough and rotavator were used for seedbed preparation by selecting four different treatments, namely; $T_1$: Cross cultivation by cultivator, $T_2$: M.B.Plough + cultivator, $T_3$: 2 x rotavator and $T_4$:1 x rotavator using a Randomized Block Design with five replications. The parameters evaluated were travel reduction (wheel slippage), draft, speed of operation, drawbar power, soil volume disturbed, fuel consumption, field efficiency and soil pulverization. Results indicated that single pass of rotavator ($T_4$) was economical as well as it performed satisfactory for seed bed preparation in comparison to the other treatments with respect to the parameters evaluated. The hourly cost required for tillage operation under $T_1$: Cross cultivation by cultivator, $T_2$: M.B. plough + cultivator, $T_3$: 2 x rotavator and $T_4$: 1 x rotavator was rupees 311.25, 327.91, 410.54 and 280.17, respectively. The operational cost of single pass of rotavator ($T_4$) was observed lowest. So, amongst all implements used for seed bed preparation, the mini tractor drawn rotavator performed very well from the point of efficiency, soil pulverization and total hourly cost.

**KEY WORDS :** Seed bed preparation, Fuel consumption, Draft, Wheel slip, Soil volume disturbed, Field efficiency, Soil pulverization

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Indian farmers are using tractor drawn improved agricultural implements like MB plough, disc plough, rotary ploughs etc. for primary tillage operations. Soil tillage may be defined as the mechanical manipulation of the soil aimed at improving soil conditions for crop production; the goal of proper tillage is to provide a suitable environment for seed germination, weed control, excess moisture removed and reduction of surface runoff by increasing infiltration. According to Raney and Zingg (1957), the tillage plays an important role in controlling weeds and managing crop residues but the primary purpose of tillage is to change the soil structure. The degree of soil compaction, soil bulk density and soil moisture condition are important factors that influence seedling emergence and crop yield. Gill and Vanden (1968) defined tillage as a process aimed at creating a desired final soil condition for seeds from some undesirable initial soil condition through manipulation of soil with the purpose of increasing crop yield. So, the farmers have to select best option to get desirable soil tilt with minimum cost of operation. The tillage implements transfer the soil physical properties by pulverizing, macerating, overturning and mixing the soil layers that provide proper aeration and oxygen to the soil. Sometimes farmers use plow based methods that overturn the soil that in turn mixes the organic contents into the surface layers. This addition of organic matter in the top soil, improves its fertility and productive capability that results in greater yields and plant health. Majority of farmers are not conscious to select correct power source and corresponding implements to meet their requirement to perform various farm operations so they use traditional as well developed implements for seedbed preparation and other farm operations irrespective to the quality of work and cost of operation. Mahal *et al.* (2012) studied that tillage is an operation performed to obtain a desirable soil structure for a seedbed or root bed. The research work carried out by Ahmad and Haffar (1993) and Iqbal *et al.* (1994) as well as by Finner and Straub (1985) indicate 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. 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. Taniguchi *et al.* (1999) and Naderloo *et al*. (2009) suggested that the draft required for a given implement is directly depends on the soil conditions and the geometry of the tillage implement. Tillage implement like cultivators are equipped with number of tynes for easy penetration into the soil to accomplish the tillage and to break the clods. Cultivators usually have two or three rows of tynes at specified space. Guruswami (1986) concluded that the tyne type cultivators were much better than that of conventional method of cultivation. The mould board plough is an improved tillage implement over the country plough. This is probably one of the first implements to be introduced from abroad to India. The advantage of using the mould board is that a layer of soil is separated from the underlying sub-soil and is inverted. Mishra *et al.* (1989) tested M.B. plough in the field and they observed that average depth of cut and width of cut was more as compared to cultivator performance. Actual field capacity and theoretical field capacity in case of cultivator was better than the M.B. Plough. Rotavator (also called as rotary tiller) is a tractor operated cultivating implement that breaks the soil with the help of rotating blades. The use of rotavator is increasing due to its versatility in doing a good quality tillage job with minimum number of passes. Singh *et al.* (1998) studied that rotavator required the minimum time for the operation and transferring the tractor power through PTO is more efficient than through traction wheels for a traction dependent implement. So, by keeping in mind all the above points, it is clear that tillage is a most costly operation than other farm operations, the choice of tillage implements depends on the soil type, soil surface condition, vegetative growth, required depth of cultivation, crops to be grown, draft, and power requirement. So, all above points and the views of the researchers are useful to select proper power source (tractor or power tiller) and matching implement (cultivator, M.B.plough, rotavator etc.) for seed bed preparation in terms of required field performance with reduced cost of operation. Once the proper power source is selected for seedbed preparation, the same will be efficiently used for rest of the field operations because other operations requires less power as compared to seedbed preparation as suggested by Ahmad (1981) and Iqbal *et al.* (1994).In India, majority of farmers have one and two hectare of land so, economically it is not feasible for them to own big tractors for their various farm operations. Animal power is also decreasing due to their higher feeding expenditure against their utilization. From last few years, some tractor manufacturing companies have introduced the tractors of less than 20 horsepower along with the matching implements which are capable to accomplish various field operations as performed by big sized (30 hp and more) tractors. So, by keeping in mind the land holding capacity of the farmer and soil conditions of the area, it is quite need for researchers to introduce a low cost tractor-implement technology to perform various farm operations. Though seed bed preparation requires maximum power among other farm operations, a research work was carried out for seed bed preparation in sandy loam soil conditions of this region. For this a mini tractor of 15 hp and three different types of matching implements-cultivator, M.B.Plough and rotavator were selected and a field study was undertaken at College of Agricultural Engineering and Technology, Godhra (Gujarat) to ascertain the best one to achieve essential level of seed bed preparation with minimum cost of operation under sandy loam soil condition of the region. The research trial was formulated by deciding four treatments as explained in "material and method" with the following objectives:

–Performance evaluation of the three mini tractor (15 hp) drawn implements for seed bed preparation under sandy loam soil conditions.

–To work out the hourly cost involved in each tractor-implement treatment.

–To find out the most economical implement for seed bed preparation among three.

## ■ METHODOLOGY

The study was planned to evaluate the performance of mini tractordrawn selected tillage implements for seed bed preparation under sandy loam soil conditions of middle Gujarat region. The experimental site is located in middle Gujarat Agro-climatic Zone of Gujarat State. All the parameters of the tractor-implement performance were measured and recorded in line with the recommendations of RNAM test codes. The used tractor was Mahindra Yuvraj (15 hp) and the matching implements for seed bed preparation were; (1) cultivator, (2 ) M.B. plough and (3) rotavator. The experiment was established in the college field with four treatments as under:

$T_1$: Tillage operation by cultivator (2 pass), $T_2$: Tillage operation by M.B.plough + cultivator,$T_3$: Tillage operations by rotavator (2 pass) and $T_4$: Tillage operations by rotavator (1 pass)

### Parameter studied :

The details of parameters studied are as follows:

### Soil texture :

Soil texture of middle Gujarat region was found sandy-loam type.

### Soil moisture content :

Moisture content for soil is computed on dry basis. Soil samples were collected from 0 to 20 cm depth of soil surface before operations for determination of moisture content and bulk density. The samples were collected from five randomly selected sites across the field by core sampler.The moisture content was determined in the laboratory by oven dry method.

The moisture content (dry basis) was determined by the following formula:

$$\text{Moisture content (\%)} = \frac{W_w - W_d}{W_d} \times 100$$

where,

$W_w$ = Weight of wet soil sample, and

$W_d$ = Weight of dry soil sample.

### Bulk density :

The bulk density is the weight of soil is to its volume. The bulk density depends upon various factors *viz.*, soil, texture and organic matter, history of tillage and moisture content.

$$\text{Bulk density (g/cc)} = \frac{\text{Weight of dry soil sample (g)}}{\text{Volume of the core sampler (cc)}}$$

### Operating speed :

Outside the long boundary of the test plot, two poles 20 m apart were placed approximately in the middle of the test run. On the basis opposite side also two poles were placed in a similar position 20 m apart so that all four poles form corners of a rectangle, parallel to one long side of the test plot. The speed was calculated as the ratio of the distance (20 m) to time taken for the machine to travel the distance.

### Travel reduction (wheel slip) :

A mark was made on the tractor drive wheel with colored tapes and the distance the tractor moves forward at every 10 revolutions under no load and the same revolution with load on same surface was measured. It can be expressed mathematically as:

$$\text{Travel reduction (\%)} = \frac{M_2 - M_1}{M_2} \times 100$$

where,

$M_2$=Distance covered at every 10 revolutions of the tractor drive wheel at no load (m),

$M_1$=Distance covered at every 10 revolutions of tractor drive wheel with load (m).

**Draft :**

Implement width, operating depth and speed are factors that affect draft of a tillage implement. Draft also depends on soil conditions and geometry of the tillage implements (Upadhyaya *et al.*, 1984). Draft was measured using a digital drawbar dynamometer attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor through the drawbar dynamometer. The auxiliary tractor pulls the implement-mounted tractor with the latter in neutral gear but with the implement in the operating position. Draft was recorded in the measured distance of 20 m. On the same field, the implement was lifted off the ground and the draft recorded. The difference between the two readings, gives the draft of the implement. This procedure was repeated for each of the tractors evaluated.

**Fuel consumption :**

The fuel consumption for seed bed preparation under each treatment was measured by the standard method, the fuel tank was filled upto top level by keeping the tractor on level land and after completing the operation, the fuel tank was filled up again. The difference of two observations gave the fuel consumed in the concerned operation.

**Field capacity :**

The effective field capacity of machine can be expressed as the actual rate at which, it can do work, taking into account such non-productive operations as turning at the ends of the field, stopping to add seed or fertilizer and stopping to check the performance of a particular equipment. The effective field capacity (E.F.C) was determined by the following formula:

$$\text{E.F.C. (ha/hr)} = \frac{\text{Area coverd (ha)}}{\text{Time taken (hr)}}$$

The theoretical field capacity (T.F.C.) was determined by the following formula :

$$\text{T.F.C. (ha/hr)} = \frac{\text{Width of coverage (m) x speed of travel (km/hr)}}{10}$$

**Energy requirement:**

It was assumed that on average 1.96 MJ per hour is developed by one man in completing a particular field operation of a concerned crop. Therefore, for a variety of manual operations involved, manual energy was calculated by multiplying 1.96 MJ per labour or operator with number of hours of work done by labour in each operation. In case of tractors, the mechanical energy consumed in the respective field operations was calculated on the actual fuel consumption basis. The diesel consumption for operation was calculated and multiplied by 56.31 MJ to obtain tractor energy and converted to energy unit according to time taken per unit area (Guruswamy, 1997).

**Soil volume disturbed :**

The soil volume disturbed in $m^3$/hr was calculated by multiplying the field capacity with the depth of cut (Ahaneku *et al.*, 2011).

$$V = 10000SD$$

where,

V = Soil volume disturbed ($m^3$ /hr)

S = Effective field capacity (ha/hr)

D = Depth of cut (m).

**Soil pulverization :**

Pulverization is the process of breaking of soil into small aggregates resulting from the action of tillage forces. The mean mass diameter (MMD) of the soil aggregates is considered as index of soil pulverization and can be determined by the sieve analysis of the soil sample through a set of standard test sieves (IS: 460-1982). Sieve provides a simple means for measuring the range of clod size and relative amount of soil in each size class. For this the soil sample was passed through a set of sieves and weighing of the soil retained on the largest aperture sieve passed through each sieve and retained on the next sieve and passed through the smallest aperture sieve is done (Mehta *et al*., 1995).

**Drawbar power :**

Drawbar power was evaluated using the relation between draft and speed as follows:

$$\text{Drawbar power (hp)} = \frac{\text{Draft (kg) x operating speed}\left(\frac{\text{m}}{\text{sec}}\right)}{75}$$

OR

$$\text{Drawbar power (kW)} = \frac{\text{Draft (kN) x operating speed}\left(\frac{\text{km}}{\text{hr}}\right)}{\text{3.6 (constant)}}$$

**Cost analysis :**

In order to evaluate the effectiveness of the treatments and to ascertain the most remunerative treatment, the initial investment cost of tractor plus all three matching implements along with fixed and variable cost was calculated and then the total cost incurred for the seed bed preparation under each treatment (Rs./ha as well as Rs./hr) were computed and added (Sahay, 2010). The less expensive operation by the tractor-implement combination was worked out and identified the most suitable matching implement for 15 hp mini tractor to achieve required level of seed bed preparation under sandy loam soil conditions.

## RESULTS AND DISCUSSION

The results of the field experiments of various parameters are presented under the following main heads:

**Physical properties of soil :**

The average soil moisture content and bulk density were 15.89 per cent and 1.32 g/cc at the time of field testing of the implements.

**Performance parameters :**

*Travel reduction* (*Wheel slip*) :

Travel reduction affects the traction efficiency of any tractive device. The results of the travel reduction derived from the field test of mini tractor drawn cultivator, M.B.Plough and rotavator were 5.54 per cent, 7.54 per cent and -2.63 per cent, respectively. The mini tractor with rotavator gave the lowest values of travel reduction or wheel slip during the operation. This low wheel slip may be due to the fact that rotavator exerts a forward force / thrust to the tractor driveline (Bernacki *et al.*, 1972). The field test was carried out as Fig. 1.

**Fig. 1 : Wheel slip during seed bed preparation with M.B. plough and rotavator**

**Draft :**

The results of the draft measurement derived from the field test of mini tractor drawn cultivator, M.B.Plough and rotavator were 290 kg, 370 kg and 195 kg, respectively. The results shown that speed of operation and depth of cut affected the draft of the implements. Draft was highest in case of M.B.plough due to higher depth of cut in comparison to other implements.

**Fuel consumption :**

The parameters for fuel consumption showed considerable differences between the different treatments. The result of (Table 1) indicated that the fuel consumption for seed bed preparation per hectare under treatment $T_1$ (2 x cultivator) is lowest (9.46 lit/ha) followed by treatment $T_4$, $T_2$ and $T_3$, respectively. The measurement of fuel consumption by standard method is shown in Fig. 2 and 3.

**Table 1: Fuel consumption**

| Treatments | Average fuel consumption to cover 112 m² (lit) | Average fuel consumption to cover 1 ha (lit/ha) |
|---|---|---|
| $T_1$ : 2 x cultivator | 0.106 | 9.46 |
| $T_2$ : M.B. plough + cultivator | 0.150 | 13.39 |
| $T_3$ :2 x rotavator | 0.233 | 20.80 |
| $T_4$ :1 x rotavator | 0.140 | 12.50 |

Fig. 2 : Measurement of fuel consumption

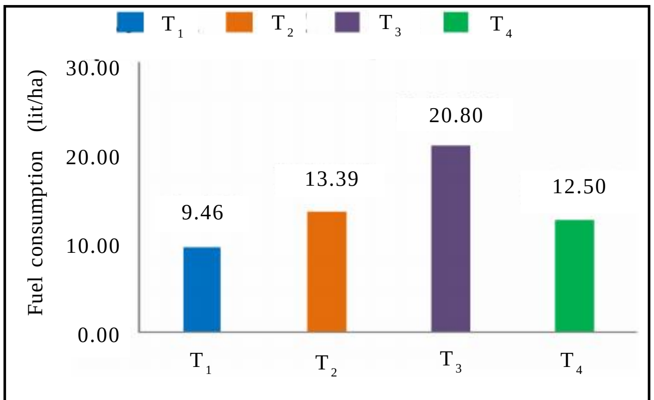


Fig. 3 : Showing fuel consumption

**Energy requirement :**

The total energy consumption in case of $T_1$, $T_2$, $T_3$ and $T_4$ was observed 545.96 MJ/ha, 777.12 MJ/ha, 1191.61 MJ/ha and 714.61 MJ/ha, respectively.

**Field efficiency :**

Field efficiency and soil disturbance has been reported as two major factors in determining the performance of tillage implements. The field efficiency received during treatment $T_{1,}$ $T_{2,}$ $T_3$ and $T_4$ was 79.39 per cent, 77.80 per cent, 79.72 per cent and 79.82 per cent, respectively. The treatment $T_4$ (one pass of rotavator) resulted highest value of field efficiency due to only single operation as well as lowest travel reduction compared to other treatments.

**Soil volume disturbed :**

Soil volume disturbed depends on the effective capacity and the depth of cut. The soil disturbance during treatment $T_{1,}$ $T_{2,}$ $T_3$ and $T_4$ is 252.45 $m^3$/h, 270.40 $m^3$/h, 178.56 $m^3$/h and 145.60 $m^3$/h, respectively. The soil volume disturbed observed highest under treatment $T_2$ (M.B.Plough +cultivator). Though the depth of cut is highest in case of tillage with M.B.Plough, the results indicated that the depth of cut affected soil volume disturbed positively.

**Soil pulverization (MMD):**

Singh and Panesar (1991) concluded that the clod mean weight diameter (MWD) has been considered as an index for indirect measurement of soil tilt during seed bed preparation. The clod mean-mass-diameter is an index for indirect measurement of tilth of soil. It has been indicated that soil aggregates of size 12 to 14 mm in the final seedbed were adequate for sowing crops. This result is in agreement with the findings of Singh *et al.* (2002). The observed data for MMD under $T_1$, $T_2$, $T_3$ and $T_4$ was 16.85 mm, 18.41 mm, 10.32 mm and 12.95 mm, respectively (Fig. 4 and 5). There is a considerable improvement in soil pulverization with the use of the rotavator due to the ability of rotating blades to make fine particles by the forward motion of the machine. This findings correlates with the results obtain by Hughes and Baker (1977) who compared traditional plough, rotary cultivation and no tillage in a silt loam soil and found that the rotary cultivation treatment resulted in the greatest proportion of soil in the smaller aggregate size fraction at all sampling dates.

Fig. 4 : Determination of MMD in laboratory

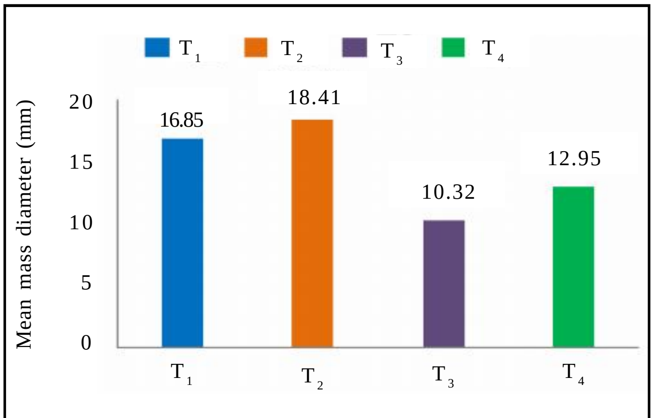


**Fig. 5 : Showing MMD results**

## Drawbar power :

Drawbar power is a function of draft and speed. The results pertaining to the drawbar power are presented in Table 2.

As per results Table 2, mini tractor with M.B.plough gave the highest drawbar power of 2.23 KW since a large pull will result in a large drawbar power. In the same way, mini tractor with rotavator gave the lowest drawbar power of 1.51 kW.

## Cost analysis:

The cost analysis under each treatment for seed bed preparation involves the fixed cost of the machines and the variable cost due to fuel and labour charges. The results are shown in Table 3.

The results shown in the Table 3 revealed that the total hourly cost under treatment $T_4$ and $T_1$ were Rs. 280.17 and Rs. 311.27, respectively due to lower initial capital investment of respective implements as well as better fuel efficiency as compared to $T_2$ and $T_3$. The total hourly cost under treatment $T_2$ and $T_3$ were higher due to theirhigher fuel consumption. The total cost per hectare under treatment $T_1$, $T_2$, $T_3$ and $T_4$ was Rs.1047.98, 1576.49, 2132.67 and 1539.40, respectively.

## Summary and conclusion :

The main objective of this study was to compare the performance of the mini tractor (15 hp) drawn different tillage implements *i.e.* cultivator, M.B.Plough and rotavator for seed bed preparation under sandy loam soil conditions of middle Gujarat regions. Each mini tractor– implement combination was evaluated for different performance parameters in the field and the cost analysis was also worked out for different treatments in order to recommend the most cost effective mini tractor (15 hp) drawn implement suitable for seed bed preparation under the sandy loam soil conditions of this region.

**Based on the results obtained from the field experiment, the following conclusions were drawn:**

Among all the three tillage implements, the draft requirement in case of rotavator was found lowest (195 kg) which decreased the power requirement (1.51 KW) during the operation.

The lowest wheel slip (-2.63 %) received during the field operation in case of rotavator increased the field efficiency.

Among all the treatments, the highest field efficiency

**Table 2: Drawbar power calculation**

| Name of implement | Draft (kgf) | Draught force (KN) | Operating speed (km/h) | Drawbar power (KW) |
|---|---|---|---|---|
| Cultivator | 290 | 2.84 | 2.67 | 2.11 |
| M.B.plough | 370 | 3.63 | 2.21 | 2.23 |
| Rotavator | 195 | 1.91 | 2.85 | 1.51 |

**Table 3: Cost analysis**

| Treatments | Tractor cost | | Implement cost | | Total cost (Rs./h) | Total cost of operation (Rs./ha) |
|---|---|---|---|---|---|---|
| | Fixed (Rs./hr) | Operating (Rs./hr) | Fixed (Rs./hr) | Operating (Rs./hr) | | |
| $T_1$ : 2 x cultivator | 36.75 | 257.85 | 10.65 | 6.00 | 311.25 | 1047.98 |
| $T_2$ : M.B.plough + cultivator | 36.75 | 256.00 | 22.49 | 12.67 | 327.91 | 1576.49 |
| $T_3$ : 2 x rotavator | 36.75 | 347.90 | 16.56 | 9.33 | 410.54 | 2132.67 |
| $T_4$ :1 x rotavator | 36.75 | 217.53 | 16.56 | 9.33 | 280.17 | 1539.40 |

(79.82 %) was received under the treatment $T_4$ (one pass of rotavator).

According to the cost analysis, the total cost for seed bed preparation under $T_4$ (single pass of rotavator) was lowest *i.e.* Rupees 280.17 per hour.

From the research study, the mini tractor (15 hp) drawn rotavator is found most suitable for seed bed preparation under sandy loam soil conditions of this middle Gujarat region with respect to lowest draft and power requirement, highest field efficiency and lowest cost of operation.

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