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Research Article

COMPARATIVE PERFORMANCE OF TRACTOR DRAWN IMPLEMENTS TILLAGE SYSTEM WITH ROTAVATOR TILLAGE SYSTEM

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Abstract- Field tests were conducted to evaluate the performance of four different sized tractor – implement (rotavator) combination of at College of Agricultural Engineering and Technology, Anand Agricultural University Godhra, District: Panchmahal. The four different ranges of available tractors, i.e. power tiller (13 hp), mini tractor 1 (12 hp), mini tractor 2 (15 hp) and medium size tractor (35 hp) were used for seedbed preparation in the field under identical operating conditions using rotavator as matching implement in order to evaluate the performance of rotavator with each tractor and to suggest the small farmers in selecting suitable tractor for cost-effective operation. The parameters evaluated were travel reduction (wheel slippage), draft, speed of operation, drawbar power, volume of soil disturbed, fuel consumption, field efficiency and soil pulverization. The experimental plots were laid side by side in a randomized block design (RBD). Results indicate that mini tractor (Yuvraj 215) of 15 hp performed better in comparison to the other tractor – implement (rotavator) combination for seed bed preparation with respect to the parameters evaluated. It was found that the cost required for tillage operation by medium size tractor (Sonalika DI-35), mini tractor (Yuvraj 215), mini tractor (Captain DI-2600) and power tiller (VST Shakti 130 DI) was 1655.93, 1396.44, 1598.42, 2497.00 Rs/ha respectively. The operational cost of mini tractor (Yuvraj 215) was observed lowest. The mini tractor (Yuvraj 215) was therefore recommended among the three tractors from the standpoint of operational efficiency and economy.

Keywords- Comparison, Evaluation, Performance, Rotavator, Tractor, Tillage.

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Introduction

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. 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 [1]. Tillage is defined 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 [2]. 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. It is observed that the power requirement increased with increase of rotar speed and the power requirement decreased with the decrease of rotor speed [3]. It is found that the maximum field efficiency was obtained with cultivator attachment when it was compared with the field performance of other attachment of multipurpose tool bar such as plough riger and bund formers. Cost of operation of cultivator attachment observed was Rs. 110/ha which was less than that cost of operation of other attachments. When the cultivator was operated black soil at 14.40 per cent moisture content with operating speed 5 km/ha field efficiency observed was 15.12%, which was more than other attachments [4].

The tyne type cultivators were much better than that of conventional method of cultivation. Effective use of implement helps to improve moisture retention capacity of deep black soil enhance the crop yield when implement was used single or in combination [5].

The effect of machinery management on energy requirements according to them the system using double rotavator operations are energy efficient and gave the highest yield and energy inflow outflow. The use of rotavator results into time saving (18.3 to 66.67%) as well as energy saving (10.9 to 23.35%) for one and two rotavator operations over the prevalent practices [6].

The tillage operation is most costly operation in the budget of farmer because among all other agricultural operations like drilling, spraying, inter culturing, harvesting etc. tillage machinery requires maximum amount of power for seedbed preparation. The old practices of excessive tillage not only deteriorate soil structure but also become a reason for delay in sowing of the following crops. It may therefore reduce the crop production in the range of 1 percent per day and those tillage practices are also energy as well time consuming which results in increased cost of production also.

By rapid increase in population as well as industrialization, the agricultural lands are also becoming less and less thereby increase in the population of small land holders. In addition, the youth of the villages are also migrating in big cities for the employment so; the required manpower in the villages is also insufficient to perform various farm operations. Hence, it is the urgent need for small farmers to introduce the cost-effective farm mechanization as they can purchase such small tractors or power tillers along with their matching implements otherwise can hire the same with negligible hiring charges for timely sowing of their crops.

So, under these circumstances researchers have the challenge to introduce mechanized seedbed preparation for any crop which saves time and energy with less expenditure as compared to the conventional seedbed preparation. 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. Rotavator required the minimum time for the operation and transferring the tractor power through PTO, which is more efficient than through traction wheels for a traction dependent implement. Since 90 percent of the required power passes through the PTO, the rotavator has potential for reducing the energy loss through wheel slippage during the tillage [7]. At the same time it provides increased soil pulverization and mulch incorporation in comparison to conventional implements and hence use of rotavator compared to conventional tillage systems can save an enormous amount of energy and labour.

Keeping above in view, a study project will be conducted with four different ranges of available tractors, i.e. power tiller (13 hp), mini tractor 1 (12 hp), mini tractor 2 (15 hp) and medium size tractor (35 hp) for seedbed preparation in the field under identical operating conditions using rotavator as matching implement in order to evaluate the performance of rotavator with each tractor and to suggest the small farmers in selecting suitable tractor for cost-effective operation with the following objectives a) to determine the field efficiency for each tillage operation, b) to evaluate each tractor-rotavator combination for quality seed bed preparation, c) to estimate the cost involved under each treatment and suggest the most economical one.

Material and Methods

A field experiment was conducted at college of Agril. Engineering, A.A.U. Godhra during the year 2012-2013 to study the comparative performance of power tiller and different sized tractor drawn implement tillage system with rotavator tillage system. Different combinations of different sized tractor for tillage operations were selected as T1=Tillage operation by Medium size tractor 1 (35 hp), T2=Tillage operation by Mini tractor 2 (15 hp), T3=Tillage operation by Mini tractor 3 (12 hp), T4=Tillage operation by Power tiller (13 hp). Five replications of each combination were taken in the field for more accuracy of results. The tractor drawn implements produce best performance only in rectangular field therefore rectangular plots of 20 m x 4.8 m were marked for each trial. Performance of different sized tractors with rotavator varies considerably according to the type of Soil, moisture content of soil, weeds, crop residues and traveling speed. Therefore the conditions of the test have to be clearly stated and before starting the test at various field conditions moisture content on dry basis was determined and all tests were conducted as per the RNAM test code [8].

The tested tractors were from medium size tractor (Sonalika DI-35), mini tractor 2 (Yuvraj 215), mini tractor 3 (Captain DI-2600) and power tiller (VST Shakti 130 DI) and their specifications are shown in [Table-1]. The implement used for the trials was rotavator. The specifications of the matching implements are shown in [Table-2].

Determination of 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 in each plot. The moisture content was determined in the laboratory by oven dry method and the samples were collected by core sampler from the soil.

Fig-1 Medium Tractor (T1) Under Operation

Fig-2 Mini Tractor (T2) Under Operation

Fig-3 Mini Tractor (T3) Under Operation

Fig-4 Power Tiller (T4) Under Operation

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

$$\text{Moisture content (\%)} = \frac{\text{Ww} - \text{Wd}}{\text{Wd}} \text{ x } 100 \ldots\ldots\ldots\ldots \text{[1]}$$

Where, W_w = Weight of wet soil sample, and W_d = Weight of dry soil sample

Determination of Bulk density:

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

Table-1 *Technical specifications of different sized tractors.*

Sr. No.	specification	Model of tractor			
		T1	T2	T3	T4
1	Effective output (hp)	35	15	11.8	13.0
2	Type of Engine	3-Cylinder	1-Cylinder	1-Cylinder	1-Cylinder
3	Type of Fuel	Diesel	Diesel	Diesel	Diesel
4	Type of Steering System	Mechanical	Mechanical	Mechanical	Mechanical
5	Transmission	8F x 2R	6F x 3R	6F x 2R	6F x 2R
6	Type of Injector Pump	In-line injector	In-line injector	In-line injector	In-line injector
7	Firing Order	1-3-2	1	1	1
8	Fuel Tank Capacity (L)	55	19	14.9	11
9	Rated Engine Speed(rpm)	2000	2300	2600	2400
10	Type of Cooling System	Water-Cooled	Water-Cooled	Water-Cooled	Water-Cooled
11	Country of Manufacture	India	India	India	India
12	Front tyres (size)	6.0 – 16	5.20-14	5.20-14	5.6
13	Inflation Pressure (Psi)	36.26	24	24	22
14	Rear Tyres (size)	13.6-28	8-18	8-14	-
15	Inflation Pressure (psi)	15.95	24	24	-
16	Total Weight (Kg)	2000	800	845	280

Table-2 *Specifications of matching implements*

Sr. No	Specifications	Rotavator matching with		
		Medium size tractor (35 hp)	Both minitractors (15 & 12 hp)	Power tiller (13 hp)
1	Number of blades	36	16	18
2	Width of cut (mm)	150 cm	120 cm	60 cm
3	Total weight	399 kg	185 kg	125 kg

Bulk density was determined by the following formula.

$$\text{Bulk density}\left(\frac{g}{cc}\right) = \frac{\text{Weight of dry soil sample (g)}}{\text{Volume of the core sampler (cc)}} \ldots\ldots\ldots [2]$$

Operating speed:
Operating speed was measured by a distance traveled in specific time.

Travel reduction (wheel slip):
A mark was made on the tractor drive wheel with coloured 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. Expressed mathematically as:

$$\text{T. R. (Wheel slip)} = \frac{M2 - M1}{M2} \times 100 \ldots\ldots\ldots [3]$$

Where, T.R. = travel reduction (%), 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:
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 up to 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 was determined by the following formula:

$$\text{Effective field capacity}\left(\frac{ha}{hr}\right) = \frac{\text{Area covered (ha.)}}{\text{Time taken (hr.)}} \ldots\ldots\ldots [4]$$

The theoretical field capacity was calculated by the following formula:

$$\text{Theoretical field capacity (ha/hr)} = \frac{\text{Width of coverage (m) x Speed of travel (km/hr)}}{10}$$

After getting both the values as above formula, the field efficiency was calculated by the following formula:

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}\left(\frac{ha}{hr}\right)}{\text{Theoretical field capacity}\left(\frac{ha}{hr}\right)} \text{x } 100 \ldots [5]$$

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.

Soil volume disturbed:
The soil volume disturbed in m^3/hr was calculated by multiplying the field capacity with the depth of cut.
V = 10000SD
Where; V = Soil volume disturbed (m^3/hr), S = Effective field capacity (ha/hr), D = Depth of cut (m)

Soil pulverization:
Soil 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.

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

$$\text{Drawbar power (kw)} = \frac{\text{Draft (kN)x Operating speed} \left(\frac{\text{km}}{\text{hr}}\right)}{3.6\ \text{(constant)}} \ldots\ldots [6]$$

Cost Analysis:
In order to evaluate the effectiveness of the treatments and to ascertain the most remunerative treatment, the cost incurred for the seed bed preparation under each treatment were computed and added. The cost analysis is divided under two heads known as fixed cost and operating cost which is as follows:

Fixed cost:
Depreciation
It is the loss of value of a machine with the passing of time.

$$D = \frac{C - S}{L\,X\,H} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [7]$$

Where, D = Depreciation per hour, C = Capital investment, S = Salvage value, 10% of capital, H = Number of working hours per year and, L = Life of machine in years.

Interest
Interest is calculated on the average investment of the machine taking into consideration the value of the machine in first and last year.

$$D = \frac{C + S}{2} \times \frac{i}{H} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

Where, I = Interest per hour, I = % rate of interest per year.

Housing
Housing cost is calculated on the basis of the prevailing rates of the locality but roughly speaking, the housing cost may be taken as 1% of the initial cost of the machine per year.

Insurance
Insurance charge is taken on the basis of the actual payment to the insurance company but roughly speaking, it may be taken as 1% of the initial cost of the machine per year.

Taxes
Taxes are calculated on the basis of the actual taxes paid per year but roughly speaking, it may be taken as 1% of the initial cost of the machine per year.

Operating cost:
Fuel cost
Fuel cost is calculated on the basis of actual fuel consumption in the tractor.
Lubricants
Charges for lubricants should be calculated on the actual consumption, but speaking the lubricants cost varies between 30 to 35% of the fuel cost.
Repair and maintenance
Cost of repair and maintenances between 5 to 10% of the initial cost of the machine per year.

Wages
Wages are calculated on the basis of actual wages of the workers.

Results and Discussion
Soil moisture content: The results revealed that the average moisture content is as recorded at 0 – 15 cm depth is 13.79%

Bulk density: The results revealed that the average bulk density was as recorded at 0 – 15 cm depth is 1.53 g/cc.

Operating speed
The operating speed was measured under each treatment and found that the average speed for treatment T1, T2, T3 and T4 was 3.55km/hr, 2.84km/hr, 2.48km/hr and 1.23km/hr, respectively.

Travel reduction (Wheel Slip)
Travel reduction affects the traction efficiency of any tractive device. The medium tractor gave the lowest values of travel reduction or wheel slip during the operation. This low wheel slip may be due to the fact that rotavators exerts a forward force/thrust to the tractor driveline. Also the reduced draft of rotavators resulted in less wheel slip at tractor tyre – soil interface, thus improving field productivity and efficiency.
Draft
The results of the draft measurement on the four tractors are shown in [Table-3]. Lighter tractors (mini tractor 1, mini tractor 2 and power tiller) exhibited higher total draft force when compared with that from the heavier (medium size) tractor.

The results show that speed of operation and depth of cut affected the draft of the implements. Draft was highest with the mini tractor (T3) in comparison to other tractors. This may be attributable to the higher depth of cut achieved by the tractor during the operations

Fig-6 Draft measurement using drawbar

Fuel consumption
The parameters for fuel consumption show significant differences between the different sized tractors [Table-3]. The fuel consumption for seed bed preparation per hectare was recorded minimum in case of power tiller. However, the largest amount of fuel was consumed with the use of medium size tractor for the same area and operation. The higher fuel consumed by this tractor could be ascribed to its larger width of implement, higher speed of travel with a higher depth of cut.

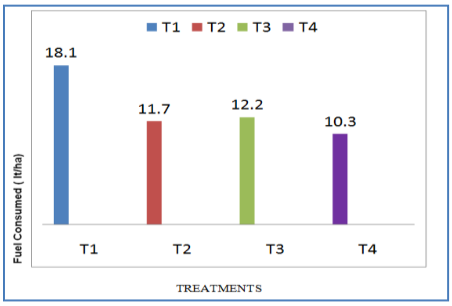

Fig-7 Fuel consumption during treatments

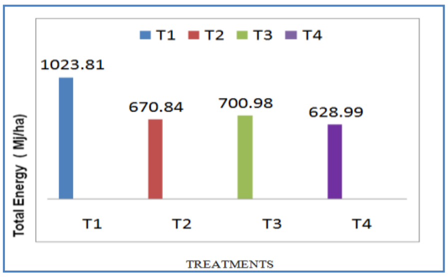

Fig-8 Energy Requirement during Treatments

Energy requirement

The operational (mechanical) energy consumption was computed for the different treatments during seedbed preparation. Operational energy refers to the energy used for mechanization, i.e. direct energy (fuel and human labour). As can be observed from [Table-3], the total operational energy consumption was highest for medium tractor (1023.81 MJ/ha) it is due the high rate of fuel consumption in comparison to the small size tractors

Field capacity

Field capacity and soil disturbance has been reported as two major factors in determining the performance of tillage implements [9]. The field capacity of a machine is a function of its width, speed and efficiency of operation. The data regarding these parameters is presented in [Table-3].

The medium with relatively higher values of width of cut, speed of operation and field efficiency achieved better results for field capacity. The power tiller gave the least field capacity. This could be explained by the higher travel reduction associated with the tractor model during tillage operations. This result is in agreement with the findings of travel reduction has effect on field capacity[10].

Soil volume disturbed

Soil volume disturbed depends on the effective capacity and the depth of cut. The comparative performance of the four different sized tractors in terms of soil disturbance shows that medium size tractor with the same implement achieved highest soil disturbance. The results also indicated that higher speed of operation affected soil volume disturbed positively. Thus, tractors operating at higher speed yielded higher disturbed soil volume.

Soil pulverization

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 are adequate for sowing crops. This result is in agreement with the findings of KP Singh, Bachchan Singh and TP Singh, 2002.

There was a significant improvement in soil pulverization with the use of the rotavator. The mean mass diameter (MMD) of clods in seedbeds in treatments T1, T2 and T3 was significantly smaller than in T4.

Drawbar power

Drawbar power is a function of draft and speed. Like draft, mini tractor (T3) gave the highest drawbar power of 2.66 kW since a large pull will result in a large drawbar power. In the same vein, power tiller gave the lowest drawbar power of 1.03 kW, followed by mini tractor (T2) and medium tractor with 2.41 kW and 2.61 kW respectively.

Cost Analysis

The cost analysis under each treatment for seed bed preparation involves the fixed cost of the machine and the variable cost due to fuel and labour charges.

The result shown in the [Table-3] revealed that the total cost per hectare under treatment T2 and T3 is Rs. 1484.72 and Rs. 1595.42 respectively due to lower initial capital investment as well as better fuel efficiency as compared to medium size tractor (T1). The total cost per hectare in case of power tiller is higher due to its significantly lower field capacity. The operating costs of mini tractors T2 and T3 is Rs. 242.01 and Rs. 223.36, which is significantly lower than that of medium size tractor due to better fuel efficiency.

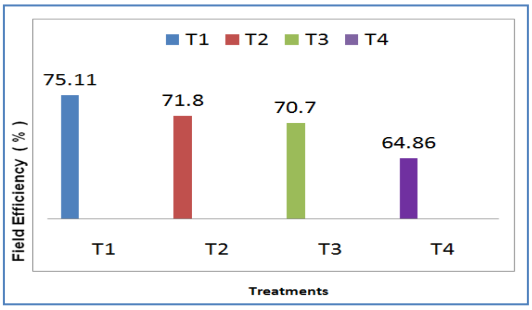

Fig-9 Field Efficiency during Treatments

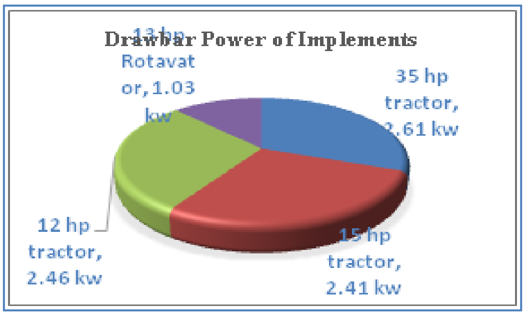

Fig-10 Drawbar Power of Implements

Table-3 *Results of field test performed on tractors and power tiller with rotavator.*

Sr. No.	Parameters*	TRACOR MODEL			
		T1	T2	T3	T4
1	Travel reduction (%)	-0.25	-2.66	-2.91	-1.47
2	Width of cut (cm)	160	80	80	60
3	Depth of cut (cm)	16	13	10	07
4	Speed of operation (km/hr)	3.55	2.84	2.48	1.23
5	Effective field capacity(ha/hr)	0.426	0.163	0.140	0.040
6	Theoretical field capacity(ha/hr)	0.568	0.227	0.198	0.074
7	Operation time (hr/ha)	2.35	6.13	7.14	25
8	Field efficiency (%)	75.11	71.80	70.70	64.86
9	Draught force (kN)	2.65	3.06	3.58	3.02
10	Fuel consumption (L/ha)	18.10	11.70	12.20	10.30
11	Fuel consumption (L/hr)	7.71	1.91	1.71	0.41
12	Soil volume disturbed (m3/hr)	681.60	211.90	140.00	28.00
13	Drawbar Power (kW)	2.61	2.41	2.46	1.03
14	Energy requirement (MJ/ha)	1023.81	670.84	700.98	628.99
15	Soil pulverization MMD (mm)	11.75	14.71	14.09	19.10
16	Cost of Operation (Rs/ha)	1655.93	1426.93	1598.42	2497.00

T1=Medium size tractor (35 hp), T2=Mini tractor$_2$ (15 hp), T3=Mini tractor$_3$ (12 hp), T4=Power tiller(13 hp)

* Parameter values are average of five replicates

Conclusion

Amongst different performance parameters tested in the study, according to the factor of soil pulverization the clod mean-mass-diameter for medium size (T1) tractor was the lowest showing best tilth of soil as compared to the others. The soil pulverization achieved by the mini tractors was also significantly good. The total draft of the implements using four different sized tractors was close except for the medium tractor (T1) which was found to be lowest because of greater drawbar power as compared to the others. Among the two mini tractors evaluated the performance parameters such as field capacity and soil volume disturbed was found higher for the mini tractor (T2), also the draft and wheel slip for it is less, which shows that it is better one. According to the cost analysis, the total cost (Rs/ha) for the mini tractor (T2) is Rs. 1396.44/- which is the lowest as compared to the others. Though the four tractors – implement (rotavator) combinations performed well based on established standards, however, from the standpoint of efficiency and fuel economy, the mini tractor (T2) is suggested for the small and marginal farmers of this region of Panchmahal district region of Gujarat, India.

Table-4 *Comparative performance in terms of Cost savings.*

Treatments	Cost, Rs/ha	Cost saving (%) compared to			
		T4	T3	T2	T1
T1	1655.93	33.68	-3.59	-16.48	-
T2	1426.93	42.85	10.72	-	13.83
T3	1598.42	35.99	-	-12.02	3.47
T4	2497.00	-	-56.21	-74.99	-50.79

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Author Contributions: planning, execution and completion of research work during the year 2012-2013

Abbreviations:
%= Percent
cm= Centimeter
d.b.= Dry basis
etc.= Etcetera
F.E.= Field Efficiency
g/cc= Gram per Cubic Centimeter
h= Hour
ha= Hectare
hp= Horsepower
Km/hr= Kilometer per Hour
MMD= Mean Mass Diameter
PTO= Power take off
RNAM= Regional Network For Agricultural Machinery
Rs.= Rupees
SVD= Soil Volume Disturbed

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.- by Rangapara Dineshkumar, Dabhi K. L and A. D. Makwana

Conflict of Interest: None declared

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