



ISSN (E): 2277- 7695

ISSN (P): 2349-8242

NAAS Rating: 5.23

TPI 2021; 10(4): 254-258

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[www.thepharmajournal.com](http://www.thepharmajournal.com)

Received: 17-01-2021

Accepted: 21-03-2021

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## Energy expenditure measured for various tillage practices for various speeds of operation at different depths of cut in two different soil types

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**DOI:** <https://doi.org/10.22271/tpi.2021.v10.i4d.5936>

### Abstract

Tillage involves a lot of energy expenditure, generally in terms of fuel consumed by the tractor. The fuel consumption for the different tillage practices needs to be quantified and this paper presents quantification for the same. The experiment was carried out at the fields of two different soil types viz. sandy loam (S1) and silty loam (S2). Six tillage practices, designated as P1, P2, P3, P4, P5 and P6, were undertaken in the present study. The six practices were one pass of harrow-cultivator-planker combination (P1), two passes of harrow-cultivator-planker combinations (P2), one pass of rotavator (P3), two passes of rotavator (P4), one pass of spading tillage machine (P5) and two passes of spading tillage machine (P6). Different implements have their own, i.e. different recommended speeds and depths of operation. For experimental study, two different depth of cut ranges, designated as D1 & D2 and two forward velocity ranges, designated as V1 & V2, suitable to every implement, were selected. The conventional tillage practices consumed more fuel and time as compared to multi-powered tillage tools practices but were found to move considerable volume of soil and shows lower rate of fuel consumption per unit of soil moved than other practices, whereas, rotavator and spading machine takes lesser time and fuel for tillage operation.

**Keywords:** Fuel consumption, tillage, rotavator, spading machine, harrow, cultivator, Planker

### Introduction

Energy is the driving force of this world. Therefore it is our duty to make optimum use of energy to save it for our nearby future. For humans, it is the food which provides us with the required energy. Further, a lot of energy is used to produce food via agriculture. Therefore, the precise use of the resources is of utmost importance. The importance of tractor lies mainly in the improvement of soil cultivation and transport in the field of agriculture. The availability and cost of tractor fuels is constantly changing and has shaken the foundation of the farm economy through out the world. The factors that affect fuel consumption are speed of operation, width of cut, depth of cut, type of soil and skill of operator. In order to save the cost of fuel, field operators have changed their route from ploughing to no till method. Also, tractor designers have turned their mind from diesel operated tractors to alternate energy operated tractors. Hence, fuel consumption has gained a unique importance in the field of mechanization (Thakare and Deshmukh 2009) <sup>[1]</sup>. The study was undertaken to find fuel consumption for different agricultural operations in two different soil types to calculate the energy required in terms of fuel consumption by the tillage practices under study.

### Materials and Methods

#### Independent parameters of the study

Different independent parameters were selected for determining the fuel consumption of different tillage practices and the parameters that express the quantity of fuel consumed are discussed as per following sub heads:

1. Soil type
2. Tillage practices
3. Forward velocity
4. Depth of operation

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## 1. Soil type

The relative content of particles of miscellaneous sizes like sand, silt and clay in the soil are indicated by soil texture and is the most important property of soil (Shete *et al.* 2019) [2]. Field plots at two different locations of varied soil texture described henceforth as S1 and S2 were selected. The soil texture has been characterized by ascertaining the soil physical parameters. i.e. per cent sand, silt and clay. Soil samples were taken from at least four different locations of the selected plot i.e. from S1 and S2 separately. Samples taken from fields S1 and S2 were mixed separately and part of soil samples (S1 and S2) were taken to soil testing laboratory of the Department of Soil Science, Punjab Agricultural University, Ludhiana for analysis work.

## 2. Tillage practices

Three different tillage practices were taken for the present study and described as per following sub heads:

1. Conventional tillage practice
2. Tillage with rotavator
3. Tillage with spading machine

### Conventional tillage practice

Three tillage implements, *viz.* disc-harrow, cultivator and planker, used commonly for conventional tillage were selected. All implements were operated once, one after the other i.e. first disc-harrow, then cultivator and then planker (one pass each) and this practice has been designated as P1. Another tillage practice has been considered for the present study by using two passes of each one after the other, of all the selected implements and designated as P2. The specific but brief information regarding the different implements has been given as follows.

A semi mounted double action disc harrow (Amsons) was used with 16 discs arranged on two gangs as shown in Figure 1. Mild steel angle welded frame structure was mounted on the individual gang of discs. Curved discs with plane sharp cutting edge were used. The disc harrow was hydraulically lifted for locomotion.



**Fig 1:** A stationary view of Disc harrow

An 11 Tyne cultivator with spring loaded tynes (Amsons) was used as shown in Figure 2. Heavy springs provide safety to the tynes against shock and impact loads encountered during field operations. Width of cultivator was 2.4 m.



**Fig 2:** A stationary view of 11 Tyne cultivator

A mild steel planker of width 3 m (Amsons) was used for the top finishing operation of the soil shown in Figure 3.



**Fig 3:** A stationary view of Planker

### Tillage with rotavator

A horizontal shaft forward rotary rotavator with L-shaped blades has been used for the study. Two tillage practices of rotavator were taken in the study *viz.* one pass of rotavator designated as P3 and two passes of rotavator designated as P4. The specific but brief information about rotavator has been given as follows. The rotavator (Dasmesh) used for the study comprises of 36 L-type blades, as shown in Figure 4. The rotavator was designed to operate at 540 PTO rpm and had a rotor speed of 270 rpm. Physical dimensions of the rotavator *viz.* width x height x length were 1.77 m x 0.94 m x 1.35 m. Working width of the rotavator was 1.52 m.



**Fig 4:** A stationary view of the rotavator with L type blades

### Tillage with spading machine

A spading machine (Selvatici, 150.75 series, 1105 model) having 1.1m width has been used for the study. Two tillage practices of spading machine were taken i.e. one pass of spading machine designated as P5 and two passes of spading machine designated as P6. The spading machine manufactured by Bologna (Italy) based farm machinery manufacturing company, Selvatici was used in the present investigation as shown in Figure 5. This is a compact machine equipped with five spades and works on a width of 110 cm. The depth of working has been adjustable up to a maximum of 30 cm.



**Fig 5:** A view of spading machine used in the study

Tractor selected in the experiment was JOHN DEERE 55 hp equipped with a fuel flow meter shown in Figure 6.



Fig 6: A view of tractor equipped with the fuel meter

### 3. Forward velocity

Two different ranges of forward velocities henceforth described as V1 and V2, for the tillage implements has been taken. V1 has been taken as the lower manageable velocity range while V2 has been taken as the higher manageable velocity range. Appropriate velocity ranges have been selected so that all implements could confirm the selected ranges. The forward velocity of implements was measured by standard velocity measurement relationship given in equation 1.

$$v = d/t \quad \dots\dots\dots 1$$

where,

v = forward speed, m/s

d = distance in meters, m

t = time taken to cover the designated distance in seconds.

### Depth of operation

Two different depth ranges, henceforth described as (D1 and D2) for operating each of the tillage implements has been taken. The shallower depth range has been designated as D1 and the deeper depth range of operation as D2. The required depth of operation was maintained by the hydraulic control of lower links and the top link adjustment of three-point linkage system of tractor. Test runs were conducted for the depth adjustment of different implements before actual experimental runs. Appropriate depth ranges have been selected so that all implements could confirm the selected ranges. A ruler (30 cm length) with a least count of 1 mm, was used to measure the depth of operation of various implements, as shown in Figure 7.



Fig 7: A view of depth of operation measurement using a ruler

### Fuel Consumption

Estimating the amount of fuel consumption of an agricultural tractor during various tillage operations will help the selection of the best conservation practices for farm equipment (Amer 2019) [3]. Fuel consumption of each of the tillage practices were recorded with the help of the tractor mounted fuel flow meter shown in Figure 8. A volume flow meter (Aqua Metro VZO 4, Swiss made) was installed between the diesel tank and fuel filters of the tractor to ascertain the fuel consumption of the tractor. All fuel passing through the flow meter was consumed by the tractor engine. An additional fuel filter was also installed upstream of flow meter to rule out choking. The fuel meter gives only the quantity of fuel passed through the meter. The quantity of fuel metered was accurate up to 1 ml. A stopwatch was used to record the time of run of tractor for the measurement of fuel consumption. Fuel consumption can be measured in the field simultaneously with the measurement of speed, time, field capacity, depth and width of cut of implements used (Goyal *et al.* 2010) [4].



Fig 8: Tractor mounted fuel meter

### Layout of experimental plots

Paper chits with the name of different treatments were prepared by writing designated tillage practices, forward velocities and depth of operations as factors. The paper chits were thoroughly mixed and random draw of lot was performed one by one till the end of lot. Then, accordingly the names of the treatments were written and plotted accordingly in a randomized fashion, on the field.

### Results and Discussion

#### Layout of experimental plots

The experiments were laid on fields of research farms of department of farm machinery and power engineering, PAU, Ludhiana. The fields were demarcated as per the experimental layout. The two soil types were divided into 24 plots for the tillage treatments. Length of run was 27m and 25m for S1 and S2, respectively.

#### Independent parameters of the study

Different operating ranges were selected for different independent parameters depending upon nature of tillage implements used in the present study.

#### Soil type

The soil samples of two different sites, selected for the experimentation, were analyzed for particle size distribution (soil texture). The S1 soil composes of 76% sand, 12% silt and 12% clay, hence termed as sandy loam texture whereas S2 soil composes 20% sand, 55% silt and 25% clay, hence falls under silty loam texture.

### Tillage practices

Six different tillage practices, viz.

1. One pass each of harrow followed by cultivator and plunger (P1),
2. Two passes each of harrow followed by cultivator and plunger (P2),
3. One pass of rotavator (P3),
4. Two passes of rotavator (P4),
5. One pass of spading machine (P5) and
6. Two passes of spading machine (P6), were considered for the present study.

Therefore, a total of five different tillage implements were used for the experimental study.

### Forward velocity

All the implements have their own recommended speed of operation. For experimental study, two different forward speed ranges, suitable to every implement, were selected. The lower speed range (V1) of all tillage implements were maintained between 1.63 km/h to 5 km/h. The lower speed of operation in the conventional tillage practices P1 and P2, disc harrow, cultivator and plunger was operated at about 3.9-5 km/h, in practices P3 and P4, rotavator was operated at about 1.63–2.46 km/h. Rotavator plays a vital role in helping the farmer to plough their land in a much faster and effective way (Kankal *et al.* 2016) [5]. For practices P5 and P6, spading machine was operated at about 1.92–2.31 km/h. The higher speed range (V2) of all tillage implements were maintained between 2.37 km/h to 7.47 km/h. In the conventional tillage practice P1 and P2, disc harrow, cultivator and plunger was operated at about 5.4–7.47 km/h, in practices P3 and P4,

rotavator was operated at about 2.37–2.85 km/h and in practices P5 and P6, spading machine was operated at about 2.5–3 km/h.

### Depth of operation

Similarly, different implements have different depth of operation. For the experimental study, two different ranges of depth of operation were selected. The shallower depth ranges of operation (D1) maintained for the selected implements were between 5 cm to 10 cm. For the lower depth, the conventional tillage practices P1 and P2, disc harrow, cultivator and plungers were operated at about 10 cm, in practices P3 and P4, rotavator was operated at about 5 cm and in practices P5 and P6, spading machine was operated at about 5 cm. The deeper depth ranges of operation (D2) were maintained between 10 cm to 15 cm for all the implements under study. For the deeper depth, the conventional tillage practices P1 and P2, disc harrow, cultivator and plungers were operated at about 15 cm, in practices P3 and P4, rotavator was operated at about 10 cm and in practices P5 and P6, spading machine was also operated at about 10 cm.

### Fuel consumption in tillage practices

The fuel consumed by tractor in different tillage practices selected under the study were determined. The length of run for the different tillage treatments were 27 m and 25 m for soil S1 and soil S2, respectively. The average values of fuel consumption (rounded to nearest ml), time of run for different practices (s), volume of soil moved (m<sup>3</sup>) and fuel consumed per unit of soil moved (ml/m<sup>3</sup>) recorded in different tillage treatments are given in the Table 1.

**Table 1:** Fuel consumption for the tillage practices for both soil S1 and S2

Treatment	Soil S1				Soil S2			
	Fuel consumed, ml	Time of run, s	Volume of soil moved, m <sup>3</sup>	Fuel consumption, ml/m <sup>3</sup>	Fuel consumed, ml	Time of run, s	Volume of soil moved, m <sup>3</sup>	Fuel consumption, ml/m <sup>3</sup>
P1V1D1	85	57	16.20	5.25	90	60	15.00	6.00
P1V1D2	90	63	23.09	3.90	110	81	21.38	5.15
P1V2D1	94	50	16.20	5.80	110	53	15.00	7.33
P1V2D2	114	50	23.09	4.94	110	67	21.38	5.15
P2V1D1	190	160	32.40	5.86	210	175	30.00	7
P2V1D2	166	146	46.18	3.59	240	181	42.76	5.61
P2V2D1	262	138	32.40	8.08	280	179	30.00	9.33
P2V2D2	258	145	46.18	5.58	310	171	42.76	7.24
P3V1D1	50	42	2.03	24.69	50	47	1.88	26.67
P3V1D2	50	41	4.05	12.35	50	46	3.75	13.33
P3V2D1	60	35	2.03	29.63	60	38	1.88	32.00
P3V2D2	60	34	4.05	14.81	60	35	3.75	16.00
P4V1D1	120	102	4.06	29.55	120	110	3.76	31.91
P4V1D2	100	94	8.10	12.34	110	106	7.50	14.66
P4V2D1	130	86	4.06	32.01	140	88	3.76	37.23
P4V2D2	140	92	8.10	17.28	150	97	7.50	20.00
P5V1D1	40	44	1.49	26.94	40	36	1.38	29.09
P5V1D2	40	35	2.97	13.47	40	34	2.75	14.55
P5V2D1	50	34	1.49	33.67	50	31	1.38	36.36
P5V2D2	60	33	2.97	20.20	50	30	2.75	18.18
P6V1D1	100	101	2.98	33.55	90	74	2.76	32.60
P6V1D2	100	96	5.94	16.83	110	83	5.50	20.00
P6V2D1	110	84	2.98	36.91	110	69	2.76	39.85
P6V2D2	110	82	5.94	18.51	110	69	5.50	20.00

The fuel consumption, of certain tillage treatments that consists of two passes of implements, composes fuel consumed during headland turning. The fuel consumed varied

between 40 ml for P5V1D1 and P5V1D2 tillage practices to 262 ml for P2V2D1 practice in soil S1 and from 40 ml for P5V1D1 and P5V1D2 practices to 310 ml for P2V2D2

practice. The time of run for different practice for soil S1 varied from 33 s in P5V2D2 practice to 160 s in P2V1D1 practice. It was observed that conventional tillage practices consumed more fuel and time as compared multi-powered tillage tools practices. The reason is due the fact of more number of implements were involved in conventional practices. Similarly, the volume soil moved is considerably more in conventional practices as compared to rotavator and spading machine practices.

The fuel consumption per unit of soil moved by different practices were found to vary between 3.90 ml/m<sup>3</sup> for P1V1D2 practice to 74.07 for P6V2D1 ml/m<sup>3</sup> in soil S1 and from 5.15 ml/m<sup>3</sup> for P1V2D2 practice to 80 ml/m<sup>3</sup> for P6V2D1 practice in soil S2. Fuel consumption per unit of soil moved was found to lower for conventional practices as compared to rotavator and spading machine practices. This reason behind this is the amount of soil moved, which is considerably more in conventional practices.

### Conclusions

The experiment was carried out at the fields of two different soil types *viz.* sandy loam (S1) and silty loam (S2). Six tillage practices, designated as P1, P2, P3, P4, P5 and P6, were undertaken in the present study. The six practices were one pass of harrow-cultivator-planker combination (P1), two passes of harrow-cultivator-planker combinations (P2), one pass of rotavator (P3), two passes of rotavator (P4), one pass of spading tillage machine (P5) and two passes of spading tillage machine (P6). Different implements have their own, i.e. different recommended speeds and depths of operation. For experimental study, two different depth of cut ranges, designated as D1 & D2 and two forward velocity ranges, designated as V1 & V2, suitable to every implement, were selected. The conventional tillage practices consumed more fuel and time as compared multi-powered tillage tools practices but were found to move considerable volume of soil and show lower rate of fuel consumption per unit of soil moved than other practices, whereas, rotavator and spading machine takes lesser time and fuel for tillage operation.

### Acknowledgment

I, Abhishek Kumar, want to thank my mother, Anita Sharan, who's non ending wishes and moral support stood firm with me throughout in all the diversified situations of life.

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