Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 08, Issue, 08, pp.5293-5298, August, 2017

RESEARCH ARTICLE

FIELD PERFORMANCE EVALUATION OF TRACTOR DRAWN TILLAGE IMPLEMENT USED IN HILLY REGIONS OF ARUNACHAL PRADESH

***Singh, M. U.**

Faculty, Agricultural Engineering Department, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli 791109 (Arunachal Pradesh, India)

ARTICLE INFO

Article History:
Received 25th May, 2017
Received in revised form
15th June, 2017
Accepted 04th July 2017
Published online 31st August, 2017

Key words:

Tillage implement,
Field performance,
Field time, Delay time.

ABSTRACT

Selecting a most energy efficient tillage system often require the field performance data of various tillage implements under varying local conditions. Performance and energy input data for many of these tillage implements are not available with farmers of the hill regions of Arunachal Pradesh. Such information will probably guide the farmers to select suitable and energy efficient tillage implements. Keeping the importance of such information in mind, the present study was conducted to determine and compare the field performance of tractor drawn 2-bottom mouldboard plough, 2-bottom disk plough and spring loaded 7-tine cultivator. The percentages of implement width actually utilized (average effective width) were measured to be 86.67 % (52 cm), 84.7 % (59.3 cm) and 61.21 % (101 cm) for mouldboard plough, disk plough and tine cultivator respectively. Among the implements the spring loaded tine cultivator recorded the minimum draft per unit width (3.34 kNm^{-1}) and power (3.29 kW) followed by disk plough (9.01 kNm^{-1}) & (5.03 kW) and mouldboard plough (11.69 kNm^{-1}) & (7.1 kW). The spring tine cultivator also recorded the highest average field capacity (0.22 ha/h) and lowest fuel consumption of 18.13 L/ ha (4.01L/h). The average effective field capacity and fuel consumption of mouldboard plough and disk plough were respectively 0.168 ha/h & 26.87L/ha (4.48 L/h) and (0.16 ha/h) & 24.79 L/ha (3.95 L/h). The maximum field efficiency was observed in disk plough (83.75 %), followed by mouldboard plough (78.75 %) and spring tine cultivator (64.1%). The minimum delay time (time lost) per hectare was obtained with used of disk plough (1.16 h/ha), followed by mouldboard plough (1.28 h/ha) and spring tine cultivator (1.63 h/ha).

INTRODUCTION

Timeliness in agricultural operations right from the seed bed preparation to threshing and harvesting crops are essential for land labour productivity. Farm equipment acts as a device to ensure that other input give the desired results. Thus, it may be said that farm equipment and the techniques associated with its use broadly constitute the field of agricultural mechanization (O. Oduma *et al*, 2015). Energy is another important key in agricultural operations. Updhyaya *et al*, (1984) asserts that energy plays key role in various land tillage, seeding/planting and harvesting of agricultural productivities. Tillage is the base operation in agricultural systems and its energy represents a considerable portion of the energy utilized in crop production (Larson, D.L. and H.E. Clyma, 1995 (2). Sale *et al*, (2013), stress that agriculture is very sensitive to timely operations and weather conditions, and huge amount of money is spent on investment, therefore there is the need to evaluate the capacitive performance of agricultural machines for proper machinery selection, optimization and farm scheduling. Machines can be evaluated over a short period in productive work- equivalent to speed trials or they can be monitored over-time taking into account associated delays (Yohannah and Ifem, 2003). Draft and power requirements are important parameters for measuring and evaluating performance of tillage implements and therefore are considered to be essential when attempting to correctly match a tillage implement to a tractor (Grisso *et al*. 1996; Al-Janobi and Al-Suhaibani 1998). Efficient machinery management requires accurate performance data on the capabilities of individual machines in order to meet a given work schedule and to form balanced mechanization systems by matching the performance of separate items of equipment (Whiteney, 1988). Selecting a most energy efficient tillage system often require the field performance data of various tillage implements under varying local conditions. Unfortunately the performance and energy input data for many of these tillage implements are very rear in the hill regions of Arunachal Pradesh. Such information will

****Corresponding author:*** **Singh, M. U.**
Faculty, Agricultural Engineering Department, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli 791109 (Arunachal Pradesh, India)

probably guide the hill and valley farmers in selection of suitable tillage implements. The present study is carried with an aim to evaluate and compare the field performance of tractor drawn tillage implements namely, 2 bottom mouldboard plough, 2 bottom disk plough and spring loaded 7 tine cultivator under similar field conditions.

MATERIALS AND METHODS

The experiment was conducted at Research and Experimental field, Department of Agricultural Engineering of North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli, Arunachal Pradesh (India). The soil at the experimental site was sandy loam; topography was flat and was covered with grassy weeds. Prior to the field experiment, soil samples were collected randomly from ten spots and three soil depth 5 cm, 15 cm and 25 cm using soil samplers. Initial weights of all the samples were taken on digital balance and dried it at 105^{o} C for 24 hours. The volume of the soil sampler were measured, the dried samples collected from the oven and final weights were recorded. Moisture content on dry weight basis and bulk density was computed for each sample and average moisture content (db) and bulk density were computed. Table 1(a) shows the soil type, soil composition, moisture content and bulk density values for the experiment.
Cone index indicates soil hardness and is expressed as force per square centimeter required for a cone to penetrate into soil. Cone penetration resistance was measured by a digital cone penetrometer having 30^{o} cone angle and a base diameter of 12.83 mm (0.51 in.). According to ASAE standards, the device was driven into the soil at a constant speed of 0.02 m/s and the readings were recorded at various depths. Cone index was measured at 10 different spots over 0 - 25 cm depth range. Table 1 (b) shows the results of soil cone index of the experimental field.

Table 1 (a) shows the soil type, average moisture content (db), and bulk density determined for the field used for the experiment

Type of soil	Sandy loam	
Soil Composition	(%)	
Sand	72.50	
Silt	5.50	
Clay	2.00	
Silt	22.50	
Clay	5.00	
Moisture content (db), Soil bulk density and Cone index		
Depth(cm)	Average soil moisture content (%)	Average soil bulk density (g/cc)
7.00	8.50%	1.30
13.00	13.40%	1.40
19.00	16.50%	1.40
25.00	18.20%	1.60

Table 1(b). shows the average soil cone index over 0 - 25 cm depth range taken at 10 different spots

Depth (cm)	Cone index (kg/cm2)
2.00	0.00
7.00	8.20
13.00	11.20
19.00	17.50
25.00	22.15

Tillage Implements and Tractors

Three tillage implements namely mouldboard plough, disk plough and a cultivator were used in the experiment. The implements were tractor mounted tillage implements most commonly used for tillage operation such as ploughing, seed bed preparation, etc in hill valleys of Arunachal Pradesh. For the field trial, the depth of cut was set at 20 cm for all the implements. The disc angle and tilt angle of the disc plough was set at 40^{o} and 15^{o} respectively. General descriptions of the selected implements are given in the following section. Two tractors were used in this experiment, one as test tractor John Deer 5038 D (4wd, 38 Hp) and the other one as auxiliary tractor HMT 3522 (35 Hp). Figure (1) shows the tillage implements, auxiliary and test tractors and Table (2) shows the specification of the tillage implements.

Description of the implements

Two Bottom mouldboard plough: The mouldboard plough is primary tillage equipment and it is a general purpose having two bottoms each of 30 cm width of cut. It cuts trash and buries it completely.

Two Bottom disk plough: The plough consists of common main frame, disc beam assemblies, rocker shaft category-1, a heavy spring loaded furrow wheel and a gauge wheel. The disc angle ranges from 40^{o}-45^{o} to obtain the desired width of cut and the tilt angle ranges from 15-25^{o} for penetration. Disc plough is used for primary tillage operation especially useful in hard and dry, trashy, stony or stumpy land conditions and in soil where scoring is a major problem.

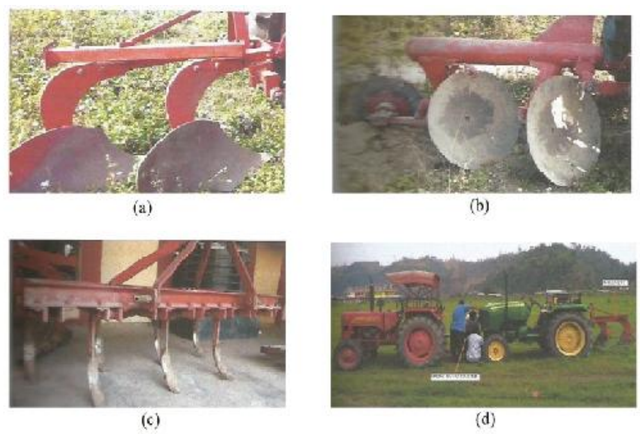

Figure 1 (a) 2 Bottom Mouldboard Plough (b) 2 Bottom Disk Plough (c) Spring Loaded 7 Tine Cultivator (d) Auxiliary Tractor (HMT) and Test Tractor (John Deer)

Spring loaded 7 tine cultivators: Cultivator consists of a rectangular frame, tines (spring loaded) having reversible shovels and 3-point hitch system. Primarily used for intercultural operation after the crop has come up a few centimeters above the ground, opening the land, preparing the seed bed and also used for intercultural operation by adjusting the tines as per row spacing.

Other equipment: Other equipment used in the field experiment includes a spring dynamo meter (1000kg), measuring tape, ranging rods, stop watches, steel/iron chain used for pulling the test tractor by the auxiliary tractor for implement draft measurement and a graduated glass cylindrical container for measuring fuel consumption.

Table 2. Specifications of selected tillage implements used for experiment

Particulars	Mouldboard plough	Disk plough	Spring loaded 7 tine cultivator
No. of bottom(s)/ tines	2	2	7 tines
Operating width	30 x 2 cm	35 x 2 cm	165 cm
Depth of cut	Upto 40 cm	Upto 30 cm	12.7 - 22.5 cm
Weight	244 kg	236 kg	180 kg
Power requirement	30 - 40 Hp	25 - 60 Hp	25 - 60 Hp

Experimental Design and Treatment Applications: The experimental design was a complete randomized block design. Treatments were three different types of tractor drawn tillage implements - a mouldboard plough, disk plough and spring tine cultivator. Four replications of each treatment were taken in the field, resulting in a total of 12 plots. The size of each plot was 40 m x 3 m (120 m^2). The field layout is shown in Figure (2)

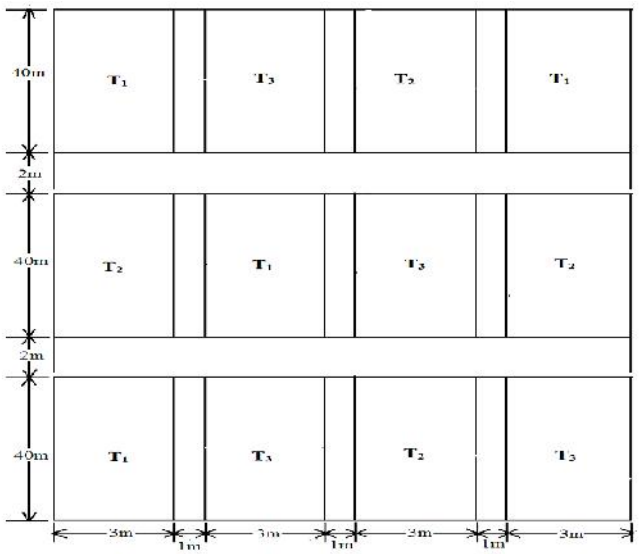

Figure 2. Field layout of the experimental area

Treatments: T_1: Mouldboard plough, T_2: Disk plough T_3: Spring tine cultivator

Field test performance parameter: The parameters measured for determining the performance of the tractor drawn tillage implements in the experiment includes operating speed, effective operating width, depth of operation, implement draft, productive time, delay time, area covered in unit time and fuel consumption.

These parameters were used for determining the performance indicators like actual/effective field capacity, field efficiency, theoretical field capacity, specific fuel consumption and power requirement of the tillage implements.

Measurement of draft:

- Attached a tillage implement on the three point hitch linkage system of the test tractor (John Deer 5038) such that the implement was kept in the operating position.
- Attached a direct reading spring dynamometer in front of the test tractor and its gear was kept in neutral position.
- An auxiliary tractor (HMT) was link with the test tractor through the spring dynamo meter.
- The auxiliary tractor pulled the test tractor at constant speed with the latter in neutral gear but with the implement in the operating position (RNAM test code),
- Draft was recorded for a measured distance of 40 m plot length.
- On the same plot, the implement was lifted up (implement in idle position) form the ground and draft of the test tractor only was recorded.
- The draft of the implement is given by the difference of between the two readings.

Hence the draft of the implement is determined as follows:

$$D_P = D_{PT} - D_T \quad \text{.................(1)}$$

Where, D_P is the draft of the implement (kg)
D_{PT} is the draft of test tractor with implement in operating position (kg)
D_T is the draft of test tractor (unloaded) (kg)

This procedure was carried out for all the tillage implements and four replications were made for each implement.

Measurement of total field time: Total time (total field time) is the time spent in the field while covering a given area and it includes the productive time (effective time), and any delay time. Delay time includes time spent in turning at the head lands, time spent in minor machine adjustment, time spent in cleaning clogged equipment etc. during the operation. Thus total time is calculated as follows:

$$T_T = T_P + T_D \quad \text{...................(2)}$$

Where, T_T is the total field time (s)
T_P is the productive (effective) time (s)
T_D is the delay time which includes turning time at the head lands, minor adjustment, cleaning clogged equipment during operation (s)

Measurement of operating speed

For measurement of operating speed of test tractor implement combination, time taken to cover the entire plot length (i.e. 40 m) was considered. The operating speed is calculated as plot length divided by the time required traveling the plot length. Then the speed is determined by taking average of such four readings in each plot.

$$V = \frac{L}{t} \quad \text{................(3)}$$

Where, V = Speed in meter per second (m/s)
L = Plot length (40 m) in meter (m)
t = Time taken to cover the plot length (i.e. 40 m) in second (s).

Measurement of power requirement: Having measured the operating speed of test tractor implement combination in the test plot, the power required for the operation is calculated as follows:

$$P = \frac{(D_P * V)}{75} \quad ……………(4)$$

Where, P = Power in Hp
D_P = Draft in kg
V = Average operating speed (m/s)

***Measurement of effective field capacity, theoretical field capacity and field efficiency*:** For determining the actual field capacities of the tillage implement, the test tractor with implement was operated in the field plot at a constant speed. During the operation, the time taken to cover the plot length, time required for actual tilling operation, time spent in turnings at the head lands, and any delay time encountered during the operation such as minor machine adjustment, cleaning clogged equipment etc. were all recorded using stop watches in each plot for each implement. The width of cut was also measured at various points along the straight rows in all the plots using steel rule and average value determined.

Effective (actual) field capacity is determined as follows:

$$EFC = \frac{A * 0.36}{(T_P + T_D)} \quad …………..(5)$$

Where, EFC is effective (actual) field capacity (ha/h)
A is the area of test plot in m^2 = 120 m^2
T_P is the productive (effective) time (s)
T_D is the delay time which includes turning time at the head land, minor adjustment, cleaning clogged equipment during operation (s)

Theoretical field capacity is determined as follows:

$$TFC = W_E * V * 0.36 \quad …………..(6)$$

Where, TFC is the theoretical field capacity (ha/h)
W_E is the average effective operating width measured in the field (m)
V is the average operating speed (m/s)

Field efficiency: It is the ratio of effective field capacity to theoretical field capacity, in %. Field efficiency includes the effect of time lost in the field such as time spent in turning etc. and failure to utilize the full width of the machine.

$$FE = \frac{EFC * 100}{TFC} \quad …………..(7)$$

Where, FE is field efficiency (%)
EFC is the effective field capacity (ha/h)
TFC is the theoretical field capacity (ha/h)

Measurement of fuel consumption: The test tractor started working the plot with its full tank capacity. A graduated glass cylinder of 1 liter capacity was used to top up the fuel tank immediately after the completion of each plot. The total quantity of fuel needed to refill and top up the tank and the time taken to complete the plot area were recorded. The fuel consumption in liter per hectare or liter per hour is determined as follows:

$$FC_A = \frac{Q_L * 10000}{A} \quad ………..(8)$$

Where, FC_A is the fuel consumption in liter per hectare (L/ha)
Q_L is the reading of glass cylinder in liter (L)
A is the area of field plot in meter square (m^2)

$$FC_H = \frac{Q_L * 3600}{T_T} \quad …………..(9)$$

Where, FC_H is the fuel consumption in liter per hour (L/h)
Q_L is the reading of glass cylinder in liter (L)
T_T is the time taken to complete the plot (area 120 m^2) in second (s)

RESULTS AND DISCUSSIONS

The field performance of selected tillage implements which are most commonly used in hill regions of Arunachal Pradesh, namely mouldboard plough, disk plough and spring tine cultivator are evaluated in the field where the soil was sandy loam type. In the field trails, the performance parameters of tillage implement such as operating speed, effective operating width, depth of operation, implement draft, productive time, delay time, area covered in unit time and fuel consumption were measured. Using the data obtained from the field trials, performance indicators such as field capacity, field efficiency, theoretical field capacity, power requirement and fuel consumption, were determined and evaluated for each type of implement under similar field conditions. Table (3, 4 and 5) represent the performance evaluation of mouldboard plough, disc plough and spring tine cultivator respectively. Prior to the trial, the soil moisture content (db), bulk density, soil cone index were measured and presented in Table 1 (a) and Table1 1 (b).

Speed of operation and effective width of cut: In the field trial, the depth of cut for all the tillage implements was set at 20 cm using the hydraulic depth control lever of the test tractor. The average operating speed of the test tractor with mouldboard plough, disc plough and spring tine cultivator were measured as 1.15 m/s (4.14 km/h), 0.92 m/s (3.31 km/h) and 0.96 m/s (3.45 km/h) respectively. Among the implements, mouldboard plough recorded the highest percentage of width actually utilized (average effective width of cut) in the tillage operation followed by disk plough and tine cultivator. The percentages of width actually utilized (average effective width) were measured to be 86.67 % (52 cm), 84.7 % (59.3 cm) and 61.21 % (101 cm) for mouldboard plough, disk plough and spring tine cultivator respectively (Table 3, 4 & 5).

Draft and power require: The average draft required for the mouldboard plough, disk plough and spring tine cultivator were measured as 619.53 kgf (6.08 k N), 544.75 kgf (5.34 k N) and 343.56 kgf (3.37 k N) respectively (Table 3, 4, 5). The highest draft per unit width of operation was recorded for mouldboard plough (11.69 kNm^{-1}), followed by disk plough (9.01 kNm^{-1}) and spring tine cultivator (3.34 kNm^{-1}). The average power needed to operate the mouldboard plough was found to be 7.1 kW (9.46 hp), followed by disk plough 5.03 kW (6.7 hp) and spring tine cultivator 3.29 kW (4.39 hp). The higher draft and higher power required for mouldboard may be attributed to its heavy weight 244 kg (Table 2), handling lager volume of soil and higher average working speed of 1.15 m/s as compared to the disk and spring tine cultivator. The minimum draft of 343.24 kgf (3.37 kN) and power 3.29 kW (4.39 hp) for the spring loaded tine cultivator may be attributed to its is lighter weight 180 kg (Table 2) and less volume of soil handling per unit time during operation.

Field efficiency and effective field capacity: The spring loaded seven tine cultivator shows the highest average field capacity of 0.22 ha/h and lowest field efficiency of 64.1% (Table 5). Higher field capacity of tine cultivator may be attributed to its higher average operating width of 101 cm as compared to 59.3 cm and 52 cm of disk plough and mouldboard plough respectively.

Table 3. Performance evaluations of two bottom mouldboard plow

Sl. No.	Particulars	Plot 1	Plot 2	Plot 3	Plot 4	Average
1.	Plot size, m^2	120	120	120	120	120
2.	Average effective width, cm (m)	53 (0.53)	48 (0.48)	53 (0.53)	54 (0.54)	52 (0.52)
3.	Average speed, m/s (km/h)	1.17(4.21)	1.17(4.21)	1.11(4.0)	1.13(4.07)	1.15(4.14)
4.	Draft, kgf (kN)	628.60(6.17)	618.47(6.07)	593.95(5.83)	637.10(6.25)	619.53(6.08)
5.	Draft per unit width of cut, kNm^{-1}	11.64	12.64	10.99	11.57	11.71
6.	Power, kW (hp)	7.36	7.24	6.59	7.19	7.1 (9.46)
7.	Total field time, s (h)	250.00(0.07)	270.0(0.07)	254.0(0.071)	260.0(0.072)	258.5(0.072)
8.	Productive time, s (h)	195.0(0.054)	215.0(0.6)	205.0(0.057)	198.0(0.6)	203.25(0.056)
9.	Delay time, s (h)	55.0(0.0153)	55.0(0.0153)	49.0(0.014)	62.0(0.017)	55.25(0.015)
10.	Effective field capacity, ha/h	0.173	0.16	0.17	0.17	0.168
11.	Theoretical field capacity, ha/h	0.22	0.20	0.21	0.22	0.213
12	Field efficiency, %	78.0	80.0	81.0	76.0	78.75
13.	Fuel consumption, L/ha	23.33	30.83	25.00	28.33	26.87
14	Fuel consumption, L/h	4.03	4.93	4.25	4.71	4.48

Table 4. Performance evaluation of disk plough

Sl. No.	Particulars	Plot 1	Plot 2	Plot 3	Plot 4	Average
1.	Plot size, m^2	120	120	120	120	120
2.	Average effective width, cm (m)	57(0.57)	58 (0.58)	63 (0.63)	59 (0.59)	59.3 (0.593)
3.	Average speed, m/s (km/h)	0.96(3.46)	0.902(3.25)	0.91(3.28)	0.925(3.33)	0.924(3.33)
4.	Draft, kgf (kN)	550.0(5.4)	535.0(5.25)	546.0(5.36)	550.0(5.4)	544.75(5.34)
5.	Draft per unit width of cut, kNm^{-1}	9.46	9.05	8.50	9.14	9.01
6.	Power kW(hp)	5.23	4.82	7.97	5.09	5.03 (6.7)
7.	Total field time, s (h)	262.0(0.73)	275.0(0.08)	275.0(0.08)	270.0(0.075)	270.5(0.075)
8.	Productive time, s (h)	221.0(0.06)	230.0(0.064)	210.0(0.06)	220.0(0.061)	220.25(0.061)
9.	Delay time, s (h)	41.0(0.011)	45.0(0.013)	65.0(0.02)	50.0(0.014)	50.25(0.015)
10.	Effective field capacity, ha/h	0.16	0.16	0.16	0.16	0.16
11.	Theoretical field capacity, ha/h	0.20	0.22	0.18	0.20	0.2
12.	Field efficiency, %	84.0	84.0	86.0	81.0	83.75
13.	Fuel consumption, L/ha	20.83	27.50	27.50	23.33	24.79
14.	Fuel consumption, L/h	3.44	4.32	4.32	3.73	3.95

Table 5. Performance evaluation of spring tine cultivator

Sl. No.	Particulars	Plot 1	Plot 2	Plot 3	Plot 4	Average
1.	Plot size, m^2	120	120	120	120	120
2.	Average effective width, cm (m)	102.8 (1.028)	101.1(1.011)	98.9 (0.988)	101 (1.010)	101 (1.01)
3.	Average speed, m/s	0.97	0.94	0.98	0.94	0.96
4.	Draft, kgf (kN)	346.29 (3.4)	341.20 (3.35)	346.29 (3.4)	341.20 (3.35)	343.24 (3.37)
5.	Draft per unit width of cut, kNm^{-1}	3.30	3.31	3.44	3.31	3.34
6.	Power, kW (hp)	3.37	3.20	3.39	3.21	3.29 (4.39)
7.	Total field time, s (h)	183.8(0.051)	203.5(0.057)	186.5(0.052)	205.0(0.057)	194.7(0.054)
8.	Productive time, s (h)	120.0(0.033)	126.5(0.035)	124.3(0.034)	126.3(0.035)	124.3(0.034)
9.	Delay time, s (h)	63.75(0.017)	77.0(0.021)	63.0(0.018)	78.75(0.022)	70.63(0.096)
10.	Effective field capacity, ha/h	0.24	0.21	0.23	0.21	0.22
11.	Theoretical field capacity, ha/h	0.36	0.34	0.35	0.34	0.35
12	Field efficiency, %	65.7	62.3	66.7	61.7	64.1
13.	Fuel consumption, L/ha	15.83	19.17	16.67	20.83	18.13
14.	Fuel consumption, L/h	3.72	4.07	3.86	4.39	4.01

Table 6. Field time, productive time and delay time

Sl. No.	Tillage Implement	Average Field time per hectare, h	Average Productive time per hectare, h	Average Delay time per hectare, h
1	2 Bottom Mouldboard Plough	5.98	4.7048	1.28
2	2 Bottom Disk Plough	6.26	5.098	1.16
3	Spring Loaded 7 Tine Cultivator	4.51	2.88	1.63

Disk plough recorded the maximum field efficiency of 83.75 % followed by mouldboard plough 78.75 %. Average effective field capacity of mouldboard plough and disk plough were 0.168 ha/h and 0.16 ha/h respectively (Table 3 &4).

Fuel consumption: Among the implements tested, the spring tine cultivator recorded the lowest fuel consumption of 18.13 L/ha (4.01 L/h), followed by disk plough 24.79 L/ha (3.95 L/h) and mouldboard plough 26.87 L/ha (4.48 L/h) (Table 3, 4 & 5). Ploughing with mouldboard plough requires much tractive effort, it handles a large volume of soil per unit time and self weight of mouldboard plough is heavy and these may be the reasons for highest fuel consumption.

Field time, productive time and delay time: Total field time is the sum of productive time (effective time) and delay time that may encountered during operation. The average field time, productive time and delay time per hectare for the tillage implements are presented in Table (6). From the experiment it is found that the spring tine cultivator recorded the highest delay time of 1.63 h/ha whereas the disk plough recorded a minimum of 1.16 h/ha followed by mouldboard plough 1.28h/ha. Higher delay time in case of spring tine cultivator may be due to its wider operating width which increases time spent in turning at headlands and time spent in clearing the tines from clogging with thrash and weeds. With wider equipment, turns at headlands are longer with raised implements not in use and headland areas are often larger.

Conclusion

The field trials for performance evaluation of the tractor drawn tillage implements namely two bottom mouldboard (60 cm), two bottom disk plough (70 cm) and seven tines spring loaded cultivator (165 cm) were carried out in the Research and Experimental Field, Agricultural Engineering Dept. NERIST Nirjuli (Arunachal Pradesh). The spring tine cultivator recorded the highest effective field capacity, lowest fuel consumption and minimum power requirement whereas the mouldboard plough recorded the highest draft force and fuel consumption while the disk plough recorded the highest field efficiency and lowest delay time.

REFERENCES

Al-Janobi AA, Al- Suhaibani SA. 1998. Draft of primary tillage implements in sandy loam soil. *Appl Eng Agric* 14 (4): 343-348.

Larson, D.L. and H.E. Clyma, 1995. Electro-osmosis effectiveness in reducing tillage draft force and energy forces. Transactions of ASAE, 38: 1281-1288.

Grisso RD, Yasin M, Kocher MF. 1996. Tillage implements forces operating in silty clay loam. Trans ASAE 39(6): 1977-1982.

O. Oduma, J.E. Igwe, D.I. Ntunde, 2015.Performance Evaluation of Field Efficiencies of Some Tractor Drawn Implements in Ebonyi State. IJET (5) 199-203.

Upadhyaya, S.K., Williams, T.H, Kemble, L.J and Collins N.E.1984. Energy Requirement for Chiseling in Coastal Plain Soils. Transactions of the ASAE, 27(6).1643-1649.7:2.

Whitney, B. 1988. Choosing and using farm machines. Longman Publishers (Plc) Ltd Singapore.

Yohanna J.K and Ifem, J.L.C. 2000. Performance evaluation of field efficiencies of farm Machinery in Nasarawa and Plateau States. Pp. 88-92

Sale, N.A, Gwarzo, M.A., Felix O.G and Idris S.I. 2013. Performance evaluation of some selected tillage implements. Proceeding of NIAE Vol 34. Pp 71.77.

Jadhav, R.T., Rupnawar, H.D., Suryvanshi, B.B., and Patil A.P. 2013. Development of indigenous plough for ridging and inter cultural operations for sugarcane crop. ETI Vol. 4: 1-6

Majdaldin Rahamtallah Abualgasim and Mohamed Hassen Dahab 2013. The Study of suitable effective use of machinery in farming research station (Elrawakeeb) –west of Khartoum - Sudan. *Res. J. Agric. Environ. Manage*. Vol. 2(7), pp. 164-168.

Saeed Ranjbarian, Mohammad Askari and Javad Jannatkhah 2015. Performance of tractor and tillage implements in clay soil. *Journal of the Saudi Society of Agricultural Sciences*.

****