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Comparative performance evaluation of spade plough: A case study

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Abstract
Tillage implements are agricultural tools and machines used for soil preparation and cultivation. These implements are designed to perform various tasks to create an ideal seedbed, improve soil structure and facilitate the growth of crops. Different types of tillage implements are used based on the specific soil conditions and the requirements of the crop being grown. This study aims to compare the performance of different deep plough (Spade plough, cultivator, chisel plough, MB plough) for tillage operation. The experiment was conducted at Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (C.G.) 2022-23. In this experiment different ploughing implement was used ie. cultivator (T_1), chisel plough (T_2), spade plough (T_3) and MB plough (T_4) laid-out in strip plot design with four treatments and four replications. The performance parameters on the basis of its field capacity, field efficiency, weed index, soil pulverization, material capacity, its cost economics were analyzed. The mean working capacity of the machines were observed to be 0.54, 1.12, 0.45, 0.203 ha/h with field efficiency of 85.46%, 80.38%, 75.54/5 and 76.54% were obtained respectively. The operational cost of spade plough, cultivator, chisel plough and MB plough were found to be Rs. 788.66, 797.49, 844.33 and 906.69 per hour respectively. The total cost of operation of a spade plough, cultivator, chisel plough and MB plough were observed 924.28 Rs/ha. 808.34 Rs/h872.74 Rs/h and 937.69 Rs/h respectively.

Keywords: Spade plough, depreciation, cost economy, MB plough, field capacity

1. Introduction

Soil Tillage is usually defined as the mechanical manipulation of the soil aimed at improving soil conditions for crop production. It is a process to modify soil properties by- Pulverization, cutting, inversion or movement of the soil resulting in improved soil conditions for optimal crop growth and yield (Grisso *et al*. (1982) [11]. Tillage implements are agricultural tools used for soil preparation and cultivation, aiming to create ideal seedbeds, improve soil structure, and facilitate crop growth. Deep tillage impacts soil properties, including compaction and nutrient availability. Soil compaction is caused by mechanization, intensive agriculture and continuous use of farm machinery. It affects soil physical properties, plant growth, root growth, and crop yield. Conservation farming is necessary to lessen stress on the soil and chiseling to remove hardpan.

Farm mechanization in Chhattisgarh is increasing due to time savings, labor costs, and increased crop yields. Heavy machines like tractors, combine harvesters, reapers, paddy threshers, cultivators, and mould board ploughs are used to increase crop productivity. However, heavy farm work can compact soil, affecting physical parameters like bulk density, moisture content, cone index, water storage, soil penetration resistance, and infiltration rate.

Mechanized ploughing with tractors offers advantages over manual or animal-driven ploughing, enabling faster and more productive land preparation, increased yields, and uniform seedbeds. Modern technology contributes to sustainable farming practices and resource optimization, leading to improved efficiency, better crop yields, and sustainable agricultural practices.

2. Material and methods

2.1. Location

During the year 2022-23, the performance of tractor operated spade plough was evaluated in Swami Vivekananda college of Agricultural engineering, Indira Gandhi Krishi Vishwavidyalaya Raipur.

2.2. Lay-out of experimental plots

The experiment was conducted with 4 treatments and 4 replications at IGKV Raipur. The details of experiment are shown in Table 1.

Table 1: Layout of experiment

Details	Particulars
Design	Strip-plot design
Experimental plot size	60m×20m
Treatment	4
T_1	Cultivator
T_2	Chisel plough
T_3	Spade plough
T_4	MB plough
Replication	(R_1, R_2, R_3, R_4)
Total no. of experiments	4×4

The performance parameters studied were field capacity, theoretical field capacity, soil bulk density, soil pulverization, soil cone index, soil inversion, wheel slip, and fuel consumption.

2.3. Effective field capacity

It was defined as the actual area covered by the implement, based on its time consumed and its width. The effective field capacity was calculated by dividing the area covered by the hour of actual time.

$$EFC = \frac{A}{T}$$

Where,
EFC = Effective field capacity of the machine, ha/h.
A = Area covered, ha.
T = Time taken to cover area, h.

2.4. Field efficiency

From the actual and theoretical field capacity, the field efficiency was calculated by following formula (Bainer, *et al.* 1987),

$$\text{Fieldefficiency}(\%) = \frac{EFC}{TFC} \times 100$$

Where
FE=Field efficiency.
AFC=Actual field capacity (ha/h); and
TFC=Theoretical field capacity (ha/h).

2.5. Soil bulk density

Soil bulk density was calculated by before and after tillage treatments using core cutter drawn randomly from the individual test plots.
The wet bulk density is calculated using the following formula.

$$Y_{wet} = \frac{W_2 - W_1}{V}$$

Where,
Y_{wet} = Bulk density, (kg/m^3)
W1 = Empty weight of core cutter, (kg)
W2 = Weight of core cutter + soil,
V = volume of core cutter, (($\pi d^2/4$)×H), m^3
d = Inner diameter of core cutter, m and
H = Height of core cutter, m.

2.6. Soil pulverization

The degree of soil pulverization was measured by determining the MMD by using sieve analysis technique.
The soil mass retained on each sieve was weighed and was calculated

$$MMD = \frac{\sum W_i - D_i}{W_t}$$

Where,
Di= Average diameter of i& (i+1)th sieve and Di<Di+1,mm
Wi= Mass of soil retained on the ith sieve, g
Wt = Total mass of soil sample, g; and
i = Number of sieve.

2.7. Cone index of soil

Soil cone index was determined to measure penetration resistance of the soil before and after applying various treatments at field. Cone penetrometer was calibrated with known weights and the relationship between applied load and dial gauge deflection was determined by following.

CPR = 0.648+0.025X, kg/cm^2

Where,
X = dial gauge deflection, small divisions
To determine cone index, a cone penetrometer (Model BL, 250 EC, Baker Mercer type C10, LC=0.002 mm) having 2.618 mm diameter of cone base with cone angle of 20 was used.

2.8. Soil inversion

As per IS test code a square ring (1m×1m) was placed in the field before ploughing. The numbers of weeds and stables enclosed with in the ring were counted. The above process after ploughing the field was recorded and calculation of soil inversion was as follows:

Soil inversion

$$= \frac{W_A - W_B}{W_A} \times 100$$

Where,
W_A =No. of weeds after ploughing; and
W_B=No. of weeds before ploughing.

2.9. Wheel slip

Slip is the measure of relative motion between the device and soil. The distance covered by the wheel for the N number of revolutions on no load and on load was measured. The wheel slip was calculated as.

Wheel slip

$$(\%) = \frac{L_0 - L_1}{L_0} \times 100$$

Where,
L_0 = Length on no load, m; and
L1=Length on load, (m).

2.10. Fuel consumption
Fuel consumption (FC) was calculated using the top-up method. Before the operation, the fuel tank was fully charged. After an hour of work, it was back to full capacity. A measuring cylinder was used to determine the amount of fuel noted.

$$FC\left(\frac{lit}{ha}\right) = \frac{\text{Consumption of fuel}\left(\frac{lit}{h}\right)}{\text{covered area}\left(\frac{ha}{h}\right)}$$

2.11. Cost economics
Cost economics was performed in order to estimate the cost of various operations. The cost economic was categorized as fixed cost and operating cost. Cost of operation of spade plough, cultivator, chisel plough, MB plough were calculated on the basis of the prevailing market price labour charges, repair and maintenance and fuel charges.

3 Results and Discussions
The results obtained from the experiment carried out on the effects of the forward speed on the performance of different plough are shown in Tables 2.

3.1. Effect of forward speed on effective field capacity
The minimum mean effective field capacity of 0.126 ha/h was recorded in the case of treatment T_4 (MB plough), while maximum mean value of 0.786 ha/h was recorded in T_2 (Chisel plough).

3.2. Effect of forward speed on field efficiency
The minimum mean field efficiency of 75.54% was recorded in the case of treatment T_3 (Spade plough), while maximum mean value of 85.46% was recorded in T_1 (cultivator). The field efficiency of spade plough was found lower then other plough.

3.3. Effect of forward speed on bulk density
The effect of forward speed on soil bulk density was significant at 5% level of significance. Bulk density decreases with increase in forward speed (S) of plough. The minimum mean bulk density of 1.48 g/cm^3 was recorded in the case of treatment T_3 (spade plough), and maximum mean bulk density was recorded in T_1(cultivator). The graphical representation of the effect of speed of operation on bulk density shown in Fig.2.

3.4. Effect of forward speed on soil pulverization
The effect of forward speed on soil pulverization was studied. The minimum mean soil pulverization of 10.92 mm was recorded in the case of treatment T_2 (Chisel plough), while maximum mean value of 12.15 mm was recorded in T_3 (spade plough). The Fig.3 clearly shows that mean soil pulverization of various selected individual tillage implements tested in the field varied from 10.52 mm to 13.34 mm and increased with increase in tractor forward speed, whereas soil pulverization decreased with increase in implement working depth.

3.5. Effect of forward speed on cone index
The minimum mean cone index of 652.38 kPa was recorded in the case of treatment T_3 (Spade plough), while maximum mean value of 670.35 was recorded in T_1 (cultivator).This may be attributed to the fact with increased forward speed (S), bite length increased with resulted in bigger sized clods of ploughed soil after tillage, this led to increase of resistance to penetration into the soil. A lower cone index value indicates less soil compaction and better soil structure, which is favorable for root growth and water infiltration. Proper adjustments in forward speed and plough selection can help to reduce soil compaction, enhance root penetration, and improve overall agricultural productivity.

3.6. Effect of forward speed on Soil inversion
The minimum mean soil inversion of 50.90% was recorded in the case of treatment T_1 (cultivator), while maximum mean value of 73.35% was recorded in T_4 (MB plough). Higher forward speeds may lead to more effective soil inversion, as the plough covers more ground and turns over the soil more efficiently. Certain plough types may have better features or cutting mechanisms that result in more effective soil inversion.

3.7. Effect of forward speed on wheel slip
The minimum mean wheel slip of 6.41% was recorded in the case of treatment T_3 (Spade plough), while maximum mean value of 17% was recorded in T_4 (MB plough). The wheel slip of tractor is mainly associated with the depth and width of implement.

3.8. Effect of forward speed on fuel consumption
The minimum mean fuel consumption of 4.02 l/h was recorded in the case of treatment T_3 (spade plough), while maximum mean value of 5.64 l/h was recorded in T_4 (MB plough). The spade plough consume less fuel as compare to other plough.

Table 2: Comparison of field parameters for different treatments (Plough)

S. No.	Parameters	T_1 (Cultivator)	T_2 (Chisel plough)	T_3 (Spade plough)	T_4 (MB plough)
1	Depth of operation, mm	150	250	250-300	160
2	Width of operation, mm	2200	450	1800	830
3	Speed of operation, km/h	5.5	3.4	2.26	3.6
4	Bulk density, g/cm^3	1.52	1.50	1.48	1.51
5	Soil pulverization, mm	11.47	10.92	12.15	11.12
6	Soil inversion, %	50.90	56.56	70.39	73.35
7	Cone index, kPa	670.35	661.67	652.38	654.13
8	Field efficiency, %	85.46	80.38	75.54	76.54
9	Wheel sleep, %	11.22	12.18	6.41	17.00
10	Fuel consumption, l/h	4.44	5.11	4.02	5.64

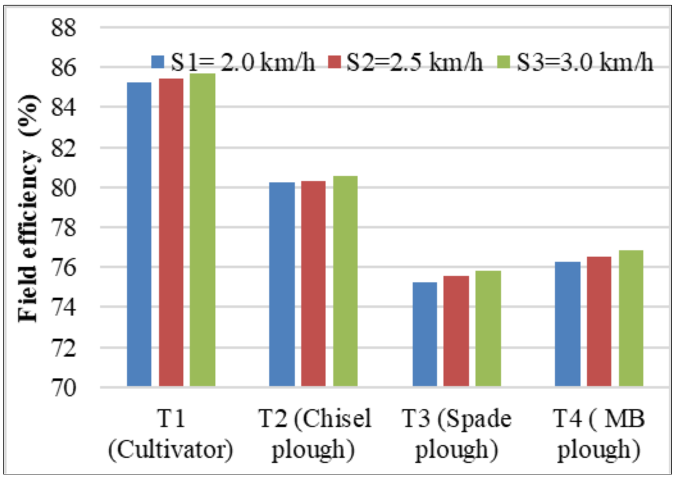

Fig 1: Effect on forward speed on field efficiency

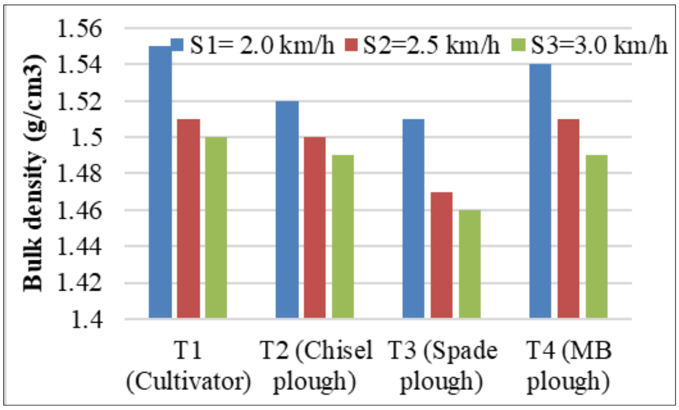

Fig 2: Effect on forward speed on bulk density

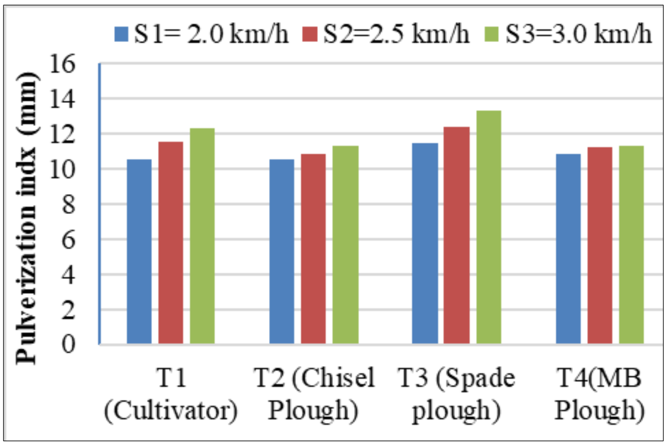

Fig 3: Effect on forward speed on pulverization index

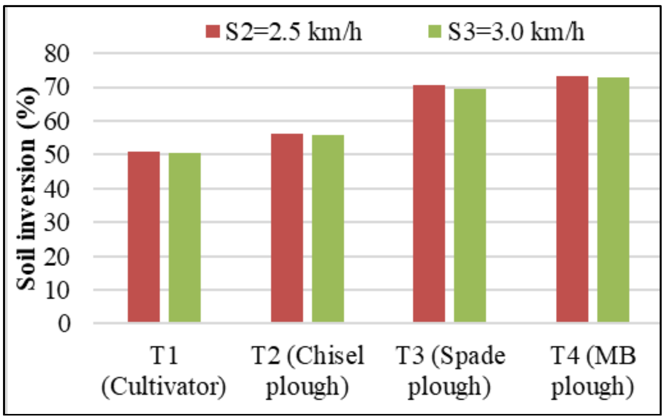

Fig 4: Effect on forward speed on soil inversion

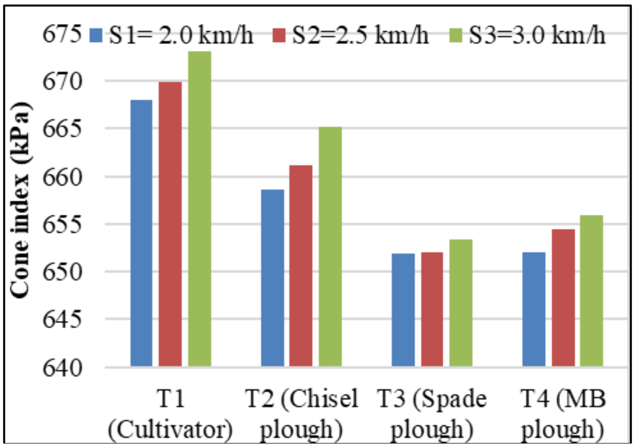

Fig 5: Effect on forward speed on cone index

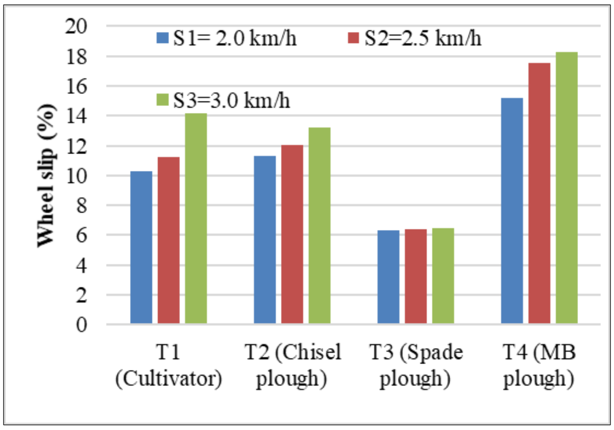

Fig 6: Effect on forward speed on wheel slip

Fig 7: Spade plough under field condition

3.9. Cost of operation

The cost of operation of developed tractor operated spade plough was calculated. The depreciation cost of spade plough was calculated by straight line method. The operational cost of spade plough, cultivator, chisel plough and MB plough with tractor was calculated by assumption according to present economic condition. The detail cost of operation of each machines are depicted in the Table 3.

Table 3: Comparative cost analysis of different plough

S. No.	Particulars	Various associated cost of the tractor along with implements				
		Tractor	Cultivator	Chisel plough	Spade plough	MB Plough
Fixed cost Rs./h						
1	Cost of machine, Rs.	650000.00	42000.00	55000.00	350000.00	60000.00
2	Life of the machine (year)	10.00	10.00	10.00	10.00	10.00
3	Annual use (Working hour per year)	1000.00	600.00	300.00	400.00	300.00
4	Salvage value, @10%	65000.00	4200.00	5500.00	35000.00	6000.00
5	Depreciation, Rs./ h	58.50	6.30	16.50	78.75	18.00
6	Interest investment @10% per annum	35.75	3.85	10.08	48.13	11.00
7	Housing cost @1% of cost of machine	6.50	0.70	1.83	8.75	2.00
Total (4 to 7) Total Fixed cost Rs./h		100.75	10.85	28.42	135.63	31.00
Operating cost Rs./h						
1	Repair and maintenance cost @ 10% of initial cost, Rs./h	65.00	7.00	18.33	87.50	20.00
2	Wage of 1 operator (300 Rs./ 8 h)	37.50	37.50	37.50	37.50	37.50
3	fuel cost (95.44 Rs/h)	429.48	458.11	487.70	383.67	538.28
4	Lubrication	85.896	91.62	97.54	76.73	107.66
5	Hiring charges of tractor without fuel and lubrication cost	-	203.25	203.25	203.25	203.25
Total (1 to 5)	Operational cost, Rs./h	617.88	797.49	844.33	788.66	906.69
(A+B)	Total cost of operation, (Rs./h)	718.63	808.34	872.74	924.28	937.69

4. Conclusion

As per the objectives of the present study and result obtained, following conclusion could be drawn.

- The average bulk density, soil inversion, cone index, pulverization index, wheel slip, fuel consumption of spade plough were found 1.48 g/cm 70.39%, 652.38 kPa 12.15 mm, 6.41%, 4.02 l/h respectively. The spade plough shows a negative slip while operating at various depth of cut and operating speed. The average field efficiency of tractor operated spade plough was found 75.54%.
- The cost of operation of a spade plough was observed to the 450.12 Rs/ha. The cost of operation of cultivator, chisel plough, and MB plough 808.34Rs/h and 872.74 Rs/h, 937.69 Rs/ha respectively. The Breakeven point of spade plough was 141.98h. The payback period of spade plough was 3.24 year.

5. Conflict of Interest

The authors have not affirmed any conflict of interest.

6. Reference

1. Ahmed R. Performance Evaluation of Draught Animal Power Cultivator. Asian Journal of Applied Science and Engineering. 2014;3(8):111-117.
2. Anonymous. Indian Standard Guide for Estimating Cost of Farm Machinery Operation. Indian Standard Institution, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002. 1979;9164:1-12.
3. Dhiman M. Performance evaluation of tractor operated spading machines. Un-published M.tech. (Ag) thesis, Punjab Agricultural University, Ludhiana; c2016. p. 20-54.
4. Dogra R, Dogra B, Gupta PK, Sharma BD, Kumar A. Effect of spade angle and spading frequency of spading machine on specific soil resistance and pulverization. Agricultural Engineering International: CIGR Journal. 2017;19:65-73.
5. Vaiieln I. An experimental study of the mortality factors of larval Muscoautumnalis De Geer. Ecol. Monogr. 1969;39:199-225.
6. Geethu M, Meera T, Nair S. Performance evaluation of tractor operated spading machine. Unpublished PhD Thesis, KAU, Tavanur Kerala, India; c2018, 1-66.
7. Kathirvel K, Manohar Jesudas D, Selvakumar D. Development and evaluation of tractor operated rotary spading machine. AMA-Agricultural Mechanization in Asia Africa and Latin America. 2011;42(2):28-32.
8. Pezzi F. Traditional and new deep soil tillage techniques in Italy Trans ASAE. 2005;48(1):13-17.
9. Maheshwari TK, Thakur TC, Varshney BP. Comparative performance of spiked clod crusher and planker as combination tillage tools with tractor drawn cultivator under different soil conditions. New Agriculturist. 2004;15(1/2):13-17.
10. Stoyanov Y. Theoretical study of a spading machine with a horizontal arm. In AIP Conference Proceedings, AIP Publishing LLC. 2022;2449(1):0500111-0500117.
11. Grisso T, Sales BD, Bayless S. Law-related courses and programs in graduate psychology departments. American psychologist. 1982 Mar;37(3):267.