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Original Research

An Analytical Study on Evaluating the Performance of Developed Cultivator Mounted Seed Metering Mechanism

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Abstract

Prototype cultivator-cum-seed drill was designed, fabricated and tested for sowing of paddy. The machine consisted of cultivator frame, tines, seed box, seed tubes, metering mechanism, power transmission unit, furrow opener and hitching attachments. The selection of materials and fabrication was done following the standard manufacturing process. The cultivator-cum-seed drill with shovel type furrow openers was tested for sowing of the paddy. The performance of the machine was evaluated considering the effect of field capacity, field efficiency, energy requirement and cost of operation in relation with conventional seed drill in the laboratory as well as in the field. The seed rate of cultivator-cum-seed drill was found to be 80.87 kg/ha and that of conventional seed drill was found to be 80.26 kg/ha.when seed drill was half filled and flute exposure was 14.9 mm & 13.8 mm. The standard deviation for inter row variation for sowing paddy with cultivator-cum-seed drill was 0.46 with CV of 1.8 % and that for conventional seed drill was 0.41 and 1.5 % respectively.The effective field capacity of the cultivator-cum seed drill was 0.537 ha/h with field efficiency of 82.8 % as compared to conventional seed drill which was 0.596 ha/h and 82.32 %. The cost of operation for cultivator-cum-seed drill was 591.08 Rs/ha and that for conventional seed drill was 535.016 Rs/ha. The Energy requirement for cultivator-cum-seed drill was found to be 454.18 MJ/ha and that for conventional seed drill was found to be 416 MJ/ha.

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INTRODUCTION

The drill + blade harrow was evaluated with the performance of a traditional method of sowing and applying fertilizer (behind plough). The drill + blade harrow saved 46.7 man-h/ha, 53.3 bullock-h/ha, while sowing ground nut seed and applying fertilizer aver traditional methods (Kaleemullah, 1997). The no-till seed drill has resulted in a 17.09 % increase in yield, 83.22 % saving in energy and 80.34 % saving in cost of production. There was no appreciable effect of no-tillage system on bulk density and shear strength of the soil below ploughing depth. The overall benefit was Rs 2140.33 per ha (Dixit, 2004).

Dubey (1985) found that shoe type furrow opener was found most suitable, both under dry and wet soil condition without mush disturbance of soil. To overcome the problem of clogging, the bottom of opener is closed and delivery of seed and fertilizer is from back side. It was observed that in rough, cloddy and trashy conditions 150 mm shoe length and above were better.

Orifice velocity was a critical factor in picking up one seed at a time, in one of the better test. The nozzles delivering speeds at rates from 1½ to 6 seeds per sec, had one seed attached 80 % of the time and two seeds attached 20 % of the time (Short, 1970). Cone angle of 90º developed the highest retaining force. Two mathematical models were derived for the prediction of pressure distribution and forces on the ball. Model derived from stagnation point flow and boundary layer theory accurately predicted the pressure and forces on the ball for the 1.59 mm orifice over the range of cone ball clearance yielding high retaining forces (Shafaii, 1990).

MATERIALS AND METHODS

Laboratory test

Following test were carried out during laboratory testing.

1) Calibration of cultivator-cum-seed drill.
2) Effect of quantity of seed in hopper.
3) Mechanical damage to seed by metering mechanism.

Calibration of cultivator-cum seed drill

It was calibrated in the laboratory for metering desired quantity of seed

i. The nominal width (w) of machine was calculated as follows,

$$W = M \times S$$

Where, M = Number of furrow openers; S = The spacing between the openers (m) and W = Width (m)

ii. The circumference of the ground driving wheel was measured,

$$C = \pi \times D$$

Where, D = Diameter of ground wheel (m) and C = Circumference of driving wheel (m).

iii. Area covered in one revolution of wheel was calculated, $A = \pi \times D \times W$

iv. The calibration was done for 20 revolution of the ground wheel. Therefore the area covered in 20 revolutions of wheel was calculated from the area covered in one revolution multiplied by 20 (No. of revolution).

v. Ground wheel drive was made free to rotate by jacking up the drill. One mark was puton the drive wheel and another mark on the body of the drill so that the revolution was counted correctly

vi. Hopper was filled with the seed in respective chamber of the hopper. Polythene bags were tied at the open end of the seed delivery tube.

vii. The rate control adjustment for the seed was set for maximum drilling.

viii. The drive wheel was rotated for 20 revolutions and the seed collected in the bags were weighed.

ix. The seed rate was calculated by the following formula,
Seed rate (kg/ha) = weight of seed collected/ area covered.

Above procedure was repeated by adjusting suitably the rate control till required seed rate ofseed was obtained.

Effect of Quantity of Seed in Hopper

Seed box was completely filled by seed and the seed rate was checked. The process was repeated by filling the hopper for full, ¾, ½, and ¼ capacity and the corresponding seed rates were measured

Mechanical Damage to the Seed by Metering Mechanism

During calibration, seeds were collected from below the furrow openers and visually broken seeds were counted. The broken seeds were weighed and percentages of damaged seeds were determined.

$$\text{Broken Seeds (\%)} = \frac{\text{Weight of broken seeds}}{\text{Weight of total seeds collected}} * 100$$

Field Test

The field performance was conducted in order to obtain actual data for overall machine performance, operating accuracy, work capacity, and field efficiency. The conventional seed-drill in operation is shown in Figure1.

Figure 1: Conventional seed-drill

The prototype cultivator-cum-seed drill was field tested for its mechanical performance in 0.21 ha at Faculty of Agricultural Engineering, IGKVV, Raipur. Following observations were recorded during the field tests.

1. Moisture content of the soil
2. Bulk density of the soil
3. Time lost in turning at head land, adjustment and refilling the hopper.
4. Depth of placement of the seed.
5. Effective width of coverage.
6. Total time of sowing operation.
7. Uniformity of seed placement.

Moisture Content

Moisture content (%) on dry basis of soil was measured by oven drying method. The soil samples from different locations within a plot were taken using core sampler 37 mm in diameter and 125 mm in length and a soil auger. The collected soil sample from each location were weighed initially and then kept in an oven for 24 hours at 105 ^{0}C for obtaining dry weight of soil and moisture content was calculated as follows:

$$\frac{w_1 - w_2}{w_2} * 100$$

Where, MCd = Moisture content of soil on dry weight basis; W1= Weight of wet soil and W2= Weight of dry soil

Bulk Density

Bulk density of the soil is the oven dry mass per unit volume of the soil. It was measured by using core sampler having 37 mm diameter and 60 mm length by taking different soil samples from different locations of the field. The bulk density was calculated by using formula:

$$\delta = \frac{M}{V}$$

Where,

δ = bulk density of soil, g/cm^3

M = oven dry mass of soil, g

V = Volume of core sampler, cm^3

Speed of Operation

To calculate the speed of operation two poles 20 m apart were placed approximately in the middle of test run. The speed was calculated from the time required for the machine to travel the distance of 20 m.

Measurement of Time Lost in Turning

In the plot of 70330 m the cultivator-cum-seed drill was operated length wise from one end to other. Time required to travel and turning at headland was measured. The time loss in h/ha was also calculated.

Depth and Width of Operation

The depth of sowing was measured at different locations with the help of scale and average was taken, for measurement of actual width of operation of the machine the width covered in three passes of the machine was measured with tape and actual width of operation was calculated.

Measurement of Wheel Slip

To calculate the wheel slip the tractor was operated at implement with load and without load condition. A mark on tractor drive wheel with colored tapes and the distance the tractor moves forward is measured , 10 revolutions under no load (A) and on the same surface and with the same number of revolutions with load (B), wheel slip was calculated as follows:

$$\text{Wheel Slip (\%)} = \frac{A - B}{A} * 100$$

Where, A =No. of revolutions of drive wheel for a given distance under no load and B= No. of revolutions of drive wheel for the same distance at load.

Seed Emergence

Number of plants emerged were counted in one meter of row in one run at the stage when almost all the plants were growing up to three leaves. Different sampling areas should be randomly selected in a test plot.

Plant Population Achieved

An area of 1 sq. m was selected and the numbers of plants in that area were counted for each crop. The plants were counted in different places for 1 sq. m and the average value was taken.

Field Capacity and Field Efficiency of the Machine

Theoretical field capacity and effective field capacity were determined on the basis of area covered per unit time.

Theoretical field capacity

On the basis of width of furrow and speed, theoretical field capacity was calculated by following formula,

$$\text{Theoretical field capacity} \left(\frac{ha}{h}\right) = \frac{W * S}{10}$$

Where, S = Speed of operation, km/h; W = Theoretical width covered and m = Number of furrow openers multiplied by distance between the furrow opener, m.

Effective Field Capacity

The seed drill was continuously operated in the field for 0.21 ha to assess its actual coverage. The time required for complete sowing was recorded and Effective field capacity was calculated.

$$\text{Effective field capacity} = \frac{A}{T}$$

Where, A = Actual area covered, (in ha.) and T = Total time required to cover the area, (in hrs.)

Field Efficiency

$$\text{Field efficiency } (\eta) = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} * 100$$

Cost of Operation

The cost of operation of machine was calculated on the basis of the time and the number of operations required for sowing of the seed.

Energy Requirement

The operational energy requirement for cultivator-cum-seed drill was calculated on the basis of fuel, labour and time required for the sowing and other related operations.

RESULTS AND DISCUSSIONS

Specifications of the tractor drawn cultivator-cum-seed drill (Figure 2) are as follows,

Length, mm	: 2160 mm
Width, mm	: 2100 mm
Height, mm	: 1750 mm
Row spacing, mm	: 230 mm
Furrow opener	: Shovel type

Moisture Content and Bulk Density of Soil

Moisture content on dry basis of soil was measured by oven dry method five soil samples were taken randomly at 5.6, 5.8, 6.2, 6.6 and 6.8 cm depth from surface of soil using core sampler of 5.6 cm diameter and 8.6 cm height.

Moisture content at 5.6, 5.8, 6.2, 6.6 and 6.8 cm depth was found to be 16.44, 16.49, 16.44, 15.70, and 16.57on dry basis respectively. Bulk density of soil was measured by core sampler. Bulk density of soil (before operation) was found to be 1.18, 1.03, 1.15 1.19, and 1.19 g/cm^3 at the respective depth. And after operation was found to be 0.868, 0.856, 0.829, 0.918, 0.938 g/cm^3 at respective depth (Table 1).

Speed of Operation

The speed of operation was calculated from the time required by the machine to travel the distance of 20 m. the average speed of operation was found to be 4.5 km/h (Table 2).

Time Lost in Turning

The average time loss during turning at head land was 11.76 S. the average time loss in h/ha found to be 0.22 (Table 3).

Figure 2: Field performance test for prototype cultivator

Table 1: Moisture content and bulk density

No	Depth , cm	Moisture content % (db)	Bulk density g/cm^3 (Before operation)	Bulk density g/cm^3 (After operation)
1	5.6	16.44	1.18	0.868
2	5.8	16.49	1.03	0.856
3	6.2	16.44	1.15	0.829
4	6.6	15.70	1.19	0.918
5	6.8	16.57	1.19	0.938

Table 2: Data pertaining to the field test of cultivator

S N	Distance (in m)	Time (in sec)	Speed (in m/sec)
1	20	15.19	1.316
2	20	15.16	1.319
3	20	15.25	1.311
4	20	17.00	1.176
5	20	16.50	1.212
Average	**20**	**15.82**	**1.266**

Table 3: Time lost in turning at head land

No	Time lost in one turn (s)	Area covered in one turn (m^2)	Average time loss (h/ha)
1	11.5		
2	11.7		
3	11.6	2.10370 =147	0.22
4	12.0		
5	12.0		

Wheel Slippage

The average wheel slippage for cultivator was found to be 14.4 (Table 4).

Depth of Operation

The average depth of operation was found to be 129.2 mm (Table 5).

Soil Inversion

The soil inversion was observed to judge the quality of work with the developed tillage implement. It was observed by counting number of inverted weeds before and after operation.

Table 6 shows that soil inversion increased from 75.83 to 77.20 % with increase in depth from 8.2 to 12.5 cm respectively. The average weed efficiency was found to be 76.42 %. The data showed that the effective field capacity of the cultivator was 0.826 ha/h with field efficiency 87.40 %. The average depth of operation was 129.2 mm .The cost of operation was 434.43 Rs/ha and energy requirement was 51.04 MJ/ha.

Laboratory Test

Calibration

The Tractor drawn prototype cultivator-cum-seed drill was calibrated in the laboratory for desired seed rate by adjusting the exposed length of the flutes.

For paddy seeds, the highest seed rate 124.14 kg/ha was found with 18.6 mm exposed flute length and one fourth filled. Whereas minimum seed rate 49.07 kg/ha was with 11.2 mm exposure of flute and hopper completely filled. The seed rate close to recommended seed rate was found 80.87 kg/ha when seed drill was three fourth filled and flute exposure was 10 mm. It is also revealed that, for all the capacities of hopper one fourth, half, three fourth and full with 14.9 mm flute exposure the seed rate was close to the recommended seed rate. The observed seed rates for 14.9 mm flute exposure were 77.45 kg/ha, 78.44

kg/ha, 80.87 kg/ha, and 86.87 kg/ha for full, three fourth, half, and one fourth hopper capacity (Table 8)

Mechanical Damage to Seed by Metering Mechanism

Visual observations for mechanical damage due to metering mechanism were recorded broken seeds were separated and weighed. The results are shown in table 9.

Seed collected in 10 revolutions
Area covered in 10 revolutions, sq.m = 29.18

The average mechanical damage of seeds due to metering was 1.8 % for rice. This value was within the permissible limit.

Table 4: Tractor wheel slippage for cultivator

No	Expected dist covered by tractor wheel at no load (cm)	Observed dist covered by tractor wheel at load (cm)	Wheel slip (%)	Average (%)
1	3832	3295.5	14	
2	3832	3372.1	12	
3	3832	3295.2	14	14.4
4	3832	3218.8	16	
5	3832	3218.8	16	

Table 5: Depth of operation with cultivator

No	Depth of operation , mm	Average depth, mm
1	105	
2	110	
3	124	129.2
4	145	
5	162	

Table 6: Soil inversion with cultivator

No	Depth (cm)	No of weeds before operation per unit area	No of weeds after operation per unit area	Soil inversion (%)	Average (%)
1	8.2	240	58	75.83	
2	8.6	230	55	76.08	
3	10.5	218	52	76.14	76.42
4	12.2	242	56	76.85	
5	12.5	215	49	77.20	

Table 7: Field Capacity, Field Efficiency, Cost of Operation and Energy Requirement of cultivator

1	Actual operating time, min	15.28
2	Time lost owing to	
	I) Turning, sec.	58
	II) Adjustment, min	1.12
3	Actual area covered, ha	0.21
4	Effective working width, m	2.10
5	Traveling speed, km/h	4.5
6	Theoretical field capacity, ha/h	0.945
7	Effective field capacity, ha/h	0.826
8	Field efficiency, %	87.40
9	Wheel slip of tractor %	14.4
10	Fuel consumption, lit/ha	4.08
11	Weeding efficiency, %	76.42
12	Cost of operation, Rs/ha	434.43
13	Energy requirement, MJ/ha	51.04

Table 8: Calibration of tractor drawn cultivator cum seed drill for exposed length and hopper capacity

No	Crop	Exposed length (mm)	Seed rate, kg/ha for different hopper capacity			
		11.2	**49.07**	55.41	64.94	67.99
1	paddy	14.9	77.45	78.44	**80.87**	86.87
		18.6	102.50	107.74	117.54	**124.09**

Table 9: Mechanical damage to seeds

No	Crop	Weight of broken seeds, (g)	Total weight of sample (g)	Broken seeds (%)	Average mechanical damage % of seeds	σ	cv
1	Paddy	3.9	226	1.72	1.8	0.099	5.5
		4.0	228.9	1.74			
		4.6	236	1.94			

Moisture Content and Bulk Density of Soil

Moisture content on dry basis of soil was measured by oven dry method five soil samples were taken randomly at 5.2, 5.6, 6, 6.2 and 6.8 cm depth from surface of soil using core sampler of 5.6 cm diameter and 8.6 cm height.

Moisture content at 5.2, 5.6, 6.0, 6.2 and 6.8 cm depth was found to be 14.43, 14.72, 14.01, 15.45, and 14.32 on dry basis respectively.Bulk density of soil was measured by core sampler. Bulk density of soil was found to be 1.20, 1.19, 1.20, 1.20, and 1.19 g/cm^3 at the respective depth (Table 10).

Speed of Operation

The speed of operation was calculated from the time required by the machine to travel the distance of 20 m. the average speed of operation was found to be 3.09 km/h (Table 11).

Wheel Slippage

The average wheel slippage for cultivator-cum-seed drill was found to be 8.8 % (Table 12).

Table 10: Moisture Content and Bulk Density of Soil at respective depth

No	Depth (cm)	Moisture content % (db)	Bulk density (g/cm^3)
1	5.2	14.43	1.20
2	5.6	14.72	1.19
3	6.0	14.01	1.20
4	6.2	15.45	1.20
5	6.8	14.32	1.19

Table 11: Data pertaining to the field test of cultivator-cum-seed drill

No	Distance (m)	Time (s)	Speed (m/s)
1	20	23.0	0.869
2	20	23.10	0.865
3	20	23.16	0.863
4	20	23.50	0.851
5	20	23.40	0.854
Average	**20**	**23.23**	**0.860**

Table 12: Tractor wheel slippage for cultivator-cum-seed drill

No	Expected dist covered by tractor wheel at no load (cm)	Observed dist covered by tractor wheel at load (cm)	Wheel slip (%)	Average (%)
1	3832	3448.8	10	
2	3832	3487.12	9	
3	3832	3448.8	10	8.8
4	3832	3563.7	7	
5	3832	3525.4	8	

CONCLUSIONS

The average mechanical damage to seed by cultivator-cum-seed drill was found to be 1.8 % with standard deviation of 0.099, with CV of 5.5 % and that of conventional seed drill was 1.95, 0.109 and 5.6 %.The effective field capacity of the cultivator-cum seed drill was 0.537 ha/h with field efficiency 82.8 % as compared to conventional seed drill which was 0.596 ha/h and 82.32 %. The average depth of seed placement with cultivator-cum-seed drill was found to be 57.8 mm and that of conventional seed drill was 60.6 mm. The cost of operation for cultivator-cum-seed drill was 591.08 Rs/ha and that for conventional seed drill was 535.016 Rs/ha. The Energy requirement for cultivator-cum-seed drill was found to be 454.18 MJ/ha and that for conventional seed drill was found to be 416 MJ/ha.

Conflict of Internet

Authors expressed no conflict of Interest

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