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Performance evaluation of tractor operated two row forward reverse rotavator for sugarcane crop

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Abstract
India is the world's second - largest producer of sugarcane after Brazil, contributing 19.98% to global production, making sugarcane an important cash crop in the country. Although machinery for the sugarcane crop has been produced, it has not been widely used as it could have been. There is a large mechanization deficit as a result, particularly in the areas of sugarcane intercultural, planting, harvesting, and ratooning. Numerous intercultural procedures are necessary for sugarcane to control weeds, earth up, save moisture, and create a better environment for plant growth in general. In light of the aforementioned factors, a machine has been constructed, and its performance has been assessed, in an effort to lessen the laboriousness associated with inter-cultural operations. During the design phase, a number of design parameters, including horsepower, the number of blades, speed reduction, shaft diameter, and allowable stresses, were determined. The tractor-operated two - row forward-reverse rotavator executes two operations, namely intercultural and earthing-up. During forward rotation, the machine performs intercultural operation; however, during reverse rotation, earthing up operation is performed by throwing soil outward near the crop base. The machine's performance was evaluated by taking into account factors including working depth, speed of operation, and moisture content. The study's findings showed that the effective field capacities for forward and reverse directions were 84% and 73%, respectively. The field efficiency was found to be 83.32% and 80.85% in the forward and backward directions, respectively. The height of the ridge created after the reversal procedure was measured at 25-35 cm. Fuel usage for forward and reverse directions was measured at 6.91 l/ha and 8.01 l/ha, respectively.

Keywords: Earthing up, intercultural, mechanization, weeding

1. Introduction

Due to the subsistence nature of Indian agriculture, there is limited scope to expand the area that can be used for cultivation. As a result, intensive farming is required to increase production, which calls for optimum management methods to make better use of resources. One crucial management technique that considerably influences crop output is weeding. It has a corresponding impact on soil moisture retention, nutrient loss in rainfed areas and crop yield overall. In fields that were completely overgrown with weeds as opposed to fields that were weed-free, showed a 40-50% loss in crop output [7]. Weed lowers crop yields, degrades crop quality, and drives up production costs [5]. Weeding with a tractor-drawn weeder is probable in widely spaced row crops. In most cases, weeding and inter-culturing tasks on the farm are carried out using tractor-mounted cultivators. The soil is precisely stirred with a rotational type weeder or rotavator, which also breaks up and removes weed roots. Furthermore, it keeps the soil loose so that sufficient aeration can take place. Mostly for crops with broad row spacing like maize, cotton, red gram, and sugarcane where the tractor can be run in the rows. The main benefit of powered rotary tillers is that they require less draught when operating because the blades are propelled, which reduces wheel slip and enhances field performance. This will cut down on tire wear and the cost of adding extra ballasting weight to the back tire. While tractive efficiency is substantially higher, the energy consumption for spinning operation is quite low. The superior capacity of rotary tilling to mix, flatten, and pulverize the soil has led to its widespread use in tillage operations.

However, due to its high energy consumption, the usage of rotary tillers is strictly limited to "shallow" tillage [6]. Paper presents a performance evaluation of tractor operated two row forward reverse rotavator considering parameters, efficiencies, working depth, operating speed, etc.

2. Materials and Methods

The conceptualization of a tractor operated two row forward reverse rotavator was started with the consideration of the power source being a tractor. Blade selection was a primary task during the development stage. The selection of the blade's rotation direction was a crucial parameter for executing its intended tasks. Both forward and reverse rotations were chosen. In the forward direction, the machine performs weeding operations, while in the reverse direction, it engages in earthing up operations. When employing forward rotation, each blade cuts an increment of undisturbed soil upon entering from the surface, whereas with reverse rotation, the soil increment is cut from the bottom upward (Hendrick and Gill, 1971) [8].

The power from the tractor was divided into two sides of the rotavator. The main shaft, originating from the tractor power outlet (i.e., PTO shaft), was connected to the centrally located gearbox. The power from the main gearbox was then transferred to each rotary unit using separate propeller shafts. Chain drives were employed to transmit power to the rotary units. The necessary power reduction was achieved by varying the number of teeth on the driving and driven gears. The dimensions of the rotary unit height, width, and length were selected based on the crop's growth stages. The rotavator comprises two rotary units that operate in two separate rows. The rotary units were mounted on the main frame using a nut and bolt arrangement, facilitating the adjustment of the working width. A skid was used to maintain a uniform depth of operation. The rotary tiller was equipped with 18 J-shaped blades on each unit, offering the advantage of achieving maximum depth. The J-shape blades were arranged in both left and right orientations. This orientation was advantageous, as right-facing blades throw soil to the right side, while left-facing blades throw soil to the left side when working in reverse direction. The nature of the blades throwing soil outward and near the base of sugarcane results in earthing up operations, forming a ridge near the base of the sugarcane crop while working reverse direction (Ferdows *et al*., 2023) [9]. In the forward direction, the soil is tilled at an optimum depth and weeds are removed and mixed with the soil. A trailing board is provided at the rear side of the rotavator.

Table: 1 Overall dimensions of prototype of tractor operated two row forward-reverse rotavator

S. No.	Particulars	Dimensions
1.	Length, mm	2130
2.	Width, mm	1220
3.	Height, mm	1150
4.	Mass, kg	420
5.	Type of blades	‘J’ Type
6.	Number of blades	18 x 2 = 36 nos.
7.	Width of each Rotory unit, mm	762

Fig 1: Field trial of tractor operated two row forward-reverse rotavator

2.1 Performance evaluation of developed tractor operated two row forward reverse rotavator

2.1.1 Moisture content on a dry basis

The moisture content was determined on a dry basis, using oven dry method. Soil samples were dried in the oven for 24 hours at 105 °C. The dried sample was re-weighed and the weight was recorded. Soil moisture content (dry basis) was estimated by using the formula.

$$Moisture\ Content\ (\%) = \frac{Weight\ of\ moist\ soil - Weight\ of\ dry\ soil}{Weight\ of\ dry\ soil} \times 100$$

2.1.2 Bulk density

Undisturbed soil cores were collected by driving with an iron hammer 10 cm diameter metal cylinder into the depth in the plot. Bulk density was calculated based on volumes and dry weights of the soil samples by using a core penetrometer of 10 cm diameter and 13 cm height. Bulk density (g/cc) was measured with the help of the following formula.

$$Bulk\ Density, \left(\frac{gm}{cc}\right) = \frac{Weight\ of\ soil(gm)}{Volume\ of\ soil(cc)}$$

2.1.3 Wheel slip

The wheel slip was determined by making a mark on tractor and power drive wheels with colored tape and measuring the distance traveled by wheels for a particular number of revolutions under no load on the firm surface and with the same number of revolutions under the actual field operations. The slip was calculated as given below.

$$Wheel\ slip\ (\%) = \frac{(A - B) \times 100}{A}$$

Where,

A= the distance traveled by the drive wheel under no-load conditions in known number of (say in 10) revolutions on the firm surface.

B= the distance traveled by the drive wheel under actual field operation in the same number of (say in 10) revolutions.

2.1.4 Fuel consumption

For measuring the tractor fuel consumption the fuel tank was filled before and after the test. The amount of refueling after the test was the fuel consumption for the particular operation. While filling up the tank, careful attention was paid to keep the tank horizontally and not to leave any space in the tank. For checking the proper level of the tank spirit level was used.

2.1.5 Theoretical Field Capacity

For calculating the theoretical filed capacity, working width and travelling speed were taken in to consideration. It is always greater than the actual field capacity. Theoretical field capacity was calculated by using following formula.

$$Therotiical\ field\ capacity, (ha/h) = \frac{Width(m) \times Speed(km/h)}{10}$$

2.1.6 Effective field capacity

The actual operating time along with time lost for every event such as turning, refueling, and machine trouble were recorded for completion of a particular operation. The effective field capacity was calculated as follows.

$$\text{Effective field capacity, (ha/h)} = \frac{A}{(Tp + T1)}$$

Where,
A= Area covered, ha.
T_P= Productive time, h.
T_1= Non Productive time, h.

2.1.7 Field Efficiency

Field efficiency was calculated by taking ratio of effective field capacity to theoretical field capacity. It is always expressed in percentage. It was estimated by following formula.

$$\eta\,(\%) = \frac{EFC \times 100}{TFC}$$

2.1.8 Height of ridge

The height of ridge form during the reverse rotation of rotor blade was recorded using the measuring scale**.**

3. Results and Discussion

To evaluate the performance of the rotavator various tests were performed in a laboratory as well as field conditions [3]. There were eight field trials were carried out at Sugarcane research fields, MPKV, Rahuri. The Sugarcane, Co - 86032 variety plot with two to three month after plantation with 1.5 m row to row spacing was selected for trials. The field trials were carried out at an average moisture content of 10.75 percent whereas, the average bulk density of soil was 1.43 g/cc. During the reverse operation of rotavator the ridge was formed of average 250-350 mm height. The tests results are presented in the table 2. These results are in strong agreement with previous works of [1, 10].

Table 2: Test results of tractor operated two row forward-reverse rotavator for sugarcane crop (Interculturing Operation Forward Direction)

Sr. No.	Parameters	Test trials								
		I	II	III	IV	V	VI	VII	VIII	Average
1.	Net duration of test, h	3.0	4.0	4.5	2.5	3.5	2.5	4.0	3.0	27.0 (T)
2.	Gear used	L-2								
3.	Engine speed, rpm - No load	2000	2000	2000	2000	2000	2000	2000	2000	-
	- On load	1850	1800	1850	1800	1800	1850	1800	1800	-
4.	Bulk density, g/cc	1.36	1.40	1.45	1.48	1.39	1.52	1.45	1.40	1.43
5.	Soil moisture, %	11.50	9.50	11.50	10.00	9.00	12.00	12.50	10.00	10.75
6.	Forward speed, km/h	3.2	3	3.3	3.39	3.13	3.18	3.5	3.1	3.23
7.	Avg. depth of cut, cm	11.50	12.00	11.88	12.16	11.62	12.00	11.50	12.00	11.83
8.	Av. width of cut, cm	311	311	311	311	311	311	311	311	311
9.	Area covered, ha/h	0.83	0.80	0.83	0.91	0.81	0.81	0.91	0.80	0.84
10.	Time required for one ha, h	1.21	1.25	1.21	1.10	1.24	1.24	1.10	1.25	1.20
11.	Theoretical Field capacity, ha/h	1.00	0.93	1.03	1.05	0.97	0.99	1.09	0.96	1.00
12.	Field efficiency, %	83.07	85.74	80.55	86.12	82.77	81.70	83.60	82.98	83.32
13.	Fuel consumption, l/h	5.84	5.65	5.75	5.81	5.69	5.7	5.94	5.75	5.77
14.	Fuel consumption, l/ha	7.07	7.06	6.96	6.40	7.05	7.05	6.53	7.18	6.91
15.	Operating cost of the machine, Rs/ha	1038.15	1072.75	1038.15	945.15	1065.14	1062.13	943.08	1072.75	1029.66
16.	Net saving by using the machine over traditional method, (Forward Operation), Rs/ha	1461.85	1427.25	1461.85	1554.85	1434.86	1437.87	1556.92	1427.25	1470.34

Table 3: Test results of tractor operated two row forward-reverse rotavator for sugarcane crop (Earthing up Operation Reverse Direction)

Sr. No.	Parameters	Test trials					
		I	II	III	IV	V	Average
1	Net duration of test, h	3.5	3.5	3.2	3.5	3.1	16.8 (T)
2.	Gear used	L-2					
3.	Engine speed, rpm - No load	2000	2000	2000	2000	2000	-
	On load	1850	1800	1800	1850	1800	-
4.	Height of ridge during reverse operation, mm	250-350					-
5.	Bulk density, g/cc	1.36	1.40	1.48	1.52	1.40	1.43
6.	Soil moisture, %	11.50	9.50	10.00	12.00	10.75	10.75
7.	Forward speed, km/h	2.9	3.1	2.8	2.8	2.9	2.9
8.	Avg. depth of furrow, cm	30.0	28.0	31.0	32.0	31.0	30.4
9.	Avg. width of cut, cm	311	311	311	311	311	311
10.	Area covered, ha/h	0.74	0.76	0.71	0.70	0.75	0.73
11.	Time required for one ha, h	1.39	1.28	1.40	1.45	1.34	1.37
12.	Theoretical Field capacity, ha/h	0.90	0.96	0.87	0.87	0.90	0.90
13.	Field efficiency, %	79.83	80.90	81.82	79.07	82.62	80.85
14.	Fuel consumption, l/h	5.90	5.70	5.95	5.80	5.8	5.84
15.	Fuel consumption, l/ha	8.19	7.31	8.35	8.42	7.78	8.01
16.	Operating cost by the machine, Rs/ha	1191.94	1100.26	1204.49	1246.35	1151.70	1178.95
17.	Net saving by using the machine, Rs/ha	3808.06	3899.74	3795.51	3753.65	3848.30	3821.05

4. Conclusion

Based on the established technique, the developed machine was assessed; the findings revealed that the actual area covered was 0.84 ha/h with an efficiency rate of 83.32 percent at a forward speed of 3.23 km/h. The constructed machine performed satisfactorily. Machine accomplish two operations, save time, more efficient, have lower operating costs, and boost productivity.

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