Sugarcane (Saccharum officinarum) is a vegetatively propagated crop grown in more than 80 countries. India is the second largest global producer of sugarcane next to Brazil and the world’s leading sugar consumer. India’s total sugarcane cultivation area is 5.08 million ha. Uttar Pradesh, Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu are the major sugarcane growing states contribute about 81% of the total production in India. Maharashtra is a leading producer of sugarcane crop. Adsali, pre-seasonal and seasonal or suru are the three different periods of sugarcane crop in Maharashtra. Sugarcane crop cultivation is very labour consuming (Kumar et al., 2018). Sugarcane is one crop in which there has been little mechanization in India, all farm operations from planting to harvesting being labour dependent. Sugarcane requires number of intercultural operations for weed control, moisture conservation and creation of better environment for overall growth of plant. Mechanization can eliminate the drudgeries involved in sugarcane crop cultivation. Mechanization has been
identified as the major factor for increasing agricultural productivity worldwide (Tiwari et al., 2019). Weeding and earthing up of sugarcane crop are the important intercultural operations. Earthing up operation is done when 2 to 3 internodes are visible. It is done to support the plants with soil and avoid the direct contact of water of plants. Earthing up plays an important role in maintaining the growth, yield of the sugarcane plant. Besides, it has added advantages in terms of pruning/cutting of old roots, moisture conservation, addition of organic matter, enhanced availability and uptake of plant nutrients, efficient utilization of solar radiation, suppression of weeds and preventing canes from lodging (Yadav and Shukla, 2008). These intercultural operations mostly done with the help of farm labour and self-propelled machineries which directly affects the productivity of crops.

**Material and Methods**

**Development of tractor operated two row forward reverse rotavator**

Tractor operated two row forward reverse rotavator was designed using specific work method (Bernacki et al., 1971 and Zareinforoush et al., 2010).

**Specific work**

It is the work carried on by rotary tiller at each rotation of tillage blades per the volume of broken soil.

**Power requirement**

It is calculated by the following equation

\[ N_c = \frac{10A_c AB v}{75\eta_c \eta_z} \]

Where,

\( \eta_c = \) Tractor efficiency = 0.8 - 0.9

\( \eta_z = \) Coefficient of reservation of tractor power = 0.7-0.8

\[ N_c = \frac{10 \times 155 \times 1.2 \times 15 \times 0.083}{75 \times 0.85 \times 0.8} \]

\[ N_c = 45.40 \text{ hp} \approx 45 \text{ hp} = 33.09 \text{kW} \]

**Length of slice**

Length of slice is calculated using following equation,

\[ L = \frac{2\pi R}{\lambda \cdot Z} \]

\[ L = \frac{2 \times 3.14 \times 20}{5 \times 2} = 12.5 \text{ cm} \]

**Design of Rotary Shaft**

The maximum tangential force \( (K_s) \) is calculated by

\[ K_s = C_s \frac{75\eta_c \eta_z}{\mu_{\text{min}}} \]

Where,

\( C_s = \) Reliability factor = 1.5 for non-rocky soil and 2 for rocky soil

\[ \lambda_{\text{min}} = \frac{2\pi R}{z L_{\text{max}}} \]

\[ \lambda_{\text{min}} = \frac{2 \times 3.14 \times 20}{2 \times 12} = 5.23 \]

\[ u_{\text{min}} = v \lambda_{\text{min}} \]

\[ u_{\text{min}} = 0.83 \times 5.23 = 4.34 \text{ m/s} \]

\[ K_s = 1.5 \frac{75 \times 0.8 \times 0.85 \times 45}{4.34} = 793.20 \text{ kg} \]

The maximum moment on rotor shaft is,

\[ M_s = K_s \times R \]

\[ M_s = 793.20 \times 20 = 15864.05 \text{ kg cm} \]

**Allowable Stresses**

The rotor will be made from roll steel (AISI302) having yield stress 520 MPa.

As the allowable stress in rotor calculated by

\[ \tau_{\text{all}} = \frac{0.577 \sigma_y}{F} \]

Where,

\( \sigma_y = 500 \text{ MPa} \)

\( F = \) Factor of safety = 2

\( K = \) coefficient of stress = 0.75

\[ \tau_{\text{all}} = \frac{300 K}{2} \]

\[ \tau_{\text{all}} = \frac{300 \times 0.75}{2} = 112.5 \text{ MPa} = 1147.18 \text{ kg/cm}^2 \]

**Diameter of rotor shaft**

The diameter of rotor shaft calculated using the equation of torsional moment

\[ d = \sqrt{\frac{16M_s}{\pi}} \]
Width of rotary tiller

Let, moment acting, \( M = \frac{A \times z \times l \times a \times b_m}{2\pi} \)

Rotary tiller width,

\[ b_m = \frac{2 \times 3.14 \times 15866.05}{1.31 \times 2 \times 15 \times 12} = 209.65 \text{ cm} \approx 210 \text{ cm} \]

Number of blades

\[ \frac{\text{Width of one unit}}{\text{Distance between blades}} = \frac{65}{3.6} = 18 \]

Total no of blades on both unit = 18 × 2 = 36

Angle of blade inclination

\[ \frac{360^0}{\text{No. of blades}} = \frac{360^0}{18} = 20^0 \]

Design of Power Transmission System

a. Speed reduction

First stage speed reduction: Assume number of teeth on pinion gear which mounted on input shaft as 13 with speed ratio 1.76:1. No of teeth on crown gear, which mounted on gearbox shaft was calculated by using following formula (Khurmi and Gupta, 2006).

\[ \text{Speed ratio} = \frac{T_2}{T_1} \]

Where,

\[ T_1 = \text{No. of teeth on pinion gear which mounted on input shaft} \]
\[ T_2 = \text{No. of teeth on crown gear which mounted on gearbox shaft} \]

\[ \frac{T_2}{13} = 1.76 \]
\[ T_2 = 1.76 \times 13 \]
\[ = 22.88 \approx 23 \]

Selected no. of teeth on crown gear as 23.

The speed of gearbox shaft in power train of transmission system was calculated using the formula.

\[ \frac{N_1}{T_1} = \frac{N_2}{T_2} \]
\[ N_2 = \frac{N_1 T_1}{T_2} \]

Where,

\[ N_1 = \text{Speed of input shaft (rpm)} \]
\[ N_2 = \text{Speed of gearbox shaft (rpm)} \]
\[ T_1 = \text{No. of teeth on pinion gear which mounted on input shaft} \]
\[ T_2 = \text{No. of teeth on bevel gear which mounted on gearbox shaft} \]

Fig. 1: Block diagram showing power transmission of tractor operated two row forward reverse rotavator.
First reduction stage: 

Given: 

- Tractor P.T.O speed = 540 rpm
- Number of teeth on sprocket mounted on secondary propeller shaft = 12
- Speed ratio = 1.25:1

To find:
- Speed of secondary propeller shaft

Using the formula:

\[ L = \frac{N_3 T_3}{2} + \frac{2C}{P} + \frac{T_2 - T_1}{2\pi^2} + \frac{P}{C} \]

Where,
- \( N_3 = \) Speed of gear box shaft, rpm
- \( N_4 = \) Speed of Secondary propeller shaft, rpm
- \( T_1 = \) Number teeth in pinion
- \( T_2 = \) Number teeth in sprocket
- \( C = \) Center to Center distance between the pinion and the sprocket, cm
- \( P = \) Pitch distance, cm

Calculations:

\[ L = \frac{13 \times 15}{2} + \frac{2 \times 48}{2.54} + \frac{15 - 13}{2\pi^2} + \frac{2.54}{48} \]

\[ = \frac{13 \times 15}{2} + \frac{2 \times 48}{2.54} + \frac{2.54}{48} \]

\[ = 51.94 \approx 52 \]

Therefore, the length of chain was 52 pitches selected.

Performance evaluation of tractor operated two row forward reverse rotavtor

During the performance test of rotavator methodology followed as per IS: 17045:2018 and different observation were taken for assessment of the machine performance. The more than one hectare area of the test plot was selected. The ratio of width and length of the plot was as possible as 1:2. Soil moisture content, bulk density, fuel consumption, etc. were recorded.

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

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

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
Development of Tractor Operated two Row Forward Reverse Rotavator for Sugarcane Crop

3 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.

4 Theoretical field capacity

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

\[ \text{Theoretical field capacity (ha/h)} = \frac{\text{Width (m)} \times \text{Speed (km/h)}}{10} \]

5 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:

\[
\text{Effective field capacity (ha/h)} = \frac{A}{(T_p + T_1)}
\]

Where,

- \( A \) = Area covered, ha.
- \( T_p \) = Productive time, h
- \( T_1 \) = Non Productive time, h.

6 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:

\[
\eta (%) = \frac{EFC \times 100}{TFC}
\]

7 Height of ridge

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

### Table 1: Test results of tractor operated two row forward-reverse rotavator for sugarcane crop (Inter culturing Operation Forward Direction and reverse direction).

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Parameters</th>
<th>Forward direction</th>
<th>Reverse direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Net duration of test, h</td>
<td>27.0 (T)</td>
<td>16.8 (T)</td>
</tr>
<tr>
<td>2.</td>
<td>Gear used</td>
<td>L-2</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Engine speed, rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No load</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>- On load</td>
<td>1800</td>
<td>1700</td>
</tr>
<tr>
<td>4.</td>
<td>Bulk density, g/cc</td>
<td>1.43</td>
<td>1.43</td>
</tr>
<tr>
<td>5.</td>
<td>Soil moisture, %</td>
<td>10.75</td>
<td>10.75</td>
</tr>
<tr>
<td>6.</td>
<td>Forward speed, km/h</td>
<td>3.23</td>
<td>29</td>
</tr>
<tr>
<td>7.</td>
<td>Avg. depth of cut, cm</td>
<td>11.83</td>
<td>-</td>
</tr>
<tr>
<td>8.</td>
<td>Average Ridge height, cm</td>
<td>-</td>
<td>30.4</td>
</tr>
<tr>
<td>9.</td>
<td>Av. width of cut, cm</td>
<td>311</td>
<td>311</td>
</tr>
<tr>
<td>10.</td>
<td>Area covered, ha/h</td>
<td>0.84</td>
<td>0.73</td>
</tr>
<tr>
<td>11.</td>
<td>Time required for one ha, h</td>
<td>1.20</td>
<td>1.37</td>
</tr>
<tr>
<td>12.</td>
<td>Theoretical Field capacity, ha/h</td>
<td>1.00</td>
<td>0.90</td>
</tr>
<tr>
<td>13.</td>
<td>Field efficiency, %</td>
<td>83.32</td>
<td>80.85</td>
</tr>
<tr>
<td>14.</td>
<td>Fuel consumption, l/h</td>
<td>5.77</td>
<td>5.84</td>
</tr>
<tr>
<td>15.</td>
<td>Fuel consumption, l/ha</td>
<td>6.91</td>
<td>8.01</td>
</tr>
<tr>
<td>16.</td>
<td>Operating cost of the machine, Rs/ha</td>
<td>1029.66</td>
<td>1178.95</td>
</tr>
<tr>
<td>17.</td>
<td>Net saving by using the machine over traditional method (Forward Operation), Rs/ha</td>
<td>1470.34</td>
<td>3821.05</td>
</tr>
</tbody>
</table>

Results and Discussion

The experimental setup for performance of developed tractor operated two row forward reverse rotavator shown in Fig. 3. The tractor was calibrated in the field using the combination of changing the lever position of gear and high-low stages of gears. Finally, the desired speed level of tractor *i.e.* 2 km.h⁻¹ was set for second gear at low lever position with gradual adjustment of the hand throttle. The rotary unit width was adjusted according to the crop row spacing; the depth controlling mechanism was positioned at second for optimum depth. Two poles at 25 m distance apart were fixed for calculating the time taken to cover the 25 m length. Then after preliminary check-up of machine, the machine was operated in the sugarcane field. Both performance trials were carried out, while working in forward direction as well as in reverse direction. The necessary field data was recorded for further calculation. Table 1 depicts the results obtained during the test trials of developed tractor operated two row forward reverse Rotavator for forward direction and reverse direction, respectively. The overall field efficiency was 83.32 in forward operation whereas 80.85 was during
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reverse direction. The fuel consumption in forward direction was 6.91 l/ha and in reverse operation 8.01 l/ha was recorded.

**Conclusion**

1. Field efficiency of machine was 83.32% in forward operation whereas 80.85% during reverse direction.
2. The ridge height during reverse operation was 250 - 350 mm.
3. The net saving over conventional method 1470.34 Rs/ha and 3821.05 Rs/ha for forward and reverse operation respectively.
4. Overall performance of developed tractor operated two row forward reverse rotavator was found satisfactory.

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**References**


