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Performance evaluation of a modified offset rotavator in Guava orchard

■ **SHARAD KUMAR NAMDEV, RAJNARAYAN PATERIYA, BHABANI SHANKAR DASH AND RAJESH MODI**

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See end of the Paper for authors' affiliation

Correspondence to :

SHARAD KUMAR NAMDEV
Department of Farm Machinery and Power Engineering, School of Agriculture, ITM University, GWALIOR (M.P.) INDIA
Email : sharadsftr@gmail.com

■ **ABSTRACT :** Rotary tillage implements are now projected as important tillage machinery for better seedbed preparation; however, the ordinary rotavator being in line with the tractor center line at the rear cannot be used in orchards due to the hindrance posed by narrow space between the plants. Therefore, the concept of a modified offset rotavator was proposed, which could perform intercultural operation between the plants. The study was conducted to evaluate the performance of the modified offset rotavator in guava orchard of Horticulture Research Center, Pantnagar. It was found that the draft (negative) for the L-shaped blades increased (1203.4 to 1841.4 N) as the forward speed increased (2.0 to 3.0 km/h) with Increase in depth of cut (80 to 120 mm) for the shield kept in the lowered (down) position and fuel consumption was higher 9.93 l/h at given forward speed 3.0 km/h with 120 mm depth of cut. Soil break up (mean mass diameter) resulting from the Impact action of L-shaped blades on soil was found increased (1.05 to 1.95 mm) as the forward speed increased (2.0 to 3.0 km/h). The extent of residue incorporation was the maximum 97.30 % at forward speed 2.0 km/h with 120 mm depth of cut, whereas at higher forward speed 3.0 km/h, field performance index was observed 88.28 %. The minimum area uncovered near the girth was reported 0.143 m^2 at higher girth 0.48 m while plant injury at 3.0 km/h resulted due to impact of sensing assembly with plants was found 50 % in form of scratch on the girth.

■ **KEY WORDS :** Tillage, Modified offset rotavator, Field performance, Guava orchard

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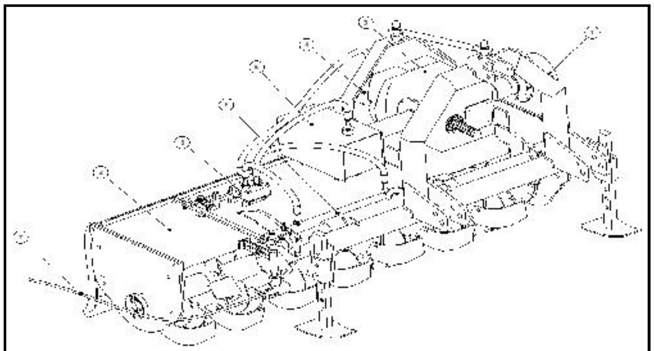
The rotavator (derived from rotary cultivator) is a tractor mounted active tillage implement comprising of blades mounted on flanges with affixed to a shaft that is driven by the tractor (PTO). Rotavator performs (one plowing and two harrowing) operation in single pass therefore, rotavator is accepted by the majority of farmers in India, as a time-saving equipment under low land and high land conditions. It gave higher quality of work (25–30%) than the cultivator (Sahay *et al.,* 2009). The power available at the drawbar of tractor is about 40-56% of net engine power, when transmitting power through the soil-tyre interface, whereas about 80-85% for PTO driven active tillage tools (Chertkiattipol *et al.*, 2008). Rotavator obtain their energy in more than one manner reduce the draft requirement and have greater versatility in manipulating the soil to obtain the desire result (Cakmak *et al.,* 2010). Thus, rotavator also reduces the time required to get an optimum seedbed by combining the primary and secondary tillage operation. The degree of soil pulverization attained by the rotavator is more comparable with the use of a mould board plough, and harrow (twice) and spiked tooth harrow (thrice) and energy required per unit volume of soil for rotavator is about 39.2 to 47.0 MJ/m^3 while, 70.7 to 116.3 MJ/m^3, 62.2 to 103 MJ/m^3 and 53.3 to 110.2 MJ/m^3 for mould board plough, desi plough and cultivator, respectively (Salokhe and Ramalingam, 2003). Depending on the soil constitution the fuel consumption increases per centimeter ploughing depth between 0.5 and 1.5 l/ha (Filipovic *et al.*, 2004). In a conventional cropping system the greatest energy consumer is soil tillage (Zimmer *et al.*, 2004). Therefore, farmers are increasingly accepting rotavators for high degree of pulverization (Sharda and Singh, 2004).

METHODOLOGY

The modified offset rotavator was designed and developed by CSIR-Center of Excellence for Farm Machinery, Central Mechanical Engineering Research Institute, Ludhiana (Punjab) and tested for performance evaluation by one of networking partner, Department of Farm Machinery and Power Engineering, College of Technology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). The modified offset rotavator has rotating tines mounted on a horizontal shaft and can be attached to the three point linkage of 50-65 hp tractors. It is powered by PTO and provided with adjustable mechanical sensing unit which can be adjusted at any position on the frame according to the type of orchard with a side shift of 300 mm. It has seven flanges spaced 220 mm apart and each flange carries in it six blades. It is also provided with an external gear type pump of capacity 15 l/min driven by PTO of the tractor. The different components of modified offset rotavator are presented in Fig. A.

The experiments were conducted in the Horticulture Research Center, Pantnagar. The performance of modified offset rotavator was evaluated during the field experiment in which, the independent variables were selected as machine parameter like λ- ratio, forward speed and soil parameters like moisture content, bulk density, cone index and the dependent variables were selected as draft requirement, fuel consumption, residue incorporation, actual field capacity, field performance index, area uncovered near the girth and plant injury etc. The field experiment was performed in guava orchard which follows high density pattern with plant spacing of 5×5 m from each other and some of the selected parameters related to plant geometry were taken during field experiments and these data is shown in Table 3.



1. Secondary transmission system
2. Frame
3. Primary transmission system
4. Hydraulic pump
5. Oil tank
6. Control valves
7. Sensing rod
8. Double acting cylinder

Fig. A : Different components of modified offset rotavator

Table A : Data of different parameters observed in guava orchard

Orchard	Plant girth, m	Plant canopy, m	Heading height of branches from ground, m
Guava	0.46	4.51	1.66
	0.40	4.34	1.48
	0.42	4.15	1.30
	0.45	4.23	1.54
	0.48	3.90	1.76
Average	0.43	4.22	1.55

An experimental plot was selected for guava orchard having 6000 m^2 area and it was divided into subplots of the size of 15×30 m^2. Soil samples were taken from field plot to determine soil moisture content, bulk density and cone index. The three λ-ratios 4, 5 and 7 were determined by changing forward speed of tractor 2.0, 2.5, 3.0 km/h, respectively with constant rotor speed 243 rpm and different depths 80, 100 and 120 mm were taken into consideration. All the treatments were repeated thrice. Statistical analysis of data was carried out and the variance at 5% level of significance.

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of ª –ratio and depth of cut on the draft requirement :

The modified offset rotavator was evaluated for draft requirement at forward speed 2.0, 2.5 and 3.0 km/h (corresponding λ– ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm, respectively in guava field. Table 1 represents the draft required at different λ– ratios and depth of cut. The relation of λ– ratio and depth of cut with draft is shown in Fig. 1. The draft at forward speed 2.0 km/h (7 λ– ratio) and depth 80 mm was observed 1203.4 N. With an increase in forward speed to 2.5 km/h (5 λ– ratio) and depth 100 mm, then draft was observed 1542.5 N and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth 120 mm, the draft was observed 1841.4 N. It was observed that, the increase in forward speed with depth of operation draft increased. This was mainly due to increasing the forward speed because the more specific energy per unit volume of soil requires to cut the soil mass in less time and blade has to handle more volume of soil, similarly as increasing the depth of operation the blades cut more volume of soil per unit time thus, soil metal friction increases. It was revealed that orchard field, λ– ratio and depth of cut have significant effect on the draft at 5% level of significance.

Effect of ª– ratio and depth of cut on fuel consumption :

The modified offset rotavator was evaluated for fuel consumption at forward speed 2.0, 2.5, 3.0, (corresponding λ – ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm, respectively. The fuel consumption during the experiment for guava orchards field at different λ– ratio and depth of cut is presented in the Table 2. The relation of λ– ratio and depth of cut on the fuel consumption shown in Fig. 2. The fuel consumption at forward speed 2.0 km/h (7 λ– ratio) and depth of cut 80 mm was observed 4.34 l/h. When increase in forward speed 2.5 km/h (5 λ– ratio) and depth 100 mm, then fuel consumption was observed 7.80 l/h and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth of cut 120 mm, the fuel consumption was observed 9.93 l/h. The results show that, as increase in forward speed with depth of operation, the fuel

Table 1 : Effect of ª-ratio and depth of cut on draft requirement of a modified offset rotavator under guava orchard

Experiment no.	λ - ratio	Depth of cut, mm	Average of draft, N
1	4	80	1585.6
2	4	100	1748.3
3	4	120	1841.4
4	5	80	1412.1
5	5	100	1542.5
6	5	120	1671.8
7	7	80	1203.4
8	7	100	1327.9
9	7	120	1479.8

Table 2 : Effect of ª-ratio and depth of cut on fuel consumption for modified offset rotavator under guava orchard

Experiment no.	λ - ratio	Depth of cut, mm	Average of fuel consumption, l/h
1	4	80	8.64
2	4	100	9.30
3	4	120	9.93
4	5	80	6.48
5	5	100	7.80
6	5	120	8.94
7	7	80	4.34
8	7	100	5.48
9	7	120	6.53

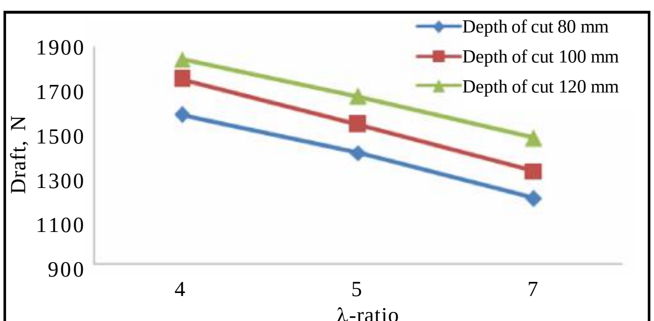


Fig. 1 : Effect of different ª– ratio and depth of cut on draft requirement for guava orchard

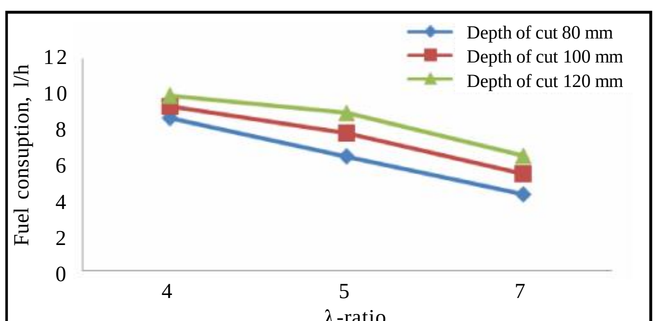


Fig. 2 : Effect of different ª– ratio and depth of cut on fuel consumption for guava orchard

consumption increased. The main fact that, by increasing forward speed tends to increase in specific energy per unit volume of soil requires to cut the soil mass in less time and similarly by increasing the depth of operation the blades comes contact more volume of soil thus, soil metal friction increases hence, fuel consumption increases. Statistical (ANOVA) result indicated, that orchards field, λ– ratio and depth of cut have significant effect on the fuel consumption at 5% of significance.

Effect of different a– ratio and depth of cut on mean mass diameter :

The modified offset rotavator was evaluated for mean mass diameter at forward speed 2.0, 2.5 and 3.0 (corresponding λ – ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm for guava orchard. Mean mass diameter during the experiment at different λ– ratio and depth of cut are presented in the Table 3. The variation in the mean mass diameter due to the effect of λ– ratio and depth of cut for Guava orchards is shown in Fig. 3. The mean mass diameter at forward speed 2.0 km/h (7 λ – ratio) and depth 80 mm was observed 1.05 mm. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then mean mass diameter was observed 1.47 mm and further increase in forward speed 3.0 km/h (4 λ – ratio) and depth of cut 120 mm, the mean mass diameter was observed 1.95 mm. It is found from above result that, as increase in forward speed, then mean mass diameter increases corresponding to all level of forward speed and depth of operation. It may be due to when forward speed increases, the blade impact forces on soil decreased. Therefore, mean mass diameter of soil particle increases at all level of forward speed. The statistical analysis (ANOVA) is expressed that, λ– ratio and orchards field have significant effect on the mean mass diameter at 5%.

Table 3 : Effect of a -ratio and depth of cut on mean mass diameter, (mm) under guava orchard

Experiment no.	λ - ratio	Depth of cut, mm	Average of mean mass diameter, mm
1	4	80	1.50
2	4	100	1.63
3	4	120	1.95
4	5	80	1.14
5	5	100	1.47
6	5	120	1.79
7	7	80	1.05
8	7	100	1.28
9	7	120	1.59

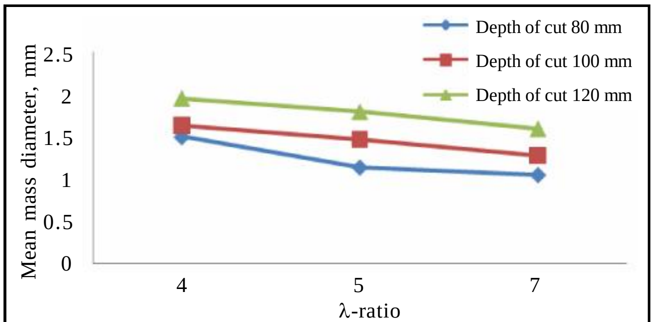


Fig. 3 : Effect of different a– ratio and depth of cut on mean mass diameter for guava orchard

Effect of different a– ratio and depth of cut on residue incorporation :

The modified offset rotavator was evaluated for residue incorporation at forward speed 2.0, 2.5 and 3.0 km/h (corresponding λ– ratio 7, 5, and 4) for the depth of operation 80, 100 and 120 mm for guava orchard. The Residue incorporation, during the experiment at different λ– ratio and depth of cut is presented in the Table 4. The variation in the residue incorporation due to the effect of λ– ratio and depth of cut is shown in Fig. 4. The residue incorporation at forward speed 2.0 km/h (7 λ – ratio) and depth 80 mm was observed 94.03 per cent. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then residue incorporation was observed 92.27 per cent and further increase in forward speed 3.0 km/h (4 λ– ratio) and depth of cut 120 mm, the residue incorporation was observed 90.39 per cent. It was observed that, as increase in forward speed then residue incorporation decreased. This may due when forward speed increased then blade impact forces on

Table 4 : Effect of a -ratio and depth of cut on residue incorporation for modified offset rotavator under guava orchard

Experiment no.	λ - ratio	Depth of cut, mm	Average of residue incorporation, %
1	4	80	86.30
2	4	100	88.20
3	4	120	90.39
4	5	80	91.66
5	5	100	92.27
6	5	120	93.54
7	7	80	94.03
8	7	100	95.32
9	7	120	97.30

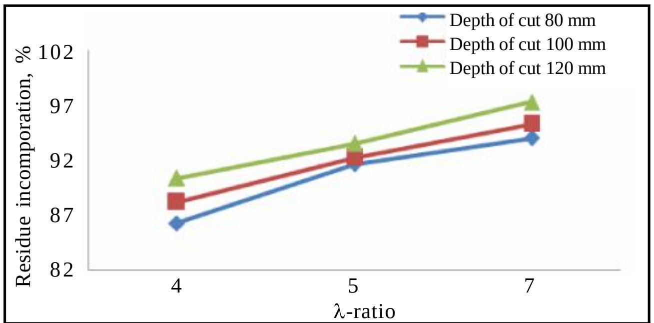


Fig. 4 : **Effect of different ^{a} – ratio and depth of cut on residue incorporation for guava orchard**

the soil also deceased resulted in less impact on soil which causes less amount of residue incorporation. The statistical analysis (ANOVA) exhibited that, depth of cut and orchards field have significant effect on the residues incorporation at 5%.

Effect of ^{a}– ratio on field performance index :

Field performance index during experiment for guava orchard at different λ– ratio is presented in the Table 5. The variation in the field performance index due to λ– ratio is shown in Fig. 5. The field performance index at forward speed 2.0 km/h (7 λ– ratio) was observed 77.58 per cent. When increase in forward speed 2.5 km/h (5 λ– ratio), then field performance index was observed 81.61 per cent and further increase in forward speed 3.0 km/h (4 λ– ratio), the field performance index was observed 88.28 per cent. The result shows that, when forward speed increased then field performance index increased with increase in actual field capacity. The statistical analysis (ANOVA) showed, that λ– ratio has significant effect on the field performance index at 5% level.

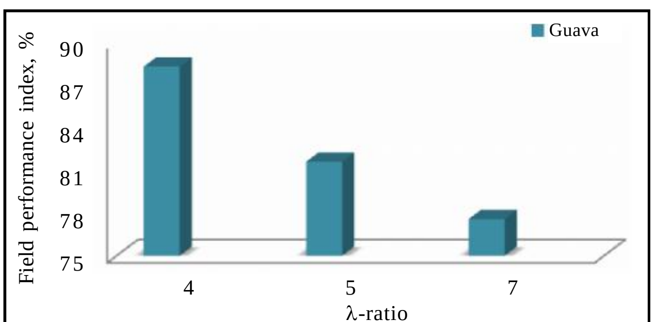


Fig. 5 : **Effect of different ^{a} – ratio on field performance index for guava orchard**

Table 5 : Effect of ^{a}-ratio on field performance index under guava orchard

Experiment no.	λ- ratio	Average of field performance index, %
1	4	88.28
2	5	81.61
3	7	77.58

Effect of girth on area uncovered near the girth :

The Area uncovered near the girth corresponding to girth for guava orchard is presented in Table 6. The variation in the area uncovered near the girth is shown in Fig. 6. The area uncovered near the girth at 0.43 m girth was observed 0.161 m^2. When increase in girth at 0.45 m, then area uncovered near the girth was observed 0.155 m^2 and further increase in girth at 0.48 m, the area uncovered near the girth was observed 0.143 m^2. The result shows, that as increase in girth of Guava orchard, the area uncovered near the girth decreased because of modified offset rotavator has definite side sift of 370 mm which depends on the hydraulic shift actuated by hydraulic piston and independent from forward speed of operation and depth of cut. Therefore, area uncovered near the girth mainly depends on girth of the orchard. Thus, when the girth of the orchard increased then the area uncovered near the girth decreased and *vice versa*. The statistical analysis (ANOVA) shows that, girth had significant effect on the area uncovered near the girth

Table 6 : Effect of girth on area uncovered near the girth under guava orchard

Experiment no.	Orchard girth, m	Average uncovered area near the girth (m^2)
1	0.43	0.161
2	0.40	0.173
3	0.42	0.167
4	0.45	0.155
5	0.48	0.143

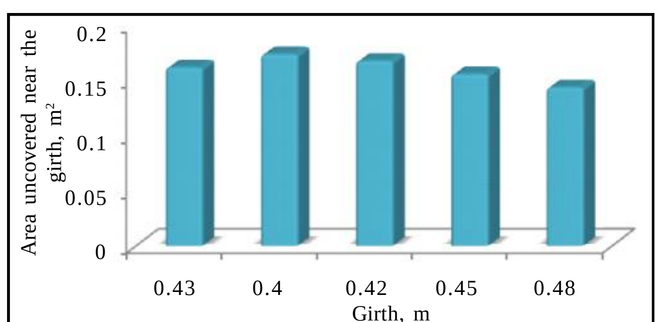


Fig. 6 : **Effect of girth on area uncovered near the girth for guava orchard**

at 5% level.

Effect of ª- ratio on plant injury :

The modified offset rotavator was evaluated for plant injury at forward speed 2.0, 2.5 and 3.0, (corresponding λ– ratio 7, 5, and 4) for guava orchard. The plant injury corresponding to different forward speed is given in Table 7. The effect of forward speed on plant injury corresponding to forward speed is shown in Fig 7. The results exhibited that plant injury was found 0.0 per cent at 2.0 km/h (7 λ– ratio). At 2.5 km/h (5 λ– ratio) forward speed average plant injury was recorded 33.3 per cent and further increase in forward speed 3.0 km/h (4 λ– ratio) the average plant injury was observed 50.0 per cent. The results indicated that when the forward speed increased the damage of plant also increased. This may be due to when sensing assembly of modified offset rotavator struck with stem of orchard with higher forward speed then due to the higher inertial impact of sensing assembly results plant injury near to the stem in form of scratch on the orchard. Similarly, when the forward speed decreases, then inertial impact decreases and less tends to injured plant girth. The statistical analysis (ANOVA) Table A_9 showed that λ– ratio has significant effect on the field plant injury at 5% level.

Table 7 : Effect of ª–ratio on plant injury (%) for guava orchard

Experiment no.	λ-ratio	No of plant, 30 m row	No. of injured plant, 30 m row	Average plant injury, %
1	4	6	3	50.0
2	5	6	2	33.3
3	7	6	0	0.0

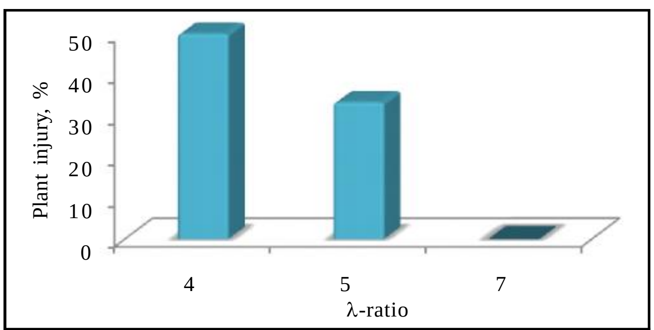


Fig. 7 : Effect of ª– ratio on the plant injury for guava orchard

Conclusion :

The maximum draft requirement in guava orchard was found 1841.4 N at a λ– ratio of 4 and depth of cut 120 mm. For same field, minimum draft was found 1203.4 N at λ– ratio of 7 and depth of cut 80 mm and fuel consumption ranged 9.93-4.34 l/h. The maximum mean mass diameter for guava orchard was recorded to be 1.95 mm at a λ– ratio of 4 and depth of cut 120 mm. The excess residue incorporation for guava orchard was found to be 94.03 % at λ– ratio of 7 and depth of cut 80 mm.

The maximum field performance index for guava was found to be 88.28 % at λ– ratio while minimum field performance index were found to be 77.58 % at λ– ratio 7.

The maximum uncovered area near the girth for guava orchard was found to be 0.173 m^2 at 0.40 m girth and minimum uncovered area near the girth was found to be 0.143 m^2 at 0.48 m girth whereas maximum plant injury was found to be 50 % per cent at λ– ratio of 4 and null plant injury was found at λ– ratio of 7.

Authors' affiliations:
RAJNARAYAN PATERIYA AND BHABANI SHANKAR DASH, Department of Farm Machinery and Power Engineering, College of Technology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S. NAGAR (UTTARAKHAND) INDIA
Email : rnpateriya@yahoo.co.in; dash.bhabani2009@gmail.com

RAJESH MODI, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Punjab Agriculture University LUDHIANA (PUNJAB) INDIA
Email : rmodi0701@gmail.com

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