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PERFORMANCE EVALUATION OF A MODIFIED OFFSET ROTAVATOR IN MANGO ORCHARD

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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 mango orchard of Horticulture Research Center, Pantnagar. It was found that the draft (negative) for the L-shaped blades increased (1086.8 to 1651.3 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 9.40 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 (1.21 to 2.20) as the forward speed increased (2.0 to 3.0 km/h). The extent of residue incorporation was the maximum 96.68% 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 89.54%. The minimum area uncovered near the girth was reported at higher girth while plant injury resulted from impact of sensing assembly with 83.3% in form of scratches on the plant girth.

Key words: tillage, modified offset rotavator, field performance, mango orchard

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INTRODUCTION

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 Indian, as a time-saving equipment under low land and high land conditions. It gave higher quality of work (25–30%) than the cultivator [1]. 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 [2]. 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. 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 [4] and energy required per unit volume of soil for rotavator is about 39.2 to 47.0 MJ/m³ while, 70.7 to 116.3 MJ/m³, 62.2 to 103 MJ/m³ and 53.3 to 110.2 MJ/m³ for mould board plough, desi plough and cultivator respectively [4]. Depending on the soil constitution the fuel consumption increases per centimeter ploughing depth between 0.5 and 1.5 l/ha [5]. In a conventional cropping system the greatest energy consumer is soil tillage [6]. Therefore, farmers are increasingly accepting rotavators for high degree of pulverization [7].

MATERIAL AND METHODS

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. 1.

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 mango 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 was shown in Tab. 1.

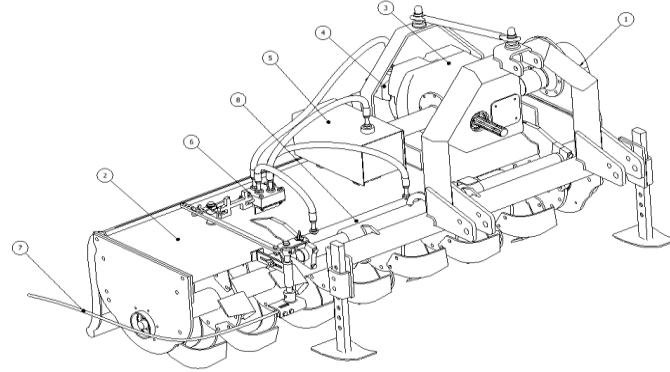


Figure 1. Different components of modified offset rotavator
1. Secondary transmission system, 2. Frame, 3. Primary transmission system,
4. Hydraulic pump, 5. Oil tank, 6. Control valves, 7. Sensing rod,
8. Double acting cylinder

Table 1. Data of different parameters observed in mango orchard

Orchard	Plant girth [m]	Plant canopy [m]	Heading height of branches from ground [m]
Mango	0.92	4.82	1.72
	0.90	4.52	1.45
	0.93	4.95	1.53
	0.95	5.05	1.86
	0.98	4.74	1.97
Average	0.94	4.82	1.71

An experimental plot was selected for mango orchard having 6000 m² area and it was divided into subplots of the size of 15×30 m². 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

Effect of λ -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 mango field. Tab. 2 represents the draft required at different λ -ratios and depth of cut. The relation of λ -ratio and depth of cut with draft was shown in Fig 2. The

draft at forward speed 2.0 km/h (7 λ - ratio) and depth 80 mm was observed 1086.8 N. With an increase in forward speed to 2.5 km/h (5 λ - ratio) and depth 100 mm, then draft was observed 1321.0 N and further increase in forward speed 3.0 km/h (4 λ - ratio) and depth 120 mm, the draft was observed 1651.3 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.

Table 2. Effect of λ - ratio and depth of cut on draft (N) requirement of a modified offset rotavator under mango orchard

Experiment no.	λ - ratio	Depth of cut [mm]	Average of draft [N]
1	4	80	1350.4
2	4	100	1520.9
3	4	120	1651.3
4	5	80	1178.9
5	5	100	1321.0
6	5	120	1457.2
7	7	80	1086.8
8	7	100	1201.5
9	7	120	1337.7

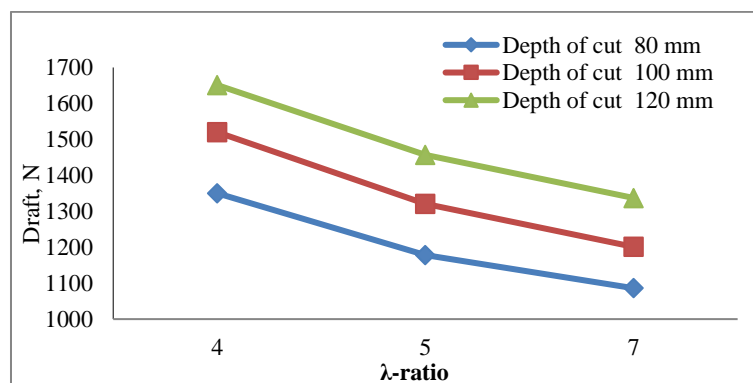


Figure 2. Effect of different λ - ratio and depth of cut on draft requirement for mango orchard

Effect of λ - 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 different orchards field at different λ - ratio and depth of cut is presented in the Tab. 3. The relation of λ - ratio and depth of cut on the fuel consumption for mango orchards is shown in Fig. 3. The fuel

consumption at forward speed 2.0 km/h (7 λ - ratio) and depth of cut 80 mm was observed 3.84 l/h. When increase in forward speed 2.5 km/h (5 λ - ratio) and depth 100 mm, then fuel consumption was observed 7.3 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 9.40 l/h. The results show that, as increase in forward speed with depth of operation, the fuel 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 result indicated, that orchards field, λ - ratio and depth of cut have significant effect on the fuel consumption at 5% of significance.

Table 3. Effect of λ -ratio and depth of cut on fuel consumption for modified offset rotavator under mango orchard

Experiment no.	λ - ratio	Depth of cut [mm]	Average of fuel consumption [l/h]
1	4	80	7.20
2	4	100	8.47
3	4	120	9.40
4	5	80	6.14
5	5	100	7.3
6	5	120	8.0
7	7	80	3.84
8	7	100	4.46
9	7	120	5.87

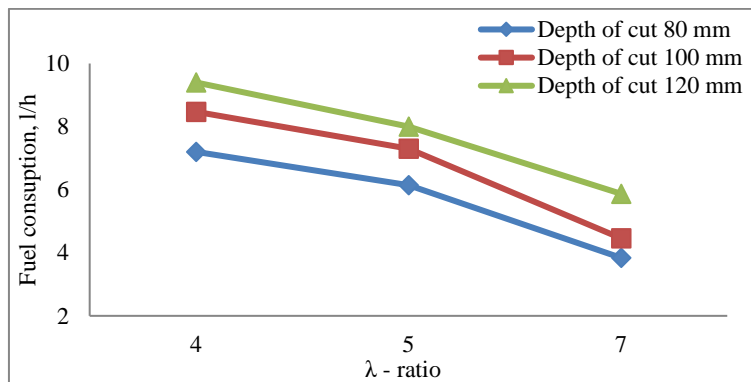


Figure 3. Effect of different λ - ratio and depth of cut on fuel consumption for mango orchard

Effect of different λ - 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 mango orchard. Mean mass diameter during the experiment for mango orchard at different λ - ratio and depth of cut are presented in the Tab. 4. The variation in the mean mass diameter due to the effect of λ - ratio and depth of cut for mango orchards is shown

in Fig 4. The mean mass diameter at forward speed 2.0 km/h (7 λ – ratio) and depth 80 mm was observed 1.21 mm. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then mean mass diameter was observed 1.76 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 2.20 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 decreases. 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 4. Effect of λ -ratio and depth of cut on mean mass diameter, (mm) under mango orchard

Experiment no.	λ - ratio	Depth of cut [mm]	Average of mean mass diameter [mm]
1	4	80	1.72
2	4	100	2.08
3	4	120	2.20
4	5	80	1.53
5	5	100	1.76
6	5	120	1.98
7	7	80	1.21
8	7	100	1.54
9	7	120	1.86

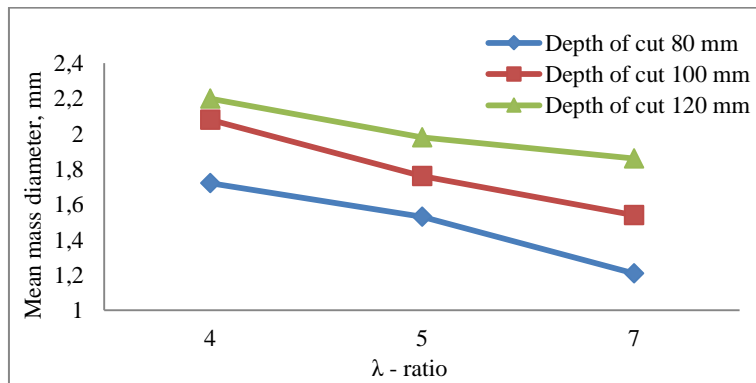


Figure 4. Effect of different λ – ratio and depth of cut on mean mass diameter for mango orchard

Effect of different λ – 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 mango orchard. The Residue incorporation, during the experiment for mango orchard field at different λ – ratio and depth of cut is presented in the Tab. 5. The variation in the residue incorporation due to the effect of λ – ratio and depth of cut for mango orchards is shown in Fig. 5. The residue incorporation at forward speed 2.0 km/h (7 λ – ratio) and

depth 80 mm was observed 93.50 percent. When increase in forward speed 2.5 km/h (5 λ – ratio) and depth 100 mm, then residue incorporation was observed 93.64 percent and further increase in forward speed 3.0 km/h (4 λ – ratio) and depth of cut 120 mm, the residue incorporation was observed 93.35 percent. It was observed that, as increase in forward speed then residue incorporation decreases. This may due when forward speed increase then blade impact forces on the soil also decreases 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%.

Table 5. Effect of λ -ratio and depth of cut on residue incorporation, (%) for modified offset rotavator under mango orchard

Experiment no.	λ - ratio	Depth of cut [mm]	Average of residue incorporation [%]
1	4	80	90.43
2	4	100	92.56
3	4	120	93.35
4	5	80	92.27
5	5	100	93.64
6	5	120	94.70
7	7	80	93.50
8	7	100	95.78
9	7	120	96.68

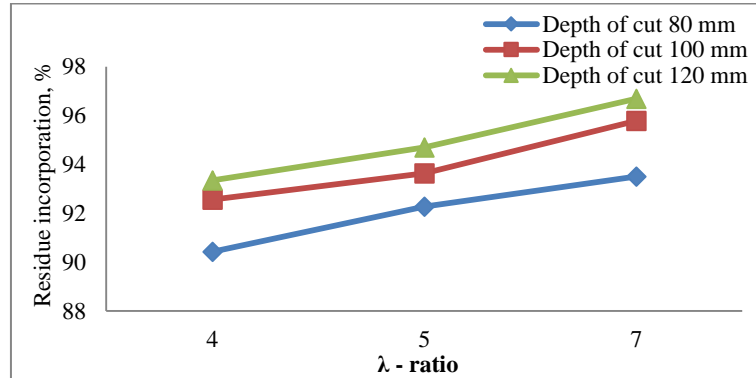


Figure 5. Effect of different λ – ratio and depth of cut on residue incorporation for mango orchard

Effect of λ – ratio on field performance index. Field performance index during experiment for mango orchard at different λ – ratio is presented in the Tab. 6. The variation in the field performance index due to λ – ratio for mango orchard is shown in Fig. 6. The field performance index at forward speed 2.0 km/h (7 λ – ratio) was observed 79.32 percent. When increase in forward speed 2.5 km/h (5 λ – ratio), then field performance index was observed 83.47 percent and further increase in forward speed 3.0 km/h (4 λ – ratio), the field performance index was observed 89.54 percent. The result

shows that, when forward speed increases then field performance index increases 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.

Table 6. Effect of λ -ratio on field performance index (%) under mango orchard

Experiment no.	λ -ratio	Average of field performance index [%]
1	4	89.54
2	5	83.47
3	7	79.32

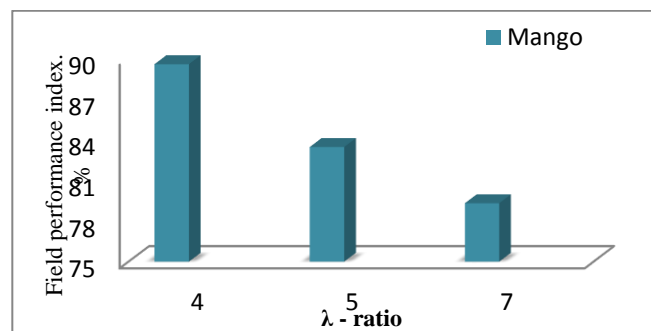


Figure 6. Effect of different λ -ratio on field performance index for mango orchard

Table 7. Effect of girth on area uncovered near the girth (m^2) under mango orchard

Experiment no.	Orchard girth, m	Average uncovered area near the girth (m^2)
1	0.92	0.076
2	0.90	0.078
3	0.93	0.071

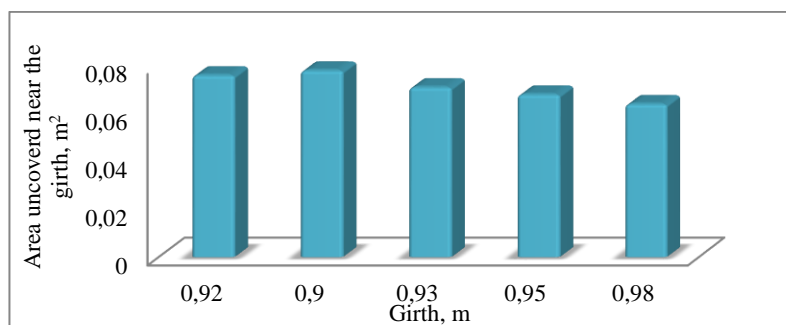


Figure 7. Effect of girth on area uncovered near the girth for mango orchard

Effect of girth on area uncovered near the girth. The Area uncovered near the girth corresponding to girth is presented in Tab. 7. The variation in the area uncovered near

the girth for mango orchard shown in Fig. 7. The area uncovered near the girth at 0.90 m girth was observed 0.078 m². When increase in girth at 0.92 m, then area uncovered near the girth was observed 0.076 m² and further increase in girth at 0.93 m, the area uncovered near the girth was observed 0.071 m². The result shows, that as increase in girth of mango orchard, the area uncovered near the girth decreases 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 increases then the area uncovered near the girth decreases and vice versa. The statistical analysis (ANOVA) shows that, girth had significant effect on the area uncovered near the girth at 5% level.

CONCLUSIONS

1. The maximum draft requirement in mango orchard was found 1651.3 N at a λ - ratio of 4 and depth of cut 120 mm. For same field, minimum draft in mango field was found 1086.8 N at λ - ratio of 7 and depth of cut 80 mm and fuel consumption was ranges 9.40-3.84 l/h. The maximum mean mass diameter for mango orchard was recorded to be 2.20 mm at a λ - ratio of 4 and depth of cut 120 mm. The excess residue incorporation for mango orchard was found to be 96.68 % at λ - ratio of 7 and depth of cut 120 mm.
2. The maximum field performance index for mango was found to be 89.54 % at λ -ratio while minimum field performance index were found to be 79.32 % at λ -ratio 7.
3. The maximum uncovered area near the girth for mango orchard was found to be 0.78 m² at 0.90 m girth and minimum uncovered area near the girth was found to be 0.64 m² at 0.98 m girth whereas maximum plant injury was found to be 83.3 percent at λ -ratio of 4 and minimum plant injury was found to be 16.6 %.

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ISPITIVANJE PERFORMANSI MODIFIKOVANOG ROTAVATORA U VOĆNJAKU

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Sažetak: Rotacioni priključci za obradu zemljišta su važne mašine za pripremu setvene posteljice. Uobičajeni zadnji rotavator u liniji sa centralnom osom traktora ne može da se koristi u voćnjacima zbog rastojanje stabala u redu. Zato je ponuđeno rešenje modifikovanog rotavatora za obradu prostora u redu. Istraživanje je izvedeno radi ocene performansi ovog modifikovanog rešenja. Utvrđeno je da se otpor kod L noževa povećao (od 1086.8 na 1651.3 N) sa povećanjem radne brzine (od 2.0 na 3.0 km/h) i povećanjem dubine (od 80 na 120 mm) sa spuštenim štittom i i povećanom potrošnjom goriva od 9.40 l/h pri brzini od 3.0 km/h.

Ključne reči: obrada, modifikivani rotavator, radne karakteristike, voćnjak

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