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Effect of λ – Ratio and Depth of Cut on Draft, Fuel Consumption, Power Consumption and Field Efficiency of an Offset Rotavator under Different Type of Orchards

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Authors' contributions

This work was carried out in collaboration between all authors. Author RP designed the study, performed the statistical analysis, wrote the protocol. Author JPB wrote the first draft of the manuscript and managed the analyses of the study. Author SC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Rotary tillage implements are now being projected as important rotary tools that result in production of fine tilth soil however the rotavator being in line with the tractor at the back cannot be used in orchards due to the hindrance posed by narrow space between the trees. Hence there is need of some tillage tool in offset to the central line of tractor so that it can reach to the area under the tree with the tractor placed in between the rows. In the offset working condition (offset rotavator) the rotary tillage unit can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height. The study was undertaken to examine the influence of λ – ratio, depth of cut at different orchards fields such as mango, guava, and Sapota with dependent parameters such as draft, fuel consumption, power consumption and field

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efficiency by an offset rotavator. In this paper the results indicated that as the λ – ratio and depth of cut increases the value of draft, fuel consumption, power consumption also increase.

Keywords: λ – Ratio; depth of cut; offset rotavator; types of orchards.

1. INTRODUCTION

Approximately 20 percent of energy for production agriculture is used for field operations, with a majority of this energy applied toward tillage operations [1]. Nearly the conventional tillage implements are passive tillage implements for soil- implement interface. The power for these implements is supplied by the tractor through soil-type interface. Only about 40-56 percent of net engine power is available at the drawbar of a tractor when transmitting power through the soil-type interface, whereas it about 80-85 percent for PTO driven active tillage tools [2]. Poor transmission efficiency, mainly due to high wheel, slippage at the soil-tyre interface, reduces the tillage implements. Conventional tillage is an energy intensive method and there is a need for implements, which should ensure timeliness of field operations, besides being cost and energy effective. Transmission of power to the soil engaging tools through PTO of tractor reduces inefficiency of soil-tyre interface. The PTO driven tools transmit power directly to the soil rather than being pulled through it. These implements are more effective in soil pulverization, cutting ability and require less draft. The soils with moderate hardness can be prepared more rapidly by rotary powered implements. These implements can play an important role in multiple cropping systems where time is the main constraint for land preparation. Rotavator tools 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 [3]. A rotary tiller is a type of motorized cultivating equipment that breaks or works the soil with the aid of rotating blades [4]. It saved 30-35% of time and 20-25% in the cost of operation as compared to tillage by cultivator and gave higher quality of work (25-30%) than tillage by cultivator [5]. This allows the farmer to increase his farm acreage which becomes less dependent on hired farm labor, performs operations more timely and obtains higher yields [6,7,8]. The tractor power through non-reactive means could reduce draft requirements, the tractor could be made lighter which would reduce its cost and soil compaction. It has been found that the degree of soil pulverization attained by the rotavator is comparable with the use of a mould board plough, and harrow (twice) and spiked tooth harrow [9]. Energy required per unit volume of soil for rotavator is only 39.2-47.0 MJ/m3 as compared to 70.7-116.3 MJ/m3, 62.2-103 MJ/m3, 53.3-110.2 and MJ/m3 in MB plough desi plough cultivator respectively. The farmers are increasingly accepting rotavators for high degree of pulverization [10].

Rotary tillage implements are now being projected as important tools in production of fine tilth soil; however the rotavator being in line with the tractor at the back cannot be used in orchards due to the hindrance posed by narrow space between the orchards. Hence there is need of some tillage tool in offset model to central line of tractor so that it can reach canopy of orchards with the tractor in between rows. Offset rotavators have been found to be the most suitable for this purpose. An important feature of this rotary tillage tool is the side shift system, based on a hydraulic cylinder, activated from the tractor cabin, adjusts the offset working position quickly and without any effort. The side-shift rotary tiller is used mainly for tilling in vineyards and orchards and generally in row crops which require a working element which can be offset adjusted hydraulically through the tractor hydraulic device with allows an adjustable offset of about 30-50 cm.

In the offset working condition (offset rotavator) the rotary tillage unit can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height. The offset rotavator under study was imported and need to be evaluated on case to case basis to find their suitability under Indian conditions and also promote domestic manufacturing of these offset rotavator.

2. METHODOLOGY

The field experiment was carried out in the sandy clay loam soil at Horticultural Research Center, Patthar chathah, G.B. Pant University of Agriculture and Technology Pantnagar, (U.S. Nagar) Uttarakhand, during the year 2011- 2012.

The study was undertaken to examine the influence of λ – ratio and depth of cut on different parameters of an offset rotavator. During the experiment the performance of an offset rotavator at the three different orchards fields of mango, guava and Sapota were selected. A view of working operation of an offset rotavator in Orchard field is given in Fig. 1. The different dependent parameters (variable being tested and measured in an experiment) determined during the experiment were fuel consumption, draft measurement, power consumption were measured to assess the suitability of off-set rotavator in India. The independent parameter (can be changed or controlled in an experiment to test the effects on the dependent variable.) selected in the experiment was depth of cut λ – ratio and different orchards fields. The result obtained during the course of study were analyzed statistically by using the three factorial design, (RBD) randomized block design. It is powered by the power takeoff has mechanical transmission. The rotary tine set are built in three working sizes; five- flange set (55 cm), six- flange set (70 cm) and seven- flange set (85 cm). There are three possible machine size determined by the extension from the center of the tractor to the tillers right-hand outer extremity that is 1.6, 2 and 2.20 m. The rotor is powered mechanically by the spiral bevel gearbox and internal cardan shaft the shifting movement that allows for the machine to avoid plant stocks is provided by a parallel arm system supported by ball bearing, and the necessary drive is guaranteed by the independent oil hydraulic system.

3. RESULTS AND DISCUSSION

The results obtained during the course of study were analyzed statistically by using the three factorial designs (RBD). The statically analysis (ANOVA) gave different tables indicated that orchard field, λ – ratio and depth of cut have significant effect on the draft, fuel consumption, power consumption and field efficiency at 5% level of significance.

3.1 Effect of λ – ratio and Depth of Cut on the Draft

Table 1 presents the draft required at different λ – ratios and depth of cut. The maximum draft in mango, guava and Sapota orchard were found to be 115.45, 117.25 and 121.12 kgf at a λ – ratio of 2.8 and depth of cut 12 cm respectively. The minimum draft in mango, guava and Sapota orchard were found to be 74.36, 49.93 and 85.45 kgf at λ – ratio of 2.1 and depth of cut 5 cm respectively.

Fig. 1. A view of working operation of an offset rotavator in Orchard field

In general it was found that the λ – ratio increases draft will also increases. This was because of the reason as the λ – ratio increases efficiency of rotavator also increase which lead to increases in draft.

3.2 Effect of λ – ratio and Depth of Cut on the Fuel Consumption

The fuel consumption (l/h) during the experiment for different orchards field at different λ – ratio and depth of cut are presented in Table 2. The maximum fuel consumption for mango, guava and Sapota orchards were found to be 4.27 l/h at a λ – ratio of 2.8 and depth of cut 12 cm, 4.55 l/h. at λ – ratio of 2.1 and depth of cut 12 cm, 5.46 l/h. at λ – ratio of 1.3 and depth of cut 12 cm respectively. The minimum fuel consumption for mango, guava and sapota orchards were found to be 3.23 l/h at λ – ratio 1.3 and depth 5 cm, 3.86 l/h at λ – ratio 2.1 and depth 5 cm and 3.87 l/h at λ – ratio 1.3 and depth 5 cm respectively. The results show that the increases in depth of cut were also found to cause in increasing the draft requirement increase fuel consumption by the offset rotavator.

3.3 Effect of λ-ratio and Depth of Cut on the Power Consumption (kW) by an Offset Rotavator

The offset rotavator required the power during the experiment for different orchards field at different λ – ratio and depth of cut are presented in Table 3. The maximum power consumption for mango, guava and Sapota orchards were found to be 6, 6.22 and 6.66 kW at λ – ratio of 2.8 and depth of cut 5 cm respectively. For the same field condition the minimum power consumption for mango, guava and Sapota orchards were found to be 2.65, 2.68 and 3.19 kW at λ – ratio 1.3 and depth 5 cm respectively. In general as the λ – ratio increase the power consumption by offset rotavator also increase.

Table 1. Effect of λ-ratio and depth of cut on draft (Kgf) requirement by an offset rotavator under different orchards

Experiment no.	Orchards field	λ -Ratio	Depth of cut	Average value of Draft (Kgf)
1	F_1	λ_1	D_1	74.36
2	F_1	λ_1	D_2	79.0
3	F_1	λ_1	D_3	95.2
4	F_1	λ_2	D_1	75.5
5	F_1	λ_2	D_2	80.14
6	F_1	λ_2	D_3	105.0
7	F_1	λ_3	D_1	95.25
8	F_1	λ_3	D_2	110.60
9	F_1	λ_3	D_3	115.45
10	F_2	λ_1	D_1	49.93
11	F_2	λ_1	D_2	81.73
12	F_2	λ_1	D_3	95.63
13	F_2	λ_2	D_1	85.33
14	F_2	λ_2	D_2	97.12
15	F_2	λ_2	D_3	115.15
16	F_2	λ_3	D_1	90.43
17	F_2	λ_3	D_2	98.13
18	F_2	λ_3	D_3	117.25
19	F_3	λ_1	D_1	85.45
20	F_3	λ_1	D_2	89.13
21	F_3	λ_1	D_3	100.30
22	F_3	λ_2	D_1	88.55
23	F_3	λ_2	D_2	90.12
24	F_3	λ_2	D_3	114.5
25	F_3	λ_3	D_1	97.10
26	F_3	λ_3	D_2	119.15
27	F_3	λ_3	D_3	121.12

Where

F_1 = Mango orchards | F_2 = Guava orchards | F_3 = Sapota orchards

D_1 = 5.0cm | D_2 = 8cm | D_3 = 12cm

λ_1 = 1.3 | λ_2 = 2.1 | λ_3 = 2.8

3.4 Field Efficiency of an Offset Rotavator for Different Orchards

Field efficiency during experiment for different orchards field at different λ – ratio and depth of cut is presented in Table 4. The maximum field efficiency in mango orchards was found to be 98.09% at λ – ratio of 2.1 and depth of cut 5 cm. For the same condition the minimum field efficiency was found to be 89.22% at λ – ratio 1.3 and depth 5 cm. The maximum field efficiency in guava orchards was found to be 96.32% at λ – ratio of 2.1 and depth of cut 8 cm. For the same orchard the minimum field efficiency was found to be 86.98% λ – ratio 1.3 and depth of 8cm. The maximum field efficiency in Sapota orchards was found 96.82% at λ – ratio of 1.3 and depth of cut 12 cm. For the same condition the minimum field efficiency was found to be 85.07% at a λ – ratio 1.3 and depth 5 cm.

Table 2. Effect of λ-ratio, depth of cut, on fuel consumption for offset rotavator under different orchard

Experiment no.	Orchards field	λ- Ratio	Depth of cut	Average value of fuel consumption
1	F_1	λ_1	D_1	3.23
2	F_1	λ_1	D_2	3.42
3	F_1	λ_1	D_3	4.08
4	F_1	λ_2	D_1	3.28
5	F_1	λ_2	D_2	3.47
6	F_1	λ_2	D_3	4.19
7	F_1	λ_3	D_1	4.01
8	F_1	λ_3	D_2	3.90
9	F_1	λ_3	D_3	4.27
10	F_2	λ_1	D_1	3.26
11	F_2	λ_1	D_2	3.97
12	F_2	λ_1	D_3	4.17
13	F_2	λ_2	D_1	3.84
14	F_2	λ_2	D_2	4.35
15	F_2	λ_2	D_3	4.35
16	F_2	λ_3	D_1	3.95
17	F_2	λ_3	D_2	4.5
18	F_2	λ_3	D_3	4.55
19	F_3	λ_1	D_1	3.87
20	F_3	λ_1	D_2	4.48
21	F_3	λ_1	D_3	4.15
22	F_3	λ_2	D_1	4.94
23	F_3	λ_2	D_2	4.98
24	F_3	λ_2	D_3	5.26
25	F_3	λ_3	D_1	5.15
26	F_3	λ_3	D_2	5.18
27	F_3	λ_3	D_3	5.46

Where

F_1 = Mango orchards	F_2 = Guava orchards	F_3 = Sapota orchards
D_1 = 5.0cm	D_2 = 8cm	D_3 = 12cm
λ_1 = 1.3	λ_2 = 2.1	λ_3 = 2.8

Table 3. Effect of λ-ratio and depth of cut, on power consumption kW under different orchards fields

Experiment no.	Orchards field	λ- ratio	Depth of cut	Average value of power consumption, (kW)
	F_1	λ_1	D_1	2.65
2	F_1	λ_1	D_2	2.74
3	F_1	λ_1	D_3	3.02
4	F_1	λ_2	D_1	3.75
5	F_1	λ_2	D_2	3.84
6	F_1	λ_2	D_3	3.98
7	F_1	λ_3	D_1	5.46

Experiment no.	Orchards field	λ- ratio	Depth of cut	Average value of power consumption, (kW)
8	F_1	λ_3	D_2	5.73
9	F_1	λ_3	D_3	6.0
10	F_2	λ_1	D_1	2.68
11	F_2	λ_1	D_2	3.59
12	F_2	λ_1	D_3	2.52
13	F_2	λ_2	D_1	4.34
14	F_2	λ_2	D_2	4.42
15	F_2	λ_2	D_3	4.62
16	F_2	λ_3	D_1	5.70
17	F_2	λ_3	D_2	5.92
18	F_2	λ_3	D_3	6.22
19	F_3	λ_1	D_1	3.99
20	F_3	λ_1	D_2	3.40
21	F_3	λ_1	D_3	3.74
22	F_3	λ_2	D_1	4.46
23	F_3	λ_2	D_2	4.76
24	F_3	λ_2	D_3	4.97
25	F_3	λ_3	D_1	6.10
26	F_3	λ_3	D_2	6.34
27	F_3	λ_3	D_3	6.66

Where

$F_1 =$ Mango orchards $F_2 =$ Guava orchards $F_3 =$ Sapota orchards
$D_1 = 5.0$cm $D_2 = 8$cm $D_3 = 12$cm
$\lambda_1 = 1.3$ $\lambda_2 = 2.1$ $\lambda_3 = 2.8$

Table. 4. Effect of λ -ratio and depth of cut, on field efficiency under different orchards

Experiment no.	Orchards field	λ- Ratio	Depth of cut	Average value of field efficiency (%)
1	F_1	λ_1	D_1	89.22
2	F_1	λ_1	D_2	89.83
3	F_1	λ_1	D_3	95.23
4	F_1	λ_2	D_1	98.09
5	F_1	λ_2	D_2	97.33
6	F_1	λ_2	D_3	95.61
7	F_1	λ_3	D_1	97.95
8	F_1	λ_3	D_2	95.09
9	F_1	λ_3	D_3	94.14
10	F_2	λ_1	D_1	90.63
11	F_2	λ_1	D_2	86.98
12	F_2	λ_1	D_3	92.37
13	F_2	λ_2	D_1	95.42
14	F_2	λ_2	D_2	96.32
15	F_2	λ_2	D_3	93.13
16	F_2	λ_3	D_1	96.32
17	F_2	λ_3	D_2	93.14
18	F_2	λ_3	D_3	89.01
19	F_3	λ_1	D_1	85.07
20	F_3	λ_1	D_2	91.62
21	F_3	λ_1	D_3	96.82
22	F_3	λ_2	D_1	91.61
23	F_3	λ_2	D_2	94.09
24	F_3	λ_2	D_3	91.42
25	F_3	λ_3	D_1	89.58
26	F_3	λ_3	D_2	93.19
27	F_3	λ_3	D_3	91.42

Where

$F_1 =$ Mango orchards $F_2 =$ Guava orchards $F_3 =$ Sapota orchards
$D_1 = 5.0$cm $D_2 = 8$cm $D_3 = 12$cm
$\lambda_1 = 1.3$ $\lambda_2 = 2.1$ $\lambda_3 = 2.8$

4. CONCLUSION

- Experimental results revealed that as the λ – ratio increases draft will also increase. The increase in depth of cut was also found to cause in increasing the draft.
- It was observed that as the λ – ratio increases the fuel consumption; power consumption and field efficiency also increase.
- Offset rotavators have been found to be the most suitable for tilling in vineyards and orchards and generally in row crops. It can easily reach the strip of soil under low trees and vegetation where tractors could not operate because of limited height. The offset rotavator need to be evaluated on case to case basis to find their suitability under Indian conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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