Economic Affairs, Vol. 67, No. 04, pp. 415-421, September 2022
DOI: 10.46852/0424-2513.4.2022.6

AESSRA

Research Paper

Field Evaluation and Economic Analysis of Manual Drawn Rotor Weeder for Small Farms

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Received: 02-04-2022 **Revised:** 27-07-2022 **Accepted:** 05-09-2022

ABSTRACT

A manual method of weeding operation is drudgeries, labour intensive and very high costlier operation, farmer usually spent 30 to 40 percent cost on weeding of entire crop production. The objective of the research work is to study the field evaluation and economic analysis of manual drawn rotor weeder for small agricultural farms. The following parameters viz., weeding efficiency, plant damage, field efficiency, cost of operation, breakeven point, payback period and benefit-cost ratio were evaluated and compared with manual method of weeding operation. The performance evaluation of manual drawn rotor weeder was carried out with three speed ratios i.e., 1:1, 1:2 and 1:3 among which 1:2 ratio was found to be best gear ratio. The range of weeding efficiency, plant damage and field efficiency were reported as 68 to 82%, 1 to 3% and 61 to 84, respectively. The obtained cost of mechanical weeder can save cost up to 77 percent as compared manual method. The estimated breakeven point was estimated based on time and area for manual drawn weeder can save 76.45 h and 1.44 ha duly. The estimated payback period was found to be 1 year. The total cost spent in development of manual drawn weeder was noted as ₹ 4780/- The obtained B-C ratio was found to be 3:1.

HIGHLIGHTS

- The total cost spent in development of manual drawn rotor weeder was only ₹ 4780.
- The benefit cost ratio for manual drawn rotor weeder was 3:1.
- The payback period estimated for manual rotor weeder was 1 year.

Keywords: Manual rotor weeder, Weeding efficiency, Break-even point, Payback period and B-C ratio

Weeding is labour-intensive operation in agricultural crop production. Weeding operation accounts about 25% of total labour required typically spent 900 to1200 man hours per hectare during a cultivation season (Kumar *et al.* 2014 and Yadav and Pund, 2007). In Indian agriculture the farm power availability from human sources was noted as 0.091 kW/ha in 2016-17 and from draught animals the power availability has raised from 0.221 kW/ha in 1971-72 to 0.130 kW/ha in 2016-17 (Mehta *et al.* 2019). The overall average farm power availability from all the sources in India has increased from around 0.30 kW/ha in 1960-61 to about 2.02 kW/ha in 2013-14 (Surendra Singh *et al.* 2014). The wages for an agricultural worker, and draught animal are increasing and their availability is decreasing in the present scenario. These trends recommend to adopt more mechanization in the field of agriculture.

How to cite this article: Rahaman, S., Ramana, C., Rao, A.S. and Reddy, B.R. (2022). Field Evaluation and Economic Analysis of Manual Drawn Rotor Weeder for Small Farms. *Econ. Aff.*, **67**(04): 415-421.

Source of Support: None; **Conflict of Interest:** None

Weeding operation is done 2 to 3 times in crop production depending on the weed infestations and type of crop. The manual method of weeding operation cost around 4000 to 6000 ₹/ha depends on the location. Timely weeding completion helps in proper vegetative crop development and increases crop productivity.

The agricultural farm holdings are small and fragmented in the context of the Indian scenario i.e., about 80% of land holdings were below 2-hectare area which comes under small to marginal land holding. Present existing weeders are higher capacity and high initial investment, small and medium-sized farms could not afford to utilize them (Mishra *et al.* 2017). Agriculture is one of the most significant sectors of the Indian economy. The population of India is 1.39 billion in 2021 and the National Commission on Population Government of India has estimated, an increase in population of 1.807 billion by end of 2050 (Anonymous 2021). Hence, it is required to produce more food to meet the needs of growing population. This can be achieved only either increasing the land under cultivation or by adopting the farming techniques which would increase the crop yields.

Mechanical weed control is very effective as it helps to reduce drudgery involved in the manual weeding and ensures a comfortable posture of the farmer or operator during weeding. Weeder is a mechanical device which destroys the weeds from an agricultural land by partially or completely uprooting and burying the weeds into the soil. Mechanical weeders range from basic hand tools to sophisticated tractor driven and self-propelled machines. Traditional methods are costly and time-consuming operations, on the other hand bullock drawn implements have certain drawbacks like low field capacity and high maintenance cost therefore not affordable to the farmers. In this view, manually operated weeding equipment is better option due to its medium cost and small size implying better maneuverability in the small land holdings. Considering all these factors in view, a manually drawn rotor weeder has been developed and evaluated in maize crop, it performs inter-cultivation in between rows. The timely weeding operation helps in energy and time saving (Rawat *et al.* 2007 and Mynavathi *et al.* 2015). Considering all the importance, the present study was conducted with the intention for field evaluation and economic analysis of mechanical weeder to test its economic feasibility for small agriculture farms.

MATERIALS AND METHODS

Development of manual drawn rotor weeder

The development of manual rotor weeder is carried at College of Agricultural Engineering, Madakasira. The following components are used for development of manual drawn rotor weeder are rotor, shaft, bush, sprockets and chain, frame, and handle. Performance evaluation of developed implement was conducted through field experiments in maize crop at 30 and 60 DAS (days after sowing) by using standard test procedures. Experiments were conducted in field by recommended range of human walking speed i.e., usually 1 km/h (Nkakini and Hussenib, 2015, and Kachhot *et al.* 2020). For optimization of manually drawn rotor weeder, the three speed rations were selected such as 1:1, 1:2 and 1:3 with different sizes of sprockets. One among three speed ratios have selected based on field evaluation parameters i.e., weeding efficiency, plant damage and field efficiency.

Field evaluation parameters of manual drawn rotor weeder

Weeding efficiency

Weeding efficiency (Σ) is ratio of number weeds before operation to number of weeds after operation, a 1 m × 1 m plot selected to counting number of weeds per square meter area. The weeding efficiency was calculated by using Eq. 1. (Shekhar *et al.* 2010).

$$\text{Weeding efficiency (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \qquad \ldots(1)$$

Where, W_1 = Number of weeds before weeding operation and

W_2 = Number of weeds after weeding operation.

Plant damage

Plant damage (P_d) is estimated by counting number of injured plants before and after the operation in a sample plot. The plant damage was calculated by using Eq. 2. (Yadav and Pund, 2007).

$$\text{Plant damage (\%)} = \left\{1-\left(\frac{q}{p}\right)\right\}\times 100 \quad \ldots(2)$$

Where, q = Number of plants in a 10 m row length after the operation and

p = Number of plants in a 10 m row length before the operation.

Field efficiency

Field efficiency (F_e) defined as ratio of effective to theoretical field capacity and expressed as a percentage. It was calculated using Eq. 3. (Nagesh *et al.* 2014).

$$\text{Field efficiency (\%)} = \frac{E.F.C}{T.F.C}\times 100 \quad \ldots(3)$$

Where, $E.F.C$ = Effective field capacity, ha/h and $T.F.C$ = Theoretical field capacity, ha/h.

Theoretical field capacity is calculated by using Eq. 4. (Patange *et al*. 2015).

$$TFC\left(ha/h\right) = \frac{S\times W}{10} \quad \ldots(4)$$

Where, S = Forward speed, km/h and W = Width of the implement, m

Effective field capacity is usually expressed as hectare per hour and It is estimated by using Eq.5. (Manjunatha *et al.* 2014).

$$EFC\left(ha/h\right) = \frac{A}{T_P + T_{NP}} \quad \ldots(5)$$

Where, A = Area of coverage, ha T_P = Productive time, h and T_{NP} = Non-productive time, h.

Economic evaluation of manual drawn rotor weeder

Cost of operation of the developed manual drawn rotor weeder was estimated by using following economics parameters. Annual use of implement was considered as 350 h. Total operation cost of implement was estimated on per hour basis considering both fixed and variable costs. Fixed cost includes depreciation and interest on capital assets, insurance, taxes and housing, the formulas was given in Table 1. The expenditure on repair, maintenance, and wages, formulas was given in Table 2. The operating cost was converted into area basis and multiplied with effective field capacity of implement. The production cost of manual drawn rotor weeder was the sum of cost of materials used and cost of labour used for fabrication works. The break-even point was calculated area wise as well as time wise, payback period and benefit cost ratio were also calculated as per standard cost estimation methods (ISI, 9164: 1979).

Table 1: Formulas used for calculation of fixed cost

Fixed cost		
Depreciation (D), (₹/h)	$=\frac{C-S}{L\times H}$	Where, D = Depreciation (₹/h) C = Capital cost (₹) S = Salvage Value (₹) L = Useful implement life (year) H = Operating hours per year
Interest per hour I, (₹/h)	$=\frac{C+S}{2}\times\frac{i}{H}$	
Taxes, housing & insurance per hour, (₹/h)	= 2.5 % of Capital cost	S = 10 % of Capital cost Interest (i)= 10 %

Table 2: Formulas used for calculation of variable cost

Variable cost	
Repair & maintenance, (₹/h)	= 2.5 % of Capital cost
Wages of driver, (₹/h)	= 200 ₹/day of 8 h

Depreciation is the largest component of any implements total cost. It measures the amount, by which the value of an implement decreases on-time passage, whether an implement is used or not (Hunt, 2001 and Pagare *et al.* 2019). By using above formulas, the cost estimations of developed manual rotor weeder was estimated.

Breakeven point

Breakeven analysis, also called a point of no profit-, no loss, which were performed to assess the duration of work at a given price that is necessary to meet all the costs or expenditures. The breakeven point is the intersection of the lines at which the line of total cost and the line of custom hiring cost intersect each other. The breakeven point is calculated by the following formula given by (Haquel *et al.* 2014 and Alam *et al*. 2018).

$$BEP = \frac{FC}{CH - C} \quad \ldots(6)$$

Where,

BEP = Breakeven point, (h/ year),

FC = Annual fixed cost, (₹/year),

C = Operating cost, (₹/h), and

CH = Custom hiring charges, (₹/h)

= (C+25 per cent overhead) +25 per cent profit over new cost

Payback period

It is the time required for an investment to earn annual cash returns equal to its original cost. Generally, it is expressed in years for farm implements and machinery or the amount of time needed to recover the project's investment. It is calculated based on the following equation given by (Singh *et al.* 2014).

$$PBP = \frac{IC}{ANP} \quad \ldots(7)$$

Where

PBP = Payback period, (year),

IC = Initial cost of implement, (in ₹), and

ANP = Average net annual profit, (₹/year),

$$= (CH - C) \times AU$$

Where, *AU* = Annually used in hours.

Benefit Cost ratio (B-C ratio)

The ratio of gross income to gross expenditure. A project investment must have a benefit cost ratio of unity or above to be considered profitable. The ratio of unity denotes complete cost coverage with no excess profit. However, in order to provide some additional return over the costs for a clear decision, the ratio typically needs to be more than unity. It is estimated by the following formula given by (Acharya *et al.* 2020).

B-C ratio =

$$\frac{\text{Gross income with use of implement}}{\text{Total ecpenditure with use of implement}} \quad \ldots(8)$$

RESULTS AND DISCUSSION

Performance evaluation of manual drawn rotor weeder

The high weeding efficiency (Table 3.) was found as 81.93% with 1:2 gear ratio. Almost negligible plant damage was reported with gear ratios, however the plant damage reported high with 1:3 gear ratio as 2.38%. The high field efficiency was found with 1:2 gear ratio as 83.92% followed by 78.86% and 60.36% with 1:1.5 and 1:3 gear ratios. From the above performance evaluation of manually operated rotor weeder the best gear ratio was found to be 1:2. From testing and evaluation of implement in field conditions, the field capacity of developed implement was obtained 0.0188 ha/h. Depth of weeding ranged from 1 to 2 cm. Weeding efficiency, plant damage and field efficiency of developed implement were ranged 68 to 82%, 1 to 3% and 61 to 84 respectively.

Table 3: Field evaluation of manual drawn rotor weeder with different gear ratios

Gear ratios	Weeding efficiency *	Plant damage*	Field efficiency*
1:1.5	68.92[b]	1.666[a]	78.86[a]
1:2	81.93[a]	0.960[a]	83.92[a]
1:3	75.47[a]	2.38[a]	60.36[b]
CD	4.5366	NS	8.84799
CV	5.3738	13.8844	10.677
SD	4.07±0.009	2.87±0.788	7.94±0.013

** There is no significant difference between treatments with similar letters in column.*

Cost economics of manual drawn rotor weeder

Life and annual utility of implement were taken as 5 years and 350 hours per year, respectively. The fixed and variable cost of manual drawn rotor weeder was ₹ 1242.5 per year and 25.34 ₹/h. The total operating cost of manual drawn rotor weeder was calculated as 28.89 ₹/h. But in existing manual methods it requires 6805.36 ₹/ha for completion of weeding operation, with that of manual drawn rotor weeder it requires only 1536.66 ₹/ha to complete the weeding operation in hectare land. Fixed, variable cost values, cost of existed method and some other economic aspects of manual drawn rotor weeder are presented in Table 4.

Table 4: Different economical aspects of manual drawn rotor weeder

Sl. No.	Economical aspect	Value
1	Total fixed cost per year, ₹	1242.5
2	Total variable cost, ₹/h	25.34
3	Custom hiring cost in existed method of cultivation, ₹/ha	6805.36
4	Custom hiring cost in existed method of cultivation, ₹/h	25
5	Total operating cost, ₹/h	28.89
6	Total operating cost, ₹/ha	1536.66
7	Total area covered per year, ha	6.58
8	Cost saving over existed methods, ₹/ha	5268.70
9	Cost saving (%)	77
10	Breakeven point, h/year	76.45
11	Breakeven point, ha/year	1.437
12	Payback period, years	1

Estimation of breakeven point

Break-even point was determined by plotting the total cost (annual operating cost) and custom hiring cost against the usage of the implement shown in Fig. 1.

Fig. 1: Breakeven point representation for manual drawn rotor weeder

If the breakeven point value is less than the annual utility time of implement, then the farmer benefitted by owning an implement. If the breakeven point value is found more than the annual utility time of implement then owning implement can lead to a loss for the farmer, at that time going for custom hiring is the better option for farmer. The location of the intersecting point made by the two cost lines gives the number of hours of work required for break-even. Below picture "y = 25.34x + 1242.5" is the line of the total operating cost and "y = 45.14x" is the line of total custom hiring cost (existed method). In both, the lines "x" indicates the number of operating hours of implement. From the graphical representation breakeven point of the implement was calculated as 76.45 hours per year.

Estimation of Payback period

The payback period for manual drawn rotor weeder was calculated based on initial cost of implement, average net annual profit and annual utility of implement. The annual utility is based on how many working days are available for a particular operation in a year. Annual utility of manual rotor weeder was considered as 350 hours. The obtained value of payback period for manual drawn rotor weeder was 0.840 years, which is approximately considered as 1 year. It indicates that within one year, a farmer can get back their investment on purchase of manual drawn rotor weeder.

Estimation of Benefit cost ratio

The benefit cost ratio for manual drawn rotor weeder was calculated based on gross income and total expenditure with use of implement. The obtained value of benefit cost ratio for manual drawn rotor weeder was 3:1 ratio, it indicates that, three times the benefit a farmer can get by adopting the developed manual rotor weeder.

CONCLUSION

The performance evaluation of manual drawn rotor weeder carried out with three speed ratios i.e., 1;1, 1:2 and 1:3 among which 1:2 ratios was found to be best gear ratio. The field evaluation parameters *viz.*, weeding efficiency, plant damage and field efficiency were ranges from 68 to 82%, 1 to 3% and 61 to 84, respectively. The break-even point calculated on the area and time basis for the rotor weeder was 1.44 ha and 76.45 h, respectively. The payback period calculated on a year basis for the rotor weeder was 1 year. The cost of operation done by the rotor weeder can save cost up to 77 percent respectively, as compared to the manual cost of weeding. The B-C ratio was found to be 3:1. The total amount farmers spend can return within one year. The developed technology was successfully implemented because of its low cost and simple in use.

ACKNOWLEDGEMENTS

Author(s) acknowledges the source of support from Department of Farm Machinery and Power Engineering, Dr. NTR College of Agricultural Engineering, Bapatla, and College of Agricultural Engineering, Madakasira, Acharya N.G. Ranga Agricultural University, Lam, Guntur.

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SUPPLEMENTARY DATA

1. Cost of operation of manual drawn weeder

Table 5: Calculation cost of manual drawn

Fixed cost calculation		
Depreciation (₹/h)	$= \frac{4780-478}{5\times350}$	= 2.46
Interest per hour, (₹/h)	$= \frac{4780+478}{2}\times\frac{0.10}{350}$	= 0.751
Taxes, housing & insurance (₹/h)	$= \frac{4780\times0.25}{350}$	= 0.3414
	Total fixed cost (₹/h)	= 3.55
	Total fixed cost (₹/y)	= 1242.5
Variable cost calculation		
Repair & maintenance, (₹/h)	$= \frac{4780\times0.55}{350}$	= 0.341
Wages of tractor driver, (₹/h)	= 200 ₹/day of 8 h	= 25
Total variable cost, (₹/h)		= 25.34
Total operating cost of Manual drawn weeder		= 28.89 (₹/h)

Cost involved in manual weeding

Manual hours required for weeding one hectare of crop = 272.22 h ha^{-1}

Wage rate of rupees 200 per man per day of 8 hours

The cost of manual weeding per ha, ₹ $= \frac{200}{8}\times200$ = 6805.36

The cost of Manual drawn rotor weeder

Effective field capacity of Manual drawn rotor weeder = 0.0188 ha/h

Work capacity of weeder (1/EFC) = 53.19 h/ha

Cost of operation per hour by developed weeder = 28.89 ₹/h

= 53.19 × 28.89

= 1536.659 ₹/ha.

Breakeven point calculation

Fixed cost = 1242.5 ₹/year

Variable cost = 28.89 ₹/year

Custom hiring charges of manual weeding = 28.89 ₹/h

CH = manual weeding cost × 25 % over total cost of operation

CH = (28.89 + (28.89 × 0.25)) × 1.25 = 45.1406

$$BEP = \frac{1242.5}{45.1406-28.89} = 76.45 h/year$$

Payback period calculation

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Average net annual benifit}}$$

Initial cost of developed rotor weeder implement, ₹ = 4780

Custom hiring charge (CHC), ₹/h = (25 per cent over total cost of operation ₹/h)

= CH = (28.89 + (28.89 x 0.25)) × 1.25 = 45.1406

= 45.1406 ₹/h

Average net annual benefit, ₹ = (CHC – TCM) × Annual utility

= (45.1406 – 28.89) × 350

= 16.250 × 350

= 5687.71 ₹

Payback period = $\frac{4780}{5687.71}$

= 0.840 years, 1 year (appx.)

Benefit Cost ratio calculation

$$B{:}C\ ratio = \frac{\text{Gross income with use of implement}}{\text{Total expenditure with the use of implement}}$$

$$B{:}C\ ratio = \frac{6805.36-1536.66}{1536.66}$$

B:C ratio = 3.428

B:C ratio = 3.428 :1, (3:1)