Current Journal of Applied Science and Technology

40(10): 12-22, 2021; Article no.CJAST.68415
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Comparitive Field Evaluation of Roto Drill Cum Herbicide Applicator

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Authors' contributions

This work was carried out in collaboration among all authors. All authors equally contributed. All authors read, reviewed, agreed and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i1031355
Editor(s):
(1) Dr. Nhamo Nhamo, Zimbabwe Open University, Zimbabwe.
Reviewers:
(1) Mustafa Kuntoğlu, Selcuk University, Turkey.
(2) Despina Popovska Stojanov, University Ss. Cyril and Methodius in Skopje, Republic of North Macedonia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/68415

Original Research Article

Received 02 March 2021
Accepted 12 May 2021
Published 18 May 2021

ABSTRACT

Individual field operations such as ploughing, clod breaking, stubble clearance and leveling are necessary for the preparation of even and fine seed bed. These operations consume time and labor which become more economical. Strip tillage, direct paddy sowing, Zero tillage, requires minimum soil manipulation and no tillage respectively, where there incur reduced cost of operation. Timely sowing and proper weed control results in bringing out good returns. Farmers have many options for choosing equipment that is required to grow and harvest a crop. Farmers may own their own equipment, lease it, or have the field operations completed using custom operators. Considering the above facts and importance of paddy, in-order to reduce cost of cultivation a multi crop roto drill cum herbicide applicator was developed by combining three varied machines such as rotovator, seed drill and herbicide applicant or equipment at College of Agricultural Engineering, Bapatla. A tractor drawn roto drill cum herbicide sprayer was developed, evaluated and compared its cost economics with individual operations. Roto drill is the combination of rotavator, seed hopper and rocker sprayer pump. It pulverizes the soil, drills the seed and applies herbicide in single pass of tractor. The cost activity of multi crop roto drill cum herbicide applicator for performing three

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tasks was estimated as Rs/h. 641.00. While the individual costs of operation for tillage, sowing and herbicide application were computed as Rs/h. 571.00, 540.00 and 95.00 respectively. The cost of operation per one hour for developed multi crop roto drill cum herbicide applicator was 46.72% less when compared with costs of individual tasks.

Keywords: Ploughing; zero tillage; roto drill; sowing; herbicide applicator.

1. INTRODUCTION

Over the years the shift has been towards the use of electrical and mechanical sources of power. In 1960-1961, about 93 per cent of farm power was coming from animate sources, which has reduced to about 10 per cent in 2014-2015 [1]. In agriculture, mechanization is the introduction of appropriate machinery for timely field operations and effective application of various crop production inputs. On an average, for a producer to perform all field operations was estimate as $90.60 per acre [2]. According to Kansas Farm Management Data [3], machinery costs account for 40 percent of total crop production expenses.

Rice is India's pre-eminent crop and is the staple food of the people of eastern and southern parts of the country. It is considered as the master crop in the coastal regions of India. There are three principal methods of rice establishment: dry seeding, wet seeding and transplanting. Although these methods vary, each is characterized by distinct features. Dry seeding consists of sowing dry seeds on dry (unsaturated) soils. Seeds can be broadcast, drilled or dibbled. Wet seeding involves sowing pre-germinated seeds in wet (saturated) puddle soils. Transplanting involves planting of rice seedlings grown in nurseries to puddle soils. The performance of multi-crop seed cum ferti drill was evaluated over a 0.5 ha field of silt loam soil and reported that the average seed sown by multi-crop seed drill was approximately 3% higher than seed sown by zero till seed cum ferti drill [4]. Also, the average yield of plot sown by multi crop seed drill was 40.35 qt/ha as compared to the yield of 35 qt/ha which was sown by zero till drill. It is more advantageous to use multi-crop seed drill than any other seed drill, as it could be used for different crops. This increases its annual use hours and makes the machine economical as compared to other seed drills. Considering difficulties of conventional spraying methods and incapability of Indian farmers to have costly tractors for mounting and operating plant protection equipments, a bower type pattern was developed that was mounted on a trailed type unit with power tiller [5]. A power tiller operated boom sprayer was developed for spraying ground nut and other crops planted in rows [6]. According to the study, a Linear Programming technique can be used for finding the best choice of agricultural machinery and implements on the basis of minimizing farm production costs related to cultural operations [7].

2. MATERIALS AND METHODS

In today's farm economy careful planning of machinery investment and financing decisions can have a major impact on the financial success or failure of a farm operation [8]. In this study, a multi crop roto drill cum herbicide applicator was developed at workshop of College of Agricultural Engineering, Bapatla. After completion of development of the multi crop roto drill cum herbicide applicator, the roto drill and sprayer were calibrated according to the Indian standards 004212 test code [9].

Picture 1. Tractor mounted roto drill cum herbicide applicator

2.1 Cost Analysis

Many machinery cost calculations depend on current list price, a value readily derived from current market value using remaining value formulas [10]. Traditionally, remaining value was considered determined by age. Accurate assessment of future value is important because future value determines economic depreciation which affects annual machinery costs. Future value also determines potential taxable gain when a machine is sold, and hence income taxes. Machinery costs are substantial, control of them is important [11]. The total cost of operation of the multi crop roto drill cum herbicide applicator in Rs/h was estimated and compared with individual operations by considering the fixed cost and operating cost of the machine by making following assumptions.

2.1.1 Fixed costs

Fixed costs depend upon how long a machine is owned rather than how much it is used. It includes depreciation, interest, taxes, shelter and insurance.

2.1.1.1 Depreciation

It is the loss in value of the machine owing to time and use. It is calculated by using following formula.

$$\text{Depreciation (D)} = \frac{C-S}{L \times H} \quad (1)$$

Where, C = capital cost, S = salvage value, 10% of capital cost, L = life of machine, year
H = number of working hours per year

2.1.1.2 Interest

Interest is calculated on the average investment of the machine taking in to consideration the value of the machine in first and last year.

$$I = \frac{C+S}{2} \times \frac{i}{H} \quad (2)$$

Where, I= interest per hour, i = % rate of interest per year

2.1.1.3 Housing, insurance and taxes

Housing, insurance and taxes are taken as 1% of the purchase price of the machine per year.

2.1.2 Operating cost

It is also called as variable costs. It varies in proportion to the amount of machine used. The operating costs consist of variable cost viz. repair and maintenance, fuel, lubricants cost (taken as 30-35% of the fuel costs) and other costs such as labor, wages for operator.

2.1.2.1 Repairs and maintenance

These costs are considered as an essential and significant part of machinery ownership. It depends upon the usage of the machine, the more the machine is used, the greater is its need of repair. It also depends upon routine wear, accidental damage, operator's negligence and periodic overhauls. For power take off driven combine, seed drill and sprayer TAR = $0.159X^{1.4}$

Where, TAR = total cumulative repairs and maintenance costs per year.
X = 100 times the ratio of accumulated hours of use to wear out life.

3. RESULTS AND DISCUSSIONS

For the success and commercialization of any new technology, it is essential to know whether the technology is economically viable or not. Therefore; an attempt has been made to determine cost economics of operation of multi crop roto drill cum herbicide applicator. In view of economic viability, the cost analysis was carried out and compared with individual operations which was presented in component wise as follows:

3.1 Estimating the operating Cost of Tractor with Roto Drill Cum Herbicide Applicator

3.1.1 Tractor

The cost of tractor is divided under two heads known as fixed cost and operating cost.

3.1.1.1 Fixed cost

These are generally include the costs that are incurred regardless of whether the machine is actually used in production. These costs do not vary with the amount of machine use.

Table 1. Cost of tractor

Fixed cost	
Tractor model	Mahendra 575 DI
Cost of tractor (c)	Rs 5,50,000
Life of the machine (L)	10 years
Working hours per year (H)	1000 hours
Salvage value (S)	10% of initial cost
Rate of interest (I)	12% per annum
Housing, insurance and taxes	Each @ 1% of initial cost
Operating cost	
Wages for operator (per day of 8 hr)	Rs 300
Wages for labor (per day of 8 hr)	Rs 300
Diesel cost	Rs 52.97/liter
Lubrication cost	30% of fuel cost
Repairs and maintenance	6% of initial cost

a) Depreciation (D)

It accounts for the deterioration in the value of machinery because of age or technological obsolescence.

$$D = \frac{C - S}{L \times H}$$

$$= \frac{550000-55000}{10\times1000} = 49.5 \text{ Rs/h}$$

b) Interest

Investment in machinery requires capital and should therefore be assigned a capital cost regardless of whether or not money is borrowed to purchase the machinery.

$$I = \frac{c + s}{2} \times \frac{i}{H}$$

$$= \frac{550000+55000}{2} \times \frac{.12}{1000} = 36.60 \text{ Rs/h}$$

c) Housing, insurance and taxes

For most machines, these three costs are usually less than depreciation and interest, but they still need to be acknowledged. Some researchers indicate that a quick guideline would be to charge an amount equal to 1% of the purchase price to estimate the expense of all three of these costs.

Each @ 1% of capital cost
Housing = $\frac{550000\times1}{100\times1000}$ = 5.5 Rs/h
Insurance = 5.5 Rs/h
Taxes = 5.5 Rs/h

$$\text{Total fixed cost} = 49.5 + 36.30 + 5.5 + 5.5 + 5.5 = 102.3 \text{ Rs/h}$$

Therefore, the total fixed cost that does not depend on level of output was estimated as102.3 Rs/h.

3.1.1.2 Operating cost

Operating costs generally include those costs that are incurred as a direct result of the machine being used. These costs vary as machine use varies.

a) Fuel cost

Amount of fuel consumed by the tractor when roto drill cum herbicide applicator was operated = 4.618 L/hr

Cost of diesel fuel = 52.97 Rs/lit

$$\text{Fuel cost} = \text{amount of fuel consumed} \times \text{cost of fuel}$$
$$= 4.618 \times 52.97$$
$$= 244.615\ Rs/h$$

b) Lubrication cost

It is estimated on the basis 30% of fuel cost.

$$\text{Lubrication cost} = \frac{2440.615 \times 30}{100}$$
$$= 73.386 \text{ Rs/h}$$

c) Repairs and maintenance cost

It is estimated on the basis of 6% of capital cost.

$$\text{Repairs and maintanence cost} = \frac{550000\times6}{100\times1000} = 33 \text{ Rs/h=}$$

d) Wages for operator

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours.

Operator cost = $\frac{300}{8} = 37.5$ Rs/h

Total operating cost
$= 244.615 + 73.36 + 33 + 37.5 = 388.479$ Rs/h

Total cost of operating tractor
= total fixed cost + total operating cost

$= 102.3 + 388.499 = 490.795$ Rs/h.

3.1.2 Estimating cost of (rotovator + herbicide applicator)

It was divided under two heads known as fixed cost and operating cost. The initial cost of rotavator was Rs. 90, 000 and rocker arm pump, nozzles, boom etc. was Rs. 9800.

3.1.2.1 Fixed cost

a) Depreciation

$$D = \frac{C - S}{L \times H}$$

$= \frac{99890-9980}{10\times200} = 44.91\ Rs/h$

b) Interest

$$I = \frac{C + S}{2} \times \frac{i}{H}$$

$= \frac{99800+9980}{2} \times \frac{0.12}{200} = 32.934\ Rs/h$

c) Housing, insurance and taxes

Each @ 1% of capital cost.
Housing = $\frac{99800\times1}{100\times200} = 4.99$ Rs/h
Insurance = 4.99 Rs/h
Taxes = 4.99 Rs/h
total fixed cost $= 44.91 + 32.934 + 4.99 + 4.99 + 4.99 = 92.814\ Rs/h$

Therefore, the total fixed cost output was estimated as 102.3 Rs/h.

3.1.2.2 Operating costs

a) Repairs and maintenance cost

Repairs and maintenance cost = $0.159(X)^{1.4}$ (3)

Where,

$$X = \frac{100\times\text{working hours per annum}}{\text{life of the machine}\times\text{working hours per annum}} \quad (4)$$

$= \frac{100\times200}{10\times200} = 10\%$

Repairs and maintenance cost = $0.159(10)^{1.4}$

= 3.993% of capital cost

$\frac{99800 \times 3.933}{100 \times 200} = 19.625$ Rs/h

b) Wages for labor

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours.

Operator cost = $\frac{300}{8} = 37.5\ Rs/h$

$Total\ operating\ cost = 19.625 + 37.5 = 57.125\ Rs/h$

Table 2. Cost estimation of rotovator + herbicide applicator

Fixed cost	
Capital Cost of machine (C)	Rs 99800 (90,000 + 9800)
Life of the machine (L)	10 years
Working hours per year (H)	200 hours
Salvage value (S)	10% of initial cost
Rate of interest (I)	12% per annum
Housing, insurance and taxes	Each @ 1% of initial cost
Operating cost	
Wages for labor per day of 8 hours	Rs 300
Repairs and maintenance	$0.159(X)^{1.4}$

Total operating cost $= 19.625 + 37.5 = 57.125$ Rs/h

$$\text{Total cost} = \text{total fixed cost} + \text{total operating cost}$$

$$= 92.814 + 57.125 = 149.939 \text{ Rs/h}$$

Therefore,

$$\text{Total operating cost of roto drill cum herbicide applicator was} = 490.795 + 149.939 = 640.734 \text{ Rs/h}$$

The total cost operation of roto drill cum herbicide applicator was computed as 640.734 Rs/h.

3.2 Estimating the Cost of Operation of Individual Operations (Tractor +Seed Drill)

The individual cost operations of tractor and seed drill were examined and determined as follows:

3.2.1 Cost of operation of tractor

The cost operation of tractor was divided into sub-heads viz., fixed cost and operating cost.

3.2.1.1 Fixed cost

a) Depreciation (D)

It is the cost of value of a machine with the passing of time.

$$D = \frac{C - S}{L \times H}$$

$$= \frac{550000-55000}{10\times1000} = 49.5 \text{ Rs/h}$$

b) Interest

$$I = \frac{c + s}{2} \times \frac{i}{H}$$

$$= \frac{550000+55000}{2} \times \frac{.12}{1000} = 36.60 \text{ Rs/h}$$

c) Housing, insurance and taxes

Each @ 1% of capital cost.

Housing = $\frac{550000\times1}{100\times1000} = 5.5$ Rs/h

Insurance = 5.5 Rs/h

Taxes = 5.5 Rs/h

$$\text{total fixed cost} = 49.5 + 36.30 + 5.5 + 5.5 + 5.5 = 102.3 \text{ Rs/h}$$

3.2.1.2 Operating cost

a) Fuel cost

Amount of fuel consumed by the tractor when seed drill was operated = 4 L/hr

Cost of diesel fuel = 52.97 Rs/lit

$$\text{Fuel cost} = \text{amount of fuel consumed} \times \text{cost of fuel} = 4 \times 52.97 = 211.88\ Rs/h$$

b) Lubrication cost

It is estimated on the basis 30% of fuel cost.

$$\text{Lubrication cost} = \frac{211.88 \times 30}{100} = 63.56 \text{ Rs/h}$$

Table 3. Operational cost of tractor

Fixed cost	
Tractor model	Mahendra 575 DI
Cost of tractor (c)	Rs 550000
Life of the machine (L)	10 years
Working hours per year (H)	1000 hours
Salvage value (S)	10% of initial cost
Rate of interest (I)	12% per annum
Housing, insurance and taxes	Each @ 1% of initial cost
Operating cost	
Wages for operator (per day of 8 hr)	Rs 300
Diesel cost	Rs 52.97/litre
Lubrication cost	30% of fuel cost
Repairs and maintenance	6% of initial cost

c) Repairs and maintenance cost

It is estimated on the basis of 6% of capital cost.

$$\text{Repairs and maintanence cost} = \frac{550000\times6}{100\times1000} = 33 \text{ Rs/h} =$$

d) Wages for operator

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours.

Operator cost = $\frac{300}{8} = 37.5\ Rs/h$

$$\text{Total operating cost} = 211.88 + 63.56 + 33 + 37.5 = 345.94 \text{ Rs/h}$$

$$\text{Total operating cost of tractor when used with seed drill} = \text{total operating cost} + \text{total fixed costs} = 345.94 + 102.3 = 448.24\ Rs/h$$

3.2.2 Cost estimation of seed drill

The cost operation of seed drill was divided into sub-heads viz., fixed cost and operating cost.

3.2.2.1 Fixed cost

a) Depreciation

$$D = \frac{C - S}{L \times H}$$

$= \frac{48000-4800}{10\times200} = 21.6\ Rs/h$

b) Interest

$$I = \frac{C + S}{2} \times \frac{i}{H}$$

$= \frac{48000+4800}{2} \times \frac{0.12}{200} = 15.84 Rs/h$

c) Housing, insurance and taxes

Each @ 1% of capital cost.
Housing = $\frac{48000\times1}{100\times200} = 2.4$ Rs/h
Insurance = 2.4 Rs/h
Taxes = 2.4 Rs/h

$$\text{total fixed cost} = 21.6 + 15.84 + 2.4 + 2.4 + 2.4 = 44.64 \text{ Rs/h}$$

3.2.2.2 Operating costs

a) Repairs and maintenance cost

Repairs and maintenance cost = 0.159(X) $^{1.4}$

Where, X= $\frac{100\times\text{working hours per annum}}{\text{life of the machine}\times\text{working hours per annum}}$

$= \frac{100\times200}{10\times200} = 10\%$

Repairs and maintenance cost = 0.159(10) $^{1.4}$ = 3.993% of capital cost

$$\frac{48000 \times 3.933}{100 \times 200} = 9.585\ Rs/h$$

b) Wages for labor

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours

Operator cost = $\frac{300}{8} = 37.5\ Rs/h$

$$\text{Total operating cost} = 9.585 + 37.5 = 47.075 \text{ Rs/h}$$

$$\text{Total cost} = \text{total fixed cost} + \text{total operating cost}$$

$$= 44.64 + 47.075 = 91.725\ Rs/h$$

Table 4. Operational cost of Seed drill

Fixed cost	
Capital Cost of machine (C)	Rs 48000
Life of the machine (L)	10 years
Working hours per year (H)	200 hours
Salvage value (S)	10% of initial cost
Rate of interest (I)	12% per annum
Housing, insurance and taxes	Each @ 1% of initial cost
Operating cost	
Wages for labor per day of 8 hours	Rs 300
Repairs and maintenance	$0.159(X)^{1.4}$

Total cost of sowing with seed drill
= tractor operating cost
+ seed drill operating cost

$= 448.24 + 91.725 = 539.46\ Rs/h$

3.3 Estimating the Cost of Operation of Individual Operations (Tractor + Rotavator)

The individual cost operations of tractor and rotavator were examined and determined as follows:

3.3.1 Tractor

3.3.1.1 Fixed costs

a) Depreciation (D)

It is the cost of value of a machine with the passing of time.

$$D = \frac{C - S}{L \times H}$$

$= \frac{550000-55000}{10\times1000} = 49.5$ Rs/h

b) Interest

$$I = \frac{c + s}{2} \times \frac{i}{H}$$

$= \frac{550000+55000}{2} \times \frac{.12}{1000} = 36.60$ Rs/h

c) Housing, insurance and taxes

Each @ 1% of capital cost.
Housing = $\frac{550000\times1}{100\times1000} = 5.5$ Rs/h
Insurance = 5.5 Rs/h
Taxes = 5.5 Rs/h

total fixed cost $= 49.5 + 36.30 + 5.5 + 5.5 + 5.5 = 102.3$ Rs/ h

3.3.1.2 Operating cost

a) Fuel cost

Amount of fuel consumed by the tractor when seed drill was operated = 4.333 L/hr

Cost of diesel fuel = 52.97 Rs/lit

Fuel cost = amount of fuel consumed × cost of fuel
$= 4.333 \times 52.97 = 229.536$ Rs/h

b) Lubrication cost

It is estimated on the basis 30% of fuel cost.

$$\text{Lubrication cost} = \frac{229.536 \times 30}{100} = 68.56\ \text{Rs/hr}$$

c) Repairs and maintenance cost

It is estimated on the basis of 6% of capital cost.

Repairs and maintanence cost $= \frac{550000\times6}{100\times1000} = 33$ Rs/h =

d) Wages for operator

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours.

Operator cost = $\frac{300}{8} = 37.5\ Rs/h$

Table 5. Estimation of service life, annual maintenance and repair costs of tractor

Fixed cost	
Tractor model	Mahendra 575 DI
Cost of tractor (c)	Rs 550000
Life of the machine (L)	10 years
Working hours per year (H)	1000 hours
Salvage value (S)	10% of initial cost
Rate of interest (I)	12% per annum
Housing, insurance and taxes	Each @ 1% of initial cost
Operating cost	
Wages for operator (per day of 8 hr)	Rs 300
Diesel cost	Rs 52.97/litre
Lubrication cost	30% of fuel cost
Repairs and maintenance	6% of initial cost

Total operating cost $= 229.536 + 68.56 + 33 + 37.5$
$= 368.596\ Rs/h$

Total operating cost of tractor when used with rotovator
= total fixed cost + total operating cost
= 102.3 + 368.596
= 470.896 Rs/h

3.3.2 Rotovator

3.3.2.1 Fixed cost

a) Depreciation

$$D = \frac{C - S}{L \times H}$$

$= \frac{88000-8800}{10\times200} = 39.6\ Rs/h$

b) Interest

$$I = \frac{C + S}{2} \times \frac{i}{H}$$

$= \frac{88000+8800}{2} \times \frac{0.12}{200} = 29.04 Rs/h$

c) Housing, insurance and taxes

Each @ 1% of capital cost

Housing = $\frac{88000\times1}{100\times200} = 4.4$ Rs/h
Insurance = 4.4 Rs/h
Taxes = 4.4 Rs/h

total fixed cost $= 39.6 + 29.04 + 4.7 + 4.4 + 4.4 + 4.4 = 82.2$ Rs/h

3.3.2.2 Operating Cost

a) Repairs and maintenance cost

Repairs and maintenance cost = $0.159(X)^{1.4}$

Where, $X = \frac{100\times\text{working hours per annum}}{\text{life of the machine}\times\text{working hours per annum}}$

$= \frac{100\times200}{10\times200} = 10\%$

Repairs and maintenance cost = $0.159(10)^{1.4}$

= 3.993% of capital cost

$$\frac{88000 \times 3.933}{100 \times 200} = 17.56 \text{ Rs/h}$$

Therefore,

Total cost of tillage with rotovator
= tractor operating cost + rotovator operating cost
$= 470.896 + 99.4$
$= 570.30\ Rs/h$

3.4 Cost of operation of herbicide application with knapsack sprayer (Manual operated)

The cost operation of knapsack sprayer was examined and determined as follows:

3.4.1 Fixed cost

a) Depreciation (D)

It is the cost of value of a machine with the passing of time

$$D = \frac{C - S}{L \times H}$$

$= \frac{7500-750}{10\times1000} = 3.375$ Rs/h

b) Interest

$$I = \frac{c + s}{2} \times \frac{i}{H}$$

$= \frac{7500+750}{2} \times \frac{0.12}{200} = 2.475$Rs/h

c) Housing, insurance and taxes

Each @ 1% of capital cost.
Housing = $\frac{7500\times1}{100\times200} = 1.125$Rs/h
Insurance = 1.125 Rs/h
Taxes = 1.125 Rs/h

total fixed cost $= 3.375 + 2.475 + 1.125 + 1.125 + 1.125 = 9.225$ Rs/h

3.4.2 Operating cost

a) Repairs and maintenance cost

Repairs and maintenance cost = $0.159(X)^{1.4}$

Where,
$X = \frac{100\times\text{working hours per annum}}{\text{life of the machine}\times\text{working hours per annum}}$

$= \frac{100\times200}{10\times200} = 10\%$

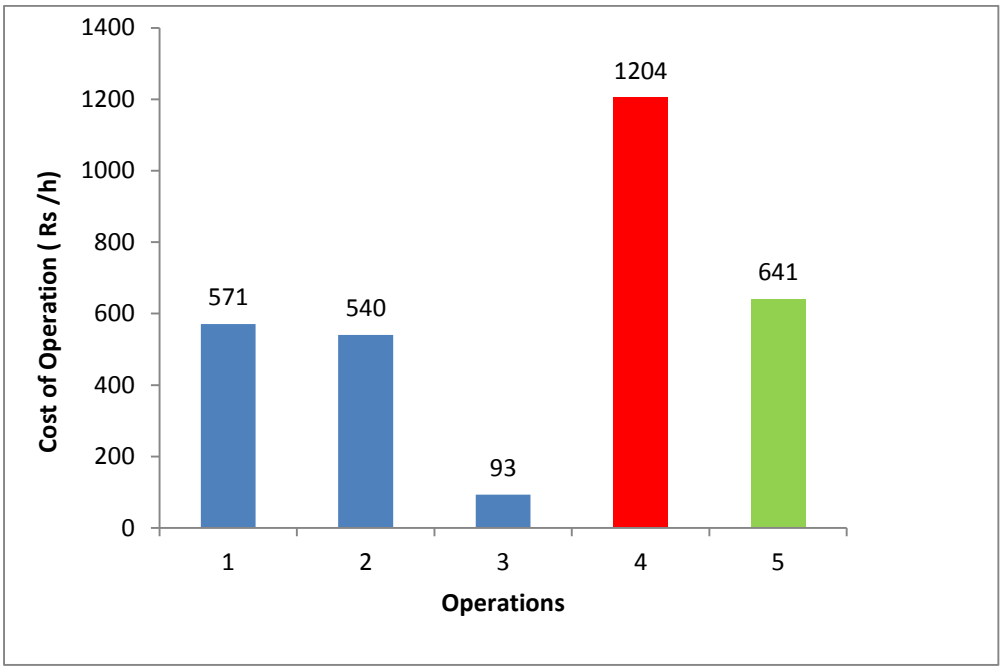

Fig. 1. Comparison of cost of operation of individual operations with roto drill cum herbicide applicator

1. Rotavation of soil, 2. Sowing, 3. Herbicide application, 4. Total cost (Rotavation + sowing + herbicide application), 5. Roto drill cum herbicide applicator

Repairs and maintenance cost = 0.159(10) $^{1.4}$

= 3.993% of capital cost

$$\frac{7500 \times 3.933}{100 \times 200} = 1.497 \text{ Rs/h}$$

b) Fuel cost

Amount of fuel consumed by the sprayer = 0.625 L/h

Cost of petrol fuel = 75 Rs/lit

$$\text{Fuel cost} = \text{amount of fuel consumed} \times \text{cost of fuel}$$
$$= 0.625 \times 75 = 46.875\ Rs/h$$

c) Wages for operator

It is estimated on the basis of local market rates i.e. 300 Rs/day of 8 hours.

$$\text{Operator cost} = \frac{300}{8} = 37.5\ Rs/h$$

$$\text{Total cost herbicide application} = \text{total fixed costs} + \text{total operating costs}$$
$$= 9.225 + 85.872 = 95.097\ Rs/h$$

4. CONCLUSION

According to the study, machinery costs play a significant role in farm profitability and are generally the second largest category on crop farms, following land cost. These equipment decisions are very important for most farms because they can greatly affect profitability. Machinery operating and ownership costs were minimized while considering labor, machine size, and the sequence and timeliness of field operations. So, the total cost of operation for the developed multi crop roto drill cum herbicide applicator for performing three operations simultaneously i.e. tillage, sowing and herbicide application was calculated as Rs/h. 641.00 While the individual costs of operation for tillage, sowing and herbicide application was also calculated and they are Rs/h. 571.00, 540.00 and 95.00 respectively. The cost of operation per one hour for developed multi crop roto drill cum herbicide applicator was 46.72% less when compared with costs of individual operations.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore

been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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