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Techno-economic Worth Assessment of Self-propelled Walking Type Paddy Transplanter

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ABSTRACT

Assessment of field performance of paddy transplanter for two-row to plant spacing's S_1 and S_2 was observed with the economic worth from the viewpoint of custom hiring operator or the progressive farmer. Actual field capacity and field efficiency were maximum and fuel consumption was minimum for S_1. The crop yield and average number of plants/m^2 were higher in the case of S_1. The total cost of mechanical transplanting was Rs. 6798.66 per ha and the break-even point was 7.68 ha/yr. which was less than the actual use of the machine per year with the optimal payback period of 6.85 years whereas, from a custom hiring service provider viewpoint, the payback period is 1.17. The benefit-cost ratio was 1.84, which is greater than unity indicating a profitable venture. The mechanical transplanting of paddy at S_1 was better than transplanting at S_2. The study showed that the use of mechanical paddy transplanting technology is a profitable and acceptable venture from both customer hiring service provider as well as from the customer farmer viewpoint with the additional benefit of saving in labor and time.

Keywords: *Break-even point, Cost, Economic, Field capacity, Fuel consumption, Paddy transplanter, Payback period, Yield,*

Introduction

Rice (*Oryza sativa* L.) is a major food of millions of humans and is grown in many countries by seedling transplanting method which is perhaps the most elaborated method where paddy seeds are sown in one place and are transplanted to another large spread area after the seedlings are grown a bit. This is done to obtain higher yield and less weeding [1]. Paddy transplanting in the state of Punjab of India is mostly done by migrant laborers from other states, but, nowadays, the laborers are not migrating in the same number as they were earlier in the last few years. During the peak transplanting period, high labor demand is adding to the vows of the farmers as the transplanting charges have gone up to Rs. 6000-9000/- ha^{-1}. As a result, manual transplanting of paddy seedlings has become a costlier and tedious operation. The number of seedlings transplanted by the laborer per m^2 is 17 plants which is also much less than the recommended value of 33 plants given by the Punjab Agricultural University, Ludhiana resulting in lower yield. Manual paddy transplanting is a work serious activity containing nursery raising, evacuating the seedlings, shipping, and relocating the removed seedlings in the fundamental fields, with a total labor requirement of approximately 250-320 hours per person per ha [2]. It was estimated that transplanting involves approximately 25% of the crop's total labor requirement [3]. Some ergonomic studies suggest that the manual work for paddy transplantation is taking a toll on the human body [4].

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Because of these problematic issues, there is a need for less labor-intensive mechanized transplanting of rice seedlings which can ensure timeliness and optimum plant population. The achievement of timeliness is also very important as a delay in transplanting by one month reduces the yield by 25% and a delay of two months reduces the yield by 70% [5].

The Punjab state gradually shifted to mechanical transplanting from manual paddy transplanting which is the process of transplanting young paddy seedlings (have been grown in a mat nursery) using a self-propelled rice transplanter [6]. The use of mechanical transplanting can become more economical and indispensable to meet targets of timeliness, and better crop stand with desired plant population to obtain higher yield. Mufti and Khan found a significant effect of seedling age and variety on the number of seedlings per hill in the Yanmar ARP-8 transplanter. Their results also showed a 30% increase in yield and a reduction of about 70% in labor requirements in transplanting with machines compared to manual transplanting. The self-propelled paddy transplanter was assessed, and it was determined that, in order to offset the costs of manual maintenance, the mechanical transplanter needed to be operated over a minimum of 28 hectares annually [8]. Their outcomes demonstrated that the expense of mechanical transplanting per hectare was about 51% lower than manual transplantingSelf-propelled walk-behind transplanters (9.3%) and self-propelled four-wheel transplanters (6.7%) were found to boost yield over farmers' practices [9]. The use of a self-propelled transplanter gives economic benefits to the farmers over the manual transplanting methods. The average net returns were Rs. 19,798.00 ha^{-1} and Rs. 27,462.00 ha^{-1} in traditional and self-propelled paddy transplanting methods of paddy cultivation, respectively [10]. In comparison to manual transplanting, the self-propelled paddy transplanter was found to have produced a net profit of Rs 1146.00 and 1319.00 per hectare when used for 300 hours per year (one season) and 500 hours per year (two seasons). The investment payback period was also found to be 10.23 years and 1 year when the annual area covered was 20 and 80 ha, respectively [11]. It was reported that as compared to hand transplanting 70% of labor and 48% of cost might be saved by using mechanical transplanting. When paddy transplanters were introduced, labour costs were found to be about 85% lower than when transplanting by hand [13]. Mechanical paddy seedling transplanting may be a viable option but lack of awareness about the transplanting machinery and difficulty of raising mat-type nurseries are the major constraints in the adoption of this technology. Also, the purchase of these machines is not economically viable for every small and marginal farmer due to meager resources. However, nowadays farmers are opting for mechanical paddy transplanter technology but there is a need to evaluate the mechanical paddy transplanting technology from the economical and technical view point. Therefore, the objective of this study was to evaluate the techno-economic performance of a self-propelled walking-type paddy transplanter for transplanting paddy seedlings and comparing it with manual transplanting.

Methods and Material

Study area and field experiments

The field trails on mechanical transplanting of paddy seedlings (variety PR 121) were conducted at three locations in district Ludhiana, State Punjab, India, situated at 30°56'' N latitude and 75°52' E longitude at an altitude of 247 m above mean sea level. The climate of the study area is characterized by the subtropical semi-arid with hot and dry summer (April mid to end of June), hot and humid summer monsoon period (early July to the September end), mild winter (October to November) and very cold winter (December to the February end). The study area for each trail was 0.4 ha and had medium soil type. A four-row self-propelled walk behind a paddy transplanter having 1.2 m working width was used to conduct the experiments. General technical specification of the walk-behind self-propelled paddy transplanter is given in Table 1.

Table 1 Technical specification of walk behind self-propelled paddy transplanter

Parameters	Specifications
Model	Walk-behind type (NSP-4W)
Overall dimension L × W × H (cm)	246×149.5×122
Weight (kg)	190
Engine	Air-cooled, 4-stroke, gasoline engine
Power (hp)	4
Type of fuel	Unleaded petrol
Fuel tank capacity (l)	3
Number of rows	4
Planting type	Compelled planting
Nursery feed mechanism	Single fiber sprocket system
Row spacing (cm)	30
Hill to hill spacing (cm)	11-20
Transplanting depth (cm)	20-80

The technology was assessed at S_1 (30 × 12 cm) and S_2 (30 × 18 cm) spacing, respectively. The row-to-row distance of the machine was fixed at 30 cm while the plant-to-plant distance was 12 cm in the case of S_1 and 18 cm for S_2. Different crop parameters such as plant population per m^2, effective tillers per plant, and crop yield (kg/ha) were recorded. As the paddy transplanter required mat type of nursery, materials such as frames of size 58×28×2 cm, seeder, polythene sheet 50-60-gauge, 90 cm wide, needle, sieves, water sprayer, wooden flat, spade and pan, jute bags were used for raising of mat type paddy nursery (Fig.1). Fuel consumption is measured by top-fill method; the fuel tank was filled before the operation at leveled surface.

The amount of fuel needed to top-fill again is the fuel consumption after completion of the process and is expressed in liters per hour [14]. The parameters like actual field capacity, theoretical field capacity, and field efficiency were determined as follows:

Actual field capacity (AFC)

Actual field capacity is the actual area covered per unit time including the time loss in turning, feeding the seedlings on tray, repair, and adjustment [15]. The following relation was used to calculate actual field capacity:

$$\mathrm{AFC}\left(\frac{\mathrm{ha}}{\mathrm{h}}\right) = \frac{A}{T_t}$$

where,
AFC = Actual field capacity, ha/h;
A = Total area transplanted, ha; and
T_t = Total operating time required for transplanting, h.

Theoretical field capacity (TFC)

It is the rate of field coverage of the implement [16], based on 100% of time at rated speed and covering 100% of its rated width. [17], suggested the following equation for theoretical field capacity calculation

$$\mathrm{TFC}\left(\frac{\mathrm{ha}}{\mathrm{h}}\right) = \frac{W \times S}{10}$$

where,
W = Working width, m
S = Speed of operation, km/h

Field Efficiency (FE)

It is a measurement of the productive work performed by a machine in proportion to the actual work performed and what could be accomplished under ideal conditions [18]. [16], [17], and [19], defined machine field efficiency as the ratio of actual field capacity to theoretical field capacity, expressed in %,

$$\mathrm{FE}\,(\%) = \frac{\mathrm{AFC}}{\mathrm{TFC}}$$

where,
AFC = Actual field capacity, ha/h
TFC = Theoretical field capacity, ha/h

Fig. 1. View of raising mat type nursery (left) and raised nursery mats (right)

Fig. 2. Operational view of self-propelled walk behind type paddy transplanter.

Fig. 3. View of paddy crop stand transplanted with mechanical transplanter.

Economic worth assessment

The economic worth assessment of using a paddy transplanter is executed by calculating the operating cost (OC) of a paddy transplanter which consists of (a) fixed cost which includes depreciation, interest on investment, taxes, insurance, and housing; (b) variable cost which includes labor, fuel, oil, repair, and maintenance. The assumptions considered during the calculation of operating cost were (1) the cost was calculated using a database of a single year; (2) inflation rates were ignored in the calculation; (3) the interest rate is considered to be 12 %.

Fixed cost

Fixed costs are costs incurred irrespective of whether or not the machinery is operated. Depreciation (D), interest on investment (I), shelter, taxes, and insurance (STI). In general, fixed costs are fixed but decrease per hectare, as the annual use of the machine increases. In the calculation of fixed cost, a straight-line depreciation is assumed and the following equation was used for calculating the annual depreciation:

$$D = \frac{P-S}{L}$$

where,
D : Depreciation (Rs./yr);
P : Principal amount of the transplanter(Rs.);
S : Salvage value of transplanter (Rs.); and
L : Life of transplanter (yr).

The interest on investment in a paddy transplanter is included in fixed cost estimation and the following equation was used for calculating the investment interest:

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

where, i : interest rate, %

Variable cost

Variable costs are expenses incurred as a result of machine operation (fuel costs, labor, and other inputs). Variable costs depend on hourly labor costs, fuel, oil, repair and maintenance costs, and the required working hours for each field operation. The cost of operator/labor was calculated as the labor rate in Rupees (Rs.) per day. The fuel and oil costs were estimated from the consumption rate and multiplied by their respective prices.

Operating cost (OC)

Operating costs are recurring costs that are necessary to operate and maintain a machine during its useful life [20]. In the present study, the annual OC of the paddy transplanter was divided into fixed cost and variable cost. All calculated fixed cost and variable costs were converted into Rs/ha and then the summation of fixed and variable costs was given OC in Rs/ha. The OC was calculated as follows:

OC, Rs./ha = Fixed cost +Variable cost

Revenue and profit

Revenue was estimated by multiplying the number of annual use and the rent-out charge and profit is estimated from the differences between revenue and total costs [21]. Revenue and profit was determined as follows:

Revenue = Average annual use (ha) × Rent out charge (Rs./ha)

Profit = Revenue (Rs./ha) – Total operating cost (Rs./ha)

Break-even point (BEP)

Many farmers do not choose or cannot afford to own all the machinery required for their farming operations. Often this is because of restricted capital, limited labor, small size of land holdings, or other reasons. For these farmers, the purchase of custom services is one method of obtaining the needed machinery services on the farm. To decide whether it is more economical to own machinery or to hire a customer operator, compare the fixed and variable costs of owning and operating the machinery to the total costs of custom service. The break-even point [22] is found accurately with the following formula:

$$BEP = \frac{F}{(R - V)}$$

where,
F = annual fixed costs
V = variable costs per unit of operation
R = custom hiring charge/rent per unit

Payback period

The payback refers to the period within which the costs of investment can be covered by revenues. In other words, it is the length of time required for the stream of cash proceeds produced by an investment to equal the initial expenditure incurred. This can be computed from the following formula:

$$\text{Payback period (yr)} = \frac{\text{Investment (total initial, Rs.)}}{\text{Net benefit (Rs./yr)}}$$

Benefit-cost ratio (BCR)

This is the ratio obtained when the gain stream is segregated by the current cost value, i.e. B: C Ratio (in our case) is Benefits/Costs. The cost exceeds the gain if the ratio is less than one. However, if the Ratio is more than one then the Benefits exceed the costs [23]; [24]. BCR is determined from the equation below.

$$BCR = \frac{\sum \text{Present worth of benefits}}{\sum \text{Present worth of cost}}$$

The investment is said to be profitable when the BCR is greater than one (>1). Depreciation and interest of investment are not included in the costs to prevent double accounting. Depreciation is accounted for by the inclusion of the investment cost while interest of investment is accounted for by the discount factor.

Payment for replacement

It is the amount and interest that accumulated to purchase another transplanter when the economic life of the old transplanter expires. Payment for replacement (PFR) has been determined as follows:

Payment for replacement (PFR), Rs/yr = $(P\text{-}S) \times \frac{i}{[(1+i)^L]-1}$

where,
P = Principal amount of transplanter (Rs.);
S = Salvage value of transplanter (Rs.);
i = Interest rate; and
L = Life of transplanter (yr).

Results and Discussion

Machine performance

Table 2 shows the results of an experiment conducted with a mechanical transplanter at a different row to plant spacing S_1 and S_2. Considering the 1.2 m and 3.42 km/h theoretical width and speed of the machine the theoretical field capacity (TFC) of the machine was found to be 0.41 ha/h. During the evaluation of field performance, the average actual field capacity (AFC) and fuel consumption (FC) for S_1 and S_2 were found to be 0.15 and 0.14 ha/h and 0.78 and 0.82 l/h respectively. The field efficiency (FE) was found to be more (38.21 %) in S_1 as compared to S_2 (33.33 %). The average number of plants/m^2 and crop yield were also found to be more in the case of S_1 compared to S_2. The average crop yield for S_1 and S_2 was observed to be 7816.67 and 7583.33 kg/ha. The higher crop yield in the case of S_1 is due to the greater number of plants /m^2 as compared to S2. The effective tiller per plant for S_1 and S_2 is 21.67 and 23.33. The coefficient of variation (CV) of fuel consumption, actual field capacity, and yield in S_1 and S_2 was 13.29% and 12.74%, 16.78% and 15.23% and 2.3% and 0.73% respectively. The variation of fuel consumption, actual field capacity, and crop yield in S_1 and S_2 is shown in Fig. 4, 5, and 6. The mechanical transplanting of paddy crop is also compared with conventional paddy seedlings transplanting (manual) and it was found that the labor requirement in mechanical transplanting was lesser (15-20 man-h/ha) in both S1 and S2 as compared to manual transplanting (150-200 man-h/ha). The crop yield is also higher in the case of mechanical transplanting (7816.67 and 7583.33 kg/ha for S_1 and S_2) as compared to the conventional transplanting method (7480.00 kg/ha). This is due to the more number of plants/m^2 in the case of mechanical transplanting with (24.33) S_1 spacing as compared to conventional transplanting (17).

Table 2 Parameters observed for mechanical paddy transplanting for S_1 and S_2 spacing

Transplanting type	Spacing	Trial	FC (l/h)	AFC (ha/h)	FE (%)	No. of plants/m²	Effective tillers/plant	Yield (kg/ha)
Mechanical	S_1	T1	0.7	0.18	43.90	24	21	7750
		T2	0.75	0.16	39.02	23	20	8020
		T3	0.9	0.13	31.71	26	24	7680
	Average		0.78	0.15	38.21	24.33	21.67	7816.67
	SD		0.10	0.03	6.14	1.53	2.08	179.54
	CV (%)		13.29	16.78	16.06	6.28	9.61	2.30
Mechanical	S_2	T1	0.85	0.13	31.71	18	23	7580
		T2	0.7	0.16	39.02	19	22	7640
		T3	0.9	0.12	29.27	16	25	7530
	Average		0.82	0.14	33.33	17.67	23.33	7583.33
	SD		0.104	0.02	5.07	1.53	1.53	55.08
	CV (%)		12.74	15.23	15.22	8.65	6.55	0.73

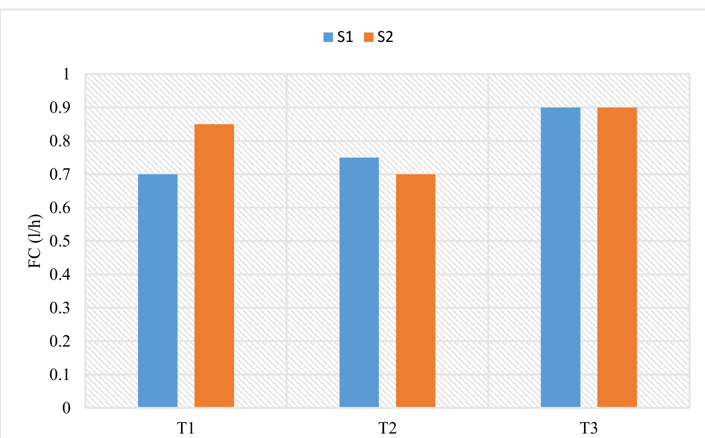

Fig. 4. Variation in fuel consumption of paddy transplanter for S_1 and S_2

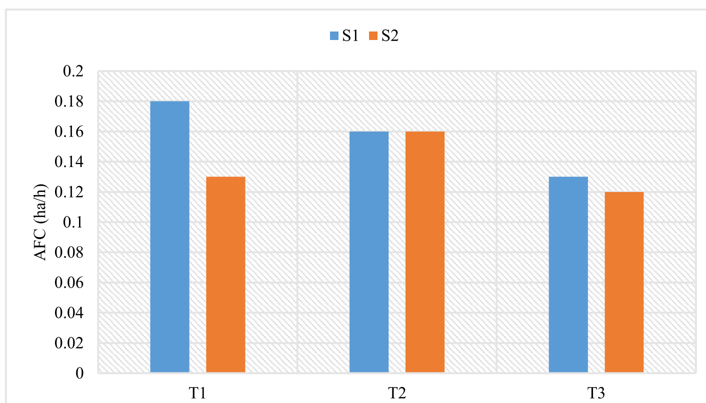

Fig. 5. Variation in actual field capacity of paddy transplanter for S_1 and S_2

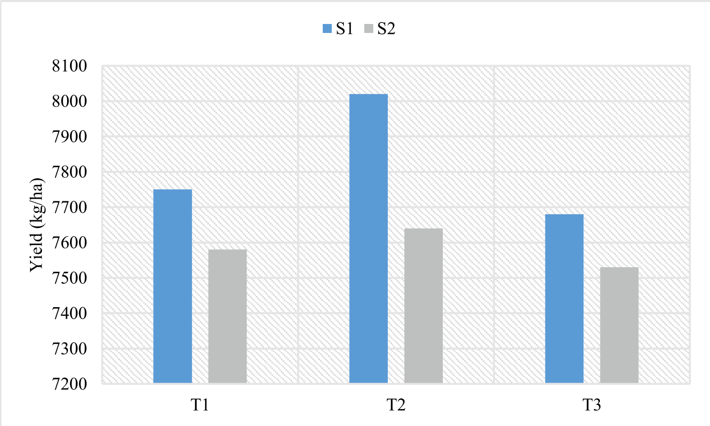

Fig. 6. Variation in crop yield of paddy transplanter for S_1 and S_2

Economic Worth Assessment

The economic worth analysis of using the paddy transplanter and various assumptions considered during the assessment of economic worth assessment is given in Table 3. The financial analysis was computed from the viewpoint of the machine owner whether he is a custom hiring operator or a progressive farmer. Based on field data and annual use information (ranging from 250 – 350 h) collected through personal interviews of custom-hire service providers, the total cost of operating the paddy transplanter and the actual field capacity of the paddy transplanter machine was estimated as Rs. 6798.66 per ha and 0.15 ha/h respectively. Fixed cost and variable cost for the machine operation were estimated at Rs. 1173.33/- and 2045.33/- per ha respectively based on the capital cost of the machine and average field data. The expenditure on raising mat-type nurseries of paddy crop is Rs. 3580/- per ha. The rental charge for using a paddy transplanter by a customer operator is Rs. 12500/- per ha. The net benefit comes out to be Rs. 5701.34/- per ha and considering the average 300 h annual use of paddy transplanter according to the custom operators, the net annual benefit or revenue was observed to be Rs. 2,56,560/-. On the other hand, considering the minimum annual machine use of 51.02 h the net annual benefit or revenue was Rs. 43788.36/-. The various itemized cost per hour is shown in **Fig. 7**.

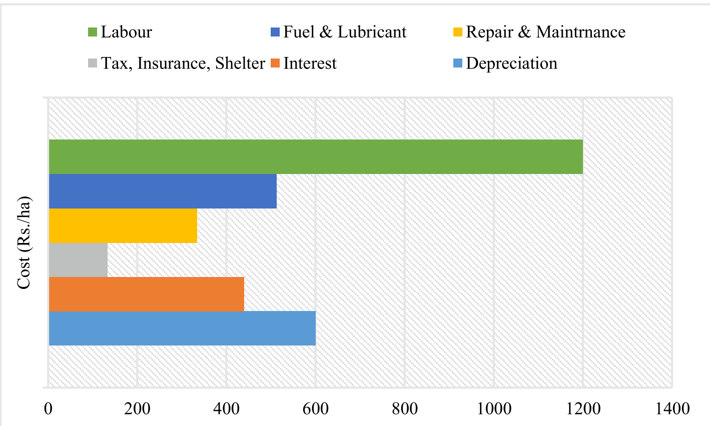

Fig. 7. Itemized cost per hour of operation

Table 3 Estimation of operating cost of the transplanter

Particulars	Value
Purchase price (P), Rs.	3,00,000/-
Salvage (S) , Rs.	30,000
Life, yr	10
Economic life, h	300
Actual field capacity, ha/h	0.15
A. Fixed Cost	
Depreciation, Rs./yr	18000
Interest on investment (i = 12%)	19800
Taxes, insurance and housing (2% of purchase price 'P')	6000
Total, Rs/yr (Rs./h)	52800 (176, 1173.33)
B. Variable Cost	
Fuel , Rs./h (2.0 l/h @ Rs. 82.0 per litre)	64
Repair and maintenance cost, Rs./h (5% of P)	50
Cost of lubricants, Rs./h (20% of fuel cost)	12.8
Cost of operator including helper, Rs/h (Operator charged Rs. 1200/ha for transplanting & transporting mats to the machine)	180
Total variable cost, Rs/h (Rs./ha)	306.8 (2045.33)
Total operating cost, Rs./h (Rs./ha)	482.8 (3218.66)
C. Expenditure on raising mat-type paddy nursery	
Expenditure on Plastic Sheet Plastic sheet (50-60 gauge) = 875 g/ha	380
Expenditure on Seed (25-30 kg/ha)	1000
Labor cost till transplanting (45-50 h) @40 Rs.	2000
Seed treatment and fertilizer (50 g Bavistin 50 WP + 2.5 g streptocycline)	200
Total expenditure on raising mat type paddy nursery	3580
D. Total cost for mechanical transplanting, Rs./ha (A+B+C)	6798.66

Considering the capital cost involved in the purchase of a paddy transplanter and assumptions considered for economic worth assessment in the present study, the break-even point comes out to be 7.68 ha per year whereas actual use of the machine is 45 ha per year from custom hiring service provider viewpoint. Considering the actual annual use of the machine the farmer or custom operator shall be able to recover his cost in 1.17 years (payback period) whereas considering the optimal or minimum annual use of the machine i.e. 7.68 ha the farmer shall be able to recover his cost in 6.85 years (payback period). All the earnings after this period while using the same paddy transplanter machine will be his earnings (**Fig. 8**). The payback period of the machine in both ways is less than the life (10 yr) of the machine and also the benefit-cost ratio is found to be 1.84 which is greater than unity (>1). Therefore, operating the machine on custom hiring and covering an area of around 45 ha per year or operating the machine around 300 h per year is an acceptable profitable venture and if a farmer purchases the machine for his own use than then he should cover a minimum 7.68 ha area annually. The payment for replacement was found to be Rs. 15355.50/- which indicates farmers/owners of the machine have to save Rs. 15355.50/- per year in a bank account as payment for replacement (PFR) so that they can buy a new transplanter when the economic life of old machine expires. All the details of economic parameters is given in Table 4.

Table 4 Economic worth evaluation of paddy transplanter

Items	Value	Remarks
Actual field capacity, ha/h	0.15	-
Rental charges, Rs./ha	12500/-	Rent taken by custom hiring service provider or machine owner
Net Benefit, Rs./ha	5701.34/-	-
Annual Benefit (Rs./yr)	2,56,560/-	Based on annual use of machine from custom hiring service provider viewpoint
Annual Benefit (Rs./yr)	43788.37/-	Based on annual use of machine for break-even point
Payback period (yr) from custom hiring service provider viewpoint	1.17	Less than life of machine (<10 yr)
Payback period (yr) from famer/owner viewpoint	6.85	Less than economic life of machine (<10 yr)
Break-even point ha/yr (h/yr))	7.68 (51.2)	Less than the area coverd by custom hiring service provider
Benefit-cost ratio (BCR)	1:1.84	Greater than unity (>1)
Payment for replacement (PFR), Rs./yr	15355.50	Annual saving amount for the purchase of new machine after the expiry of old machine life

The practical utility of paddy transplanter

Although the practical utility of using a paddy transplanter from a custom hiring service provider's viewpoint is much more it is also beneficial from a customer farmer's viewpoint. The data of comparison of material and labor costs involved in nursery rising for mechanical transplanting and conventional transplanting (manual) given in Table 5 shows that the customer farmer gets the benefit of Rs. 350/- per ha if he opts for mechanical transplanting as compared to the manual transplantation of paddy seedlings. This saving largely depends upon the labor charges for manual transplanting which varies largely according to labour availability. However, the saving of Rs. 350/- seems to be small in amount but the additional qualitative gain realized by the customer farmer is much more than the quantitative gain. In addition to monetary gains customer farmers get free from the burden of raising paddy nurseries and labor availability; get an option for selecting desired quality nurseries; saving in time, and labor.

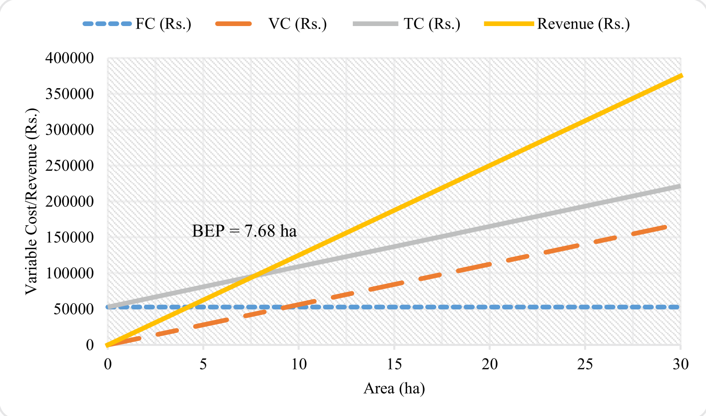

Fig. 8. Economic use of paddy transplanter machine

Table 5 Comparative cost of manual and mechanical paddy transplantation from customer farmer viewpoint

Particular	Manual transplanting (Rs.)	Mechanical transplanting (Rs.)
A. Expenditure on nursery raising		
Expenditure on Seed (27-30 kg/ha)	900/-	Not required
Labour cost till transplanting (12 hours)	480/-	
Seed treatment and fertilizer (50 g Bavistin 50 WP + 2.5 g streptocycline)	200/-	
Total	1580/-	
B. Expenditure on transplantation	11250/-	12500
C. Net Expenditure (A+B)	12830/-	12500

Conclusion

In the present study, techno-economic evaluation of mechanical paddy transplanter technology was done at two spacing S_1 and S_2. Actual field capacity and field efficiency were maximum and fuel consumption was minimum for S_1. The crop yield and average number of plants/m^2 were higher in the case of S_1. The total cost of mechanical transplanting was Rs. 6798.66 per ha and the break-even point was 7.68 ha/yr which was less than the actual use of the machine per year with the optimal payback period of 6.85 years whereas from a custom hiring service provider viewpoint, but the payback period is 1.17. The benefit-cost ratio of the machine was 1.84, which is greater than unity indicating an acceptable venture for a custom hiring operator. It is concluded that the mechanical transplanting of paddy seedlings at spacing S_1 was better than transplanting at S_2 spacing and the use of mechanical paddy transplanter technology is a profitable venture for both service provider and farmer with the additional benefit of saving in labor and time.

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