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Assessment of Cost Economics of Power Tiller Operated 2-row Vegetable Transplanter

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ABSTRACT

A 2-row vegetable transplanter was developed at Biswanath Chariali, Assam during 2023-2024 for 9.75 kW power tiller and the cost economics was assessed under actual field conditions at a forward speed of 0.9 Km/hr maintaining crop spacing of tomato (45×45 cm), brinjal (60×60 cm) and chili (45×45 cm). Average field capacity was 0.045 ha/hr for tomato and chili with field efficiency of 65.76 and 65.41%, respectively and for brinjal 0.06 ha/hr with field efficiency of 65.49%. Mechanical transplanting resulted in saving of 83-85% of productive time and 66-69% labour involved compared to conventional transplanting of bare root seedlings. Average transplanting rate was about 31 seedlings/min for the 45 cm within-row spacing, and 24 seedlings/min for the 60 cm within-row spacing. Percent missed plantings were 2.75, 1.19 and 2.63% for tomato, brinjal and chili seedlings, respectively. About 96% of tomato, 98% of brinjal and 93% of chili seedlings were planted in perfect upright orientation with no plant mortality. The average pay back period for the machine was 3.44 years (207 h) for annual use of 60 hours. The breakeven point was 38 h/year or 1.70 ha/year. The profit margin of the farm was more than that of the conventional manual transplanted farms when the sale price of tomato, brinjal and chili was more than ₹1282, ₹2215 and ₹2891 per quintal, respectively. Use of vegetable transplanter with plug seedlings is definitely profitable, and hence, is economically feasible in small and medium vegetable farms.

1. Introduction

The edible parts of a plant that are usually leaves, roots, fruits, or seeds are termed as vegetable. Vegetables and fruits are rich in nutrients, minerals, vitamins, dietary fibers and calories. Vegetables play a significant role in human nutrition being an important source of protective nutrients like vitamins, minerals, antioxidants, folic acid and dietary fibres, (Vanitha et al., 2013).

India ranks second in fruits and vegetable production in the world, after China. During the financial year 2023-24, India produced 204.96 million metric tonnes of vegetables (Anon.2023-24a). Amongst the states Uttar Pradesh retains its leading position in vegetable growing. It accounted for 14.8% of the total vegetable production in the country followed by West Bengal, Maharatra, Andhra Pradesh and Telangana (Anon. 2024b).

The collective farm power availability in northeastern region is still lower as compared to other part of the country. Topographical condition is also one of the reasons for lower level of farm mechanization in the region. A major portion of the region covered by hilly terrain, receives high rainfall, and undulating field with spread-out hills scattered by fertile plains. Therefore, bulky and heavy machines designed for plain areas are not suitable in the hilly region due to topography and small land holdings (Singh and Vatsa, 2007; Singh et al., 2014; Singh et al., 2017). Among

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the various vegetables grown in India, tomato, brinjal and chili have the high consumer demand throughout the year. These vegetables are established in the field by transplanting.

Many researchers are conducted to develop and test small size, handy, easily maneuverable gender friendly farm equipment for use in the northeastern hill region. Singh et al. (2020) conducted a field evaluation of a power tiller drawn seed drill for sowing maize on terraces in hilly regions and reported the field efficiency (63%), field machine index (77%) and fuel consumption (0.96 L/hr) satisfactory.

In the region due to heavy rainfall, weed is a major problem that requires to maintenance frequently and a huge amount of expenditure for weeding the crop field. Therefore, a field experiment was conducted on a mini power weeder for intercultural operation under the upland conditions in northeast India and modified to suit the machine as per the agro-climatic condition of the region (Singh et al. (2022). From the study, they reported the effective field capacity was 0.032 ha/hr and weeding efficiency 73.05% when the mini power tiller was operated at a forward speed between 1.5 to 2 km/hr.

Fruits and vegetable cultivation have been identified as the most profitable venture of all farming activities in Assam as it provides ample employment opportunities and generates exportable surplus leading to economic growth (Sarma et al., 2016).

There exists scope in Assam for the improvement of the yield through timeliness and precision to cultivation operations, greater field coverage over a short period, cost-effectiveness, efficiency in use of resources and applied inputs and conservation of natural resources by using improved farm implements for various cultivation practices.

Manual transplanting of bare root seedlings is very labour intensive, and requires 185–260 man-h/ha (Kumar and Raheman, 2008). Therefore, the farmers must go for the use of mechanical transplanting to increase production and productivity.

Singh (2008) reported the development and evaluation of a 2-row tractor mounted vegetable transplanter developed at PAU, Ludhiana for the bare root seedlings. The percent missed planting was found to be about 2.0–3.5 at the forward speed of 0.8–1.0 km/hr depending on plant spacing in row and skill of the operator. The yield was found to be at par with that of traditional methods.

Nandede and Raheman (2016) developed a 3-row tractor operated multi-stack vegetable transplanter for planting vegetable seedlings raised in paper pots. The average field capacity of the transplanter for transplanting chili seedlings at 60 × 45 cm seedling spacing was found be 0.111 ha/h at a forward speed of 2 km/hr resulting in a saving of 87.14% and 87.5% labour, 87.71% and 87.20% of operating time over conventional method of manual transplanting of pot seedlings and bare root seedlings, respectively.

Due to small land holdings and fragmented land of farmers in northeastern region, it is quite difficult to use these large-size tractor operated vegetable transplanters under these circumstances. Further, continuous research on power tiller operated-vegetable transplanters is showing a path in the line of agricultural mechanization in the region. Power tiller bears many advantages over tractors in some senses like most useful in undulating topography, best machine in rice growing belt, light in weight, can cover all corners during field operation, short turning is very easy, and bearable by poor farmers etc. Therefore, some power tiller- operated vegetable transplanters have been developed in India.

Mahapatra (2010) developed a power tiller operated vegetable transplanter with two types of attachments: (i) inclined press wheel attachment for transplanting on flat bed, and (ii) mould board and truncated conical ridge shaper attachment for simultaneous ridging. The effective field capacity of the machine was found to be 0.057, 0.058, 0.073, 0.046 and 0.074 ha/h for transplanting cabbage (spacing, 60 cm × 45 cm), chili (spacing, 60 cm × 45 cm), tomato (spacing, 75 cm × 60 cm), knolkhol (spacing, 45 cm × 45 cm) and brinjal (spacing, 90 cm × 75 cm), respectively. The savings in cost of transplanting for cabbage, chili, tomato, knolkhol and brinjal were found to be 51, 59, 93, 40 and 93%, respectively over manual transplanting using local method. Transplanting by the machine also reduced the drudgery to a great extent. The developed power tiller operated vegetable transplanter is a single row and used bare root seedlings where singulation of seedlings quick supply of seedling is difficult. The mortality percentage of transplanted seedlings is also more if quick maintenance and water supply are not done.

Kumar and Raheman (2011) developed a 9.75 kW power tiller operated 2-row array type vegetable transplanter for individual paper pot seedlings. The performance of the vegetable transplanter was evaluated for transplanting tomato at 45 × 45 cm spacing in the field at a forward speed of 0.9 km/h. Field capacity of the transplanter was found to be 0.026 ha/h. It resulted in the saving of 68% labour and 80% time over the conventional method of manual transplanting.

Above mentioned power tiller-operated vegetable transplanters are either heavy, bulky single row and hence difficult to operate by all farmers. In Assam, farmers use to transplant bare root seedlings. Bare root seedlings are grown in the nursery and later it is uprooted and transplanted in the prepared field. During uprooting the roots of seedling get injured resulting wilting of seedlings take place. In the case of soil block seedlings, it very easy to grow in the plug tray, easy to remove seedlings from the tray, mortality is almost nil and production is more compared to traditional seedlings.

Therefore, there is a need for the development of a power tiller-operated vegetable transplanter for plug seedlings.

Keeping these facts in view, the present study aimed to develop a 2-row vegetable transplanter for the soil block seedlings to be popularized among the farmers and assess the Cost Economics of the vegetable transplanter by transplanting tomato, brinjal and chili seedlings under actual field conditions to be popularized among the small and marginal farmers.

2. Materials and method

2.1 Geographical identity of the study area

Biswanath Chariali typically lies in North Bank Plain Agro-climatic Zone of Assam, surrounded by Arunachal Pradesh in the north, mighty river Brahmaputra in the south, Lakhimpur district in the East as well as Sonitpur district in the West (Fig. 1). The district lies in 26° 43' 32" north latitude and 93° 8' 47" degree east longitude.

The experiments were conducted in Rabi crop season at Biswanath Chariali, Assam during August 2023 to March 2024. In the experimental site, the soil was sandy loam with 19.6% clay, 20.8% silt and 59.6% sand. It had an average bulk density 1.25 g/cm^3, electrical conductivity 0.01dS/m, and pH ranged from 4.10-5.60. The nutrient status of the soil was, 188.00 to 473.09 kg/ha nitrogen, 15 to 27.03 kg/ha phosphorus, 178.50 to 523.89 kg/ha potassium, and 0.72 to 0.91% organic carbon.

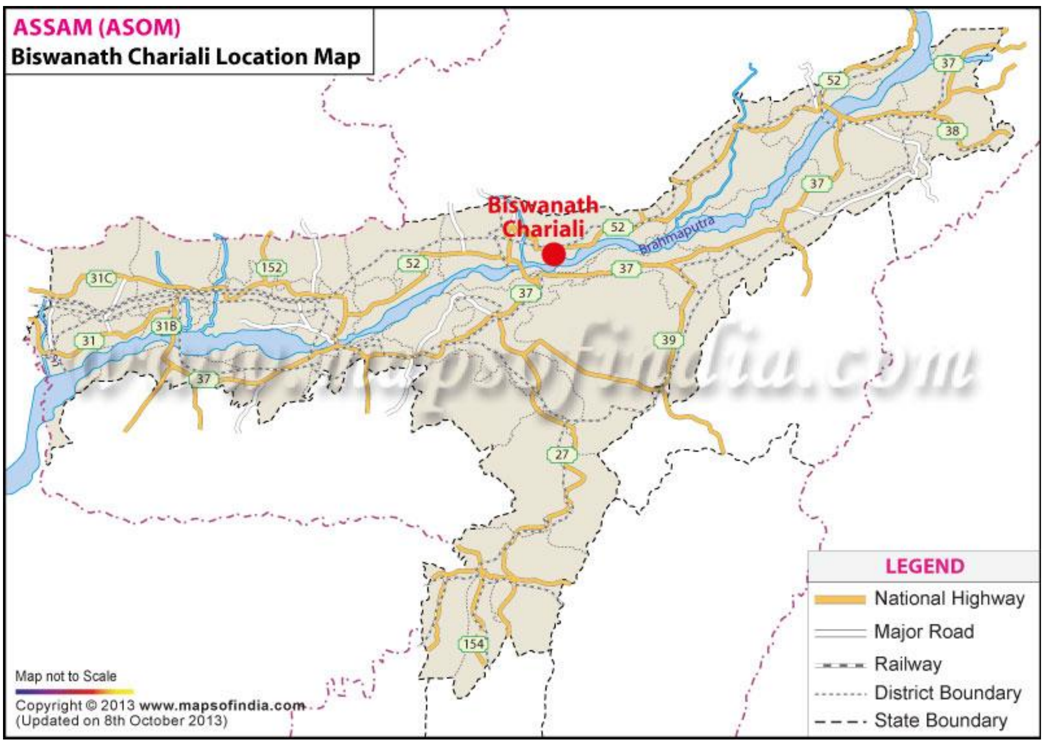
2.2 Equipment and material used

For assessment of field performance of the vegetable transplanter under actual field condition, a power tiller of 9.75kW was used as a prime mover (Fig. 2). The power tiller is useful for dry land and wet land field work and popular among the farmers for its easy maneuverability. It used plug seedlings with heavy soil block grown in plastic plug trays of 100 cm^3 cell volume (Dihingia et al., 2018). Plug seedlings of tomato, brinjal and chili with plant height in the range of 13-17 cm, 11-15 cm and 10-14 cm, respectively, were used. The tomato seedlings had 8-10 leaves, brinjal seedlings had 4-6 leaves, and chili seedlings had 6-8 leaves.

2.3 Power tiller operated vegetable transplanter

The vegetable transplanter is easily maneuverable by one person. However, two persons are required in the field to operate (1 skilled and 1 unskilled), and each of them have to regulate the forward motion of the power tiller along the straight line as well as feed the metering conveyor.

The vegetable transplanter consisted of two sets of seedling stock tray, seedling metering conveyor, hopper type planting device, seedling drop tube, reversible shovel type furrow opener, soil covering device and row marker, and a power transmission system, a power cut off device, a depth adjustment wheel and a hitching arrangement. Before



Source: MapsofIndia.com

Figure 1. Map of the study area

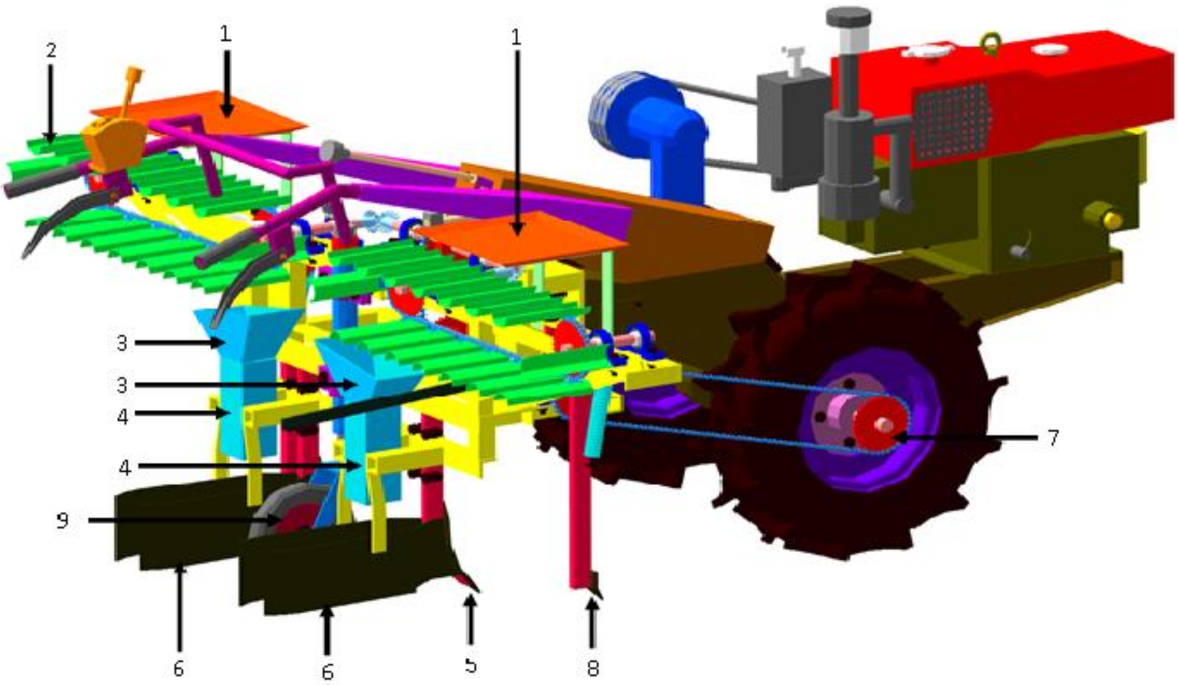
transplanting, the seedlings are to deposit in the trays and recharge the trays at the headland when required. The rotary tiller assembly along with chain drive was removed from the main body and gearbox of the power tiller, and in that space, vegetable transplanter was rigidly attached to the power tiller. There was provision to obtain 45 and 60 cm inter-row spacing 45 and 60 cm within-row plant spacing.

The power tiller operated vegetable transplanter was tested for transplanting tomato (45×45 cm spacing), brinjal (60×60 cm spacing) and chili (45×45 cm spacing) seedlings in 3 plots, each 27×18 m, with sufficient headland area for turning. The machine was operated along the length of the plot at a forward speed of about 0.9 km/hr (Fig. 3). Conventional manual planting of bare root seedlings was done in another 3 plots of the same size for the purpose of comparison. All 6 plots had a uniform distribution of plants and plant establishment. Yields of vegetables from individual plots were determined. Data collected were analyzed to determine output capacity, quality of work, crop yield and cost of operation.

2.4. Determination of cost economics

Cost of operation was determined by calculating the fixed and operating costs (Singh, 2017). Initial cost of the power tiller and vegetable transplanter was ₹150000 and ₹30000, respectively. The power tiller has an average 800 hours of annual use in small and medium holdings. The use of power tiller for vegetable transplanting represents additional hours of annual use. The life of power tiller and the vegetable transplanter was 10 years. The annual rate of depreciation, interest on capital, insurance and taxes, housing, and repair and maintenance for both power tiller and vegetable transplanter were 10, 9, 2, 1 and 6% of the initial cost, respectively. Price of fuel (diesel) was ₹60/. The lubrication oil cost was 30% of fuel cost. The labour wages for the operator of the power tiller, companion worker with power tiller and all the unskilled workers were ₹450, ₹400 and ₹280 per day (8 hours), respectively.

Cost of operation at various levels of annual use was calculated for transplanting tomato, brinjal and chili using the power tiller operated 2-row vegetable transplanter. The labour requirement for complete crop establishment (extraction of seedlings from tray cells and supply of plug seedlings to the seedling stock trays, filling missed plantings, correct planting of the tilted seedlings, proper soil covering around the seedlings etc.) was determined under actual field conditions during the performance evaluation. The cost of complete transplanting operation included the cost of operation of the machine and the cost of crop establishment as well. The cost of plug seedlings required per hectare was also added to the total cost of complete transplanting operation. Cost of complete transplanting by conventional manual method included the cost of crop establishment



1. Seedling stock tray	2. Metering conveyor	3. Hopper planting device
4. Seedling drop tube	5. Furrow opener	6. Soil covering device
7. Chain drive to metering conveyor	8. Row marker	9. Depth adjustment wheel

Figure 2. Three-dimensional solid model of power tiller operated vegetable transplanter

(replacing of dead plants, correct planting of the seedlings, proper soil covering around the seedlings etc.) as well. The cost of production of bare root seedlings was determined from the actual observation of the method followed by the farmers in the locality for the same variety of tomato, brinjal and chili.

The graphical method was used to identify the minimum area to be transplanted per year using the machine or minimum number of hours of annual use of machine required to obtain the cost of mechanical transplanting less than the manual transplanting.

The break even analysis of the vegetable transplanter was conducted. Based on the comparison of complete cost of transplanting operation, minimum annual use of vegetable transplanter was fixed. The cost of mechanical transplanting operation was determined. This excluded the cost of labour for the supply of vegetable seedlings and crop establishment, and cost of seedlings. Payback period was calculated based on the profit that can be realized by using the vegetable transplanter rather than transplanting by conventional manual method. Assuming the internal rate of return as 25% over the life of the machine (10 years), custom hiring rate was calculated. Payback period for custom hiring the vegetable transplanter was calculated. The breakeven point for owning the machine against custom hiring it was identified by graphical method. The minimum area of the vegetable crop required for the adoptability of the vegetable transplanter in the power tiller operated farms was recommended.

3. Results ad discussion

Average actual forward speed and wheel slip of the power tiller during transplanting operation was 0.86 km/hr and 4.49-4.74%, respectively. Average field capacity was 0.045 ha h-1 for tomato and chili (45×45 cm spacing) with field efficiency of 65.76 and 65.41%, respectively. Average field capacity was 0.06 ha/h for brinjal (60×60 cm spacing) with field efficiency of 65.49%.

Similar results were found by Miah et al. (2023) during their research on the design and evaluation of a power tiller vegetable seedling transplanter with dibbler and furrow type. They revealed the field capacity and field efficiency as 0.05 ha/hr and 61.18%, respectively, with a coefficient of variation of 5% or less. However, they conducted the test with brinjal crops at a forward speed of 1.2 km h-1 and a spacing of 0.7 × 0.6 m.

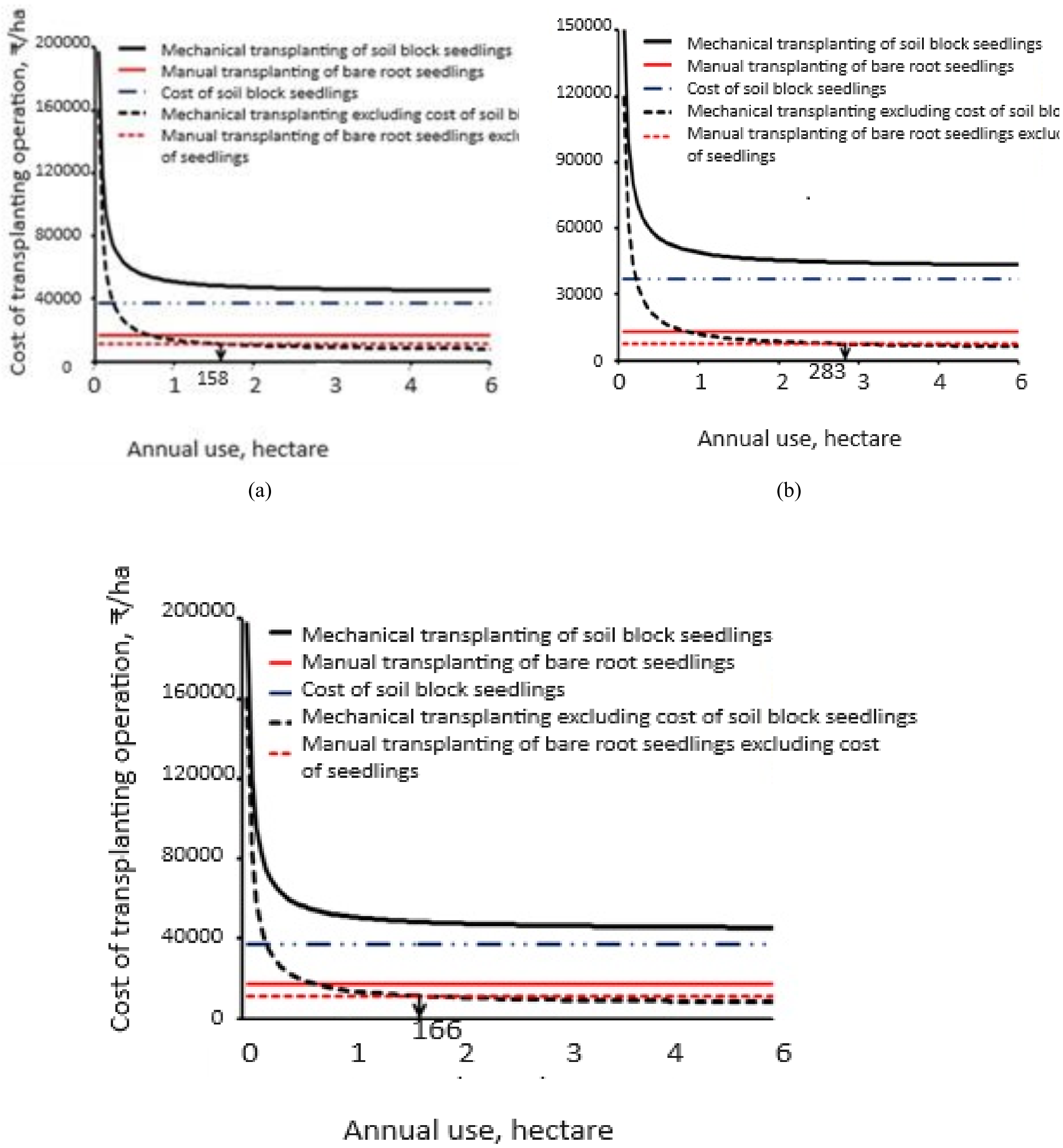
Turning the machine at the headland and adjustment in machine accounted for 23% of the total time, and loading of seedling stock trays accounted for 17% total time of mechanical transplanting. Total labour requirement for mechanical transplanting of tomato, brinjal and chili was 100, 71 and 110 man-h/ha, respectively, of which 11, 5 and 21 man-h/ha were required for filling missed plantings, proper placement and soil coverage of seedlings. Manual planting of bare root seedlings required 318, 211 and 321 man-h/ha for tomato, brinjal and chili, respectively.

Average planting rate of the transplanter was about 31 seedlings/min for the 45 cm within-row spacing, and 23.5 seedlings/min for the 60 cm within-row spacing. Percent missed plantings were 2.75, 1.19 and 2.63% for tomato, brinjal and chili seedlings, respectively. About 96% of tomato seedlings, 98% of brinjal seedlings and 93% of chili seedlings were planted in perfect upright orientation (planting efficiency). About 1.34% of tomato seedlings, 0.67% of brinjal seedlings and 3.38% of the chili seedlings tilted during mechanical transplanting. Orientation of most of tilted plantings was towards the direction of forward travel. Approximately 99.35% of plants were covered with sufficient soil. No plant mortality was observed in mechanically transplanted plots. Plant mortality of 4.44-5.42% occurred in manually transplanted plots.

The first harvest for mechanically transplanted tomato, brinjal and chili was at 102, 94 and 79 days after transplanting, respectively. Harvest for conventional manually transplanted vegetables was 8-12 days later than for mechanically transplanted vegetables. Yield of vegetables in mechanical transplanted plots was similar to, or slightly higher than, manual transplanted plots.

Variation in cost of mechanical transplanting plug seedlings of tomato, brinjal and chili at various levels of annual use is shown in Fig. 4. It indicates that the cost of mechanical transplanting of tomato, brinjal and chili decreased with increase in annual use. The cost of mechanical transplanting was higher than conventional manual method of transplanting bare root seedlings in rows. This is mainly owing to the cost of plug seedlings. Cost of soil block seedlings (₹37,037/ha) was the major expenditure, accounting for 77-83% of total cost of mechanical transplanting. Excluding cost of seedlings from total cost of operation, mechanical transplanting was economical when annual use of the machine was more than 2.00 ha or 44 hours for tomato, 3.89 ha or 65 hours for brinjal and 2.12 ha or 47 hours for chili. The cost of mechanical transplanting (excluding cost of seedlings) was ₹11140, ₹7370 and ₹11250 per ha for tomato, brinjal and chili, respectively (Fig. 5). Cost of complete mechanical transplanting including the seedling cost at the above annual use was ₹48180, ₹44410 and ₹48280 per ha for tomato, brinjal and chili, respectively. Mechanical transplanting improved labour productivity, and resulted in saving of 83-85% of productive time and 66-69% labour involved in conventional transplanting of bare root seedlings of vegetables. In general, farmers in small and semi-medium holdings grow tomato, brinjal and chili 2–3 times in a year. Growers with 0.55–0.95 ha of area under vegetables with double cropping, or 2 to 3 small growers or market gardeners (area less than 0.55 ha) together, with double cropping of vegetables in a year, can own and use the vegetable transplanter for efficient transplanting.

Based on the minimum annual use for individual vegetables crop, the average annual us of 60 hours was assumed for the power tiller operated 2-row vegetable transplanter. Cost of transplanting plug seedlings using the2-row vegetable transplanter assuming ownership by farmer was found to be ₹335 per hour or ₹7445 per hectare for transplanting tomato at 45 × 45 cm spacing. It was less than manual transplanting (₹10670 per hectare). The average pay back period was 3.44 years (207 h) for annual use of 60 hours.



(a) (b) (c)

Figure 4. Variation in cost of transplanting tomato seedlings by mechanical and manual method

The rate of custom hiring the 2-row vegetable transplanter was calculated considering internal rate of return of 25%. The custom hiring rate was ₹400/h (₹8900/ha). With this custom hiring rate the payback period was found to be 7.40 years (445 h) for an annual use of 60h. This custom hiring rate was also found to be less than the current average manual transplanting cost of ₹10670/ha. The breakeven point for owning the 2-row vegetable transplanter as against custom hiring it was identified from Fig. 5. In the Fig. 5, annual use corresponding to the cost of operation of ₹400/h is 38 hours. Therefore, breakeven point was 38 h/year. This breakeven point is equivalent to 1.70 ha/year. Therefore, minimum land holding of 1.70 ha is required by a vegetable grower to justify the ownership of vegetable transplanter. Thus, mechanized transplanting can eventually be accepted by vegetable growers having vegetable cultivation area less than 1.70 ha, if custom hiring services of vegetable transplanter are available. However, owning the 2-row vegetable transplanter was also justified if farmer operates the machine on custom hiring basis after transplanting his own fields.

A comparison of observed investment and quantity of produce harvested from the plots of tomato, brinjal and chili grown by mechanical transplanting using the 2-row vegetable transplanter (PVT) and manual transplanted using bare root seedlings (MTB) is shown in Table 1. Total cost of production by the use of vegetable transplanter was higher than the cost of manual transplanting. Difference between cost of production by mechanical transplanting and manual transplanting was ₹1442, ₹720 and ₹1445 for tomato, brinjal and chili, respectively.

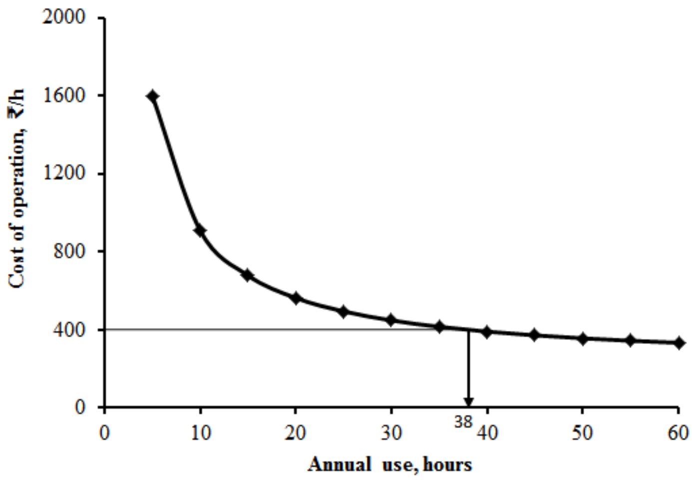


Figure 5. Break even analysis of power tiller operated 2-row vegetable transplanter

Table 1. Comparison of Observed Investment and Quantity of Produce Harvested from the Plots of Tomato, Brinjal and Chili

Sl. No.	Particulars	Tomato PVT	Tomato MTB	Brinjal PVT	Brinjal MTB	Chili PVT	Chili MTB
1.	Field area, m^2	486	486	486	486	486	486
2.	Cost of seed, ₹	-	23	-	20	-	30
3.	Cost of nursery bed preparation, ₹	-	83	-	83	-	83
4.	Cost of application of FYM, neem cake, VAM, Enriched super phosphate, Furadon, ₹	-	67	-	67	-	67
5.	Cost of Polythene / plastic for nursery bed, ₹	-	33	-	33	-	33
6.	Cost of picking up of seedlings, ₹	-	67	-	67	-	67
7.	Cost of seedlings per plot, ₹	1800	273	1013	270	1800	280
8.	Cost of transplanting, ₹	362	519	271	343	362	519
9.	Cost additional labourers for seedlings delivery, ₹	76	-	57	-	76	-
10.	Cost of crop establishment, ₹	19	23	8	15	35	28
11.	Total cost of transplanting, ₹	2257	815	1348	628	2272	827
12.	Cost of weeding, irrigation and crop management, ₹	4082	4082	4082	4082	4082	4082
13.	Total cost of production, ₹	6339	4897	5431	4711	6335	4909

14.	Quantity harvested during early season, kg	250	0	295	145	330	150
15.	Total quantity harvested, kg	1610	1560	1390	1395	1380	1375

PVT - Power tiller operated vegetable transplanter
MTB - Manual transplanting of bare root seedlings

The early harvest of vegetable benefits the grower with increase in sale price, ultimately earn more profit. Research also reveals that the early harvest grain possesses higher preservability of taste after cooking and the texture remain the same when kept at 25°C for 24 h (Arai and Itani, 2000). There was early season harvest in the fields where vegetables were transplanted mechanically. The manually transplanted brinjal and chili also had the early season harvest, but it was less than that of mechanically transplanted fields. It is assumed that sale of early harvest fetch at least 25% more price than the average price at which the particular vegetable is sold in the season.

Variation in profit / loss at various sale price of vegetables is shown in Fig. 6. When sale price of vegetables is low, there is loss. As the sale price increased, profit was realized, and the profit increased with increase in sale price. The profit from the mechanical transplanted vegetables was less than manual transplanted vegetables up to a certain sale price, but with increase in sale price, profit from mechanical transplanted vegetables was higher than manual transplanted vegetables.

When the sale price of tomato was more than ₹314 and ₹379 per quintal, manually transplanted and mechanical transplanted tomato crop, respectively was profitable (Fig. 6a). The profit from the mechanical transplanted tomato was more than manual transplanted tomato when the sale price of tomato was more than ₹1282/quintal. The production of brinjal by conventional method of transplanting was profitable when the sale price of brinjal was more than ₹329/quintal. When the sale price of brinjal was more than ₹371/quintal, production of mechanical transplanted brinjal was profitable (Fig. 6b). Further, profit by mechanical transplanted brinjal crop was more than conventional manual transplanted crop when the sale price of brinjal was more than ₹2215/quintal. 6c). The profit from the mechanical transplanted chili field was higher than manual transplanted field when the sale price of chili was more than ₹2891/quintal.

4. Conclusions

The cost economics analysis from the production of tomato, brinjal and chili in the experimental plots revealed that the use of power tiller operated vegetable transplanter for transplanting plug seedlings is definitely profitable, and hence, is economically feasible in small and medium vegetable farms. Hence, it can be recommended for mechanical transplanting of vegetables in the power tiller operated farms in India.

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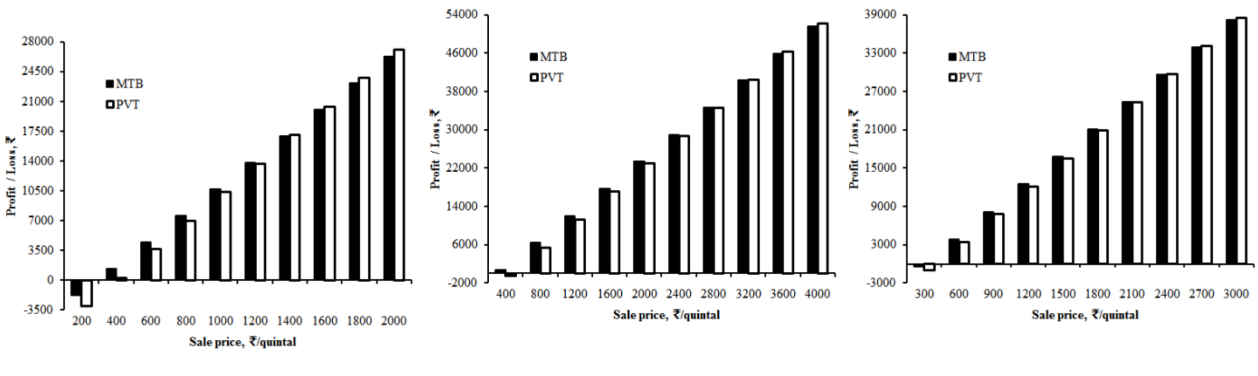

(a) (b) (c)

Figure 6. Profit / loss at various sale price for tomato, brinjal and chili.

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