

Performance Evaluation of Single Row-Low Horse Power Tractor Operated Vegetable Transplanter

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Authors' contributions

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

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ABSTRACT

Mini tractor (18 hp) operated single row vegetable transplanter was developed for Tomato and Brinjal crop transplanting. A simple rotating magazine type metering system was attached to the transplanter. The performance evaluation was done in was 20× 10 m at 1.0, 1.5 and 2.5 km/h. But at low speed i.e 1.0 km/h the results were in acceptable range. The main parameters of the developed transplanter were planting angle and missing percentage. Planting angle was 3.02 and 2.45°, similarly missing percentage was 9.5 and 8.78 % for Tomato and Brinjal respectively. The field-capacity and transplanting-efficiency were obtained 0.05 ha h⁻¹ and 83.3% respectively. Breakeven area obtained as 0.42 ha and payback period was 44.71 h.

Keywords: *Low horse power; missing percentage; planting angle; rotating magazine type and transplanting.*

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1. INTRODUCTION

India's vast climate makes availability of different varieties of vegetables. Vegetables play a very important role in human health because vegetables are rich source of antioxidants, fibres, vitamins, minerals and essential amino acids. The cultivated area under vegetable production has been gradually increased from 2004-2005 to 2018-2019 i.e. from 6.74 mha to 10.10 mha [1]. Moreover, the most important vegetable crops are contributing 11.2% global vegetable production, such as potato, tomato, okra, cabbage, peas and cabbage (Department of Agriculture, Cooperation & Farmers Welfare, 20).

Basically, the cultivation of vegetable crops started with transplanting. This transplanting of vegetable becomes more expensive and laborious. Because, seeding grown in nurseries and transplanting them into another field almost done by manually and requires 40% of total cultivation hours [1]. The global population involved in agriculture decreased from 44.36% to 42.75% from 2015 to 2017. At limited mechanization, production and productivity are limited. In general, 240-320 man/ha- h⁻¹ are required in conventional transplanting of vegetables [2]. To mitigate the shortage of agriculture labour, many studies focussed on development of mechanized vegetable transplanter.

Many attempts have been made developing manually operated vegetable transplanter [3], bullock drawn vegetable transplanter [4], Power tiller operated [5], tractor mounted vegetable transplanter [6], semi-automatic transplanter [7] and automatic transplanters ([8], [9], [10]). Still there is no single vegetable transplanter commercially available in the Indian market. Previous studies mostly focussed on higher power hp tractors and automation, but there is a limited research was done on small power rating operated vegetable transplanter. In India the population of farmers whose land holding capacity is 2 -10 ha much higher than the farmers whose land holding is more than 10 ha. Under such scenario small horse power tractors are most preferable. The small hp tractor economic feasibility and better fuel efficiency compared to high horse power tractors drawing farmer's attention towards its usage. Hence this present study focussed on the development of small hp tractor powered vegetable transplanter.

2. MATERIALS AND METHODS

2.1 Features of the Developed Vegetable Transplanter

A vegetable transplanter was developed for the operation transplanting of brinjal and tomato seedling. The developed transplanter is a single row and mini tractor mounted unit. It consists of revolving magazine type metering unit for metering and dropping of seedling in the furrows. A ground wheel was given for power transmission to the metering unit. It consists of two transport wheels for transplanter transportation as well as to control depth under actual field condition. In addition to that, there were seedling holding trays nearer to the operator seat to pick up the seedlings and drop the seedling into the cells of metering mechanism. There was a seating facility was provided on frame for comfortably sit on the transplanter and to feed the seedlings. With help of three point hitch system, the developed vegetable transplanter could be attached to tractor. The line diagram of developed transplanter is shown in Fig. 1. The following headings explain the function of each component of developed vegetable transplanter.

2.2 Metering Mechanism

Vegetable transplanter consist mainly metering mechanism because it plays a vital role in placing seedling into the soil. There are various types of metering systems such as pockets type and split cone cups [11], vertical descending cups or buckets types ([12] and [13]), conveyor type ([14] and [8]) and revolving magazine type or rotary cup type [7]. Among those, rotating magazine was selected because of its simplicity in construction and easy manoeuvrability [7].

2.3 Power Transmission System

There was a chain and sprocket, and bevel gear arrangement to transfer the power from ground wheel to metering system as in Fig. 2. The number of teeth on driver and driven sprocket were 10 and 21 respectively. A set of bevel gears consist of 24 and 17 number of teeth. The power transmission ratio of 2.9 was maintained to deliver seedling at appropriate time with proper spacing.

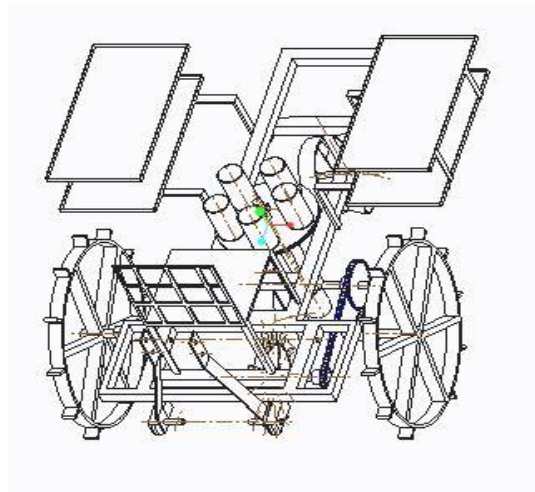


Fig. 1. Mini tractor operated single row vegetable transplanter

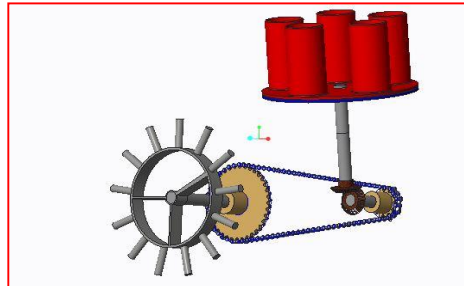


Fig. 2. Drive train of the developed transplanter

2.4 Seedling Dropping Tube

A hollow GI pipe of 75cm diameter and 45 cm height was selected based on seedlings parameters. At 150mm from the bottom of the tube the parabolic cut was created to support the seedling in the furrow while transplanting.

2.5 Furrow Opener

Double disc type furrow opener was selected because it forms the clear furrows and hence placement of seedlings on such furrows is easy. The soil type of experimental site was coarse sand and gravels. Under such soil condition double disc type furrow openers perform well than remaining type furrow openers. Two discs are made of high carbon steel and their diameter was 210 mm. These two discs are inclined outside at angle of 7° from vertical [15].

2.6 Soil Covering Devices

Pair of rolling press wheels was engaged for the purpose of placing soil around seedlings and

compact it. The diameter of rolling press wheels was 260 mm. It was placed at an angle of 15° with vertical [16].

3. PERFORMANCE AND FIELD EVALUATION OF DEVELOPED VEGETABLE TRANSPLANTER

The size of the test plot was 20 × 10 m. The texture analysis of soil was performed and results presented in Table 1. At the time of field evaluation, the age of the Tomato and Brinjal seedlings was thirty days. The physiological characteristics of the seedlings (height, stem thickness and diameter of canopy) were measured with help of 30 cm scale and vernier caliper which has an accuracy of 1 mm and seedling physiological parameters presented in Section 4.

Speed of operation, draft, power requirement, field capacity and transplanter field efficiency were measured and average values were recorded. The vegetable transplanter was tested

at 1.0, 1.5 and 2.5 km/h respectively. The results were analysed statistically by adopting the Completely Randomized Design with anova single factor.

Table 1. Soil texture analysis

Parameters	Value
Soil type	sandy clay loam
Sand (%)	68
Silt (%)	14.5
Clay (%)	17.5

3.1 Plant - Plant Spacing

The spacing between consecutive seedlings in each row was measured with help of steel rule and the average calculated.

3.2 Missing Seedling Percentage

It is the one of performance parameters which indicates the better transplanting efficiency of vegetable transplanter. It denotes the number of seedlings missed during transplanting and it is expressed in terms of percentage (7). It is calculated as follows

$$\text{Missing percentage} = \frac{n}{N} \times 100 \quad (1)$$

Where, n= Sum of missed hills in a row
N= Total number of hills in that row

3.3 Planting Angle

The procedure to measure the plant stand was reported by [4] and the percentage of plant stand was calculated using the following formula

$$\text{Planting angle} = \frac{m}{M} \times 100 \quad (2)$$

Where, m = Number of seedlings inclined at less than 30° to the vertical in a row
M = Total number of seedlings transplanted in that row

3.4 Field Efficiency of Transplanter

Field efficiency of transplanter was determined by the ratio of actual time required to transplant one hectare of land to theoretical time required to transplant one hectare of land [17].

$$F_e (\%) = \frac{EFC}{TFC} \times 100 \quad (3)$$

Where,

E.F.C = Effective field capacity, ha h⁻¹

and

T.F.C = Theoretical field capacity, ha h⁻¹.

3.5 Cost Economics

The cost economics of planter was estimated by considering fixed and operational costs of planter and power source. The labour charges and fuel cost are considered based on the prevailing market rates at the time of machine development period. The operating cost of vegetable transplanter was determined using straight line method as per IS 9164:1979.

$$\text{Total cost/ hour} = \text{Fixed cost/ hour} + \text{variable cost/ hour}$$

Breakeven area of Vegetable transplanter is calculated by using the following relationship [18,19].

Breakeven area, ha =

$$\frac{\text{Annual Fixed cost, Rs}}{\text{Cost of conventional manual transplanting, Rs/ha} - \text{Variable cost, Rs/ha}} \quad (4)$$

3.6 Payback Period

Payback period of vegetable transplanter is calculated by the following relationship [18],

Payback period, h =

$$\frac{\text{Total investment, Rs}}{\text{Cost of conventional manual transplanting, Rs/h} - \text{Cost of machine transplanting, Rs/h}} \times \frac{1}{EFC} \quad (5)$$

4. RESULTS AND DISCUSSION

Different physiological characteristics of seedlings were presented in Table 2. The seedling height varied from 96.3-120 mm and 102-110 mm for Tomato and Brinjal respectively. Similarly stem thickness also measured. It's around 54-55 mm and 54-61.2 mm for Tomato and Brinjal, respectively. Similarly spread diameter of seedlings was also measured.

4.1 Theoretical and Effective Field Capacity

The effective capacity of vegetable transplanter was measured at three different forward speeds. The effective field capacity varied from 0.05- 0.11 ha h⁻¹ as the change in speed of operation from 1.0 to 2.5 km/h [16]. The field capacity increased

with respect to speed may be due to the increase in rated time of operation. Fig. 3 shows the effect of operating speed on field capacity of developed transplanter.

4.2 Transplanter Field Efficiency

As like field capacity, field efficiency also computed. It was observed that, the field efficiency varied from 83.3 to 73.3 % as the change in speed of operation from 1 to 2.5 km/h. It may be due to the less theoretical time consumed while increasing in speed. The Fig. 3 shows the effect of operating speed on field efficiency of developed transplanter. Bharat, 2010 also developed the plug seedling planter and obtained with similar results. But they had compared the transplanting field efficiency over conventional method.

4.3 Seedling spacing

After the operation of transplanting with developed machine, the spacing between two immediate seedlings in a row was measured.

The average values of spacing between seedlings were presented in Table 3.

4.4 Missing Seedling Percentage

As like seedling spacing, missing percentage also calculated based on Eq(1) and the average values were presented in Table 3. The missing percentage varied from 3.02 - 4.52 % for tomato and 2.45 - 4.44 % for brinjal seedling at three forward speeds. The results found in this study are agreement with the results of [20]. There is significant effect of varying operating speeds on missing percentage of tomato and brinjal seedlings at 5% level of significance and the standard deviation of the results presented in Table 4. Ningthoujam et al. [20] also got the similar results for onion bulb planter. The difference is due to manual error to feed the seedlings into the rotating metering plate at higher speeds. These variations are shown in Fig 4. At 1.0 km/h the developed vegetable transplanter shows better results for missing percentage for both Tomato and Brinjal.

Table 2. Physiological characteristics of tomato and brinjal seedling

Seedling parameter	Tomato			Brinjal		
	T ₁	T ₂	T ₃	T ₁	T ₂	T ₃
Plant height (mm)	120	104	96.3	102	110	105
Stem thickness (mm)	55	54	54.6	61.2	56.3	54
No. of leaves	2	4	3	4	6	4
Spread diameter of plant (mm)	62	78	61	75	76.3	78.1

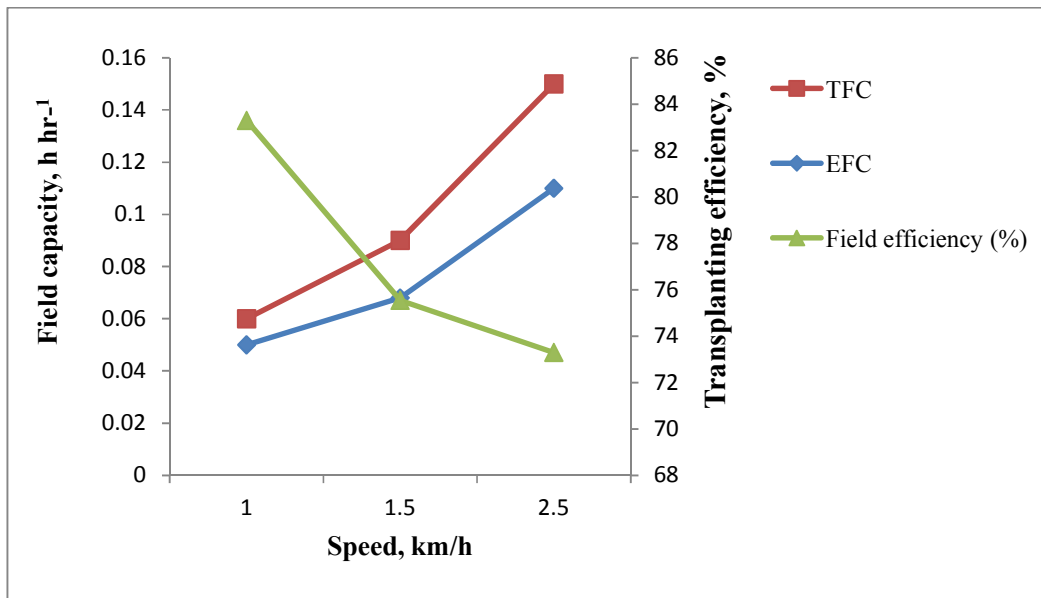


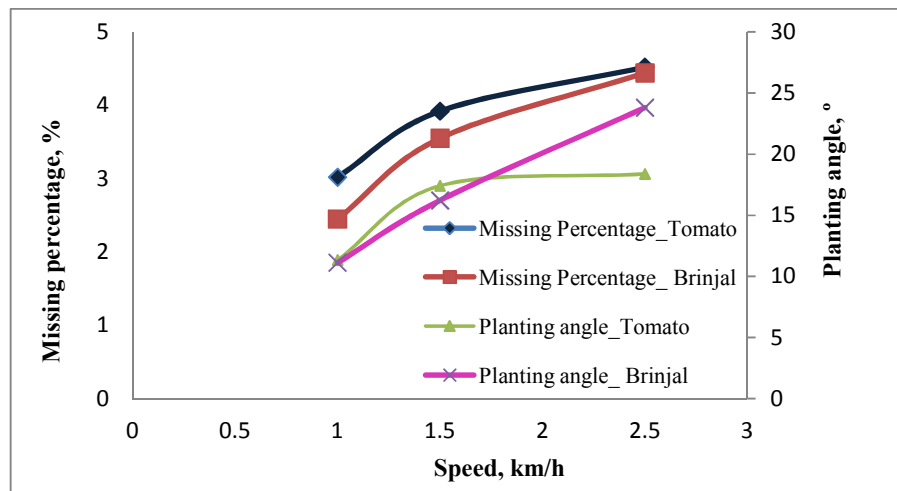
Fig. 3. Effect of operating speed on field capacity and transplanting efficiency

Table 3. Average values of different quality parameters

Parameter	Operating speed, km/h					
	1.0		1.5		2.5	
	Tomato	Brinjal	Tomato	Brinjal	Tomato	Brinjal
Seedling spacing, cm	44.26	44.71	42.90	43.02	41.49	40.29
Missing percentage, %	3.02	2.45	3.92	3.55	4.52	4.44
Planting angle, °	9.5	8.78	12.60	11.84	17.41	16.22

Table 4. Standard deviation of the planting angle and missing seedling percentage

Speed	Planting angle		Missing seedling percentage	
	Tomato	Brinjal	Tomato	Brinjal
1	0.751	0.425	0.413	0.392
1.5	0.671	0.840	0.469	0.512
2.5	1.301	0.812	0.358	0.426

**Fig. 4. Effect of operating speed on Missing percentage and Planting angle**

4.5 Planting Angle

The change in planting angle with respect to the operational speed of the transplanter is depicted in Fig 4. The obtained seedlings were in acceptable range i.e 0-30° [7]. For tomato seedling, angle was 9.5° and for brinjal 8.78° at 1.0 km/h respectively. But there is a significance difference among the three different forward speeds on the seedling angle. Table 4 shows the standard deviation of the results. The planting angle is less for brinjal as compared to tomato seedlings because the stem thickness and stiffness of seedling.

4.6 Cost Economics of Vegetable Transplanter

Operating cost of developed transplanter for transplanting was determined using straight line

method. Total cost of operation of the developed transplanter was found to be Rs. 3742.6/ha and actual field capacity of transplanter was 0.05 ha h⁻¹. Whereas Rs.7500/ ha for conventional transplanting. Thus, there was a net saving of Rs.3758/ha by the developed vegetable transplanter over manual transplanting.

Breakeven area of developed transplanter was also calculated based on Eq(4) and obtained as 0.42 ha. Thus, transplanting in an area of 0.42 ha is to be done by the developed transplanter in a hour, So that the cost of transplanting by the transplanter will be equal to the cost of conventional transplanting. If the transplanter is used more than 0.42 ha area, the cost of transplanting will be lower than conventional transplanting. Payback period of vegetable transplanter was determined (Eq(5)) and obtained as 44.71h.

5. CONCLUSIONS

A single row mini tractor operated transplanter was developed having the dimensions of 1125 mm× 1425 mm× 970 mm. While during the field evaluation, the developed machine got better transplanting results at low speed (i.e 1.0 km/h). At that low speed the effective field capacity was 0.05 ha h⁻¹ and transplanting efficiency was 83.3 %. However, planting angle was 3.02 and 2.45°; similarly missing percentage was 9.5 and 8.78 % for Tomato and Brinjal respectively. Breakeven area of developed transplanter was 0.42 ha. Payback period of transplanter was 44.71 h. Regarding the developed transplanter, there is a need to develop a transplanter for future research with more number of rows and multistage metering system to reduce the delay in placement of seedlings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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