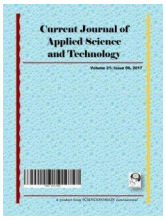

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Development and Performance Evaluation of Manually Operated Seedling Planter for Horticultural Crops

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Authors' contributions

This work was carried out in collaboration between both authors. Authors KH and AKS designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author AKS guided the analyses of the study. Authors KH and AKS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A low cost manually operated single row vegetable seedling planter was developed for transplanting of plug and pot type vegetable seedlings on ridges and mulch beds. It consisted of jaw assembly, delivery pipe, lever, handle and spacing marker. Operating principle of the developed transplanter involves the raising the transplanter up to one feet height and allow to free fall in the soil, dropping the seedling in the seedling delivery tube, pressing the lever in upward direction which enable the jaw to open the soil and seedling was placed in the soil by gravity and lifting the transplanter with open jaw and close the after raising the transplanter by one feet height. It was evaluated for inter and intra-row spacings of 45×45 cm. Manual transplanting on plastic mulch beds (MPMB) was compared with developed transplanter on plastic mulch beds (TPMB). The transplanting rate using single labour was found to be 5 and 12 seedlings /min for MPMB and TPMB respectively. The field capacity was calculated as 0.0031 and 0.0166 for MPMB and TPMB. Similarly, field efficiency was

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21-28% and 42-57%. Moreover, cost of operation (Rs/ha) in was found to be 9218 and 1753Rs/ha. The time saving over manual transplanting is 80.96% by using seedling planter. The weight of developed transplanter is 2.4 kg and cost is Rs. 500. It is completely made up of stainless steel Developed vegetable transplanter found more suitable for vegetable transplanting as compare to traditional method of manual transplanting. The aim of this study is to reduce the human effort, to increase the field efficiency, to reduce the cost of operation and to increase the field capacity while planting horticultural crops.

Keywords: Manual seedling planter; single row; vegetable seedlings; ridges; mulch bed.

1. INTRODUCTION

Vegetables play an important role in human nutrition and vegetable production is essentially a small-farm venture that benefits thousands of families in urban and rural areas. Growing vegetables in the country, offers self-employment to families who are engaged in different aspects: crop-cultivation, harvesting, transporting, preparation for the market and selling for about 175 types of vegetables [1]. It is estimated that the per capita fruits and vegetables availability in India is less than 190 to 200 g per day, which is below the recommended quantity of 230 g per capita per day. On other side, growth in the vegetable and fruit sectors offers considerable opportunities for increased diversification of agricultural income and nutrition in the future in Indian farming conditions. The estimated demand for vegetables in India by the end of 2020 is 220 million metric tons and this can be achieved by increasing the area under vegetable cultivation and mechanised operation of vegetable seedlings cultivation. In the past one decade, the change in cropping pattern is more towards the horticulture sector and commercial crops [2].

Presently at most of the area is covered by hybrid seeds for vegetable cultivation, seeds are costly but give higher yield and quality produce. Indian farmers allocate a relatively small proportion of their land [3]. Two techniques are followed in vegetable transplanting *viz*., raised bed and flat planting. In raised bed, the nursery bed seedlings are transferred manually in rows at a recommended spacing in the raised bed and soil is placed around the seedling and compacted. The raised seed-bed (90 to 120 cm), ridges and furrows (10-15 cm wide and 15-30 cm high) prepared manually, bullock and by tractor-drawn implements. Whereas, in case of flat planting, seedlings are transferred manually in rows, covered, compacted with soil. Suitable soil working component used in vegetable transplanter with the reduced draft to be selected. Three types of seedlings are transplanted in the field bare root, plug and pot/soil block seedlings [4]. In small scale vegetable gardening, holes dug by hand at desired spacing and seedling placed and packed with soil or soil with manure. In case of medium to large scale farming system, the furrows are opened using bullock or tractor-drawn implements and seedlings are planted in furrows by hand. The acceptable limit of soil coverage is near about 100% [5].

These series of operations are not affordable for large-scale operation, difficult to timely operation and often results in non-uniform plant distribution. It is time consuming, tedious, labour-intensive and expensive operation. Mechanical transplanters such as semiautomatic transplanter were developed [6]. Soil is opened by mechanical means and seedlings are fed to the metering mechanism by labourer. About 15-72 seedlings per minute have been reported in several researches. However, these transplanter cost is very high and operated by power tillers/tractors, not feasible for small farms [7]. Presently, most of the operations under vegetable cultivation are accomplished manually. These operations are accomplished in kneeing posture or squatting posture. Therefore, they are more tedious, uncomfortable, tiresome and drudgery prone [8]. Raised bed planting type traditional method of vegetable seedling transplanting requires 185 man-hours/ha for onion. While, flat planting method requires about 260 man-hours/ha for transplanting tomato [9]. Since the majority of Indian farmers having small land holdings, they are unable to procure high cost machinery for vegetable cultivation [10]. The cheaper technologies which can be beneficial over the traditional cultivation practices are the current need of vegetable farming [11,12].

The objective of the present study is to develop a seedling planter for horticultural crops and to distinguish the field efficiency, field capacity and cost of operation for planting between traditional

method of planting and planting by seedling planter.

2. MATERIALS AND METHODS

The stainless steel manually operated single row vegetable seedling planter consists with simple jaw type mechanism mounted at bottom and operated by lever with thin stainless-steel wire. The jaw mechanism is developed with combination of spring, Hexagonal bolt, frame support. Other parts are handle, seedling feeding pipe, lever, marker holder and marker pointer. The overall weight of seedling planter is 2.41 kg. A CAD drawing of the manually operated single row vegetable seedling planter is shown in Fig. 1.

The details of the different components of the developed transplanter are explained below.

2.1 Seedling Feeding Pipe

The seedling feeding pipe was made up of stainless steel and the diameter measured was 65 mm, which was calculated as approximately 1.5 times the root media maximum dimension (plug/pot seedlings) when the plant in upright condition i.e., 30 to 40 mm. The height of pipe was set as 1000 mm which was lower than 5th percentile value of standing elbow height of Indian farmer worker (i.e., 1000 mm) for easiness in operation for easy operation of transplaning the handle was arranged as per the elbow angle of worker i.e. 150 to 170°.

2.2 Handle

The handle was mounted at top of the seedling feeding pipe, made of stainless steel pipe and opposite to movable jaw which was at the bottom of pipe. It was used to control, hold and penetrate the jaw in the soil bed. The height of handle from ground was fixed on the basis of average standing elbow height of operator i.e. 900 mm and diameter of 25 mm was decided on the basis of the average hand grip of human and length of handle was kept 200 mm.

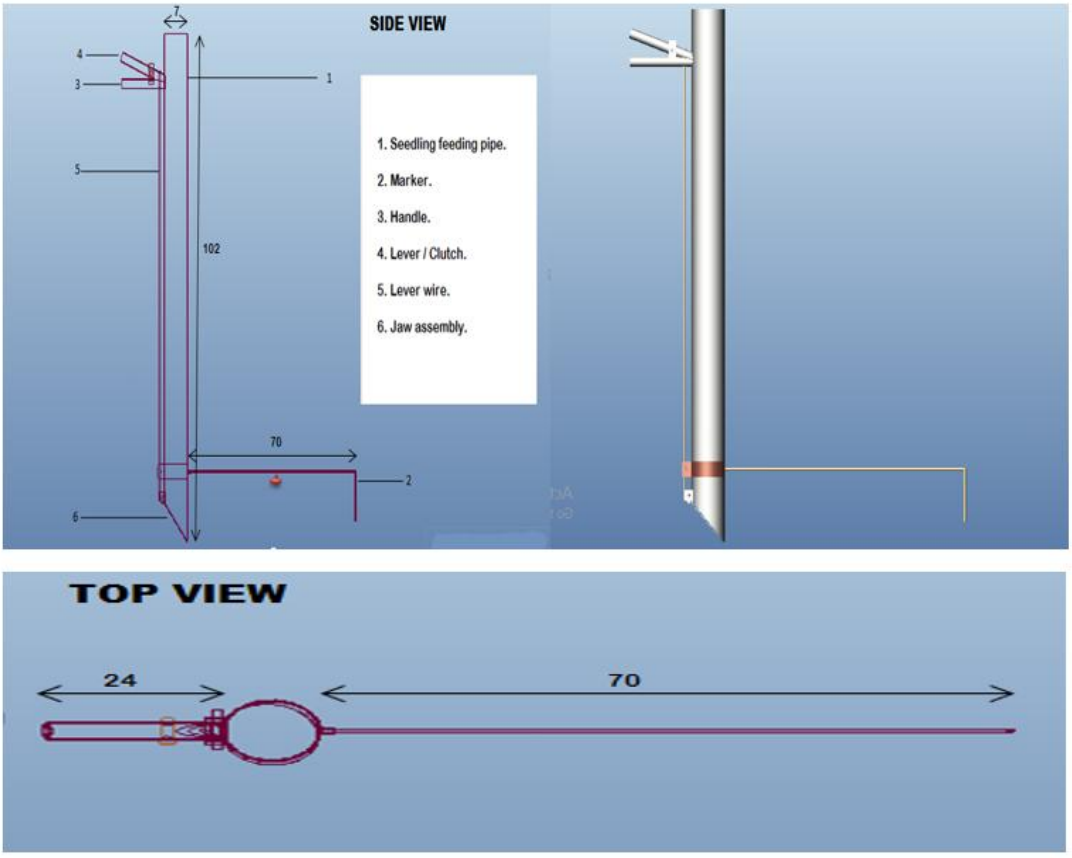

Fig. 1. Manually operated single row vegetable seedling planter

2.3 Jaw Assembly

It is a soil engaging part of equipment, which makes opening for placing the seedling. The jaw was fabricated with two sections, one section is end of the seedling feeding pipe and other one was movable against the axis provided at top of jaw. This movable section of the jaw was fitted with stud and spring mounted at one end to regain its closed position against stainless steel wire. The angle between the two sections of the jaw was kept 215.5° for easy operation. The complementary angle to this, sometimes named as apex angle 2θ, which is inclined angle formed between the two edges, ranges from 36 to 60° for proper penetration of implement into the soil; therefore, apex angle of jaw was taken as 47.26°.

2.4 Lever

The lever was used to operate the jaw, which was made up of stainless steel pipe. The length of lever is 200 mm, width was 20 mm and the thickness of lever was 2 mm. A wire is provided to give leverage to open the soil by jaw.

2.5 Marker

The marker was provided in order to indicate the location of seedling to be transplanted. In the present equipment, there was provision to mark laterally as well as longitudinally. This can be adjusted as per the spacings of crop. The maximum and minimum spacings which can maintain in marker is 300 mm to 750 mm respectively.

The technical specifications of the manually operated single row transplanter are given in Table 1.

2.6 Work Quality

The formation of dug and hole in the plastic mulch is tedious job. Manual transplanting by traditional method a labourer has of carry the seedling tray along with him and needs more time in manoeuvrability. Developed machine provided the combination of operation at a time such as formation of hole, pacing of seedling, covering the soil, marking for transplanting, carrying the ability of portray having provision of to place the seedling on the developed prototype. The hole prepared by jaw is of uniform in size and depth. It facilitate the hole formation, putting of seedling in the hole, covering the soil, carrying the seedling along with machine, and spacing marking operation in standing posture and help to increase the forward speed of operation which results in higher capacity and increases the efficiency of the labour at reduced efforts. The developed machine always plant the seedling in the centre of punch.

Working principle of the machine is one has to hold the prototype in vertical position with handle and as the jaw in a closed position to the height of 15-30 cm and allow to fall or press it to penetrate into soil bed, one seedling has to be picked up from tray and put it in to the seedling feeding pipe, it will be dropped and held into the jaw from inside. Then, pulling the lever towards handle to open the jaw inside the soil and the moment the jaw is opened the seedling resting inside the jaw will drop by gravity into the pit/hole made by jaw. Lift the transplanter lever in pressed position (jaw open) and the soil accumulated at periphery of jaw roll back towards the root zone of seedling thus stabilizing the seedling in the pit/hole and covering the seedling root zone by soil. The different components were designed based on the

Table 1. Technical specifications of the manually operated single row seedling planter

Parameter of transplanter	Details
Length of the transplanter, mm	1000
Diameter of seedling feeding pipe, mm	65
Diameter of hole punched in soil, mm	70
Depth of operation, mm	**75**
Height of handle from ground, mm	900
Diameter of handle, mm	25
Types of clutch used	Lever type
Overall weight, kg	2.410
Adjustment of plant spacing, mm	300 - 750

seedling characteristics (*viz*., Dimension of seedlings, soil-root containment), human subject strength, reach, clearance limits (*viz*. Operating force requirement, diameter and clearance between handle and lever, height of equipment), working environment (soil cone index, raised bed /ridge/ mulch).

2.7 Field Performance Evaluation

Testing of the developed transplanter was evaluated in research farm of Horticulture, JNKVV, Jabalpur. Ridges and furrows were made by manually operated plastic mulch laying machine. Height and top width of ridge was 20 cm and 90 cm. The length of ridge was 35 m length. Moisture content of the soil was 17-18% (db) soil type is vertisol. Plastic mulch on ridges was covered by manually operated plastic mulch laying machine and plastic mulch as time taken for number of seedlings transplanted were recorded by stop watch and transplanting rate, field capacity, field efficiency, labour requirement, cost of operation and saving in labour and cost was calculated by standard formula and methods [13,14]. The developed machine was tested in 35 x 9.5 m area for each method and tomato seedlings of 20 days old raised in 104 cell portray were used. Average seedling height was 150 mm. Portrays were irrigated one day before the transplanting [15,16]. Formulae used to evaluate the performance of the vegetable seedling planter are as follows

2.8 Seedlings Delivered

The seedlings delivered per minute were calculated by observing the average time required for transplanting two seedlings in second, the formula of which is given as [17].

$$\text{Seedlings delivered/min} = 60/t \quad (1)$$

Where,

t= average time required for transplanting one seedling, s.

2.9 Speed

The effect of field condition on speed of operation of transplanter was observed by following relation for both plant spacing.

$$\text{Speed}_{45}\text{,km/h} = o.45 / t \times 3.6$$

2.10 Actual Field Capacity

The actual field capacity of the transplanter was calculated by using following relation [18].

$$\text{Actual field capacity, ha/h, } = (N \times W \times S) / 10 \quad (2)$$

Where,

N= number of rows covered in single pass;
W= distance between two rows, m;
S= Speed of operation, km/h

2.11 Field Efficiency

Field efficiency in percentage was calculated by taking the ratio of actual field capacity to theoretical field capacity. The theoretical speed of operation was considered as 0.7 km/h.

2.12 Labour Required

Labour required was calculated in terms of the man hours required for transplanting in one hectare area by taking inverse of actual field capacity.

2.13 Cost of Operation

The labour charges were considered as Rs. 25 /h. Hence the labour cost required (Rs.) for one hectare transplanting was calculated by multiplying man hours required for transplanting in one hectare area with 25.

2.14 Time Saving over Manual Transplanting

The time saving over manual transplanting in terms of percentage was calculated using following ratio.

TS_{MT} = Man hours required using developed transplanter / Man hours required by conventional method.

Where,

TS_{MT} = Time saving over manual transplanting

Developed one row transplanter was compared with manual transplanting by both methods.

3. RESULTS AND DISCUSSION

3.1 Conventional Method of Making Holes on Mulch Sheet and Planting Seedlings by Carrying Seedling Tray with Hands

The conventional method of making holes on mulch sheet and planting seedlings manually is the most time consume the most time consuming and labour consuming process than planting seedlings with the help of seedling planter and tray holding bag. Making holes manually the uneconomical steps which are following by the farmers are:

a. Marking at the sides of the mulch sheet for proper maintenance of plant to plant and row to row distance which requires 6 minutes for three persons to cover 35 m length bed of 1 m width.
b. Pointing the plant to plant distance of required length with sharp end wooden stick which requires 6 minutes for 1 person to cover 35 m length bed of 1 m width.
c. Making holes on the markings with the help of steel glass which has sharp edge with the impact force by stones which requires 15 minutes for 2 persons to cover 35 m length bed of 1 m width.
d. Planting the seedlings with hand by carrying the trays while planting which takes 50.4 minutes for 1 person to cover an area of 35×1 m.

The manually making holes on mulch sheet and transplanting the seedlings requires 80.96% more time i.e. 316.45 h/ha than the seedling planter i.e. 60.24 h/ha. Conventional method also required 295 man - h/ha whereas for seedling planter it requires 56.1 man - h/ha. It was also observed that by using seedling planter and tray holding bag the drudgery obtained was less than manually transplanter due to posture of subjects (Table 2).

Figs. 2 and 3 shows the above four methods for conventional planting of seedlings.

Table 2. Field performance parameters of developed single row vegetable seedling planter

Parameters	Planting with hands (traditional method)	Planting with seedling planter
Plant to plant spacing, mm	300	300
Seedlings/min	5	12
Speed, km/h	0.072	0.198
Actual field capacity, ha/h	0.0031	0.0166
Field efficiency, %	21-28	42-57
Labour required, man-h/ha	295	56.1
Cost of operation, Rs/ha	9218.75	1753.125
Saving cost, %	—	80.98
Time required for 1 hec, h/ha	316.455	60.240
Time saving over conventional method of planting seedlings, %	—	80.96

Fig. 2. Conventional method of marking and pointing on mulch sheet

Fig. 3. Conventional method of making holes on mulch sheet and planting seedlings

Fig. 4. Planting seedlings on mulch sheet with developed transplanter

3.2 Planting Seedlings with the Help of Developed Seedling Planter

Ridges and furrows were made by manually and with developed mulch machine. Height and top width of ridge was 20 cm and 90 cm. The length and width of ridge were 35 m and 1 m respectively. Soil type was vertisol. Plastic mulch on some ridges was covered manually and some ridges with developed mulch and drip laying machine. Time taken for number of seedlings transplanted were recorded by stop watch and transplanting rate, field capacity, field efficiency, labour requirement, cost of operation and saving in labour and cost was calculated.

The developed machine was tested in 35 x 9.5 m area for transplanting of tomato seedlings. The 20 day aged seedlings were used for transplanting and is kept in the 98 cell seedling tray. Average seedling height was 150 mm. seedling trays were irrigated one day before the transplanting. The spacing between plant to plant is taken as 300 mm. It has been observed that it requires 20 min to plant seedlings in 35 m length bed of 1 m width which includes two rows at 600 mm distance. The actual field capacity obtained is 0.0166 ha/h. Fig. 4 shows the Planting seedlings with developed seedling planter in field condition (Table 2).

4. CONCLUSIONS

Transplanting rate with hand held transplanter was found to be 12 seedlings/min against 5 seedlings/min in case of manual transplanting for plastic mulch bed. The field capacity was calculated as 0.003 ha/h and 0.016 for manual transplanting plastic mulch beds (MPMB), by hand held transplanter on plastic mulch beds (TPMB). Moreover, cost of operation in was found to be 9218 and 1753 Rs/ha. The time saving over manual transplanting is 80.96%. Weight of transplanter is 2.4 kg and cost Rs. 500/-. It is simple, light weight, low cost and found suitable for transplanting of vegetable seedlings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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