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Field evaluation of a semi-automatic vegetable transplanter for major vegetable crops

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ABSTRACT

A tractor operated semi-automatic two row vegetable transplanter using plug type nursery was developed. This machine makes ridges with provisions to vary row and plant spacing. Machine released the seedlings close to the ground in near vertical position without any damage. Machine was evaluated in the field for transplanting tomato, brinjal, and chilli nursery at forward speeds of 1.00, 1.25, and 1.50 km/h. Plug type nursery was used which was grown in trays having truncated pyramid shape cells of volume 16.28 cm^3 using soil-less media developed by Punjab Agricultural University. Plant missing, plant doubling, and quality of feed index was adversely affected at higher forward speeds for tomato and brinjal. Quality of feed index was 100 % for chilli up to highest forward speed of 1.5 km/h. The machine can transplant tomato, brinjal and chilli at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h respectively with plant missing of less than 4% at these recommended speeds. The machine could transplant the seedlings with inclinations less than 30°, which is considered erect. No plant mortality was observed after 20 days for all the crops studied. Field capacity of the machine for transplanting tomato, brinjal and chilli was 0.103 ha/h, 0.126 ha/h, and 0.152 ha/h, respectively as recommended for these cops. Saving in labour with the use of the machine over manual method for transplanting tomato, brinjal and chilli was 84.86%, 85.58%, and 88.41%, respectively, whereas saving in cost was 24.80%, 28.03% and 42.42%, respectively.

Key words: Brinjal, Chilli, Tomato, Transplanting, Vegetable transplanter.

Punjab is essentially an agrarian state. The farmers have adopted wheat-paddy rotation extensively. Increase in area under paddy cultivation from 0.39 million ha (1970-1971) to 2.89 million ha (2014-15) has led to over exploitation of under-ground water and electric power (Anon 2017). The Punjab government under the diversification policy has recommended to increase the area under fruits and vegetables (Anon 2015). Moreover, it has been estimated that there is a shortage of about 30 million tonnes of vegetables at present. With increase in population, India has to produce about 225 million tonnes of vegetables by the year 2030 in order to meet the demand (Vanitha *et al.* 2013). It is, therefore, necessary to shift more area under vegetable cultivation in India. Cultivation of vegetables is highly labour intensive. Labour requirements for transplanting of vegetables are 184-274 man-h/ha (Garg and Dixit 2002) which is very high and depends upon number of plants/ha. Labour requirements for transplanting of tomato, brinjal and chilli are estimated to be 254, 230 and 254 man-h/ha (Narang 2010), which is not only very high but scarce and costly also in Punjab. Non-availability of labour in time delays transplanting of the crops, which results in reduced yield and returns to the farmer. Therefore, mechanization of vegetable transplanting is essential for increase in the area especially in a state like Punjab. Two types of vegetable transplanters has been reported namely automatic and semi-automatic. Automatic vegetable transplanters are relatively complex and costly. Plug type nursery is commonly used in vegetable transplanters. However, some attempts have been made to develop and evaluate vegetable transplanters using bare root type of seedlings also (Chaudhari *et al.* 2003, Satpathy 2003, Manes *et al*. 2010). Feeding the bare root nursery in the narrow slots is a major problem of these machines. Rotating magazine type metering mechanism commercially used in semi-automatic potato planters and sugarcane planters, has been employed in the semi-automatic vegetable transplanters using plug type seedlings (Murphy 1980, Anon. 2004, Narang *et al*. 2011, Nandede and Raheman 2016). In these machines, the seedlings were dropped from a height due to which proper placement of the seedlings and plant damage are adversely affected. The machine developed has metering mechanism similar to the one reported by Craciun and Balan (2005), in which the

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seedlings are held and carried in the pockets for release in the furrow.

MATERIALS AND METHODS

Description of the vegetable transplanter

A 2-row semi-automatic tractor mounted vegetable transplanter comprising three ridger bottoms with ridge leveler/compactor, two metering units, two seats, two seedling tray stands, two ground wheels, and power transmission system was developed for transplanting important vegetable crops. The machine was operated by a tractor of 50 hp or more. The machine makes beds and simultaneously transplants the nursery seedlings in one go. The ridger bottoms can be removed in case the transplanting is not required on the beds. Metering unit assembly had a metering wheel comprising two identical metering discs, an eccentric disc, five nursery cups, ten cam assemblies, and two packer wheels. The cup assembly consisted of lower and upper parts, a pin, and two roller followers for opening and closing of the cup. The upper part of the cup had a square opening of 71 mm × 71 mm for feeding seedling into the cup and the lower part was truncated pyramid with two opposite sides in V-shape to penetrate the soil and create a hole for dropping the seedling. The cup started to open when it had penetrated into the soil up to desired depth, for releasing the seedling without any seedling damage and then it began to close when it came out of the soil.

Two seats, one for each row, were provided on the auxiliary frame for seating the operators. One nursery tray stand for each row was provided to place the nursery trays from where the operator plucked the nursery seedlings for feeding in the metering unit. A pair of inclined packer-wheels was provided in each metering unit to firm up the soil around the transplanted seedling. The machine was supported on two pneumatic type ground wheels with one ground wheel on each side of the machine. Overall gear ratio between the driving wheel (ground wheel) and the metering wheel was changed to vary the plant spacing. A stationary view of the machine is given in Fig 1 and its brief specifications of the machine in Table 1.

Fig 1 A stationary view of transplanter.

Table 1 Brief specifications of vegetable transplanter

Parameters	Specifications
Type of the machine and size	Semi-automatic, 2-row
Power required, hp	50 hp or above
Type of nursery to be used	Plug type
Metering mechanism	
Shape and size of cup (mm)	Vertical cup type having upper part square hollow section and lower part truncated pyramid V-shaped (split in the middle)
Mechanism for opening cups	Cam and roller mechanism
Drive to the metering mechanism	Pneumatic ground wheel (through chains and sprockets)
Type of bed maker	Ridger type
Row spacing (cm)	67.5 (Adjustable)
Method of changing plant spacing	By changing sprocket
Number of trays carried on the machine	8
Arrangement for firming up of the soil around the plant after transplanting	Two inclined packer wheels for each row
Weight of the machine (kg)	
without operators and nursery trays	580
with operators and nursery trays	728

The machine requires three persons apart from the tractor operator. Two persons are required for feeding the seedlings into the machine, while sitting on the machine, while another person is required for placing the nursery trays on the machine.

Field evaluation studies were conducted in the field which was prepared by irrigation followed by two operations of cultivator and two planker. Nine trials (three replications of three forward speeds) of 10 m length were conducted with the help of transplanter, while one trial of the same length was conducted for manual transplanting. The layout provided head land of 3 m to 5 m for setting the machine at the desired forward speed of travel and for the subjects to get adjusted for feeding the machine. The agronomic parameters of crop transplanted is given in Table 2.

Field performance of the developed transplanter was assessed in terms of plant missing, plant doubling, quality of feed index, plant inclination, depth of planting, and plant mortality after 20 days of sowing for tomato, brinjal and chilli at forward speeds of 1.00 km/h, 1.25 km/h and 1.50 km/h. Plug type nursery grown in trays having truncated pyramid shape cells (Top and bottom diameter 27.3 mm and 15.0 mm respectively, and height 35.4 mm) of volume 16.28 cm^3 using soil-less media developed by Punjab Agricultural University called PAU media-1 (composition undisclosed). Distance between the successive plants transplanted in the

Table 2 Agronomic crop parameters of crops transplanted

Parameter	Tomato		Brinjal		Chilli	
	TVT*	MT*	TVT	MT	TVT	MT
Variety	Punjab Ratta		PBH-3		Punjab Sindhuri	
Age of nursery (DAS)*	58		80		85	
Plant spacing (cm × cm)	67.5 × 30.0		67.5 × 45.0		67.5 × 60.0	

*TVT-Transplanted using vegetable transplanter, *MT- Manual transplanted, *DAS- Days after sowing

Table 3 Field performance results for transplanting tomato

Parameters	TVT			MT
Forward speed (km/h)	1.00	1.25	1.50	-
Plant missing (%)	3.70	16.05	28.40	0.00
Plant doubling (%)	0.00	0.00	7.41	0.00
Quality of feed index (%)	96.30	83.95	64.20	100.00
Plant inclination, angle from the vertical (deg).	5.40 (0.24)	12.03 (0.15)	17.63 (0.03)	7.24 (0.09)
Depth of planting (cm)	6.10 (0.20)	5.20 (0.09)	4.60 (0.19)	5.70 (0.08)
Plant mortality, after 20 days				

*Figure in the parenthesis are coefficient of variation.

field was measured in 8 m length of the machine transplanted field for each experiment. If the distance between the successive plants was more than 50% of the desired plant spacing, it was taken as a miss. On the other hand, if the distance between two successive plants was lesser than 50% of the plant spacing, it was taken as doubling. Quality of feed index was calculated by subtracting plant missing and doubling percentage from 100. Plant inclination with the vertical of 10 seedlings in a row, was measured by using a protractor with a flat base attached to it. Depth of planting (length of seedlings in the soil was measured by uprooting 10 seedlings randomly in each experiment) for machine transplanted as well as manually transplanted crop. The field capacity of the transplanter was calculated at a speed where the performance was in acceptable limits assuming field efficiency 75% (Anon 2004). A view of the vegetable transplanter in operation and the machine transplanted crop is shown in Fig 2.

RESULTS AND DISCUSSION

Tomato

Plant missing was observed to be 3.70%, 16.05% and 28.40% at forward speeds of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively (Table 3). This was because of lesser time available to fill successive feed pockets by the subject as the feed rates increased from 56 plugs/in to 83 plugs/min corresponding to increase in forward speed from 1.00 km/h to 1.50 km/h. Plant missing are within the reasonable limits (i.e. <5%) at forward speed of 1.00 km/h only.

Data of plant doubling presented in Table 3 indicates that the plant doubling also increased with increase in forward speed. For example, no plant doubling was observed at forward speed of 1.00 km/h and 1.25 km/h, while it was 7.41% at forward speed of 1.50 km/h. The increase in plant doubling with increase in forward speed is due to the same reasons as for increase in plant missing with increase in forward speed, as discussed earlier. Data for quality of feed index presented in Table 3 indicates that the quality of feed index decreased with increase in forward speed. For example, quality of feed index for transplanting in fields with raised bed was 96.30%, 83.95% and 64.20% at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively. Decrease in quality of feed index with increase in forward speed is because of increase in plant missing and plant doubling at higher forward speed. The quality of feed index of more than 90% was observed at a forward speed of 1.00 km/h only, in case of tomato crop. Maximum forward speed for transplanting tomato with plant spacing of 30 cm is recommended as 1.00 km/h.

Fig 2 A view of vegetable transplanter in operation and transplanted crop.

Plant inclination increased with increase in forward speed. The increase in plant inclination with increase in forward speed is due to higher momentum of plants at higher speed of the machine relative to the ground on which the plant falls. Angle of inclination of the plants at forward speed of 1.00 km/h was very close to control (manual method of transplanting), which is 7.24° in fields. Plant inclination less than 30° was considered erect by various research workers (Boa 1984, Satpathy 2003, Narang 2010, Nandede and Raheman 2016). Therefore, plant inclinations even at higher speed of 1.50 km/h also can be considered erect.

Data of depth of planting presented in Table 3 indicates that the average depth of planting within the range of forward speed studied ranged from 4.60 cm to 6.10 cm. Depth of planting data (Table 3) shows that forward speed affects depth of planting, which is on expected lines.

Field capacity of the machine at the recommended forward speed of 1.00 km/h is 0.103 ha/h. The machine thus could save 84.71% labour as well as 24.07% transplanting cost as compared to manual method.

Brinjal

Data for the effect of forward speed and type of bed on the performance of machine for transplanting plug type nursery of brinjal is given in Table 4. Plant missing was observed to be 0.00%, 3.70% and 13.73% at forward speeds of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively in fields This was because of lesser time available to fill successive feed pockets by the subject as the feed rates increased from 37 plugs/min to 56 plugs/min corresponding to increase in forward speed from 1.00 km/h to 1.50 km/h. Plant missing at forward speed of 1.50 km/h are very high.

Data of plant doubling indicates that no plant doubling was observed at forward speeds of 1.00 km/h and 1.25 km/h. Plant doublings (2.33%) were observed only at a forward speed of 1.50 km/h. Quality of feed index decreased with increase in forward speed and was 100.00%, 96.30% and 83.94% at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively. This trend of decrease in quality of feed index at higher forward speed is because of increase in plant missing with increase in forward speed. This decrease was more at forward speed of 1.50 km/h, as plant doubling was also observed at this relatively high speed due to which human errors while feeding the seedlings increased. It may be observed that plant missing and doubling were lower for brinjal as compared to tomato for similar forward speeds. This was because of higher plant spacing of brinjal (45 cm) as compared to tomato which was transplanted at 30 cm. Thus, the feed rates were lower in case of brinjal (37 to 56 plugs/min) as compared to tomato (56 to 83 plugs/min) for forward speed in the range of 1.00 km/h to 1.50 km/h. Quality of feed index was poor at forward speed of 1.50 km/h only. Therefore, recommended forward speed for transplanting brinjal at 45 cm is 1.25 km/h.

Plant inclination increased with increase in forward speed and was 6.73°, 11.20°, and 15.80° at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively. This trend is the same as for tomato for the same reasons as discussed earlier. Moreover, all the plants transplanted by the machine can be considered erect as explained earlier for tomato. Average depth of planting within the range of forward speed ranged from 5.40 to 6.30 cm in fields. Coefficient of variation of the depth of planting varied from 0.07 to 0.17. No plant mortality was observed after 20 days of transplanting. This was because the plants were placed in relatively erect position and were also placed in the desired depth range at all the forward speeds and field conditions. Field capacity of the machine at the recommended forward speed of 1.25 km/h is 0.126 ha/h. The machine thus could not only save 86.20% labour but also the cost of transplanting which was 31.46% lesser as compared to manual method.

Table 3 Field performance results for transplanting brinjal

Parameters	TVT			MT
Forward speed (km/h)	1.00	1.25	1.50	-
Plant missing (%)	0.00	3.70	13.73	0.00
Plant doubling (%)	0.00	0.00	2.33	0.00
Quality of feed index (%)	100.00	96.30	83.94	100.00
Plant inclination, angle from the vertical (deg.)	6.73 (0.24)	11.20 (0.39)	15.80 (0.27)	6.90 (0.08)
Depth of planting (cm)	6.30 (0.07)	5.40 (0.10)	5.40 (0.17)	5.50 (0.09)
Plant mortality, after 20 days	0.00	0.00	0.00	0.00

*Figure in the parenthesis are coefficient of variation.

Chilli

Data in Table 4 indicates that no plant missing was observed at a forward speed of 1.00 km/h and 1.25 km/h except at 1.50 km/h (2.08%) because, plant spacing in case of chilli crop was relatively much higher (60 cm) as compared to other vegetable crops like tomato (30 cm) and brinjal (45 cm). Feed rate required of chilli for forward speed range of 1.00 km/h to 1.50 km/h is 28 plugs/min to 42 plugs/min. Feed rates within this range were relatively much easier to feed which resulted in low plant missing even at higher speed resulting in quality of feed index more than 97.92%. There exists a potential to increase the forward speed to increase the field capacity without adversely affecting the transplanting performance.

Plant inclination increased with increase in forward speed and average plant was 16.73°, 17.35°, and 20.85° at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h, respectively. Average depth of planting within the range of forward speed ranged from 5.40 cm to 5.80 cm in fields. Coefficient of variation of the depth of planting varied from 0.08 to 0.10. No plant damage and plant mortality were observed within the range of forward speed for the same reasons as discussed for tomato and brinjal.

Estimated field capacity of the machine at forward speed of 1.50 km/h is 0.152 ha/h. There exists a potential to increase the field capacity by increasing the forward speed.

Table 4 Field performance results for transplanting chilli

Parameters	TVT			MT
Forward speed (km/h)	1.00	1.25	1.50	
Plant missing (%)	0.00	0.00	2.08	0.00
Plant doubling (%)	0.00	0.00	0.00	0.00
Quality of feed index (%)	100.00	100.00	97.92	100.00
Plant inclination, angle from the vertical (deg)	16.73 (0.13)	17.35 (0.07)	20.85 (0.07)	23.50 (0.07)
Depth of planting (cm)	5.80 (0.10)	5.50 (0.09)	5.40 (0.08)	5.38 (0.19)
Plant mortality, after 20 days				

*Figure in the parenthesis is coefficient of variation.

Labour and financial savings with the use of the machine was 85.70% and 28.97% respectively, as compared to the manual method.

Conclusions

Plant missing, plant doubling, and the quality of feed index was adversely affected at higher forward speeds for tomato and brinjal. Quality of feed index was 97.92% for chilli at a forward speed of 1.5 km/h. The machine can transplant tomato, brinjal and chilli at forward speed of 1.00 km/h, 1.25 km/h, and 1.50 km/h respectively with plant missing of less than 4% at these recommended speeds. The machine could transplant the seedlings with inclinations less than 30^{o}, which is considered erect. No plant mortality was observed after 20 days for all the crops studied. Field capacity of the machine for transplanting tomato, brinjal and chilli was 0.108 ha/h, 0.126 ha/h, and 0.152 ha/h at forward speed of 1.00 km/h, 1.25 km/h and 1.50 km/h respectively. Saving in labour with the use of the machine over manual method for transplanting tomato, brinjal and chilli was 84.71%, 86.20%, and 85.70% respectively, whereas saving in cost was 24.07%, 31.46% and 28.97% respectively.

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REFERENCES

Anonymous. 2004. Annual Report of the all India coordinated research project on farm implements and machinery. Department of Farm Machinery and Power, Tamil Nadu Agricultural University, Coimbatore, India.

Anonymous. 2015. *http://punenvis.nic.in*, Diversification plan for Punjab. Site visited on May 2017

Anonymous. 2017. *Hand Book of Agriculture*, p 3. Punjab Agricultural University, Ludhiana.

Boa W. 1984. Design and development of an automatic transplanter for field vegetables. *Journal of Agric Engg. Res.* **30:** 123–30.

Chaudhari D, Singh V V and Dubey A K. 2003. Design and development of tractor operated two row vegetable transplanter. Paper presented in 37th annual convention of ISAE held at CTAE, MPAUT, Udaipur (Rajasthan), India on 29 -31 January.

Craciun V and Balan O. 2005. Technological design of a new transplanting machine for seedlings. *J. Central Eur. Agric.* **7**(1): 164.

Garg I K and Dixit A. 2002. Design and development of tractor operated vegetable transplanter. Paper presented in 24th workshop of All India Coordinated research scheme on Farm Implements and Machinery (ICAR) held at TNAU, Coimbatore, India on 18-21 April.

Manes G S, Dixit A K, Singh S, Sharda A and Singh K. 2010. Development and evaluation of tractor operated vegetable transplanter. *AMA* **41**(3): 89–92.

Murphy Allan. 1980. Low cost rotary vegetable transplanter. *Agricultural Gazette of New South Wales* **91:** 6–9.

Nandede B M and Raheman H. 2016. A tractor drawn vegetable transplanter for handling paper pot seedlings. *AMA* **47**(4): 87–92.

Narang M K, Dhaliwal I S and Manes G S. 2011. Development and evaluation of a two row revolving magazine type vegetable transplanter. *Journal of Agric Engg* **48**(3): 1–7.

Satpathy S K. 2003. Effect of selected parameters on the performance of a vegetable transplanter. M Tech thesis, Punjab Agricultural University, Ludhiana, India.

Vanitha S M, Chaurasia S N S, Singh P M, and Naik P S. 2013. *Vegetable statics technical bulletin* 51, Indian Institute of Vegetable Research, ICAR, Varanasi, .cited from https://www.iivr.org.in Site visited on June 2017.