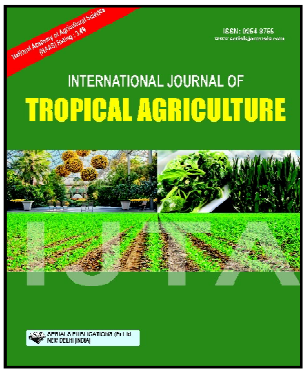

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Development of A Low Cost Manually Operated two Row Vegetable Transplanter

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Abstract: A low cost manually operated two row vegetable transplanter was developed for transplanting of plug type vegetable seedlings on ridges and mulch beds. It consisted of frame, seedling tray holder, hand lever, frame support rod, jaw assembly, seedling feeding pipe, handle, gauge wire, marker holder and marker. The developed transplanter was evaluated for inter and intra-row spacings of 45×45 cm and 60×60 cm. Manual transplanting on ridges (MTR) and on plastic mulch beds (MTP) were compared with manually operated transplanter on ridges (MOTR) and on plastic mulch beds (MOTP). The transplanting rate of vegetable seedlings using single labour was found to be 8, 5, 23 and 17 seedlings min^{-1} for MTR, MTP, MOTR and MOTP, respectively. Forward speed ranged from 0.15 to 0.41 km/h for entire range of spacing and type of transplanting selected. Similarly, field efficiency was found to be 30 and 41% (MTR), 21 and 28% (MTP), 45 and 60% (MOTR), 33 and 44% (MOTP) for spacing of 45×45 and 60×60 cm, respectively. Similarly, cost of operation (Rs/ha) was found to be 2571 and 1416; 3770 and 2121; 884 and 497 and 1200 and 675 Rs/ha, respectively. Difference in heart rate, cardiac cost and maximum oxygen consumption rate was worked out to be 33 beats/min, 203703/ha (20.37 beats/m^2) and 2.9109 l/min. Moreover rest pause during the operation was worked out to be 4.5 minute. The time saving over manual transplanting is 34% and 32% in MOTR and MOTP, respectively.

Keywords: Manual transplanter, Plug seedling, Pot seedling, Vegetables seedlings

INTRODUCTION

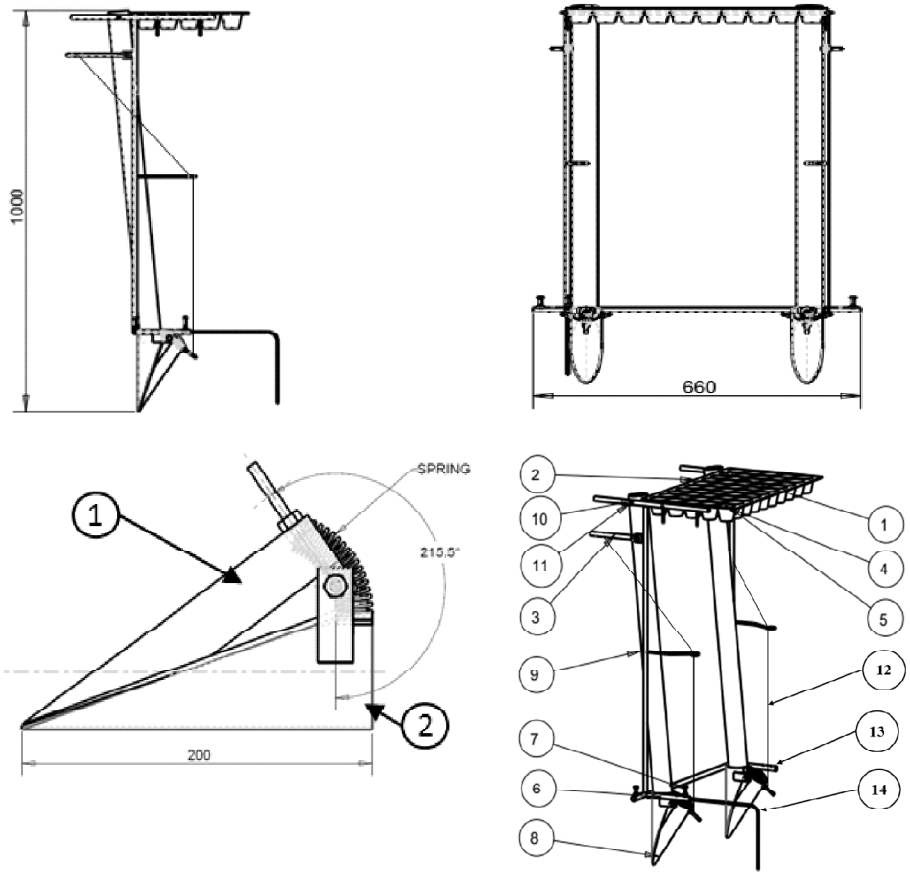
Vegetables play an important role in human nutrition and vegetable production is essentially a small-farm venture that benefits thousands of families in urban and rural areas [1]. Growing vegetables in the country, offers self-employment to families who are engaged

in crop-cultivation, harvesting, transportation and selling for about 175 types of vegetables. According to Horticultural Statistics at a Glance-2015, total vegetable production in India in the year 2014-15 was 168.30 million tonnes grown over an area of 9.54 mha with an average yield of 17.64 ton/ha [2]. It is estimated that the per capita fruits and vegetables availability in India is less than 190 to 200 g per day, which is far below the recommended quantity of 230 g/capita/day [2]. 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 [3]. The estimated demand of 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 [4]. Presently at most of the area is covered by hybrid seeds for vegetable cultivation, seeds are costly but gives higher yield and quality produce [5]. Indian farmers allocate relatively small proportion of their land [6]. Two methods are followed for vegetable transplanting *viz*., raised bed and flat planting method. In raised bed, the seedlings raised on nursery bed are transferred manually in rows at recommended spacing, soil is placed around the seedling, compacted and watered. The raised seed-bed (90-120 cm), ridges and furrows (10-15 cm wide and 15-30 cm high) prepared manually or by bullock-drawn, tractor-drawn implements [7]. Whereas, in case of flat planting, seedlings are transferred manually in rows, covered, compacted with soil and watered. Three types of seedlings are transplanted in the field bare root, plug and pot/soil block seedlings [8]. In small scale vegetable gardening, holes dug by hand at desired spacing and seedling placed and packed with soil or soil with manure [9]. 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 [10]. The acceptable limit of soil coverage is near about 100% [11]. These series of operations are not affordable for large-scale operation [12], difficult to timely operation [13] and often results in non-uniform plant distribution. These are time consuming, tedious, labour-intensive and expensive operations [14,15]. Various commercial models of hand-held transplanters for planting potato, tomato, onion, brinjal (eggplant), cabbage, chili pepper, cucumber, peanut, garlic. Average transplanting rate of the transplanter are of 100 plants per hour [16,17,18]. However, they are costly. Mechanical transplanters such as semiautomatic transplanter were developed [11,19]. The soil is opened by mechanical means and seedlings are fed to the metering mechanism by labourer. Suitable soil working component is used in vegetable transplanter with reduced draft need to be selected for minimum power requirement and better transplanting [8]. However, developed transplanters operated by power sources such as tractor and power tiller are costly, and not feasible for small farms. Presently, most of the time transplanting is accomplished manually at small farms. These operations are accomplished in kneeling posture or squatting posture. Therefore, they are more tedious, uncomfortable, tiresome and drudgery prone. While, flat planting method requires about 260 man-hours ha^{-1} for transplanting tomato [7]. Since the majority of Indian farmers having small land holdings, they are unable to procure high cost machinery for vegetable cultivation. The cheaper technologies which can be beneficial over the traditional cultivation practices are the current need of vegetable farming. Hence to enhance the efficiency of a labour, an attempt was made to develop a low cost, simple, affordable and light weight two row transplanter suitable for small farming of vegetables to simplify the transplanting operation.

MATERIALS AND METHODS

The CAD drawing of the manually operated two row vegetable transplanter is shown in Fig. 1. It

consisted of frame, seedling tray holder, hand lever, frame support rod, jaw assembly, seedling feeding pipe, handle, gauge wire, marker holder and marker. The manually operated two row vegetable transplanter was fabricated from with a frame (1) simple jaw type mechanism (8) mounted at bottom and operated by lever (3) with gauge wire (12). The jaw mechanism is developed with combination of spring, hexagonal bolts (4, 5, 7, 11) attached to frame support (6). Other parts are seedling tray (2), seedling feeding pipe (9), handle (10), Marker holder (13), Marker (14).



1. Frame, 2. Seedling tray, 3. Hand lever, 4, 5, 7 and 11. Hexagonal bolt 6. Frame support rod 8. Jaw assembly 9. Seedling feeding pipe 10. Handle 12. Gauge wire 13. Marker holder 14. Marker

Figure 1: CAD drawing of the manually operated two row transplanter

Major components of the transplanter

Seedling feeding pipe

The seedling feeding pipe made of PVC of diameter 63 mm, which was calculated as approximately 1.5 times the root media maximum dimension (plug 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 women worker (*i.e.* 1000 mm) for easiness in operation. The effort can be made when the elbow angle of 150 to 170 degree [9].

Handle

The handle was mounted near top of the seedling feeding pipe, made of mild 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 female operator *i.e.* 100 cm and diameter (2.5 cm) was decided on the basis of average hand grip of human and length of handle was 14 cm.

Jaw assembly

It is a soil engaging part of equipment, which makes opening for placing the seedling. The length of jaw was 200 mm with top width of 50 mm. the jaw was fabricated with two sections from stainless steel, one section fixed to 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 inside at one end to regain its closed position against gauge wire. The angle between the two sections of the jaw was found to be 215.5° as optimized to operate with ease. The complementary angle to this were sometimes named as apex angle 2θ, which is inclined angle formed between the two edges, it ranges from 36° to 60° for proper penetration of implement into the soil; therefore apex angle of jaw was taken as 47.26°.

Lever

The lever was used to operate the jaw, which was made up of mild steel. The length of lever was 155 mm, width was 20 mm and the thickness of lever was 3 mm.

Marker

The marker was provided in order to indicate the location of next seedling to be transplanted. it has a provision to mark laterally (13) as well as longitudinally. This can be adjustable as per the recommended crop spacing.

Working Principle of the developed machine

One has to hold the prototype of developed transplanter in vertical position with handle and as the jaw in a closed position (Fig. 2). Raise it to the height of 15-30 cm and allow to fall or press it to penetrate into soil bed/mulch bed, Pickup the seedling from tray from each hand and put it into the two seedling feeding pipes, it will be dropped and held into the jaw. 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 keep in a hole made by jaw in the soil by gravity. 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. successful transplanting is done, lifted transplanter then place at the point marked by marker for further transplanting, repeat the same procedure for transplanting to cover the field. The different components were designed based on the seedling characteristics (viz., dimension of seedlings, soil-root

Figure 2: Developed two row vegetable transplanter

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).

Field evaluation

Testing of the developed transplanter was evaluated in research farm of ICAR-Central Institute of Agricultural Engineering, Bhopal. Ridges and furrows were made by tractor operated ridge and furrow former. Height and top width of ridge was 20 cm and 5 cm. The length of ridge was 10 m length. Moisture content of the soil was 16-18% (db) soil type is vertisol. Plastic mulch on ridges was covered manually 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[19]. The developed machine was tested in 0.1 ha area for each method, and chilli seedlings of 28 days old raised in 104 cell portray were used. Average seedling height was 150 mm. Portrays were irrigated one day before the transplanting.

Formulae used to evaluate the performance of the two row handheld vegetable transplanter are as follows

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

$$\text{Seedlings delivered, min}^{-1} = \frac{60}{\text{average time required for transplanting two seedlings, s}}$$

Speed

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

$$\text{Speed}_{45}\text{, km h}^{-1} = \frac{0.45}{\text{average time required for transplanting two seedlings, s} \times 3.6}$$

$$\text{Speed}_{60}\text{, km h}^{-1} = \frac{0.6}{\text{average time required for transplanting two seedlings, s} \times 3.6}$$

Actual field capacity

The actual field capacity of the transplanter was calculated by using following relation

$$\text{Actual field capacity, ha h}^{-1} = \frac{N \times W \times S}{10}$$

Where, N= number of rows covered in single pass

W= distance between two rows, m

S= Speed of operation, km h^{-1}

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^{-1}.

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.

Cost of operation

The labour charges were considered as Rs. 25 h^{-1}. 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.

Time saving over manual transplanting

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

$$\text{Time saving over manual transplanting} = \frac{\text{man hours required using developed transplanter}}{\text{man hours required by manual transplanting}}$$

Energy expenditure (kJ/s) = 0.159×Average heart rate (beats/min) – 8.72,

ΔHR (beats/min) = Average working heart rate – average heart rate during rest

Output (m^2/h) = area covered × duration / average time,

Cardiac cost of worker per unit of output (beats/ m^2 area covered) = ΔHR × duration/ output.

The results were statistically analyzed using test of significance (t-test at 5% level of probability) and simple regression (r).

III. RESULTS AND DISCUSSION

Construction details

Developed two row transplanter was evaluated on ridges and furrow (MOTR) and plastic mulch bed (MOTP) in the field and compared with by both methods manual transplanting by hand on ridge and furrow (MTR) and manual transplanting by hand on plastic mulch bed (MTP). The details of the different components of the developed transplanter with the technical specifications are given in Table 1. Force required to open the jaw is minimum. The plant drop height by the developed machine is one meter, the range of plant spacing adjustment and depth of operation is 65-750 mm and 75 mm respectively. Weight of developed transplanter is 4.2 kg and cost is Rs. 850/-.

Table 1
Technical specifications of the manually operated two row transplanter

Parameter	*Details*
Overall dimensions, mm	1000 × 660 × 750
Type of transplanting mechanism	Jaw
Diameter of seedling feed pipe, mm	50
Diameter of hole punched in soil, mm	60
Diameter of handle, mm	25
Height of handle from ground, mm	1000
Type of clutch used	Lever
Range of plant spacing adjustment, mm	65-750
Depth of operation, mm	75
Overall weight, kg	4.2
Cost of transplanter, Rs.	850

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 increase the efficiency of the labour at reduced efforts. Developed machine always plant the seedling in the centre of punch. The plant stand in the field using MOTP and MOTR was at par as with MTP and MTR. The mortality percentage was negligible. Field evaluation of manually operated two row vegetable transplanter is shown in Fig. 3.

Figure 3: Field evaluation of manually operated two row vegetable transplanter

The seedlings were transplanted with developed manually operated two row vegetable transplanter and traditional method of manual transplanting for both 45 x 45 cm and 60 x 60 cm spacing on ridge furrow and plastic mulch bed. Number of seedlings transplanted per min with MOTR, MOTP, MTR, and MTP were 23 and 17 against 8 and 5 seedlings per min, respectively for both spacing. Field performance parameters of developed vegetable transplanter are given in Table 2.

Table 2
Field performance parameters of developed vegetable transplanter

Parameters	*MTR*		*MTP*		*MOTR*		*MOTP*	
Plant and row spacing, cm×cm	45×45	60×60	45×45	60×60	45×45	60×60	45×45	60×60
Transplanting rate, seedlings/min	8		5		23		17	
Speed, km/h	0.22	0.29	0.15	0.20	0.31	0.41	0.23	0.30
Actual field capacity, ha/h	0.009	0.017	0.007	0.012	0.028	0.050	0.020	0.037
Field efficiency, %	30	41	21	28	45	60	33	44
Labour required, man-h/ ha	102.85	57.85	150.84	84.85	35	20	48	26
Cost of operation, Rs/ha	2571	1446	3770	2121	884	497	1200	675
Time saving over manual transplanting, %	-				34		32	

Work output and efficiency

The time required for transplanting was 35 man-h per ha and 40 man-h per ha with $MOTR_{45}$ and $MOTR_{60,}$ whereas it required 102.85 man-h per ha and 57.85 man-h per ha with MTR_{45} and MTR_{60}. Further, it required 48 man-h per ha, 54 man-h per ha and with $MOTP_{45}$ and $MOTP_{60.}$ Whereas, it required 150.84 man-h per ha and 84.85 man-h per ha with MTP_{45} and MTP_{60}. Speed of operation attained with the transplanter during the testing was 0.31 km/h and 0.41 km/h for $MOTR_{45, 60}$, whereas in $MTR_{45,60}$ it was 0.22 km/h and 0.29 km/h respectively. However speed of operation reduces on $MOTP_{45,60}$ to 0.23 km/h and 0.30 km/h and $MTP_{45,60}$ to 15 km/h and 0.20 km/h, respectively.

The field capacity was calculated as 0.009-0.017 ha/h; 0.007-0.0012 ha/h; 0.028-0.050 ha/h and 0.020-0.037 ha/h for manual MTR, MTP, MOTR and MOTP at both spacing's, respectively. Field efficiency of the device for $MOTR_{45,60}$ was 45% and 60% whereas for $MOTP_{45,60}$ it was 33% and 44%, respectively. The field capacity in MTP and MTR is lower as the operation is carried out in sitting posture and time required to dig out the hole and covering the seedling with soil reduced the forward speed of operation. Moreover, the field capacity is lower in MOTP as compare to MOTR because while transplanting on plastic mulch, at certain insurances the time required to lift the transplanter after transplanting was stuck-up and reduced the forward speed of operation and resulted in lower filed capacity. Time saving with transplanter for MOTR and MOTP was 34% and 32%, respectively. Cost of operation (Rs/ha) in was found to be 2571-1446; 3770-2121; 884-497 and 1200-675 Rs/ha. Developed transplanter is simple, light weight, low cost machine found suitable for transplanting of vegetable seedlings.

Ergonomic evaluation

Heart rate, cardiac cost, oxygen consumption rate, maximum oxygen consumption rate in working conditions and work rest cycle was considered for ergonomic evaluation. The heart rate at rest position and in working condition was measured with heart rate monitor (Make: Polar). The procedure involves firstly calibrate the measuring setup in laboratory before 1 hour of operation. After calibration, sensor and receiver was tied on the chest and wrist of operator, respectively. The value of difference in heart rate during the operation of manually operated vegetable transplanter was worked out to be 33 beats per minute. Cardiac cost was worked out to be 203703/ha and 20.37 beats/m^2. Oxygen consumption rate was 0.8511 l/min and maximum oxygen consumption rate as 2.9109 l/min. The value of rest pause during the operation of manually operated vegetable transplanter was worked out to be 4.5 minute.

Energy expenditure, average working heart rate, average heart rate during rest and maximum output was found to be 16.14 kJ/s, 103 beats/min, 87 beats/min and 500 m^2/h, respectively.

CONCLUSIONS

1. Transplanting rate with single labour was found to be 23 and 17 seedlings min^{-1} against 8 and 5 seedlings min^{-1} in case of manual transplanting for raised bed and plastic mulch bed, respectively.
2. The field capacity was calculated as 0.009-0.017 ha/h; 0.007-0.0012 ha/h; 0.028-0.050 ha/h and 0.020-0.037 ha/h for manual transplanting on ridges (MTR), on plastic mulch beds (MTP), by transplanter on ridges (MOTR) and by transplanter on plastic mulch beds (MOTP) at both spacing's, respectively.
3. Similarly field efficiency was 30-41%; 21-28%; 45-60% and 33-44%. Moreover, cost of operation in was found to be 2571-1416; 3770-2121; 884-497 and 1200-675 Rs/ha. The time saving over manual transplanting is 34 % and 32% in MOTR and MOTP, respectively.

4. Difference in heart rate, cardiac cost and maximum oxygen consumption rate was worked out to be 33 beats/min, 203703/ha (20.37 beats/m^2) and 2.9109 l/min. Moreover rest pause during the operation was worked out to be 4.5 minute.

5. Weight of developed transplanter is 4.2 kg and cost is Rs. 850/-. Developed transplanter is simple, light weight, low cost machine found suitable for transplanting of vegetable seedlings.

REFERENCES

Wargovich, M. J. (2000), Anticancer properties of fruits and vegetables. *Hort Science.* 35: 573-575.

Anonymous. (2016), Horticultural Statistics at a Glance 2015. OUP Catalogue. Ministry of Agriculture and Farmers Welfare, Govt. of India.

Anonymous. (2014), *OECD-FAO Agricultural Outlook 2014*. OECD Publishing, 2014. (*http://dx.doi.org/10.1787/agr_outlook-2014-en*. 2014) pp: 98 (327).

Mittal, U. (2007), Can horticulture be a success story for India? Working paper no. 197, Indian Council for Research on International Economic Relations.

Nandede, B.M., K.R., Solanki and Roul, A. K., (2017), Development and evaluation of manually operated portray type nursery seeder. *Multilogic in Science*. **7**(23):71-75.

Birthal, P.S., Joshi, P.K., Thorat, A. (2007), Diversification of Indian agriculture towards high value crops: the role of small holders. Discussion Paper 00727, International Food Policy Research Institute, Washington, DC, USA.

Anonymous. (2004), Chapter 9 and 10, Data Book for Agricultural Machinery Design. pp: 339-396, Central Institute of Agricultural Engineering (CIAE), Bhopal-462038, India.

Nandede, B.M., Raheman H. and Deore, H.V., (2014), Selection of suitable furrow opener and furrow closer for vegetable transplanter. *Agricultural Mechanization in Asia, Africa and Latin America*. **45**(2), 40-47.

Nandede, B.M., Raheman, H. and Kumar, G.V.P., (2014), Standardization of potting mix and pot volume for the production of vegetable seedlings in paper pot. *J. Plant Nutr.* **37**(8), 1214–1226.

Ferminger, T. A. (1953), Firminger's manual of gardening for india. Thacker, Sprink and Co. Pvt. Ltd., Kolkata, West Bengal.

Nandede, B.M. and Raheman, H. (2015), Multi Stage Metering Mechanism for Transplanting of Vegetable Seedlings in Paper Pots. *Journal of Institute of Engineers*. 96 (4): 295-300.

Parish, R.L. (2005), Current developments in seeders and planters for vegetable crops. *Hort Technology*, 15(2): 1–6.

Manes, G. S., Dixit, A. K., Sharda, A, Singh S. and Singh K. (2010), Development and evaluation of tractor operated vegetable transplanter. *Agricultural Mechanization in Asia, Africa and Latin America* **41**(3): 89-92.

Haffar, I. (1995), Design and field evaluation of a low cost crop transplanter with multiple seedlings feed. *Agricultural Mechanization in Asia, Africa and Latin America* **26**(3): 29-32.

Chaudhuri, D., Singh, V.V., Dubey, A.K. (2002), Refinement and adoption of mechanical vegetable transplanters for Indian conditions. *Agricultural Engineering Today*, 26(5-6): 11–20.

Anonymous. (2016), Hand held planters. AKORM Corporation (*http://www.akorm.com/planter/sk20.htm*, Retrieved on 24, August 2017).

Anonymous. (2016), Stand and planter seeder and planter. (*http://www.standnplant.com/planter.htm,* Retrieved on 24, August 2017).

Anonymous. (2016), Hand transplanter. (*https://www.alibaba.com/showroom/hand -transplanter.html*, Retrieved on 24, August 2017).

Nandede, B.M. and Raheman, H. (2016), A Tractor drawn vegetable transplanter for handling paper pot seedlings. *Agricultural Mechanization in Asia, Africa, and Latin America* **47**(4):84-92.