

Design, Development and Evaluation of a Power Tiller Operated Vegetable Transplanter

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Abstract: Transplanting requires around 20 per cent of total labour requirement for cultivation of transplanted vegetables. Vegetable transplanting is very tiresome and labour consuming operation. In eastern and northeastern states, vegetables are grown in small plots for which tractor-operated equipment are not suitable. Power tillers are quite popular now a days and are very much useful for a wide range of farm operations particularly in small plots. Therefore, a power tiller operated vegetable transplanter was designed and developed with two types of attachments: (i) inclined press wheels attachment for transplanting on flat bed, and (ii) mould board and truncated conical ridge shaper attachment for transplanting and simultaneous ridging.

Field studies revealed that plant stand with machine transplanting was at par with manual transplanting with seedling size larger than 150 mm. 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, chilli, tomato, knolkhol and brinjal respectively. The yields of crops in different methods were found at par with each other with seedlings of size more than 150 mm. The cost of the developed transplanter with accessories was estimated as Rs 6000.00. The cost of transplanting by power tiller operated vegetable transplanter was found to be Rs 121 per hour. The savings in cost of transplanting for cabbage, chilli, tomato, knolkhol and brinjal were found to be 51, 59, 93, 40 and 93 per cent respectively over manual transplanting using local method. Machine transplanting reduced drudgery as reported by the operators.

[KEY WORDS: FINGER TRAY, POWER TILLER, VEGETABLE TRANSPLANTER, MISSING PLANTS, MULTIPURPOSE TOOL BAR, PRESS WHEEL, FURROW OPENER, PLANT STAND, PLANTS IN LYING DOWN POSITION, TRUNCATED CONICAL, RIDGE SHAPER]

Introduction: The importance of vegetables in human nutrition is a well-established fact. The share of India in the total vegetable production of the world is almost 11.5 per cent occupying first position in production of peas and ranks second in eggplant, cabbage, cauliflower, and onion, tomato, brinjal [7]. During the last ten years, India has recorded an annual increase of 2.6 per cent in vegetable production that was higher than that of the world growth rate of 1.8 per cent. However, the per capita availability of vegetables is only 210 g/day that is well behind the recommended quantity of 285 g/day. As the population is increasing at a rate of 1.8 per cent, our vegetable requirements in the year 2010 will be around 135 mt. [5] estimated the annual demand in 2030 will be around 151-193 mt. To fulfill this desired target, the production has to be increased at the rate of 200-250 per cent of the present level. Though India is almost self sufficient in food grain production, true nutritional self-sufficiency can only be achieved when each individual is ensured of a balanced diet. In a country like India where the population is predominantly vegetarian, this is only possible by

increasing the vegetable production. Production can be increased through better cultivation practices, high yielding seeds and appropriate mechanization. Seedling transplanting is the most arduous job in vegetable cultivation that is presently done manually but needs suitable mechanization.

Review: In usual practice, a bunch of about hundred seedlings is hold in one hand, each seedling is separated by the other hand and is put in the soil after making a hole with a *khurpi* or *nirani*. After that the soil is pressed around the roots with the fingers. The work is very tiresome and labour consuming as the operation is done in a bending posture. The transplanting in bending posture requires an extra energy expenditure of 8 kJ /min and increases the heart rate by 51 per cent [6]. The labour requirement in manual transplanting of vegetable seedlings is as high as 300-320 man-h/ha. Plant establishment and growth are adversely affected due to frost in winter and higher day temperatures (exceeding 15-20°C) during summer because vegetable crops are very sensitive to climatic conditions and require very timely transplanting operations. However, labour shortage during peak transplanting season causes delay in transplanting, which leads to reduced yields.

Transplanting of vegetable seedlings in countries like U.S.A, China, Holland, Japan, and Canada is being done mechanically using vegetable transplanters. Transplanters that are used in these countries are either fully automatic or semi-automatic type. In fully automatic transplanters both feeding and metering of seedlings are done mechanically where as in semi- automatic transplanters, feeding is done manually and metering is done mechanically. Fully automatic transplanters are suitable only for seedlings grown in cells or cups but semi-automatic transplanters can work with both bare root seedlings and seedlings with soil. For fully automatic transplanters, seedlings are grown in moulded trays having cups. One person is usually required in a two-row machine to feed the seedling trays. In these machines seedlings are either separated by some separating mechanism and then placed in the transplanting furrow through a drop chute or directly lifted from the cups and placed in the soil by the transplanting fingers. Semi-automatic transplanters use cup type or finger type metering mechanism. The operators on the machine feed seedlings in to the cups or fingers manually. In cup type transplanter, seedlings are placed in the furrow by gravity while in finger type transplanter, the seedlings are carried by the fingers and released in to the furrow and then soil is compacted around the plants by the press wheels. Fully automatic transplanters are costly as compared to semi-automatic type transplanters. Studies conducted in Japan revealed that minimum economical area for using automatic transplanters is 8.21 hectares [8]. The costs of vegetable transplanters available in other countries are about 0.7 to 2 lakh rupees for single row unit. Choudhury, D., Singh, V. V. and Dubey, A. K. conducted a survey to access mechanization gaps in the seeding, planting, and transplanting of vegetable crops indicated that Indian vegetable growers expressed desire for a low cost vegetable transplanter.2]. Efforts have been made in PAU, Ludhiana to design and develop tractor operated vegetable transplanters.[8]

Farm holdings are becoming smaller due to increase in population. Land fragmentation continues due to 'laws of inheritance' and 'Hindu succession Act'. Gupta J.P found that 88 % of the landowners of Bihar hold below 2 hectares of land and are categorized as small or medium farmers [3]. In West Bengal, as per statistics, the land under small and marginal holdings category is 78.2 per cent and the number of holdings

are increasing day by day, further reducing the average size of holding which is presently only 0.39 ha. Das, R. C. Pradhan, S. C. , Behera, D. and Mahapatra, M reported that the average size of land holding in Orissa is only 1.6 ha[4]. Therefore, a power tiller operated vegetable transplanter was designed and developed considering the following points in mind.

- (i) Poor socio-economical status of average Indian farmer.
- (ii) Small and fragmented land holding of average Indian vegetable farmer.
- (iii) Popularity of power tiller among the small and marginal category farmers.
- (iv) Versatility of power tiller to perform almost all types of farm operations.
- (v) The power tiller is within the reach of small farmers.
- (vi) Tractors and tractor-operated equipments are unsuitable for small and scattered land holdings as well as financially not within reach of common farmers.
- (vii) Inefficiency of bullock power for providing precision operation like transplanting.

Design: Based on the agronomical requirements, a power tiller operated vegetable transplanter was designed and developed with two types of attachments.

- (i) Power tiller operated vegetable transplanter (PTOVT) with inclined press wheel attachment for transplanting on flat bed.
- (ii) Power tiller operated vegetable transplanter with mould board and truncated conical ridge shaper (TCRS) attachment for simultaneous ridging.

Components of PTOVT with inclined press wheels

1. A multipurpose tool bar to which all other components were attached. The tool bar was operated on the power tiller.
2. A furrow opener to open a continuous furrow.
3. A seedling drop tube with funnel.
4. Two inclined press wheels to cover the furrow and press the root zone of freshly transplanted plants
5. Two side trail wheels for depth control as well as transportation of equipment attached to the power tiller.
6. A feeding and metering system for maintaining plant to plant distance in a row.

Components of PTOVT with mould boards and TCRS

The same tool bar, furrow opener, seedling dropping tube, side trail wheels, metering and feeding system were used in transplanting and simultaneous ridging system. In this system, the inclined press wheels were taken out and the following components were attached for soil gathering and pressing.

1. Two miniature mould boards to gather soil and pile it on both sides of freshly transplanted plants to form a ridge.
2. Two truncated conical ridge shapers to press the ridge to provide the desired shape and compaction.

Specification of the developed vegetable transplanter

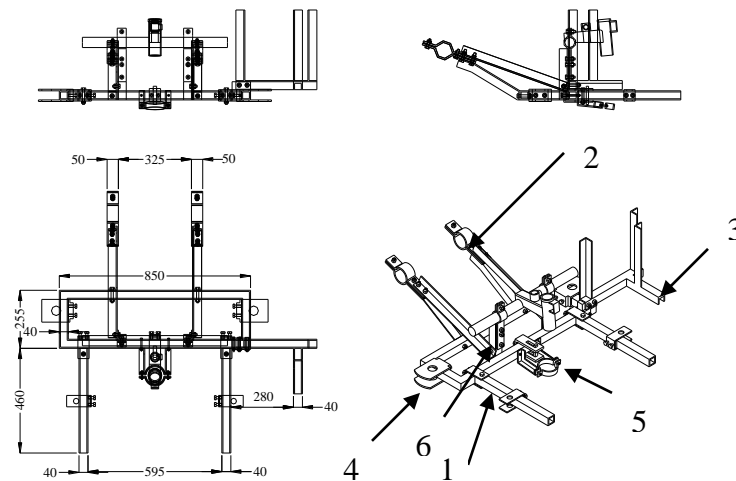
Type of implement	: Mounted type
Power source	: Power tiller
Number of rows	: one

Methods of transplanting	: (i) Transplanting on flat bed. (ii) Transplanting and simultaneous ridging
Type of feeding	: Semi-automatic type using single seedling feeding tray
Plant spacing in a row	: 750, 600, 450 and 300 mm (adjustable)
Number of operators	: One person for operating the power tiller and another for feeding the seedlings on the finger trays one by one
Overall width	: 1 m
Overall length	: 1.2 m
Overall weight	: 55 kg (excluding the weight of power tiller)

The multipurpose tool bar

The frame of the tool bar was made of 40mm×40mm square bars of mild steel. The square bars were welded together to form a rectangular frame of size 850 mm×200 mm. This frame was attached to the power tiller at two upper arms, two lower arms and two rear arms with the help of clamps as shown in Fig. 1.

Clamps have been used to attach the above components to the multipurpose tool bar (Fig. 7). Clamps have been used so that during operations other than transplanting these components can be dismantled and other components such as mould board ploughs, weeding and intercultural equipments could be fitted easily. This would increase the versatility and usefulness of power tiller and make it more cost effective by increasing the average annual use.



1: Tool bar extension, 2: Attached to upper arm of power tiller, 3: Extension for feeding and metering system, 4: Place for side trail wheel, 5: Place for seedling dropping tube, 6: Place for furrow opener

Fig. 1 Details of multi-purpose tool bar

Two side trail wheels for depth control

The original power tiller trail wheel was removed and a pair of side trail wheels was used as shown in Fig.2. The trail wheels were attached to the side frame of multi

purpose tool bar by help of two clamps. Clamps have been used to have the option of removing these wheels at the time of other field operations. Each trail wheel consists of rubber wheel of 185 mm diameter and 42 mm width fitted to the bottom of a square plate by means of a fork. The upper part of the fork is attached to a square plate by means of a movable pin, so that it can automatically follow the direction of the power tiller. The plate is rigidly bolted to an identical plate fitted to the bottom of a vertical spindle, which can be rotated by a lever fitted on the top of the spindle. The dimensions of the trail wheel assembly are given in detail in the figure. The depth can be easily adjusted manually by rotating the top lever.

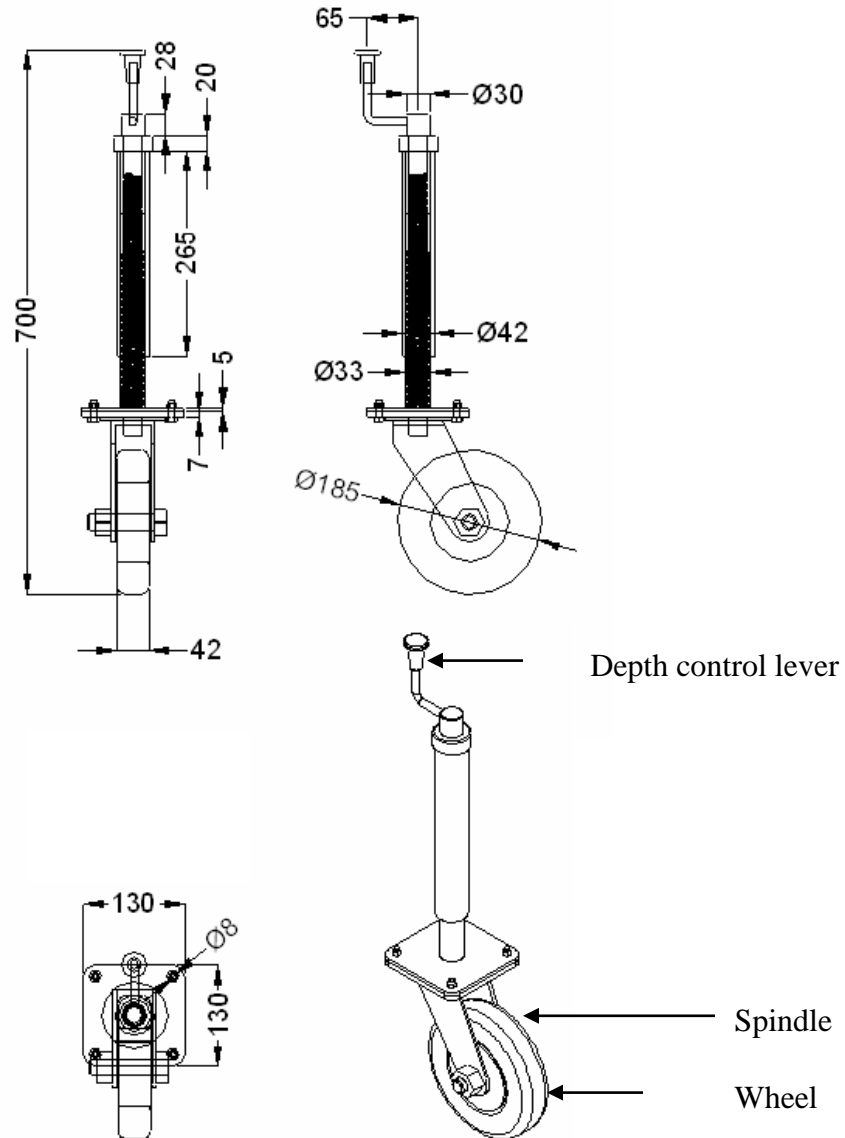


Fig. 2 Details of side trail wheels

The Furrow opener

A modified vertical soil-cutting tool was designed and fabricated for using as a furrow opener (Fig. 3).

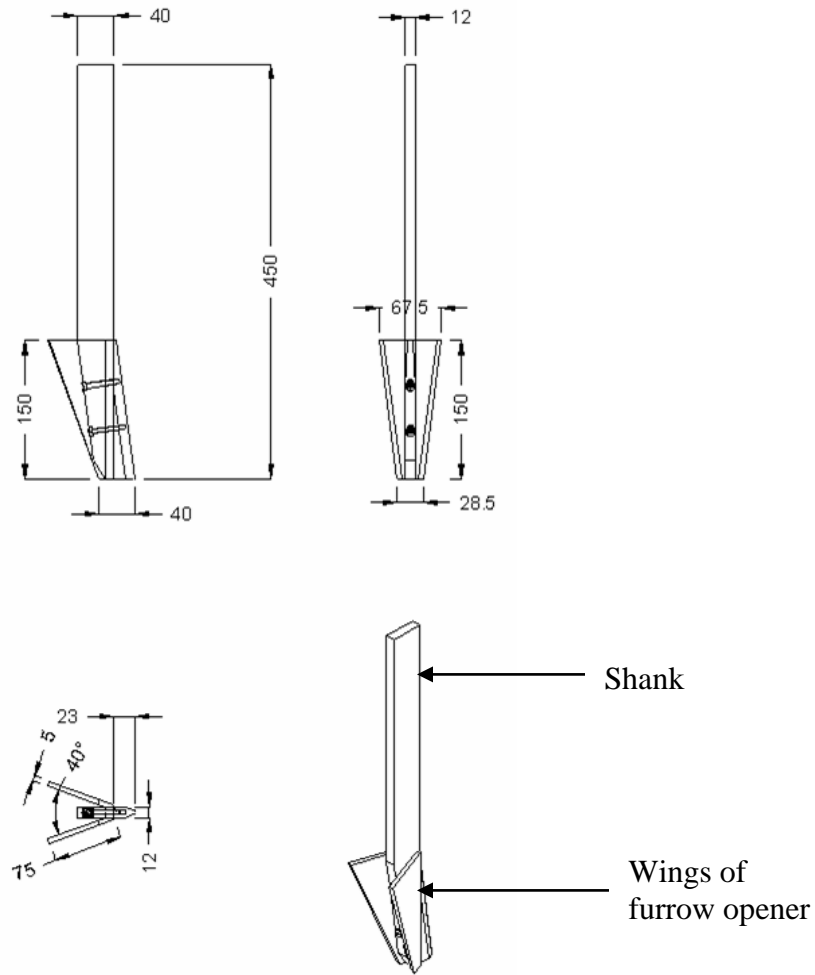


Fig.3 Details of the furrow opener designed to open the furrow

It has been designed to serve the following requirements.

1. To open a narrow furrow, sufficient to accommodate the seedling to be transplanted.
2. To allow the soil the movement of soil in both the sides and later fill the furrow formed on the rear of furrow opener from both sides with the help of a pair of press wheels designed for covering and pressing the furrow after dropping the seedlings.
3. To have provision to allow the seedling to be dropped in between two side wings of the furrow opener.

Keeping the above facts in mind the furrow opener was designed. It was formed by welding two mild steel plates at an angle of 40° in horizontal direction as shown in the figure. The angle was calculated as per the equation.

$$\tan \lambda = \frac{\tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right)}{\cos \delta} \quad (3.7)$$

Where, λ = Angle between the direction of travel and sides of the wedge in a horizontal plane.

ϕ = Angle of internal soil friction [1]

to suit heavy clay type of soil condition as occurs in the instructional farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal. The side wings of the furrow opener were made narrower from top to bottom to accommodate different sizes of seedlings as found in actual farming condition. A triangular piece is attached in the front of the opener with the help of nuts and bolts for easy cutting of the soil. This can be replaced when worn out and a new piece can be attached which will enhance the life span of the furrow opener. The rear side of the furrow opener was kept open to allow the dropping of seedlings in between the wings. An M.S. flat of size 40 x 12 x 150 mm was welded to the wings as shown in the Fig.4.3 and is called the shank of the furrow opener.

The furrow opener shank is attached to the front frame of the multi purpose tool bar with the help of a clamp. The clamp is shown in Fig.4. Provision is made in the clamp design to change the soil engagement angle of the furrow opener up to 20° to suit different soil and moisture conditions. This is done by using small packing at front or rear side of the furrow opener shank inside the clamp. The clamp used to attach the furrow opener has a rectangular hole of size 40 mm x 12 mm to accommodate the furrow opener shank.

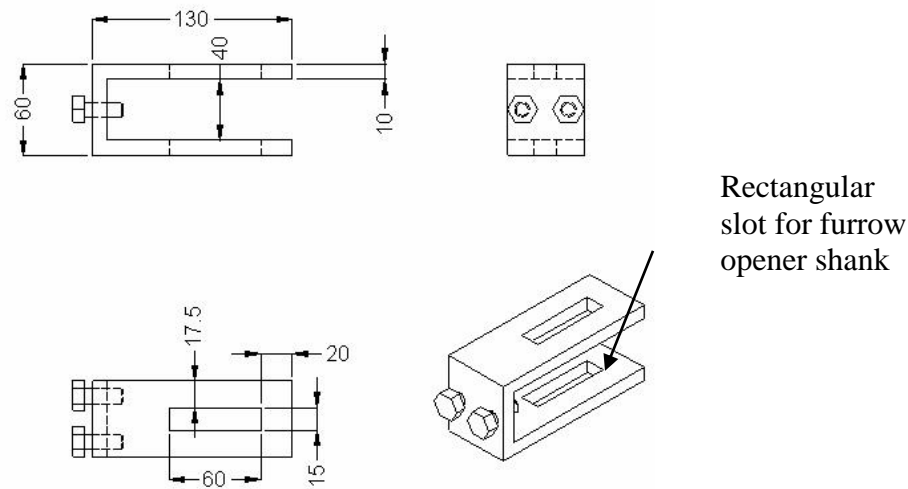


Fig. 4 Details of the clamp used to attach furrow opener with the tool bar

Funnel shaped chute for seedling dropping

Finger trays were fitted in a chain carry seedlings. Seedlings were kept manually one by one either by the power tiller operator himself or by an extra person. The seedlings were dropped in the funnel. A laboratory test was conducted to ascertain the optimum angle with horizontal the side of the funnel need for proper guiding of the seedling into the tube. The angle was found to be 71° with aluminum sheet. To be in safe side the angle was made 75° with the horizontal. Aluminum sheet was selected as funnel material for better slippage. The details of seedling tube and funnel are shown in Fig. 5.

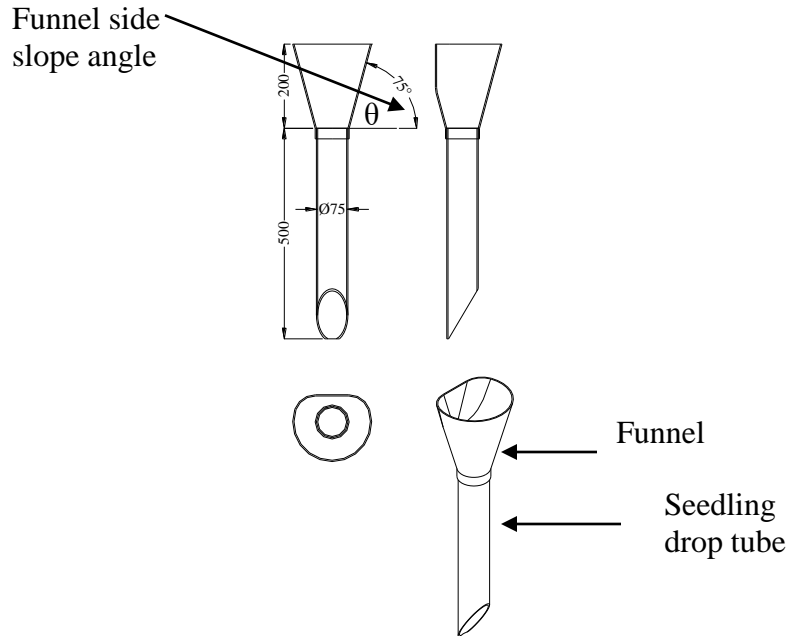


Fig. 5 The seedling drop tube with funnel

The press wheels

A set of two inclined wheels made up of MS plate were used for closing the furrow, as well as, for compressing the soil at seedling root zone just after it touches the ground after passing through the dropping chute. Nine pairs of press wheels of three different diameters, viz. 250 mm, 300 mm and 350 mm, and three different widths, viz. 55 mm, 65 mm, and 75 mm, were fabricated to determine the optimum diameter suitable for the transplanter at different soil conditions. The press wheels were attached to the extension of the multi-purpose tool bar by a set of two clamps through a sleeve arrangement. The sleeves were provided to change the angle of inclination of the press wheels with the vertical plane. The details of the press wheel and its arrangement are shown in Fig. 6.

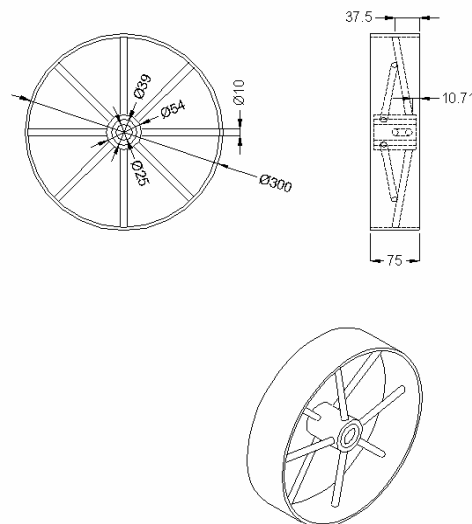


Fig. 6 Details of the press wheel with diameter 300 mm and width 75 mm.

Clamps for attaching press wheels

Clamps used to attach the press wheels to the tool bar extension have circular holes of diameter 25 mm to hold the vertical cylindrical shafts with which the press wheels were attached through sleeves. The clamp used to attach the furrow opener has a rectangular hole of size 40 mm x 12 mm on it to accommodate the furrow opener shank (Fig. 7).

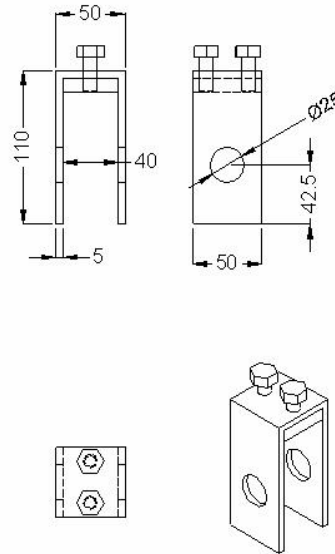


Fig. 7 Details of clamps used to attach the press wheels

The clamp used to attach the furrow opener has a rectangular hole of size 40 mm x 12 mm on it to accommodate the furrow opener shank.

Seedling feeding & metering mechanism

The seedling feeding & metering mechanism consists of (a) a feeding chain carrying ten finger trays (Fig. 8), (b) a bevel assembly and (c) a chain and sprocket assembly.

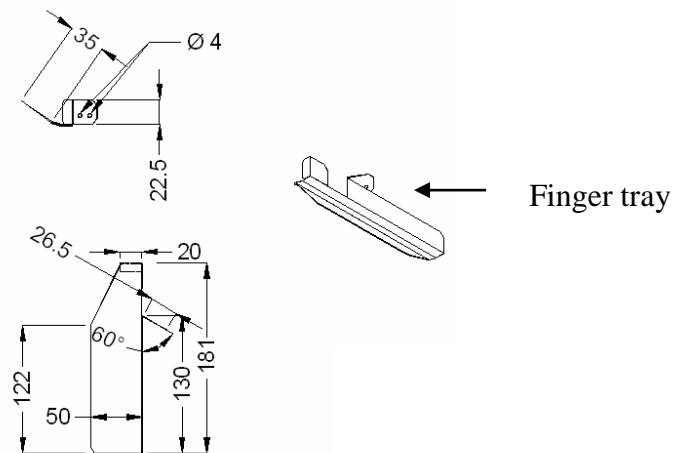


Fig. 8 Details of the finger tray

Seedlings are kept one by one manually on miniature trays referred as finger trays. Ten such finger trays have been fitted with equal intervals on a chain length of 1270 mm (Fig. 9).

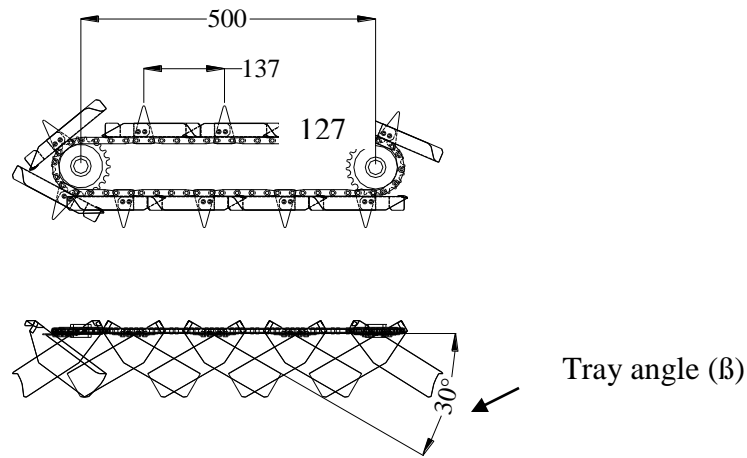
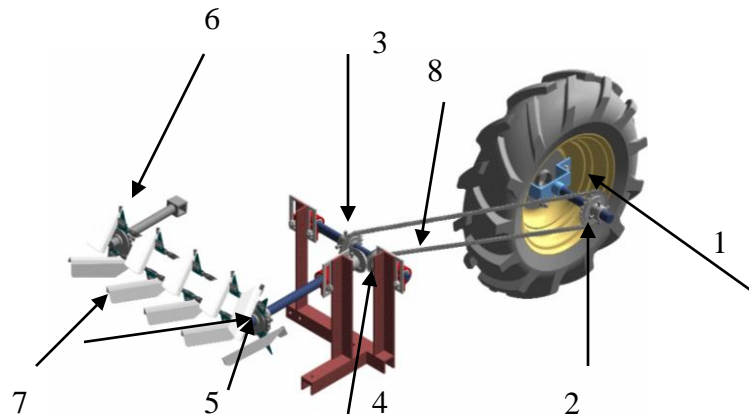


Fig. 9 Finger trays fitted with the feeding chain

The complete feeding and metering mechanism has been presented in Fig. 10. The system is fitted to the power tiller as well as to the multi purpose toolbar at different points.



1 : Bracket , 2: Sprocket “A”, 3: Sprocket “B”, 4: Bevels ‘C’ and ‘D’ in mesh, 5: Sprocket “E”, 6: Sprocket “F”, 7: Finger trays, 8:: Chain

Fig. 10 The seedling feeding and metering mechanism.

Two sprockets ‘E’ and ‘F’ having equal number of teeth and same diameter move the feeding chain. The driving sprocket ‘E’ is driven by a shaft which is fitted with a bevel gear ‘D’ at the other end. The gear ‘D’ is in mesh with another identical bevel gear ‘C’. A sprocket ‘B’ is fitted, as shown in the Fig. 4.8, on the shaft, to which bevel gear ‘C’ is attached. The sprocket ‘B’ is driven by another sprocket ‘B’ through chain. ‘A’ has been operated on a shaft, which is fixed to the right side of the power tiller right wheel through bracket as shown in Fig.4.10. The

sprockets can be changed very easily to have different plant to plant spacing in a row.

Machine components for transplanting and simultaneous ridge making

For transplanting and simultaneous ridge making operation, the press wheels are taken out and the following additional components are attached on the multipurpose tool bar.

1. Two miniature mould board ploughs fitted at both side of the furrow opener to gather soil from both sides of the transplanted seedling and pile it at the root zone to form a continuous ridge.
2. Two conical press wheels are used to press and shape the ridge.

The miniature mould board ploughs

Two miniature mould board ploughs have been fitted to the multipurpose tool bar extension with the help of two clamps. The mould boards have been fitted just behind the furrow openers and are so spaced that they remain at both sides of the furrow opener. Their main purpose is to gather soil from both sides and pile it on the furrow around the seedling root zone to form a ridge. The details of the mould boards have been described in Fig. 11.

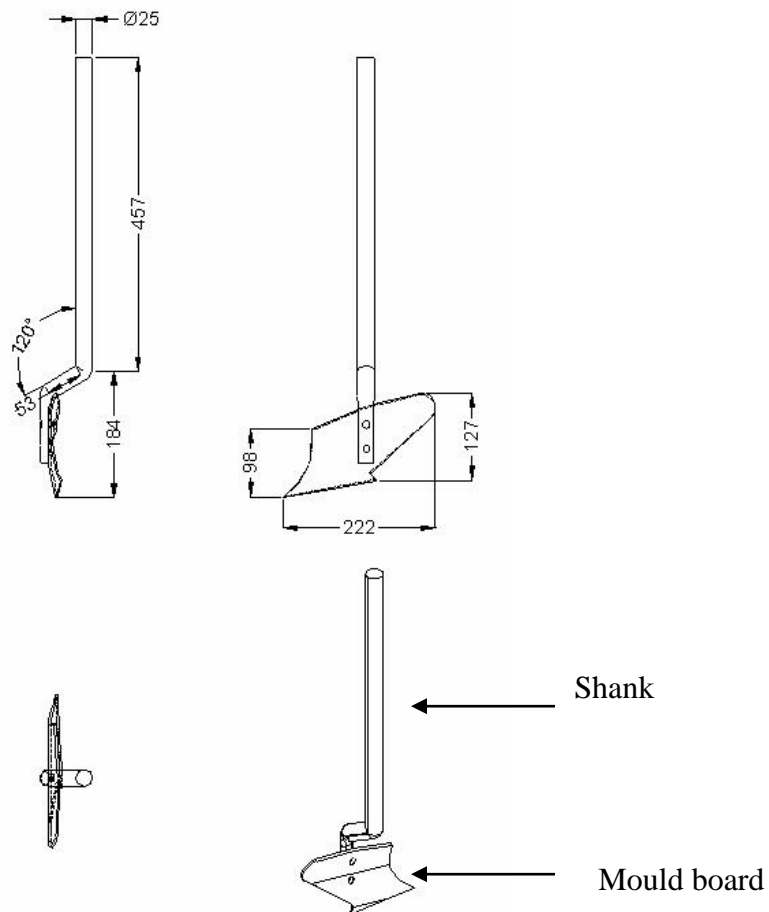


Fig. 11 Details of miniature mould boards used for soil gathering and furrow covering

The truncated conical ridge shapers (TCRS)

Two conical ridge shapers have been fitted behind the mould board ploughs. The conical ridge shapers give a perfect shape and compress the soil gathered by the two mould boards. The details of the cones used for this purpose has been shown in Fig.12. These are fitted to the tool bar extension by help of clamps described in Fig.12. The cones were fitted after removing the press wheels. The sleeve arrangement was provided to change the angle that the shaft of the cone makes with ground surface in the vertical direction.

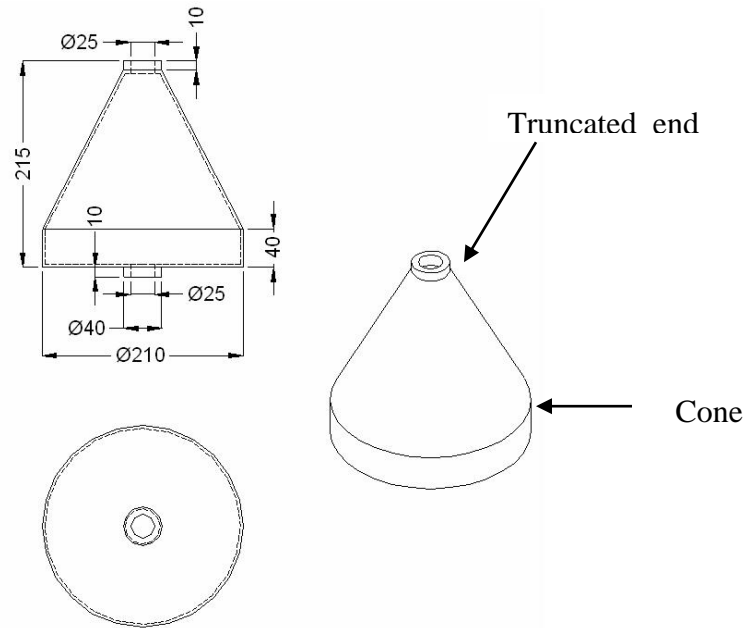


Fig. 12 Details of the cones used for soil compaction and ridge shaping

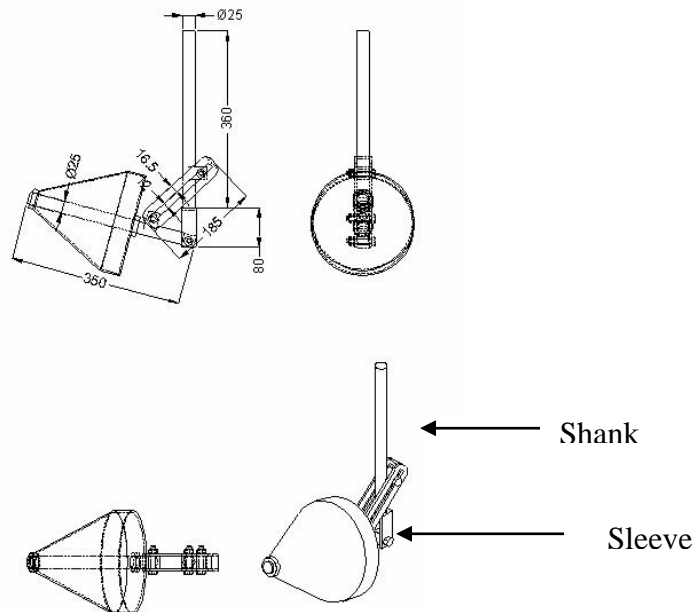


Fig. 4.13 The truncated conical ridge shaper

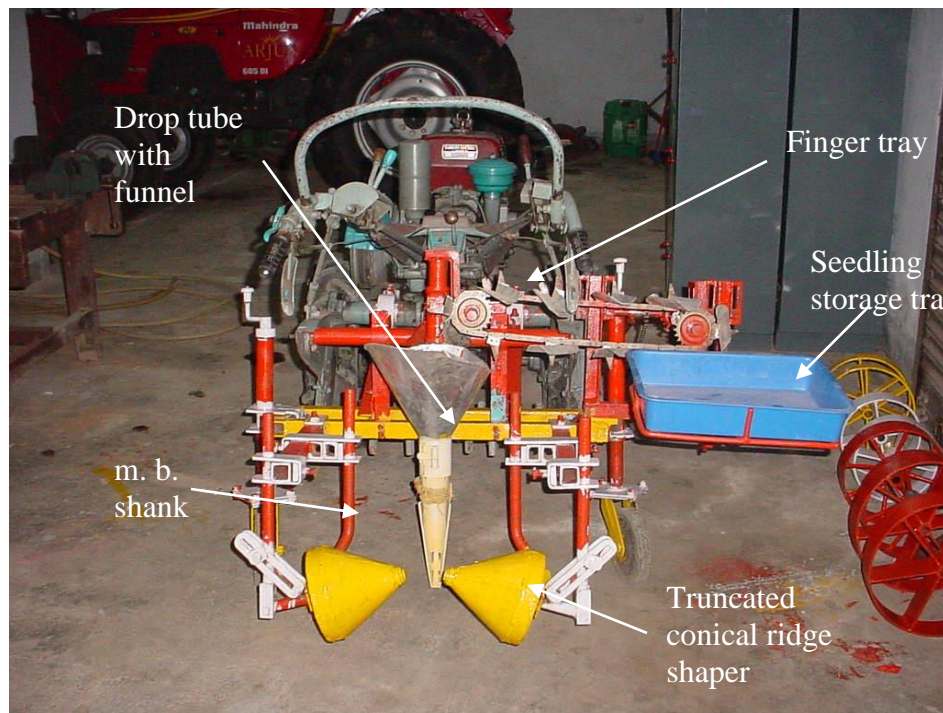


Fig. 13 Photograph of the power tiller operated vegetable transplanter with mould board and truncated conical ridge shaper for simultaneous ridging

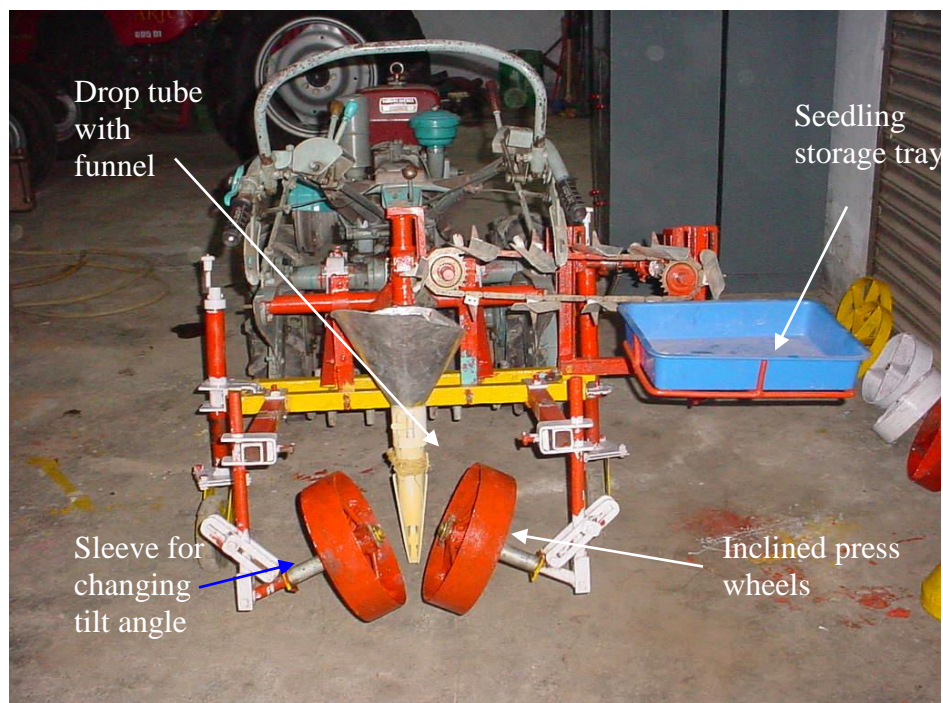
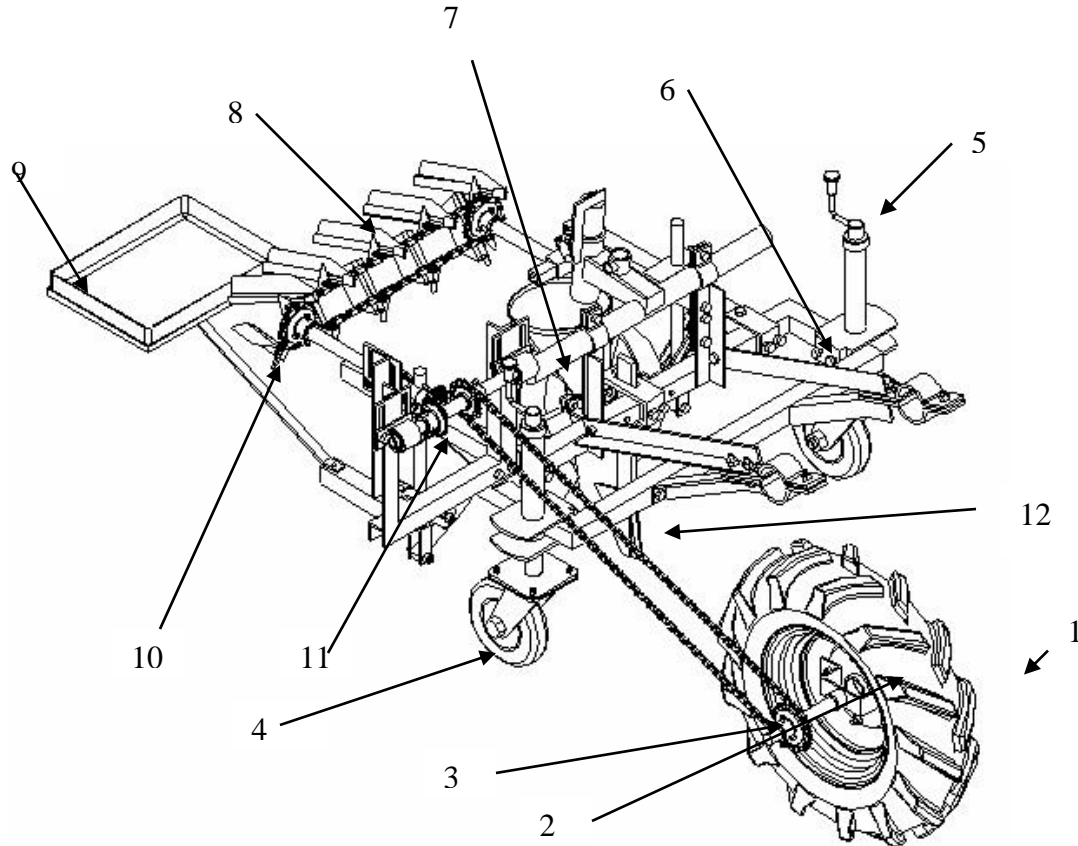


Fig. 14 Photograph of the power tiller operated vegetable transplanter with inclined press wheels for transplanting on flat bed

The full assembly of the developed vegetable transplanter is shown in Fig 13, Fig. 14 and Fig 15..



1. Power tiller right wheel 2. Bracket 3. Sprocket 4. Side trail wheel 5. Depth control lever 6. Tool bar, 7. Seedling tube 8. Finger tray 9. Storage tray 10. Feeding chain 11. Bevel gears 12. Furrow opener

Fig. 15 Full implement assembly with press wheel attachment

Effect of machine parameters on seedlings and soil conditions

The study was planned in stages as detailed below.

(A) Laboratory studies

- (i) **Laboratory Test-I:** To find out optimum finger tray angle
- (ii) **Laboratory Test-II:** To find out the optimum side slope angle of the funnel of seedling drop tube.

Field studies with brinjal

- (ii) **Field studies-II:** Brinjal was transplanted under field condition by three methods: 1. by manual method using nirani, 2. by PTOVT using the inclined press wheels, and 3. by PTOVT using mould board and TCRS with different size of seedlings to study their effect on transplanting quality as well as yield.

Salient findings of the study

(A) Laboratory studies

(i) Irrespective of the type of crop, the number of seedlings dropped properly increased as the finger tray angle with the direction of motion of feeding chain increased from 20° up to 30° where it was found maximum (100 per cent). The number of seedlings dropped properly decreased as the finger tray angle was increased above 30° . Therefore, finger tray angle of 30° was considered optimum for designing the feeding system of the power tiller operated vegetable transplanter.

(ii) It was found that, at funnel side slope angle of less than 75° with the horizontal, the per cent of seedlings slipped into the drop tube decreased as the length of seedlings increased. At side angle of funnel of 75° and more, 100 per cent seedlings were slipped into the drop tube irrespective of crop and size of seedlings. Therefore, funnel side slope angle with the horizontal was considered optimum at 75° .

(B) Controlled plot studies

(i) The effect of soil moisture content on plant stand was found significant at 1% level. Plant stand increased from 66 to 100 per cent as the soil moisture content increased from 6-10 per cent to 14-18 per cent (d.b). Plant stand remained almost equal above the soil moisture content of 10-14 per cent up to 14-18 per cent (d.b). Therefore, the soil moisture range from 10 to 18 per cent (d.b) might be taken as optimum range for vegetable transplantation.

(ii) The effect of soil moisture content on cone index of soil at plant root zone after transplanting was significant at 1 % level. As the soil moisture increased from 6-10 to 14-18 per cent (d.b), soil cone index decreased. At soil moisture range of 10-14 percent (d.b), the average soil cone index was found to be 150 to 250 kPa, which is generally the optimum range.

(iii) The effect of tilt angle of press wheel on plant stand was found significant at 1 % level. As the tilt angle was increased from 5° to 15° , the plant stand increased and 100 per cent plant stand was obtained at the tilt angle setting 15° . Therefore, for transplanting of vegetable seedlings by power tiller operated vegetable transplanter, a tilt angle of 15° might be taken as optimum value for the furrow opener.

(iv) The effect of tilt angle of press wheel on cone index of soil at seedling root zone was found significant at 1 % level. With the increase of tilt angle from 5° to 15° , the cone index decreased from 248 to 173 kPa. It might be due to the increasing tilling effect of press wheel with increase of tilt angle. At a tilt angle of 15° , cone index of soil was found in the optimum range (150-250 kPa).

(v) The effect of width of press wheel on plant stand was significant at 1 % level. The controlled plot experiment was conducted with three levels of width, i.e. 55, 65 and 75 mm. It was found that plant stand increased with increase in width of the press wheel. The width of press wheel was restricted to 75 mm considering agronomic aspects. 100 per cent plant stand was obtained with 75 mm width of press wheel. Therefore, 75 mm width was considered optimum.

(vi) The effect of width of press wheel on cone index of soil at seedling root zone was found to be significant at 1 % level. The soil cone index decreased with the increase in width of the press wheel. It happened because of increased soil metal contact area that decreased the normal load on soil per unit contact area.

(vii) The effect of diameter of press wheel on plant stand was found significant at 1 % level. Plant stand increased with increase in diameter of press wheel from 200 mm to 300 mm. The diameter was restricted to 300 mm considering the clearance available to fix it properly on the tool bar. With 300 mm diameter, 100 per cent plant stand was obtained. Thus, 300 mm diameter was considered optimum for the press wheel of the developed transplanter.

(viii) The effect of press wheel diameter on soil cone index at seedling root zone after transplanting was found significant at 1 % level. The soil cone index decreased from 248 to 173 kPa as the diameter of press wheel increased from 200 mm to 300 mm.

(ix) From the study it was found that all the four independent factors such as 1. Horizontal distance between mould board share points across the direction of travel (x), 2. Horizontal direction along direction of travel between rear of furrow opener and the line joining two fronts points of the two mould boards (y), 3. Vertical distance between lower points of furrow opener (on top) and mould boards (z) and 4. The angle at which the mould boards are set with the direction of travel affected the plant stand significantly. Optimum values for the relative placement of mould board and furrow opener of the developed transplanter were found experimentally as $x = 250$ mm, $y = 100$ mm, $z = 75$ mm and $\Phi = 50^\circ$. Transplanting by the developed machine with this setting was found 100 per cent successful at 10-14 per cent m.c.of soil with mean weight soil clod diameter of 3.7 mm for brinjal transplanting.

(x) It was found from the experiment that the distance between truncated ends of conical press wheel (h) and the vertical angle between ground surface and side of conical press wheel (ϕ) affected the plant stand and plant damage significantly. Values of $h = 75$ mm and $\phi = 45-50^\circ$ produced optimum values of soil cone index and negligible plant damage. Therefore, the above values were considered optimum values for the developed transplanter.

(xi) As the forward speed of the machine increased above 1.2 km/h, the average plant stand decreased to 85 % at 1.2-1.4 km/h from 90 % . Acceptable plant stand of above 95 % was observed at speeds below 1.2 km/h. Maximum plant stand of 98 per cent was obtained at the speed range of 0.8-1.2 km/h in both the methods of transplanting with an extra man engaged for feeding the seedlings of size longer than 150 mm. No significant difference was observed in plant stand at speeds below 1.2 km/h in both the two methods of transplanting. The effect of both the methods of transplanting on plant stand was found to be statistically non-significant. Irrespective of other factors considered in the experiment, plant stand was minimum with 100-150 mm size of seedlings. Plant stands obtained with other sizes of seedlings, i.e. larger than 150 mm, was at par with each other. It was found that plant stand was higher when an extra man was engaged for feeding the seedlings than when the power tiller operator fed the seedlings in the finger tray himself irrespective of other factors.

(xii) As the speed of the machine increased above 1.2 km/h, the average number of plants in lying down position increased to 17 % irrespective of methods of transplanting, length of seedlings and number of persons employed. 10.7, 13 and 20.7 per cent of plants were found in lying down position at the speed ranges of 0.8-1.0, 1.0-1.2 and 1.2-1.4 km/h, respectively. Plants in lying down position at speeds of 0.8- 1.0 km/h and 1.0-1.2 km/h were at par in both the methods of machine transplanting. The effects of transplanting with inclined press wheels as well as transplanting with mould board and

conical ridge shaper on number of seedlings in lying down position were at par. Maximum number of plants in lying down position, i.e. 21.7 percent was found with seedling size of 100 - 150 mm. When the seedling size was longer than 150 mm, plants in lying down position was significantly less. The effect of size of seedlings between 150 - 300 mm on the number of plants in lying down position might be considered as acceptable in both the methods of transplanting.

(xiii) The effects of speed of power tiller, size of seedlings and number of operators on missing plants were found significant at 1 % level. Missing of plants was found as high as 7 per cent with speed above 1.2 km/h, size of seedlings less than 150 mm and with only one operator. Highest missing with seedling size less than 150 mm might be due to relative difficulty in picking and separating the small plants. When the power tiller operator fed the seedlings himself on the feeding trays, more missing plants were observed. Effect of methods of planting on plant missing was found to be negligible with larger than 150 mm seedling size.

(xiv) It was found that the effect of speed of machine on the number of plants inclined at less than 30° to the vertical was found to be significant. The number of seedlings inclined at less than 30° to the vertical decreased with the increase of working speed of power tiller. As high as 12 per cent plants were found inclined more than 30° to vertical at working speed range of 1.2-1.4 km/h. The effect of methods of transplanting on the percentage of plants inclined to vertical at less than 30° is non-significant. Seedlings of size smaller than 150 mm were found to deviate more from the vertical in comparison to the other sizes. The maximum number of seedlings inclined at less than 30° to vertical with 100-150 mm length was found to be 89 per cent at machine speed of 0.8-1.0 km/h against 76 per cent at 1.2-1.4 km/h speed. When an extra man was engaged, (other than the power tiller operator) to feed the seedlings, the number of plants inclined at less than 30° to the vertical increased remarkably than when the operator himself fed the seedlings to the finger trays.

Field evaluation of the machine

The field evaluation photos are presented in Fig 16 and Fig 17

(i) Both the independent factors of method of transplanting and size of seedlings affected plant stand significantly. It was found that when transplanting was done by the machine with seedling size larger than 150 mm, plant stand was at par with manual transplanting by human labour. There was only 1-3 per cent loss in plant stand. When the seedling size was less than 150 mm, it was comparatively difficult to maintain desired plant stand.

(ii) Both the independent factors of method of transplanting and size of seedlings affected the number of plants in lying down position significantly. In case of brinjal, the number of plants in lying down position was 3.6 per cent, when transplanted by the machine using mould boards and conical ridge shapers, irrespective of the size of seedlings. As observed, the percentage of plants in lying down position was higher with seedling size of less than 150 mm. With seedling sizes larger than 150 mm, the number of plants in lying down position was below 3 per cent, i.e. within the acceptable limit.



Fig. 16 Transplanting of brinjal by PTOVT using inclined press wheel



**Fig. 17 Transplanting of brinjal by the machine using mould board and TCRS.
(Transplanting and simultaneous ridging: Close-up view)**

(iii) Both the independent factors of method of transplanting and size of seedlings affected the number of plants missing significantly irrespective of crops. Average number of plants missing was found to be of 0.9, 2.2, 1, 0.5 and 0.5 per cent in case of cabbage, chilli, tomato, knolkhol and brinjal respectively. It was observed that missing plants in case of transplanting by the machine was acceptable when the size of seedlings were larger than 150 mm. With seedling size less than 150 mm, the more number of missing plants were observed due to relative difficulty and delay in separating smaller seedlings from the bunch during manual feeding. Average numbers of plants missing were found to be of 0.9, 2.2, 1, 0.5 and 0.5 per cent in case of cabbage, chilli, tomato, knolkhol and brinjal respectively while all sizes of the seedlings were fed to the finger trays.

(iv) Both the independent factors of method of transplanting and size of seedlings affected the number of plants inclined at less than 30° to the vertical direction irrespective of crops. It was found that the number of plants inclined at less than 30° to the vertical direction was significantly less with smaller seedlings (100-150 mm). The numbers of plants inclined at less than 30° to the vertical with seedling size larger than 150 mm were at par with each other in all the three methods of transplanting. On an average, less than 3 per cent of plants were inclined at more than 30° to the vertical in case of seedling size of larger than 150 mm, which was well within the acceptable limit.

(v) It was statistically found that the effects of method of transplanting and size of seedlings on depths of transplanting were non-significant irrespective of type of crops under study. The average depths of transplanting were found to be 60.1, 58.3, 59.1, 58.3 and 60.8 mm when transplanted by the machine using inclined press wheels against 58.7, 58.3, 58.3, 58.3 and 59.8 mm in case of manual transplanting with cabbage, chilli, tomato, knolkhol and brinjal respectively.

(v) It was found that the effects of methods of transplanting on plant mortality after 2 weeks of transplanting was non-significant where as the effect of size of seedlings were found significant. Average plant mortality of 3.9, 4, 3.6, 3.8 and 2.8 per cent have been observed in case of cabbage, chilli, tomato, knolkhol and brinjal respectively while transplanting by the machine using inclined press wheels. In case of brinjal, the plant mortality of 3 per cent of plant stand was observed when transplanted by the machine using mould boards and conical ridge shapers irrespective of seedling size. It was found that plant mortality was maximum with seedling size of 100-150 mm irrespective of the crop and method of transplanting.

(vi) The effects of method of transplanting and size of seedlings on average number of new leaves after 3 weeks of transplanting were found to be non-significant irrespective of type of crop. Average number of new leaves observed in case of cabbage was found to be 3.2 per plant with both manual transplanting and machine transplanting using inclined press wheels.

(vii) The effect of methods on time spent in transplanting by two persons was found significant at 1 % level irrespective of crops. The effect of size of seedling was found non-significant for all crops under study. The average time spent for transplanting cabbage, chilli, tomato, knolkhol and brinjal by 2 persons was found to be 184.3, 187.9, 182.8, 211.8 h/ha respectively in manual transplanting against 17.6, 17.1, 13.7, 21.9 and 13.6 h/ha by machine. The average time spent for transplanting brinjal by 2 persons was found to be 13.728 h/ha by the machine using mould board and conical ridge shapers.

(viii) The effect of size of seedlings on yield was found to be highly significant in all crops under study. Mean yield of crops in different methods were at par with each other with seedlings of size more than 150 mm. It was found that the yields of crops with 100-150 mm seedlings were significantly less than longer (>150 mm) even for manual transplanting. Plant mortality due to methods of transplanting was not significant. The effect of methods of transplanting on yield was found non-significant in all crops.

(ix) The estimated fabrication cost of the developed transplanter with accessories was found to be Rs 6000. The cost of operation of a power tiller without the transplanter was calculated as Rs 102/h. The cost of transplanting by power tiller operated vegetable transplanter was found to be Rs 121/ h. The cost of transplanting cabbage, chilli, tomato, knolkhol and brinjal were found to be Rs 2132, Rs2073, Rs 1657, Rs 2645 and Rs 1646/ ha respectively by the machine using inclined press wheels against Rs 3224, Rs 3288, Rs 3199, Rs 3706 and Rs 3169/ ha in local method of manual transplanting using *nirani*. There was a saving of 51, 59, 93, 40 and 93 per cent in transplanting cost over local method in cases of cabbage, chilli, tomato, knolkhol and brinjal respectively when transplanted by the machine using inclined press wheels. In case of brinjal, the cost of transplanting was found to be Rs 1661/ ha when transplanted by the machine using mould boards and conical ridge shapers for simultaneous ridging with a saving of 91 per cent over traditional method of manual transplanting using local *nirani*. The break-even point of machine operation was found to be 2.92 hectares per year.

(x) It was found that the energy expenditure rate (E.E.R) after one hour of work was maximum of 14.583, 9.583 and 8.750 kJ/min in case of the person engaged in manual transplanting, power tiller operator and the person feeding the seedlings respectively. After 20 min of rest, the pulse rates were measured for next one hour. The maximum E.E.R.after the second consecutive hour was found to be 16.25, 12.5 and 9.5 kJ/ min in case of the person engaged in manual transplanting, power tiller operator and the person feeding the seedlings respectively. The energy expenditure rate was found to be minimum in case of the person feeding the seedlings followed by the power tiller operator. Therefore, it can be concluded that the drudgery of transplanting can be reduced by using the developed transplanter.

Conclusions

The developed machine performed satisfactorily on transplanting the seedlings of cabbage, chilli, tomato, knolkhol and brinjal in the prepared field and was found economical over manual transplanting. From laboratory and field investigation, it is recommended that for efficient and precision transplantation, the speed of the machine should not exceed 1.2 km/h and the seedling size should be more than 150 mm. Desired plant to plant spacing can also be achieved as per the requirement of the crop. The transplanting quality parameters and the yield of the crops under study when transplanted by machine were at par with manual transplanting with considerable saving in cost of transplanting. Therefore, the developed vegetable transplanter can be recommended for use in small and medium size plots suitable for power tiller.

References:

- [1] Bernanki, H., Haman, J. and Kanafojki. "Agricultural Machine: Theory and Construction, Vol. I,". 1971
- [2] Choudhury, D., Singh, V. V. and Dubey, A. K. "Survey on existing status of seeding/planting method and determination of mechanization need of planting for important vegetable crops in India." C.I.A.E. Annual Report, pp: 4-7 .1997.
- [3] Gupta, J. P. "Status of power tiller use in Bihar- A case study in Nalanda District." Agricultural Mechanization in Asia, Africa and Latin America. Vol. 32 No 1 pp: 19-22. 2001
- [4] Das, R. C. Pradhan, S. C. , Behera, D. and Mahapatra, M. "Evaluation of bullock farming and power tiller farming systems for ground nut crop in the state of Orissa, India." Agricultural Mechanization in Asia Africa and Latin America. Vol.24 No.3 pp: 19-22. 1993
- [5] Fageria, M. S., Chaudhury, B. R. and Dhaka, R. S. "Importance, achievements and future prospects. Vegetable crops production technology." pp 1-5. Kalyani publishers, New Delhi, India.2003.
- [6] Nag, P. K., Sebastian, N. C. and Mavlankar, M. G. "Occupational workload of agricultural workers. Ergonomics" 23(2): 91-102 .1980.
- [7] Rai, M. and Pandey, A. K. Meeting strict global standards. The Hindu Survey of Indian Agriculture, pp: 149-152.2005.
- [8] Tsuga, K. S. "Development of fully automatic vegetable transplanter." Japan Agricultural Research Quarterly, 34(1): 21-28. 2000
- [9] Satapathy, S. K. "Effects of selected parameters on the performance of a vegetable transplanter for different crops". Unpublished M. Tech. thesis submitted to Punjab Agricultural University, Ludhiana, India. 2003.