Chapter 7

Summary and Conclusions

India is the second largest producer of vegetables after China with a total vegetable production of 146.55 million tons in the year 2010-2011. Area under cultivation of vegetable is 8.49 million hectares with an average yield of 17.26 tons/ha. Among the various cultivation practices followed for raising vegetable crops, transplanting of good quality vegetables seedlings at appropriate depth, spacing and sufficient soil cover around the seedlings is one of the most important operations. In farms with medium and large scale vegetable production, bare-root seedlings of vegetable are manually transplanted either on ridges (ridge planting) or on a well prepared seedbed (flat planting). In small scale vegetable gardening, pits of appropriate size are dug and seedlings are manually planted in the pits. Manual transplanting of seedlings is labor intensive, expensive, time consuming and often results in non-uniformity in plant distribution. To overcome these problems, use of mechanical transplanters is highly essential.

Attempts have been made by various research institutions under the Indian Council of Agricultural Research, New Delhi to develop tractor mounted 2-row and 3-row semi-automatic vegetable transplanters for bare-root and plug seedlings. Pocket-type seedling metering units were employed in the transplanters for bare-root seedlings, The forward speed, field capacity and labor requirement have been reported to be 0.80 to 0.98 km/h, 0.082 to 0.092 ha/h and 36.58 to 44.4 man-h/ha, respectively for the machines with pocket type metering units. The machines with rotary cup type metering units had the forward speed 1.4 km/h, field capacity 0.14 ha/h and labor requirement 28.6 man-h/ha. The quality of transplanting was reported to be satisfactory for both the machines but they were having lower field capacity and required good amount of labor to feed the seedlings. Further, increase in forward speed of the transplanter increased the missed plantings and necessitated 2 laborers to feed the single row to maintain the percentage missed planting within the acceptable limits. These problems can be overcome by using multi-stack vegetable transplanters.

In India, tractors in the range of 26 – 38 kW are gaining popularity for carrying out different agricultural operations. Therefore, it was decided to develop a tractor driven multi-stack semiautomatic vegetable transplanter (MSVT). Fully

automatic vegetable transplanters require either plug or pot seedlings but in semiautomatic transplanter all types of seedlings could be used. As initial investment on the production of plug seedlings is high and mechanisms employed in removal of seedlings from the tray are complex, it was decided to use pot seedlings. Pots made with newspaper have been used for raising good quality vegetable seedlings. However, very few information is available on size of paper pot and pot mix components used for the production of paper pot seedlings. The paper pots at the end of seedlings stage have been reported to be non-uniform with respect to their dimensions and firmness. Hence, strand or chain of paper pots were made for feeding them to the fully automatic vegetable transplanters. The preparation of chain of paper pots require seedlings to be raised in nursery in a specific method, and certain machines and mechanisms to hold together several pots in series. To overcome these difficulties, it was decided to raise seedlings in individual paper pots. The pots may cuboidal, cubical or cylindrical in shape. But the cylindrical shaped pot is preferred for easiness in making and handling it as it occupies less space. However, making individual pots with news paper by hand will require a good amount of time and it may result in non-uniformity in its size. Hence, a simple pot making device may be required to overcome these problems. From the review of the published literature, it was found that neither any pot making device was available for making uniform size smaller paper pots for raising vegetable seedlings nor any tractor drawn multi-stack semiautomatic vegetable transplanter has been developed with devices to feed and meter these individual paper pot seedlings.

Keeping all the above facts in mind, the present investigation was undertaken to develop a paper pot making device, a suitable technology for raising vegetables seedlings in paper pot and a tractor drawn vegetable transplanter to meter these paper pot seedlings efficiently.

In order to fulfill these objectives, the research was undertaken in four phases. In the first phase, pot making device made from locally available babul wood was developed to make cylindrical paper pots of volume 45 cm^3, 82 cm^3 and 126 cm^3 using recycled newspaper. A parametric study was conducted to identify the best combination of pot mix and pot size for raising good quality seedlings of tomato, brinjal and chili.

In the second phase, a prototype single planting unit was developed and tested in simulated soil conditions in the soil bin to identify the suitable seedling and operational parameters for efficient operation of the planting unit. The planting unit was made multi-stack to carry more number of seedlings at a time in less space, thereby reducing the unproductive time required for filling the planting unit and helped in improving its field capacity.

Based on the results obtained in simulated field conditions, a prototype of the tractor drawn 3-row MSVT was designed and developed in the third phase of the study. The performance of the developed vegetable transplanter was evaluated under actual field conditions for transplanting paper pot seedlings of tomato, brinjal and chili in the fourth phase of the study.

In the present study, four layered cylindrical shaped paper pots made from recycled newspaper (non-glazed) were preferred as they can be prepared easily at a faster rate using the developed device. Three sizes of paper pot making devices were developed to make three different sizes of cylindrical paper pots (Fig.3.1a). Each size of device comprised one pot making tool and another hammering tool. The pot making tools were made from hollow piece of wood (locally available babul wood) cylindrical in shape having length 70 mm. The outer and inner diameter at the top were 38 and 26 mm, 50 and 38 mm, 63 and 52 mm, respectively to form paper pots of size 38.1, 50.8 and 63.5 mm. The outer portion of all the tools was tapered along the length of the tool from the middle towards the bottom end for easy removal of paper pots from the tool. The outer diameter at the bottom of the tool was 33, 45 and 58 mm, respectively for paper pots of size 38.1, 50.8 and 63.5 mm. The hammering tools were fabricated using solid cylindrical piece of wood having diameter 24, 36 and 44 mm for 38, 50 and 60 mm sizes of pot making tool, respectively. The news paper of density 50 gsm was used for making pots.

Identification of the best combination of the proportion of pot mix and pot size for raising paper pot seedlings was carried out considering the growth parameters of the seedlings, cost of preparation of pots and weight of pots for all the selected vegetables. Literature reveals that no study had been conducted in the past on identification of pot mixes and pot sizes for raising pot seedlings of tomato, brinjal and chili using farm yard manure (FYM) as a component of pot mix. In view of these facts, experiments were conducted to study the effect of various proportions (20 to 80%) of FYM in soil based mix in four layered cylindrical paper pots of 45 to 126 cm^3 volume on the growth of tomato, brinjal and chili seedlings. Four proportions of

FYM (20, 40, 60, and 80% pot volume) and rest filled with soil and sand in equal proportion and three pot sizes (45, 82 and 126 cm^3 volume) were taken considering the requirement of the mechanical transplanting of pot seedlings. The experiments were conducted in complete randomized block design with six replications for each treatment.

Overall, FYM proportion of 80% by volume in soil based pot mix in a cylindrical pot of volume 126 cm^3 for tomato and 82 cm^3 for both brinjal and chili were found to be the best for raising good quality seedlings.

Non-dominated sorting technique was followed to identify the combination of pot mix and pot size that shall encourage the growth of good quality seedlings with lower cost of preparation and lighter in weight. Based on this, paper pot of 82 cm^3 volume filled with mix of 80% FYM and rest with equal proportion of soil and sand was found to be the best proportion of pot mix and pot size for raising good quality seedlings of tomato, brinjal and chili.

Considering the final dimensions and weight of pot, it was decided to develop a single multi-stack planting unit so that it can accommodate more number of seedlings in limited width of the machine. As it was the multi-stack planting unit, a necessity was felt to check the ability of the pot to sustain multiple droppings. Therefore, drop test was conducted to determine the ability of the paper pot seedlings to sustain multiple drops from a height of 160 mm (height of the seedlings with little clearance) Three levels of moisture content of pot mix (6 ±1%, 9 ±1% and 12±1% (db)) and three types of seedlings (tomato, brinjal and chili) were tried in the drop test with six replications for each treatment. It was found that pots with m.c. of pot mix as 6 ±1% sustained highest number of drops. Reduced moisture content of the pot mix resulted in increase sustainability of the pots against multiple droppings. Two stages of dropping with three metering wheels were selected for the development of single planting unit of the MSVT.

In the second phase, a prototype of the single multi-stack planting unit of the MSVT was developed considering appropriate devices for the feeding and metering of individual paper pot seedlings based on the findings of the literature reviewed. Developed multi-stack planting unit consisted of rings to which the cups were attached at their periphery (Metering wheel) for metering of individual pot seedlings.

The pot seedlings were placed in the cups of the metering wheel in upright orientation in the form of a circular array. The metering wheels were arranged one above the other (multi-stacks) to accommodate more number of seedlings within the limited width of the machine. Three such wheels (top, middle and bottom metering wheels) were fixed to a common shaft rotated by a 2.23 kW 3-phase DC motor with DC speed controller. A slotted plate was provided at the bottom of each metering wheel leaving appropriate gap. All metering wheels moved the pot seedlings continuously in upright orientation towards the seedling discharge point. Pot seedlings on the bottom metering wheel were discharged to the furrow through a delivery tube and the empty cups of the bottom metering wheel was filled with the pot seedlings of the middle metering wheel. The empty cups of the middle metering wheel was filled with the pot seedlings in top metering wheel as they were fixed to a common rotating shaft. In MSVT, as pot seedlings placed once in the metering wheels required no human intervention to meter and drop them into the furrow at the desired spacing.

The feeding, conveying and planting of seedlings by the machine were affected by the seedling and operational parameters viz., moisture content of the pot mix and forward speed of the machine. The effect of these parameters on feeding, conveying and planting efficiencies of the single planting unit was studied under simulated soil conditions.

Experiments were conducted by placing 60 seedlings in 3 stages (20 in each metering wheel) on the planting unit and operating the developed setup till all the pot seedlings were dropped through the seedling delivery tube to the furrow made in the soil bed of soil bin. The number of seedlings damaged or tilted during feeding of pot seedlings from one metering wheel to another and seedling delivery tube, damaged or tilted during conveying towards the seedling discharge point, and failed to drop in upright orientation into the seedling drop tube were separately collected and counted to compute the feeding efficiency (FE), conveying efficiency (FE) and planting efficiency (PE). The overall efficiency (OE) was calculated as the product of feeding, conveying and planting efficiencies. In addition to these, seedling spacing (SS), angle of inclination (AI) of seedling to the vertical and soil coverage (SC) were also noted down.

The data obtained were analyzed considering all the above parameters and maximum forward speed was decided at which all the efficiencies were higher and

SS, AI and SC were well within the acceptable limit. Duncan's Multiple Range Test (DMRT) was carried out to select the best possible speed of operation for the MSVT. For the forward speed up to 2.2 km/h, FE, CE PE and OE of MSVT were found to be above 96%. Amount of soil coverage was around 100% with a maximum seedling spacing of 46.31 cm and AI as 24°. With further increase in forward speed to 3.2 km/h, only FE and CE were found to be above 98% but PE and OE were reduced to around 28% due to the problem in getting the seedlings vertically in the furrow. The SS, AI and SC were 46.25 cm, 72.61° and 11.73%, respectively and these values are not within the range of acceptable limits. Forward speed at which the performance (FE, CE, PE, OE, SS, AI and SC) of the planting unit was well within the acceptable ranges was selected for field testing of the MSVT.

In the third phase, a tractor drawn 3- row MSVT was designed and developed for seedlings raised in cylindrical pots of volume 82 cm^3. It consisted of three sets of planting unit with seedling drop tube, furrow opener, furrow closers, three point hitching arrangement and a supporting frame. Each planting unit was designed to carry 60 seedlings in three stages. Shaft of all the planting units were driven by the ground wheels with a reduction gear box using chain and sprocket drives. Seedling spacing could be changed by changing the appropriate size of sprocket in one of the chain drives. The seedling delivery tube was provided below the seedling discharge point of the bottom metering wheel of each planting unit to drop the seedlings in upright orientation into the furrow opened by the furrow opener. Shovel type furrow opener with disc type furrow closer were provided along with boots in each row to open the furrow, to support the seedling drop tube and to close the furrow. The developed MSVT was drawn by attaching it to the three point linkage of the tractor. The depth adjustment was done by moving the position control lever of the hydraulic system of the tractor to appropriate position. By changing the velocity ratio of the chain drive between the central planting unit shaft and extension shaft, seedling spacing of 45 and 60 cm could be obtained.

In the fourth phase, performance of the developed tractor drawn 3-row MSVT was evaluated for transplanting paper pot seedlings of tomato, brinjal and chili at 60 cm × 45 cm spacing in well prepared plots each of size 13.5 m × 7.2 m. The pot seedlings with average height of 12±1 cm for tomato and 10±1 cm for both brinjal and

chili at moisture content of the pot mix around 6±1% were taken. The tractor was operated at an average forward speed of 2 km/h.

Field capacity of the transplanter was found to be 0.113 ha/h, 0.113 ha/h, 0.111 ha/h with a field efficiency of 31.25%, 31.25%, 30.95% while transplanting tomato, brinjal and chili, respectively. The average labor requirement was found to be 26.74 man-h/ha. The average planting rate, percentage missed planting and percentage tilted planting obtained with the transplanter were 72 pot seedlings per min per row, 3.33 to 4.99 and 6.32 to 8.09, respectively.

The soil covering efficiency of the vegetable transplanter was found to be around 84%. About 9% of the pot seedlings were covered with excess amount of soil and about 7% of the pot seedlings were partially covered with soil. The quality of transplanting as expressed by the percent missed and tilted plantings were at par with the semi-automatic vegetable transplanters developed elsewhere in India.

The transplanting of tomato, brinjal and chili using the developed MSVT resulted in a saving of 87.26% and 89.3% labor; 91.53% and 92.87 % of operating time over the conventional method of manual transplanting of pot seedlings and bare root seedlings, respectively. The cost of transplanting paper pot seedlings was found to be Rs 1882/h for 400 hours of annual use with the cost of preparation of paper pots accounting 80.46% of the total cost of operation. A total of 65.17% of the operating time was used for placing pot seedlings in the metering wheels, 3.42% for turning at the headland and adjustments and the rest was used for planting of seedlings. The field capacity of the machine needs to be improved by reducing the refilling time of the seedlings in the machine.

Based on the obtained results, following conclusions were drawn:

i. The developed pot making tool made from locally available low cost material (wood) could successfully make cylindrical pots with news paper in 70% less time than it is required by the conventional method.

ii. Four layered cylindrical shaped pots of volume 82 cm^3 made of newspaper and filled with 80% FYM and 20% mixture of soil and sand in equal proportion was found to be the best combination of pot size and pot mix for raising seedlings of tomato, brinjal and chili suitable for mechanical transplanting.

iii. Drop test of the pots showed that it has good strength to sustain the multiple dropping at 6±1% moisture content of the pot mix in the pots. Hence, a circular array type multi-stack planting unit was developed to accommodate more pots to reduce the unproductive time of refilling to increase the field efficiency.

iv. Laboratory evaluation of a multi-stack single planting unit indicated FE, CE to be above 98% for the forward speed of operation from 0.6 to 3.2 km/h. However, its planting and overall efficiency decreased to around 20% when the forward speed increased beyond 2.2 km/h due to the problem in getting the seedlings vertically in the furrow. Hence. The maximum permissible speed of operation was limited to 2.2 km/h.

v. The soil covering of the pot seedlings with the developed single planting unit was around 100% up to a forward speed of 2.2 km/h and it reduced to around 12% with increase in speed to 3.2 km/h due to greater throw away of soil which was not available for the furrow closer to cover the seedlings.

vi. A tractor drawn 3-row MSVT was designed developed and field tested for transplanting of pot seedlings of tomato, brinjal and chili. Its field capacity was found to be 0.112 ha/h at an average forward speed of 2 km/h and with a field efficiency of 31.15%. The amount of soil coverage was around 100% with an actual seedling spacing of 45±2 cm, and AI was below 30°.

vii. The planting rate of the developed vegetable transplanter was found to be 72 seedlings per min per row. There were 3.33% to 4.99% missed planting and 6.32 to 8.09% tilted planting with a soil covering efficiency of 81.82 to 84.39%. The quality of transplanting was found to be satisfactory.

viii. Use of this planter resulted in a saving of 87.26% and 89.3% labor; 91.53% and 92.87% of operating time over the conventional method of manual transplanting of pot seedlings and bare root seedlings, respectively.

A tractor drawn multi-stack semiautomatic vegetable transplanter for individual paper pot seedlings was developed to verify the experimental mechanism. The machine worked satisfactorily and the use of machine will increase the annual use of the tractor in farms. An important advantage of this machine is that it could save a substantial

amount of labor and time involved in transplanting of vegetable seedlings in farms where paper pot seedlings are prepared in advance without depending on cropped area for nursery establishment. However, the machine requires rigorous testing in the field before recommending it for commercialization.