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Design, Development and Fabrication of A Single Row Manual Vegetable Transplanter

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ABSTRACT

Present study was carried out during the year 2015-16 to design, develop and evaluate the single row manual vegetable transplanter on three different types of vegetable crops *i.e.*brinjal, chilli and tomato at two different sites and compare it with traditional method of transplanting. The manual single row vegetable transplanter consists of different component like hopper, handle, seedling delivery tube, jaw opening lever and jaw mouth. The implement penetrates into the soil by applying little force while holding with handle, seedling is dropped into seedling delivery tube then the jaw is opened with lever. The work demonstrates the application of engineering techniques to reduce the labour efforts and time required for transplanting. The results obtained from the trial tests concluded that transplanter functioned properly as there is no miss planting, also the rate of tilted planting is negligible. The mean effective field capacity was 52.36 percent higher over traditional method of transplanting. Significantly lower labour was required with developed prototype over traditional method with an average saving of 52.83 percent of time and labour.

1. Introduction

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 (Anonymous, 2014). In Jammu and Kashmir, the total area under vegetable is 30% out of total agricultural area and the area under cultivation of vegetable is 63.10 thousand hectares with a production of 1395.5 thousand tones and productivity is 22.1 tons/ha. The main vegetables grown in J&K include tomato, onion, cabbage, brinjal, chilli *etc.* where, brinjal and tomato contributes 8.1 and 11.3 per cent of the total area under vegetable cultivation respectively. Vegetable cultivation in the state has a spectacular success story and covers about 0.51 lakh hectare in J&K. There has been an increase from 13.92 lakh Mts in the FY 2009 to 14.65 lakh Mts in FY 2011 and from 60,000 hectares to 62,000 hectares in the area under vegetable cultivation during the same period. Vegetable exports from the state has more than doubled from Rs.100 crore in the FY 2009 to Rs.225 crore in the FY 2011. Around three quarters increase is expected in the FY 2012 over the export earnings of FY 2011 (Anonymous, 2014). Mechanization of transplanting means the reduction demand for labour in cultivating operation in which the minimum damage to seedling and the maximum efficiency of cultivating is being provided. However, this requirement happens when the labour income is less than the revenue provided by machines replacement. Today there are many instruments which are designed and built for automate cultivating of vegetables seedlings, and imported equipment are being used very rare and limited.

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Most of the vegetables like cucurbits, beans, okra and leafy vegetables are sown directly in the field. Vegetables like tomato, eggplant and peppers are first sown in nursery beds and later transplanted manually either on ridges or on a well prepared seedbed. Most of farmers have small land holding and have much below living standard. It is very difficult for them to have costly agricultural machinery and equipment. Therefore development of such equipment is necessary to overcome this problem which is easy to transplant the vegetable and also labour and time saving. Gore *et al.* (1987)developed a self-feeding transplanter for tobacco and vegetable crops. Yonts *et al.* (1994)conducted an experiment on the field evaluation of three vegetable transplanter (carousel, BST and chain type) with onion transplanting. It was also noted that the higher yield was observed with BST machine and was capable of transplanting 0.4 acres per hectare of onion in field scale trial. A punch planter for corn was designed, prototyped, and evaluated for no-till conditions using a commercial seed metering unit (Molin *et al.,* 1996).Shaw (1996) developed a slide crank mechanism to give a hot dibble, hole burner an appropriate cycloidal motion. Shaw (1997) developed an automatic transplanting vegetable machine with the transplanting rate of 7000 plants per hour per row unit. An automatic vegetable transplanter was developed by Tsuga (2000) where it was found that the prototype enabled continuous transplanting work on 2 rows simultaneously, at a planting speed of 60 cells/row/min. Lawrence *et al.* (2006) designed a machine capable of placing planting holes for a wide variety of spacing in plastic mulch. Yadav *et al.* (2007) evaluated manually operated six row paddy transplanter where, the field capacity of six row manually operated paddy transplanter was found to be 0.38 ha day^{-1} while transplanting by hand it was found to be 0.04 ha day^{-1}. Garg *et al.* (2008) conducted an experiment on a two row semi-automatic vegetable transplanter where the missing of 3-4 per cent was observed at a speed of 1-1.2 km/h.Elango*et al.* (2008) also developed an automated transplanter.Kumar *et al.* (2009) evaluated the efficiency of the tractor drawn planter and found that the raised bed planter has a field capacity of 0.28 ha/h at an average speed of 2.27 km/h. Yuan *et al.* (2010) developed an automatic transplanter for plug seedling and the result showed that the automatic transplanter had reliable transplanting performance. Narang*et al.* (2011) developed a two-row vegetable transplanter with revolving magazine type metering mechanism for evaluation of brinjal crop. Kadam *et al.* (2011) while conducting an experiment on field evaluation of tractor operated onion transplanterwith finger type metering mechanism with missing percentage was 9.00-10.9. Rahmen*et al.* (2011) while conducting an experiment on walk behind type hand tractor powered 2-row fully automatic vegetable transplanter for tomato and efficiency of the developed vegetable transplanter was about 81% and the quality of transplanting was satisfactory. Adisa*et al.* (2012) while conducting the experiment on template row planter having where it was able to plant on both ridged and flat seed bed at average field capacity of 0.2ha/h. Liu (2012) while analysing the design of automatic vegetable transplanters analysed that significant improvement and technological penetration of abroad transplanting machines has not been done yet. Nandede*et al.* (2013) evaluated a multi-stage automatic transplanter for tomato cultivation in pots and found that the field capacity of machine was 0.114ha.h^{-1} and field efficiency was measured 30.6%. Patil*et al.* (2014) designed and developed a hand held vegetable transplanter with the effective transplanting capacity (0.02 ha/hr) and the field efficiency was (82.30%). Zamani (2014) designed and developed vegetable transplanter and evaluated where it was found that physical damage to the stem, leaves and roots of seedling increases by increasing of forward speed of machine. Malunjkar*et al.* (2014) designed and developed a hand held vegetable transplanter evaluated for different vegetable crops and the effective transplanting capacity observed from trail was 0.02 ha/hr and field efficiency was 82.30%.During the process of designing the semi-automatic vegetable transplanter, from laboratory test it was found that finger tray angle of 30° is the optimum value for smooth dropping of seedlings (Behera*et al.* 2015). Nazari*et al.* (2015) designed, constructed and evaluated a fully-automatic single row tomato transplanter with theoretical capacity of 0.06 ha h^{-1}. Tripathi *et al.*(2016)conducted an experiment to evaluate the performance of semi-automatic vegetable transplanter and compare it with the traditional system of manual transplanting where filed capacity of transplanter was 0.09-0.12 ha/h with field efficiency of 64 to 75 per cent. Kumar *et al.* (2013) indicated that design of a handle depends on many factors like mode of operation, anthropometric data of user population, material of handle and shape of handle.

2. Materials and Methods

The following design considerations have been considered in mind while designing the prototype:

1. Simple in fabrication with locally available materials and easy to use
2. Able to transplant vegetable seedlings in standing posture.
3. Farmer friendly, light in weight and cheap.
4. Able to transplant seedling of different vegetable crops.
5. Minimal force requirement for penetration into the soil surface.

3. Design of Different Components

3.1 Seedling delivery tube

The dimension of seedling play vital role to decide the diameter of seedling delivery tube, height of jaw and apex angle. Canopy of seedling is considered to decide the diameter of seedling delivery tube. The average size of canopy is required to avoid clogging in hollow pipe. The height of seedling should not be more than 20cm and seedling age form 30-40 days is preferable as the height at this stage ranges from 10-15 cm (Malunjkar *et al.,* 2014). For seed delivery tube, polyvinyl chloride (PVC) pipe is selected due to its light weight, easy availability and its cheapness. The diameter of tube was selected 70 mm on the basis of dimension of average canopy of seedlings which ranged from 53 to 67 mm and it was also provided with a hopper so that it is easy for seedling to go inside the delivery tube without any interruption and damage to the leaves of the seedlings from the upper edge of the feeding pipe of transplanter, if in case the floral spread is larger than 70 mm.

3.2 Height of handle of vegetable transplanter from ground

For manually operated implements, the handle is one of the most important components with which the operator controls and guides the implements properly during field operations and the height of the handle of the transplanter from the ground should be designed such that during operation the operator stands erect as far as possible to reduce musculoskeletal discomfort (Dewangan *et al.*, 2008). The height of the handle depends on elbow height (standing). It is suggested that the elbow flexion angle should be in the range of 85-110° (Grandjean, 1988). Elbow height (standing) value for the 5th percentile and 95th percentile of user's population was 94.9 cm and 108.6 cm, respectively. Taking elbow flexion angle as 101.69° for the users, the height of the handle was determined as 89 cm onthe basis of user's population, to accommodate larger population on 5th percentile value for maximum work efficiency.

3.3 Handle width

It is used to hold and penetrate the jaw in the soil bed. For maximum work efficiency, hand positioning should be such that both hands are close to their neutral position. Thus, handle width depends on elbow-elbow breadth. The 5th and 95th percentile values for elbow-elbow breadth was found to be 30.1 and 38.2 cm for male population respectively. The 5th and 95th percentile values for elbow-elbow breadth was found to be 28.7 and 38.1 cm for female population respectively. Taking a clearance of 1.4 cm on each side, the recommended handle width was 41 cm on the basis of 95th percentile value to accommodate larger population.

3.4 Hand grip span of jaw opening lever (clutch)

The grip span of the jaw opening lever should be designed in such a way that it should exceed average hand grip span of user. To accommodate larger population, 5th percentile value of grip span for user's population was used and so the recommended grip span was determined as 5 cm.

3.5 Size of jaw mouth

The size of jaw mouth depends on the required depth of transplanting of the different vegetable seedlings. The required depth for transplanting is 3 to 5 cm for the vegetable seedlings therefore, the size of jaw mouth is taken as 14 cm so that jaw could easily penetrate into the soil surface up to 5 cm depth.

3.6 Apex angle

The apex angle (θ) is inclined angle formed by the two edges between the jaw and jaw opener, according to Singh (1998). It ranges between 36° to 60° for proper penetration of implement into the soil; therefore apex angle of jaw was taken as 36.86° for easy penetration without much efforts (Figure 3.1).

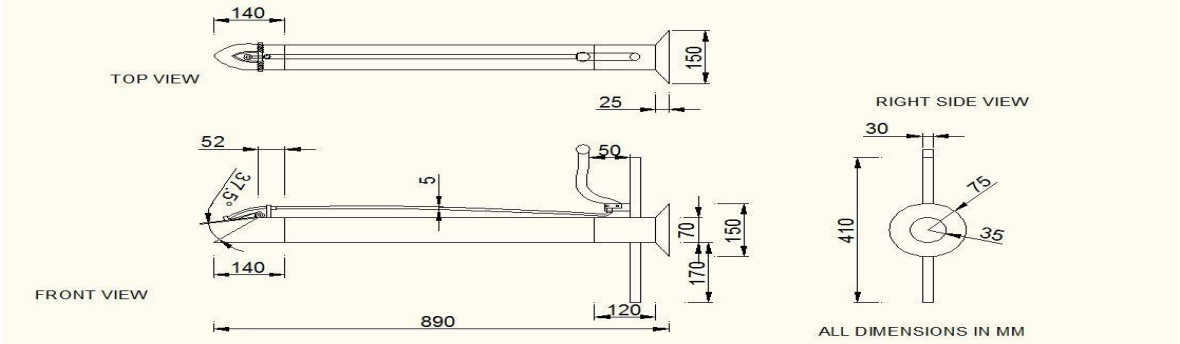

Figure 3.1. Different views single row of manual vegetable transplanter

Keeping in view the design specifications, a prototype of single row manual vegetable transplanter was fabricated and the detailed specifications along with materials of construction have been given in Table 4.1.

Table 4.1. Specification of single row manual vegetable Transplanter

S. No.	Description	Dimensions (mm)	Material used
1.	Seedling delivery tube	630	Hallow PVC pipe
2.	Hopper diameter	150	MS flat
3.	Handle length	410	GI pipe
4.	Grip span of lever	50	MS round (25mm)
5.	Clutch wire thickness	5.0	Scooter clutch wire
6	Jaw mouth length	140	High carbon steel
7.	Apex angle	36.86°	-

5. Working Principle

The main working principle of single row manual vegetable transplanter is clutch operated. This prototype has simple mechanism; the jaw is operated with clutch which is connected by gauge wire. The prototype in held position with handle as the jaw penetrate into soil bed, pick up one seedling and drop into seedling delivery tube, then pull the clutch upside and the action of clutch opens the jaw inside the soil, at that condition seedling is drop into the pit. Now pick up the implement in same position (jaw in open position), the outermost soil from jaw comes towards the root zone of seedling. The main parts of implement are hollow pipe, handle, clutch, jaw operating wire and jaw.

6. Results and Discussion

The machine was tested in the field and the data regarding clogging percentage, survival and damage percentage and these results were compared with the traditional method of transplanting. The results showed very less clogging percentage and the survival percentage was also found more than the traditional method but it showed non-significant results. However there was no damage to seedling with the developed transplanter and yield showed non-significant results between the two methods of transplanting. Field capacity and field efficiency of the developed was evaluated in the field and it was more with the developed transplanter than the traditional method of transplanting.

The effective field capacity was 52.36 per cent superior over conventional method of transplanting. Field efficiency was found to be 91.34 and 90.63 per cent with vegetable transplanter and conventional method respectively. Labour requirement and cost of operation were also extremely reduced compared to traditional method of transplanting and results revealed average saving of 52.83 per cent of time and labour over traditional method.In agriculture,transplanting is one of the important labour intensive activity and adoption of the single row manual vegetable transplanter in the present study increased not only efficiency but cost of operation was also reduced by reducing labour engagement during transplanting. The chances of injury were eliminated and provided safety to the worker, due to its better construction. Proper training to farmers on various improved implements should be provided so that they can operate these implements in a proper and safe way and it was found satisfactory and it is easy to operate. Advertisements through media and other means and practical demonstrations at various levels by departments related to agriculture should be done to educate farmers. It is farmer-friendly tool because it increases the work efficiency, reduces drudgery and provides comfortable working posture. It reduces the exertion and fatigue and farmers feels comfortable. They earn money by reducing the labour and their social life improves and they feel happy in the society. There should be co-ordination between central/state departments and NGOs to promote these improved tools and implements and hence, promoting such tools among the farm women engaged in the agricultural operation should be done at the priority.

Conclusion

1. It can be used for transplanting many vegetable crops such as potato, tomato, brinjal *etc*.
2. The field capacity of manual vegetable transplanter is more than traditional method.
3. Vegetable seedling transplanter machine made transplanting seedling easier and faster
4. High efficiency, 0.25-hectare per day which is equals to 4-5 person's efficiency.
5. Very cheap easy operation and used less manpower.

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