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Vegetable Transplanters for India: A Review

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ABSTRACT

India ranks second after China in vegetable production in the world. Vegetable transplantation is labor-intensive due to the requirement of transplanting practices. This makes it necessary to adapt the mechanization for vegetable transplantation to save money and time and increase the productivity to fulfill the food requirement of a huge population. In India, vegetables are grown in small plots. The research paper on the design development and performance evaluation of the various manual vegetable transplanters, semi-automatic vegetable transplanters, automatic vegetable transplanters are studied for the purpose to find out the most useful vegetable transplanter in Indian conditions. As per the land use pattern in India, the small and economical vegetable transplanters are beneficial. The articles in this section discuss vegetable transplanters and advances in vegetable transplanting technology used in India.

Key words: Mechanization, Seedlings, Transplanters, Transplanting technology, Vegetables.

India has huge production and consumption of vegetables followed by China. About 8.50 million ha area is under vegetable production producing almost 188.28 million tons and contributing about 15 per cent of the total vegetable production in the world (National Horticulture Board, 2020). Table 1 present the area and production of some of the vegetables in India (Ministry of Agriculture and Farmers Welfare, 2020). However, the planting and harvesting processes were mainly manual operations which makes the operation inefficient and lower quality.

At the same time, it reduced the comprehensive economic benefits of vegetable production and restricts the development of the vegetable industry (Liu *et al.*, 2016). Many horticultural seeds are sown directly into the ground where the plants develop and mature, most of the vegetables like tomato (*Solanum lycopersicum*), chili (*Capsicum annuum*), eggplant (*Solanum melongena*) are first sown in nursery beds and later transplanted manually either on ridges or on a well-prepared seedbed (Patil *et al.*, 2015). The complete job from uprooting the seedlings from the nursery to the transplanting in the field is done mostly manually. The manual transplanting of the vegetable seedlings is a laborious task for the farmers when need to be done on a large commercial scale. Non-uniform transplant outcomes necessitate more time and money than mechanized transplantation (Orzolek, 1996).

There are several activities that include preparing the field for placing the seedling, transporting the seedling from the nursery to the field, planting at appropriate spacing and depth in the vegetable transplanting operation. In India, the labor requirement for manual transplanting of vegetables varies from 240 to 320 men. h ha^{-1} (Kumar and Rahman, 2012). Mechanical transplanters can be used to perform the task of seedling transplanting in the field (Hawker and Keenlyside, 1985).

The automatic transplanting machine had a complicated structure, as well as a high maintenance and operating cost.

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Because vegetables are primarily grown in small plots in India, small machines or equipment with low operating costs and the ability to perform multiple tasks are preferred. The tray seedling transplanting technology has many significant advantages such as enhancing the ability of seedlings to resist disasters and stress, improving vegetable quality and yield and significant economic benefits (Liu *et al.*, 2012). The efficiency of semi-automatic transplanting machines was still low due to a lack of systematic research on seedling conditions, transplanting conditions and effects and the quality of transplanting operations needs to be improved (Jin *et al.*, 2018). The planting mechanism is the main component of the semi-automatic transplanting machine and it has a direct impact on many key transplanting effect indicators. The working objects of the vegetable transplanter are the potted vegetable seedlings that have been cultivated through the tray. In the transplanting operation, workers smoothly took out the seedlings from the seedling tray; sequentially put them into the mechanism of transporting seedlings and then released them into the seedling bucket. Finally, the planter planted the seedlings in the field. The planting process necessitates minimal seedling damage as well as the precise and orderly movement of various mechanisms. According to the type of planter, it can be

divided into the clamp, flexible disc, hanging cup, guide seed tube, double conveyor belt, slide branching wheel and duckbill.

European and American countries have begun to develop transplanting equipment earlier and the technology was complete and mature. To accelerate the research of vegetable plug seedling, transplanter is very conducive to the mechanization level in the promotion of dryland economic plant and the rapid development of its industry, which plays an important role in promoting farmers' income and rural economic transformation (Chen, 2019). Gore *et al.* (1987) created a self-feeding tobacco and vegetable transplanter. Narang *et al.* (2011) developed a two-row vegetable transplanter with a revolving magazine type metering mechanism for evaluation of brinjal crop. Garg *et al.* (2008) experimented 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. Shaw (1996) developed an automatic transplanting vegetable machine with a transplanting rate of 7000 plants per hour per row unit. Tsuga (2000) developed an automatic vegetable transplanter and it was discovered that the prototype allowed for continuous transplanting work on two rows at the same time, at a planting speed of 60 cells/row/min. Yuan *et al.* (2010) developed an automatic transplanter for plug seedlings and the results demonstrated that the automatic transplanter provided consistent transplanting performance. Kumar *et al.* (2013) evaluated the efficiency of the tractor-drawn planter and found that the raised bed planter has an average speed of 2.27 km/h and field capacity of 0.28 ha/h.

An automatic transplanter, compared with a semi-automatic transplanting machine, can automatically complete the whole transplanting process of seedling pick-up and planting, which has the advantages of good transplanting quality, high transplanting efficiency and low production cost (Kumar, 2008). The automatic transplanting mechanism is the core working part that determines the quality and efficiency of the transplanting machine, in which the seedling planting mechanism is relatively mature, but the seedling pick-up mechanism is the technical bottleneck that limits the development of the automatic transplanting machine, so research and development are focused on the automatic transplanter (Yu, 2014).

The paper focuses on the research and development of handheld, semi-automatic and automatic vegetable transplanting devices, as well as the mechanisms that they employ for vegetable transplantation. Fig 1 to Fig 4 shows the different types of seedlings used for transplanting operations (www.towergarden.com, n.d., https://japan-agritrading.com, n.d., Kumawat *et al.*, 2020 and www.gardeningchannel.com, n.d.).

Classification of the vegetable transplanting mechanism

Vegetable transplanters are classified on the basis of operation method and mechanism used as shown in Fig 1. Handheld, semi-automatic and automatic vegetable transplanting devices are among them. The handheld and the semi-automatic vegetable transplanting devices are unmanageable to utilize because the manual feeding of the seedlings into the hopper depends on the operation interval and expertise of the operator. The area of the seedling perimeter was extracted using machine vision and automatic seedling transplantation achieved a 98 per cent success rate (Jiang *et al.*, 2009). Fig 5 shows the classification of the



Fig 1: Bare root seedling.



Fig 2: Plug seedling.

Table 1: Area and production of some vegetable crops in India.

Name of vegetable crop	2018-19		2019-20	
	Area in thousand ha.	Production in thousand MT.	Area in thousand ha.	Production in thousand MT.
Brinjal	727	12680	744	12682
Chillies (Green)	377	3783	387	4119
Chillies (Red)	780	1743	684	1931
Tomato	781	19007	811	21173

vegetable (onion) transplanting mechanism (Kamal *et al.*, 2020).

Vegetable transplanters used in India

In India, the maximum number of farmers who grow vegetables are using the traditional practices. But nowadays manual (Handheld) and semiautomatic transplanters are also used for transplanting vegetable seedlings. The majority of farmers have small landholdings therefore they are unable to purchase costly machines such as automatic vegetable transplanter but the farmer's co-operative groups, large farmers and other financially sound organizations use the semi-automatic and automatic vegetable transplanter. Table 2 shows the vegetable transplanters available in India with their metering mechanism and types of seedlings used.



Fig 3: Chain of pots seedling.



Fig 4: Paper pot seedlings.

Manual vegetable transplanter

Dixit *et al.* (2018) designed, developed and tested a manual single row vegetable transplanter for transplanting brinjal, chili and tomato seedlings. Geetanjali (2020) fabricated a two-row manual-operated vegetable transplanter for tomatoes. A low-cost manual-operated vegetable transplanter is being developed for seedling transplanting in raised beds. It is made up of a dropping structure, the mainframe, a furrow opener, a handle and a seeding plate. The hole punching mechanism at the transplanter's lower end consisted of a pair of jaws capable of penetrating the plastic mulch film and creating a tapered hole for seedling placement. This transplanting mechanism involves simple jaws pivoted at the bottom of the seedling guide mechanism and the device holder and jaws operation lever are attached at the top end of the guide mechanism. To open the jaws inside the soil, a single person punch the transplanter into the soil and pull the lever in the upward direction, which is attached to the jaws mechanism by a gauge wire. According to the literature, for raised beds and plastic mulch beds, the transplanter can transplant 23 and 17 seedlings/min, respectively. Fig 6 shows the manual vegetable transplanter (www.indiamart.com, n.d.).

In case of manual transplanting by using traditional method high labour requirement and shortage of labour

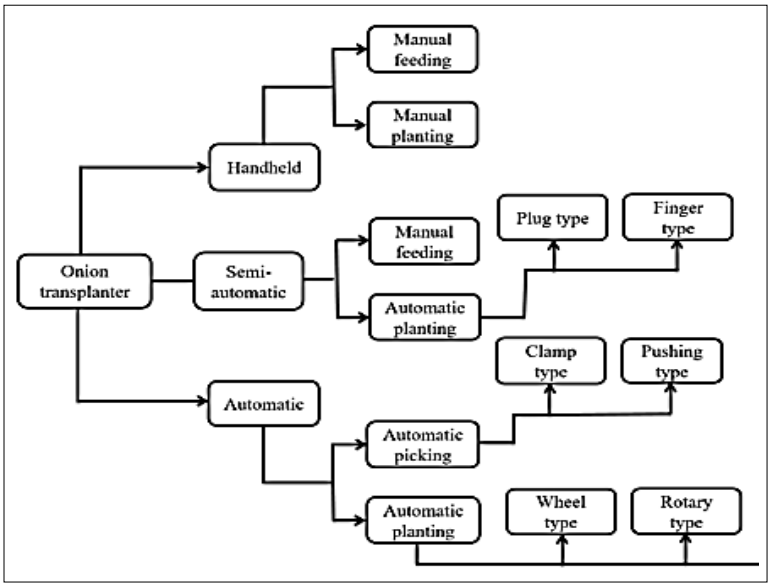


Fig: 5 Classification of vegetable (onion) transplanting mechanism.

Table 2: Vegetable transplanters in India.

Type of vegetable transplanter	Metering mechanism	Type of seedlings
Handheld (Manual)	Not required	Plug, paper pot
Semi-automatic	Pocket or finger	Bare root
	Rotating cup	Plug
	Pocket or picker wheel	Bare root
	Conveyer	Bare root
Automatic	Vertical descending cup	Plug
	Rotary planting fingers	Chain of pots
	Seedling pick-up device	Plug
	Horizontal conveyor	Plug
	Combination of horizontal and vertical conveyor	Paper pot



Fig 6: Manual vegetable transplanter.



Fig 7: Semi-automatic vegetable transplanter.

during peak transplanting season causes a delay in transplanting and affects timely operation and thereby reduces the yields. Traditional methods have very low field efficiency and required a large labour force in a planting season which increases the cost and time of plantation ultimately increasing the cost of production. The manual transplanter is a low-cost manually operated mechanism suitable for small landholding farmers in various areas and conditions (soil and climatic). It is used in plain areas as well as in hill regions and opens as well as a closed system (poly or greenhouse). It is affordable as compared to the traditional method of transplanting as it required less manpower and is used for various vegetable planting for a small area. The field capacity of manual vegetable transplanter is 0.03-ha/h which equals to 4-5 people's efficiency. It is very easy to operate and simple technology.

Semi-automatic vegetable transplanter

As the seedling transfer method for the semi-automatic transplanter, a person boards and manually transfers the seedlings. In a semi-automatic mechanism, there is a possibility of miss feeding of the seedlings when the transplanting rate is higher (Khadatkar *et al.*, 2018). The semi-automatic vegetable transplanter is difficult to use because the manual feeding of seedlings into the hopper is dependent on the operation interval and operator expertise. As the one seedling can be manually fed at a time, the semi-automated transplanter is not suitable for continuous operation for an extended period of time. The semi-automatic vegetable transplanter used plug type, finger type and cup or bucket type metering mechanism for the seedling deposition. The walk-behind type and riding type semi-automatic vegetable transplanters are available. Fig 7 shows the semi-automatic vegetable transplanter (Verma, 2018).

The semi-automatic vegetable transplanter is used for the plain area (leveled land). The semi-automatic transplanter had a field capacity of 0.09-0.12 ha/h and field efficiency of 64 to 75%. It is having more field capacity than a manual transplanter hence more area should be covered in a limited time.

Automatic vegetable transplanter

An automatic vegetable transplanter was developed by Tsuga (2000) where it was found that the prototype enabled continuous transplanting work on 2 rows simultaneously. Automatic vegetable transplanters involve the repeat process of seedling picking from the tray and planting it into the soil and reducing the labor requirement for feeding the seedlings. Fig 4 shows the schematic view of the automatic

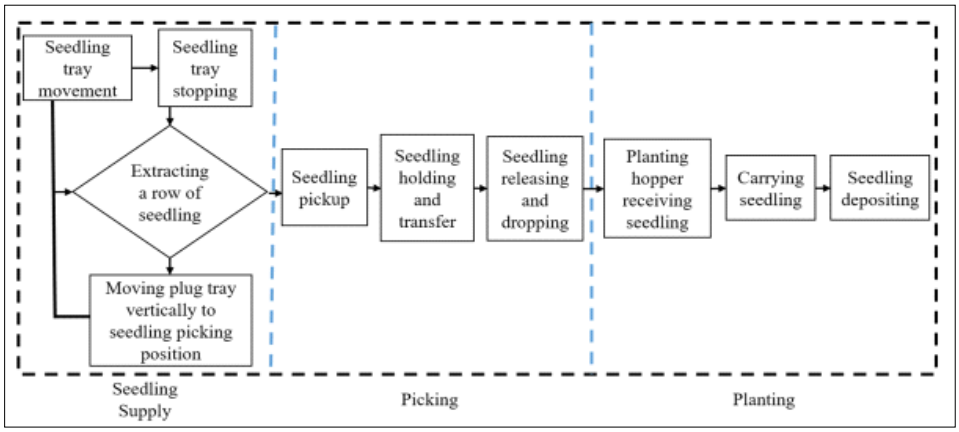


Fig 8: Automatic seedling transplanting mechanism.

seedling transplanting mechanism. Automatic transplanting devices are a synchronized combination of automatic seedling pickup and planting mechanisms To improve the low transplanting efficiencies and simplify the complex structures of current automatic transplanters, a mechanical high-speed transplanter for picking plug seedlings that is suitable for planting on plastic films was designed (Changjie *et al.*, 2021). The average plant height, number of branches per plant, plant mortality, yield/m^2, seedling missing and leaf area index was found more by machine transplanting while plant population, planting depth was found less (Kumar and Tripathi, 2016). Presently, the use of automatic transplanting machines is not popular, mainly due to the complicated mechanical structures and high production costs and it is difficult to combine agricultural machinery and agronomics effectively. The automatic vegetable transplanter can feed a row of the seedlings to the conveyor mechanism where it is further fed into the hopper of the planting device mechanically. 4 rows, 6 rows and 8 rows automatic transplanter are available commercially. Depending on the number of rows and operational capacity these transplanters are either walk-behind type self-propelled or riding type self-propelled and riding type tractor operated. Fig 8, 9 show the s automatic seedling transplanting mechanism (Jin, 2018).

The automatic vegetable transplanters on a commercial basis are not found in India. The main reason behind that is the initial cost of the machine is very high so the major Indian farmers cannot afford to purchase and the other reason is its repair and service facility was not available in nearby areas. Also, the area of vegetable plantation per farmer is very small as compared to European countries. Reasons for less adoption of automatic transplanters also include the availability of cheap labour as well as lack of policy support from the government side. It may be used on a custom hiring basis for the large vegetable growers in a specific area. As per the reference studied it is time-saving, labour-saving, less cost of operation was achieved in machine transplanting as compared to manual transplanting. Fig 9 shows the self-propelled automatic vegetable transplanter (www.indiamart.com, n.d.).



Fig 9: Self propelled automatic vegetable transplanter.

CONCLUSION

The mechanization in vegetable transplanting is important for efficient operation and increased production. Day by day the demand for vegetables is increasing due to increasing population and health consciousness, to fulfill the above demand and export the good quality of vegetables in a time-bound system the mechanization of the Indian farms is necessary. For the mechanization in Indian farms, the manual and semi-automatic vegetable transplanters are very much economical on the basis of operating and servicing costs. The field capacity and accuracy are more in automatic transplanter but having high initial cost, its complicated mechanism and servicing facility makes uneconomical in Indian farms.

Conflict of interest: None.

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