Madras Agric. J., 104 (10-12): 401-404, December 2017

Development of an Automatic Transplanting Mechanism for Protray Vegetable Seedlings

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Performance evaluation of an automatic gripping type transplanting mechanism for plug type vegetable seedlings was tested. Forty and twenty-five days old chilli, brinjal and tomato seedlings were used for the study. Well decomposed coco-pith (68.46 % moisture) was used as the medium for raising the seedlings. The tray contained 98 cells arranged in the order of 14 x 7. The growth characteristics of seedlings were recorded. A pneumatic actuated gripper for grasping and releasing the plug type seedling, pneumatic cylinder to remove the seedling from the protray cell and a linear rail used for transplanting the seedlings that moves on a linear guide way were the components of the automated system. The entire operations of transplanting mechanism were programmed in a microcontroller programmed with C^{++} software further controlled by Programmable Logic Controller (PLC) unit. Pneumatic air was supplied from compressor to the pneumatic actuated gripper and cylinder through Filter Regulator Lubricator (FRL) unit. The transplanting rate of developed mechanism was set as 20 – 25 seedlings / minute. The success ratios of automatic transplanting of seedlings were 87.22, 91.72 and 89.85, for 25 days old tomato seedlings, 40 days old chilli and brinjal seedlings, respectively. In terms of success ratio of transplanting, the average for the three kinds of seedlings was 89.59%. The pick-up device satisfactorily grasped and removed each seedling from the protray and transported it to the place where it would be precisely transplanted in the field.

Key words*:* Protray plug seedlings, Gripping mechanism, Automatic transplanter, Success ratio.

India is the second largest producer of vegetables after China. Production of vegetables in India stands at 14 per cent of the world production in 2014 - 15. The area under vegetable cultivation in India is about 8.50 million ha with a production of 146.55 million tonne (National Horticulture Board, 2015). Each field worker can set 400 plants ha^{-1} day^{-1} (Suggs *et al.,* 1989), demanding a considerable labour force. Most of the vegetables like tomato (*Solanum lycopersicum*), chilli (*Capsicum annuum*) and eggplant (*Solanum melongena*) are first sown in nursery beds and later transplanted manually either on ridges or on a well-prepared seedbed (Patil, 2015). Moreover, there are several activities involved in the vegetable transplanting operation, which include preparing the field for placing the seedling, transporting the seedling from the nursery to the field, planting at appropriate spacing and depth. Particularly, transplanting of vegetable seedlings are labour intensive. In India, labour requirement for manual transplanting of vegetables varies from 240 to 320 man. h ha^{-1} (Kumar and Raheman, 2012).

Use of automatic vegetable seedling transplanter in India is still primary stage. Many studies had been done on seedling pick-up mechanisms. A pneumatic-type manipulator of seedling picking was prepared by Zhang *et al.* (2015). It was mainly composed by a level cylinder, a lifting cylinder, a substructure, a clamping cylinder and an end-effector. During working process, travel swatches of PLC could reach up the accurate location of the manipulator for the tray, then, under the action of the clamping cylinder, the movement of gripping and loosening was done by the manipulator's end-effectors.

Ye and Yu (2011) developed a planetary-gear system seedling pick-up mechanism. In the planetary gear system, a pair of seedling pick-up arms, which were fixed in planetary noncircular gear on the one hand, rotated around central axis with planet carrier; on the other hand, made intermittent rotating, respectively with non-uniform speed relatively to planet carrier. The picking up arms moved according to the required trajectory. Two seedlings were picked up in a circle.

Hongsong *et al*. (2008) manufactured a mandrill-type seedling pick-up mechanism. The working principle was that the push rods of seedlings pushing mechanism entered the bottom of trays from the hole and push the potted vegetable seedlings against the rods, which transfer the seedlings to the required position. This study could be used for avoiding the injury of stem of seedling.

Although there are lot of transplanting mechanisms developed for plug type seedling in India, the existing system of vegetable cultivation is manual transplanting only (Zhou *et al.,* 2009). Considering

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the drudgery involved and labour requirement in transplanting operation the current research was conducted on development and performance evaluation of an automatic gripping type transplanting mechanism for plug type vegetable seedlings.

Material and Methods

Nursery management system

Well decomposed coco-pith was used as media for raising the vegetable seedlings. Tomato, chilli and brinjal seedlings (25and 40 days

old) were used for transplanting and the growth characteristics were recorded (Fig. 1). Moisture content of the growth media was recorded by using gravimetric method and it was found to be 68.46%. The tray contained 98 cells arranged in 14 x 7 fashion.

Fig. 1 Measurement of growth characteristics of protray vegetable seedlings

Conceptual design of plug type seedling gripping, picking and transplanting mechanism

While developing an automatic transplanting mechanism for vegetable seedlings raised in protray, two important parameters *viz.* movement of seedling gripping cum a picking mechanism from cell to cell in a row and movement of protray conveyor were

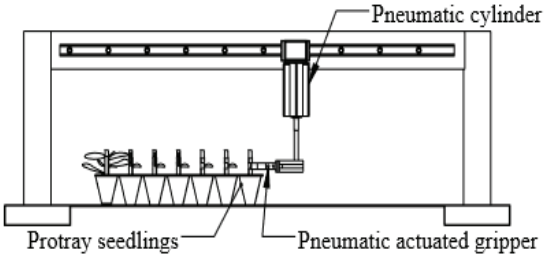

Fig. 2. Conceptual design of automatic gripping, picking and transplanting mechanism

considered. An end effector / gripper, which works like a robotic arm was used for gripping and picking the seedlings from the protray. The concept of automatic picking and dropping mechanisms is given in Fig.2.

Experimental set up for an automatic transplanting mechanism

The experimental set up for an automatic transplanting mechanism consisted of a main frame, aluminium extrusion, linear rail, linear guideway, stepper motor pulleys, stepper motor belt, M.S plates, pneumatic cylinder, pneumatic gripper, gripper arm, pneumatic hose, conveyor belt, wiper motor, solenoid valve, limit switches, electrical panel box and compressor. All the components of aluminium extrusion, electrical panel box and belt conveyer were welded with a frame made of mild steel.

Pneumatic actuated gripper for grasping and releasing the plug type seedling would open and close at regular intervals. The maximum opening was 10 mm. Based on the stem thickness of seedlings, the gripper was selected. pneumatic cylinder for remove the seedling from the protray cell was clamped with a linear rail which would move on linear guideway for the forward and reverse movement of the gripper in the horizontal direction. A vertical stroke of the pneumatic cylinder for the movement of gripper in the vertical direction would result in lifting the seedlings from the protray cell. A belt conveyer was used for the automatic movement of protray at a regular interval (Fig. 3).

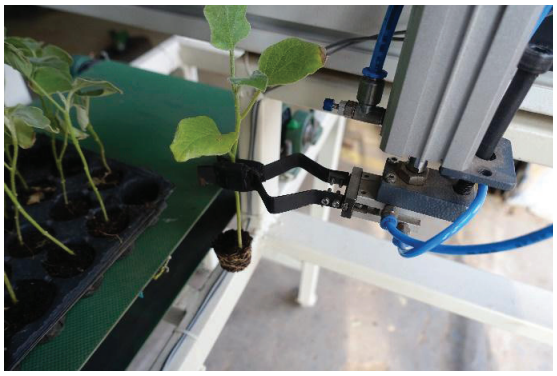

Fig. 3 Development of an experimental set up for an automatic transplanting mechanism

Performance test

The function of the seedling gripping and pick-up device are to automatically extract seedlings from the

growing trays, transfer and release them directly into the ground. In the test trails, the seedlings from 98 cell protrays were transplanted. Each test was repeated three times. The transplanting rate of developed mechanism was set as 20 - 25 seedlings / minute. The corresponding results were recorded and data analysis was done. The success ratio (%) of picking or failure, transferring, missing and damage of plug seedlings were recorded with all the three seedlings for each replication.

$$\text{Success ratio (\%)} = \frac{NFS - NMS - NEF - NSD}{NFS - NMS} \times 100$$

Where,

NFS - No. of Seedling Fed;
NMS - No. of Missing Seedling;
NFF - No. of Extraction Failure; and
NLD - No. of Seedling Damage

Results and Discussion

Growth characteristics of plug type vegetable seedling used in performance test

Development of an automatic gripping mechanism was mainly influenced by the growth characteristics of plug type vegetable seedling. After 25th day, the growth parameters *viz.,* number of leaves, shoot length (mm), root length (mm) and stem diameter (mm) were measured for tomato seedlings; whereas for chilli and brinjal 40th day old seedlings were considered. The seedlings were removed manually from the protray cells and the shoot and root lengths were recorded with a steel rule with least count of 0.5 mm. The stem diameter was measured using a digital vernier calliper with least count of 0.02 mm. Pulling force of plug seedlings was measured by force gauge meter, which can measure up to 50 N (Table 1). Coir pith was used as the medium for growing of vegetable seedlings.

Table 1. Measured growth characteristics of vegetable seedlings

Seedlings	No. of days	No. of leaves	Stem dia. (mm)	Shoot length (mm)	Root length (mm)	Pulling force (N)
Tomato	25	3-4	1.46	75.3	52.8	1.15
Chilli	40	6-7	1.35	125.3	66.0	1.25
Brinjal	40	4-5	1.40	129.8	68.2	1.29

Performance evaluation of an automatic pick-up device

The result of performance test is shown in Table 2. Seedlings in all 98 cell trays were extracted with pneumatic actuated gripper to further evaluate the performance of the pick-up device. The success ratio of automatic transplanting of seedlings were 87.22%, 91.72% and 89.85% for 25 days old tomato seedlings, 40 days old chilli and brinjal seedlings, respectively. Obviously, the success ratio for tomato seedlings was found to be the lowest among the three crops. When the number of seedling missed to the successful seedling extraction was compared, it was found that some seedlings did not grew due to picking up position. A total number of 20 tomato seedlings, 16 chilli seedlings and 18 brinjal seedlings were missed at the time of transplanting operation. To reduce the number of missing seedlings, it is recommended that the seedlings should be grown at the centre of the respective tray cells (Shaw Lawrance, 1993).

Table 2. performance test for an automatic plug type seedling pick-up device

Seedlings	No. of seedling fed	No. of missing seedling	No. of extraction failure	No. of seedling damage	Success ratios (%)
Tomato	294	20	17	18	87.22
Chilli	294	16	10	13	91.72
Brinjal	294	18	13	15	89.85

Damage to tomato seedlings was focused to be more as compared to other two seedlings. It was further observed that the seedling stem was torn by the gripper as the stem of tomato seedling was quite brittle, succumbed to easy damage during gripping by pick-up device. Hence, agronomic improvement is particularly important for automatic transplanting of tomato seedling (Mao *et al.* 2014). In terms of success ratio of transplanting, the average for all the three kinds of seedlings was 89.59%. The pick-up device satisfactorily grasped and removed each seedling from the protray and transported the seedling to the place where they would be precisely transplanted in the ground.

Conclusion

An automatic transplanting mechanism was developed for plug type vegetable seedlings. The device consisted of pneumatic actuated gripper for grasping and releasing the plug type seedling, pneumatic cylinder to remove the seedling from the protray cell and linear rail used for transplanting the seedlings in linear motion, which could move on linear guide way. The transplanting rate of the device was set as 20 - 25 seedlings / minute. The success ratios of automatic transplanting of seedlings were 87.22, 91.72 and 89.85 for 25 days old tomato seedlings and 40 days old chilli and brinjal seedlings, respectively. In terms of success ratio of transplanting, the average for all the three kind of seedlings was 89.59%. The pick-up device satisfactorily grasped and removed each seedling from the protray and transported the seedling to the place where they would be precisely transplanted in the ground.

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Received : November 22, 2017; Revised : December 15, 2017; Accepted : December 27, 2017