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Automatic protray conveying and dibbling system towards development of automatic protray seeder for vegetable nursery

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■ **ABSTRACT :** Quality and healthy seedling production is very important for successful vegetable cultivation. Recent days hybrid vegetable seedlings are raised in protrays under protected cultivation to ensure quality seedling production. Vegetable nursery raising is an upcoming successful entrepreneurship area. Growing media filled protrays are dibbled and seeded manually. This process is very tedious, labour intensive, time consuming and drudgery. Keeping this in view, an automatic protray conveying, dibbling and seeding system was designed and developed. The design and construction of automatic protray conveying and dibbling system is presented is this paper. The machine was designed suitable for 98 protray cell (Protray dimension : 530 x 275 mm and protray cavity matrix: 14 x 7 (lengthwise x widthwise) which is widely used for vegetable nursery raising. This system consisted of protray conveyor and indexing system, dibbling unit, penumatic systems, electronic controls and programmable logic controller (PLC). The main conveyor shaft was driven by a stepper motor and the stepper motor was driven by a micro-stepping drive with 3200 pulse/rev configuration. Each protray was detected by a sensor and indexed by determined distance pre-programed of PLC. The function of dibbling unit was to make 10 mm dia. x 10 mm deep depressions at the center of the each cell of the growing media filled protray. The dibbling unit was a set of conically shaped tubular pegs arranged in a common bar. The stroke of the operation was 30 mm and indenting was 10 mm deep. Proximity sensor of PNP type was used for the dead end limits of all motions and conveyor index. The sensors used were dibbling station home sensor, dibbling station lower sensor, main conveyor indexing sensor and tray detection sensor. The entire cycle was controlled by a logic programme and this synchronized the conveyor motion (position/inching) with the dibbling system. This machine was able to index the growing media protrays at the predetermined distance of 38.3 mm and to make uniform depth cavities. The dibbling capacity was found to be 300 protrays/h.

■ **KEY WORDS :** Vegetable nursery, Step seeder, Automatic protray indexing, Crop nursery mechanization, Nursery machinery

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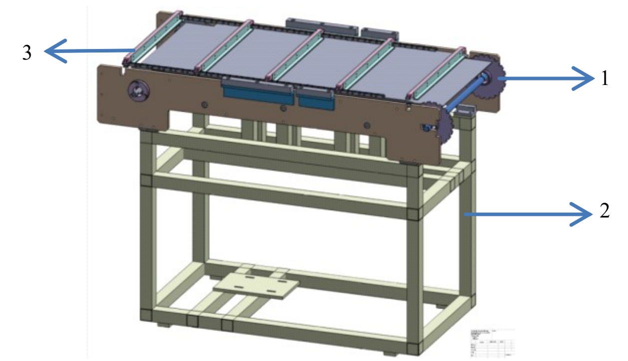
Healthy plants can beraised only when their seedlings are vigorous and healthy. Nursery is consequently the basic need of horticulture. Earlier the seedlings were produced by the farmers on flat bed nursery system. Now-a-days many progressive farmers grow vegetable seedlings in propagation trays (protray/plug trays)andthese seedlings are made available for sale to the other farmers. About 6,330 nursery units have been established in India for commercial production of horticultural planting material. Among these units 1,470 units are located in Maharashtra State (Ratha Krishnan *et al.,* 2014). Vegetable seedling production is a specialized activity and farmers buy the seedlings from these nurseries. Seedling production has come up as a specialized enterprise and it is already a commercial venture to produce the seedlings of tomato, capsicum, cauliflower and cabbage hybrids using seedling trays and protective structure. The seedling trays are filled with appropriate growing medium such as coco peat and small depressions for sowing (5 mm) are made by fingertips in the center of the cell. Individual seeds are sown in each cell manually and covered by coco peat. Due to this nurseries remain highly labor-intensive to achieve the required seedling production. The operations in nursery are also highly drudgery in nature. Hence, mechanization of nursery operation will reduce drudgery involved in this enterprising and create sizable employment opportunities for the rural masses. Few researchers have developed machinery for mechanization of seed sowing in protrays. Mandhar *et al.* (2004) developed a tray type dibbling board which was very low cost and easily adopted by small as well large scale nursery growers. This unit was a rectangular board made out of wood and board dimension and matrix of dibbling pegs were suitable for 98 cell portray. The capacity was 800 protrays/h. Carolin *et al*. (2005) designed and developed a tray type dibbler and vacuum seeder suitable for small nursery growers. Gaikwad and Sirohi (2008) designed and developed a tray indexing and indenting system as a part of development of mechanical precision seeder for nursery plug trays. In this system scotch yoke mechanism was used for protray indexing and indenting. The protrays were to be positioned exactly below the indenting assembly manually. Senthil *et al*. (2016) reported a rotary type dibbler as unit of protray dibbler cum vacuum seeder. The dibbling unit consisted of mild steel dibbler drum fitted with nylon pegs for dibbling. The rooting media filled portray was kept on the carrier trolley and pushed below the dibbler drum. The pegs make 5-10 mm deep depressions for seed sowing in all the 98 cavities of protrays. The commercially available imported machines are expensive and are becoming uneconomical for medium scale nursery growers in India. However, no repair and maintenance services and adequate spare parts are available and these machinery are becoming ideal. Hence, the authors of this paper intended to design and develop an indigenous automatic protrayseeder indigenously. As a prerequisite to design and development of automatic seeder, the growing media filled protrays are to be indexed at a pre determined distance and are to be dibbled. This paper discusses the design and construction of automatic portray conveyor and dibbling system.

METHODOLOGY

Design considerations and construction of automatic protray conveying and indexing system:

The basic structure of the machine depended on the protray commercially available in the market. The commonly used protray for vegetable nursery is 98 cavity protray of 530 x 275 mm (L xW) and protray cavity matrix is 14 x 7 (lengthwise x widthwise). In order to have higher capacity, it was decided to feed the protrays orienting lengthwise. As it was decided to handle 5 protrays at a time on the protrayconveyor *i.e.* in the order of each one before dibbling station, at dibbling station, at parallel operations at dibbling and seeding stations, at seeding station, one after seeding station and allowances for handling the protrays, the length of the base frame was considered as 1200 mm. As the lengthwise dimension of protray was 570 mm, the width of machine was considered to be 650 mm having provision for all necessary fixtures. Height of machine was considered to be 800 mm which is the average working height suitable for Indian workers. Hence, a base frame of 1200 x 650 x 800 mm (LxWxH) was fabricated out of 40 x 40 x 2 mm M.S. square tube. A M.S. flat of 1120 x 570 (LxW) of 3 mm thickness was provided inside the base frame to support the growing media filled protrayfrom sagging while in operation (Fig. A). The matrix of protraycavity is 7x 14 (width x length) and the centre to centre distance between each cavity is 37.0 mm. Hence the protray has to be indexed at every 37.0 mm. Also when the last cavity is dibbled, the protray has to be indexed to a distance of 50.0mm for positioning the dibbling unit to the first cavity of the following protray (Fig. B).

As the indexed movement of the protray was one of the very important operational factors, it was decided to a design a chain conveyor with customised specification



1.Top bed to support protrays, 2. Main frame and 3. Protray carrying slat

Fig. A : Main frame for protray indexing and dibbling system

for moving the protrays. Accordingly the chain and sprocket was designed and fabricated (Fig. C).

Details of the chain:

Chain pitch = 25.4mm (Double pitch)

Roller diameter = 7.95mm

Total length of chain (in multiples of pitch) = 120 pitches

Interval between the attachments = 12 pitches

No. of attachments = 10

Sprocket design:

Pitch (p) = 25.4 mm

Roller diameter(d_1) = 7.95 mm

Width between inner plates = 7.85 mm

Pin dia = 3.96 mm

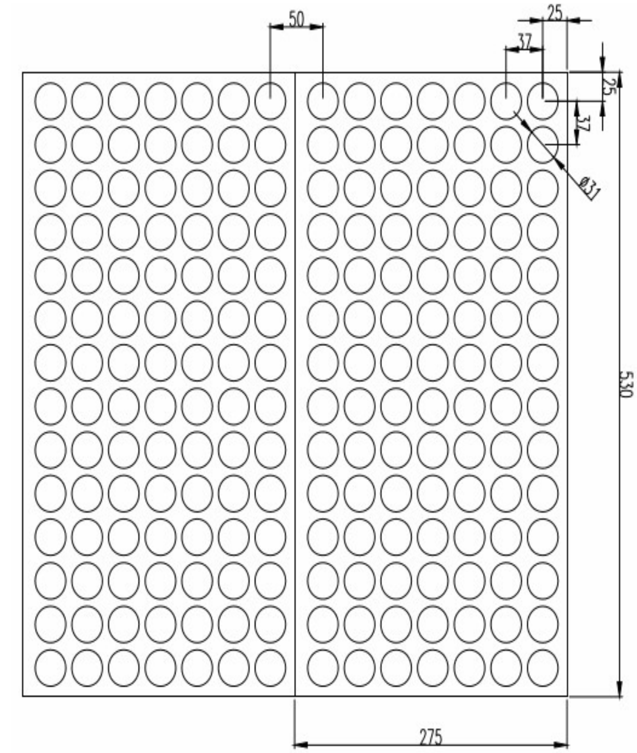


Fig. B : Sketch of array of 98 cavity protrays

Pin Length = 16.6 mm

Side plate height = 12.0 mm

Plate thickness = 1.5 mm

Number of teeth on the sprocket (z) = 22

Pitch circle dia (d) = p/sin(180/z) = 25.4/sin(180/22) = 178.47 mm

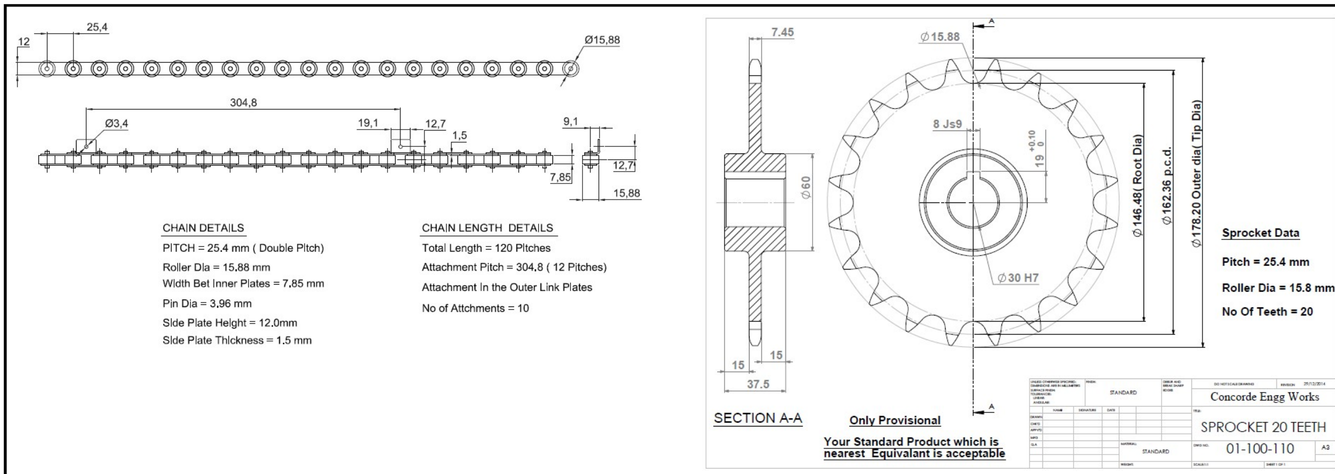
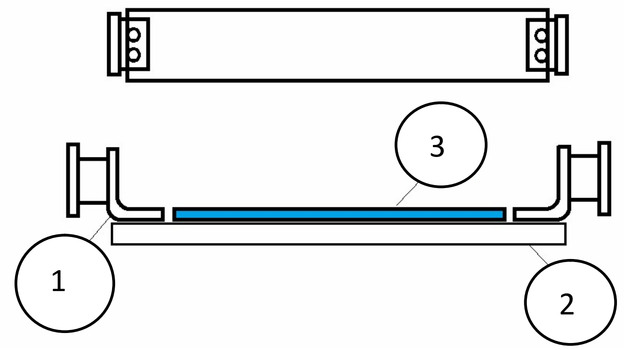


Fig. C : Design of customized chain and sprocket for protray movement



1. K-2 Attachment, 2. Carrier slat and 3. Machine Top

Fig. D : K-2 attachment with carrier for protray movement

Fig. E : Profile of protray holder fitted to carrier slat

Root diameter = $d – d_1$ = 178.47–7.95 = 170.527 mm

Tip diameter = $d + 1.25p - d_1$ = 202.27 mm

Centre distance $a_p = a_o/p$ = 1270/25.4 = 50 (multiples of pitch)

Length of continuous chain in multiples of pitch –

$$l_p = 2a_p + (z_1 + z_2)/2$$

$$2 \times 49 + (22 + 22)/2 = 120$$

To accommodate 10 attachments at equal spacing, number of pitches were selected as 120. Hence a_o becomes 49 x 25.4 = 1244.6 mm. Thus centre to centre distance between sprockets was arrived as 1244.6 mm.

The protrays were guided (from the sides) independently on the conveyor by using passive guides supported from the side plates to ensure straight line travel of the protrays.The chain had a proper tensioning arrangement in the conveyor side plates using a screw and nut mechanism to adjust tension by moving both the sprockets.There were proper guiding slats provided in the bottom of the conveyor to support the chain properly and to avoid any slack in the chain.

The main conveyor was roller chain with K-2 type attachments.There were two chains running parallel and a carrier slat was connected in between the chains using the K-2 attachment in chains (Fig. D). A protray holder was machined matching to the protray profile as in the protray to engage the tray properly (Fig. E) and fitted on the carrier slat.

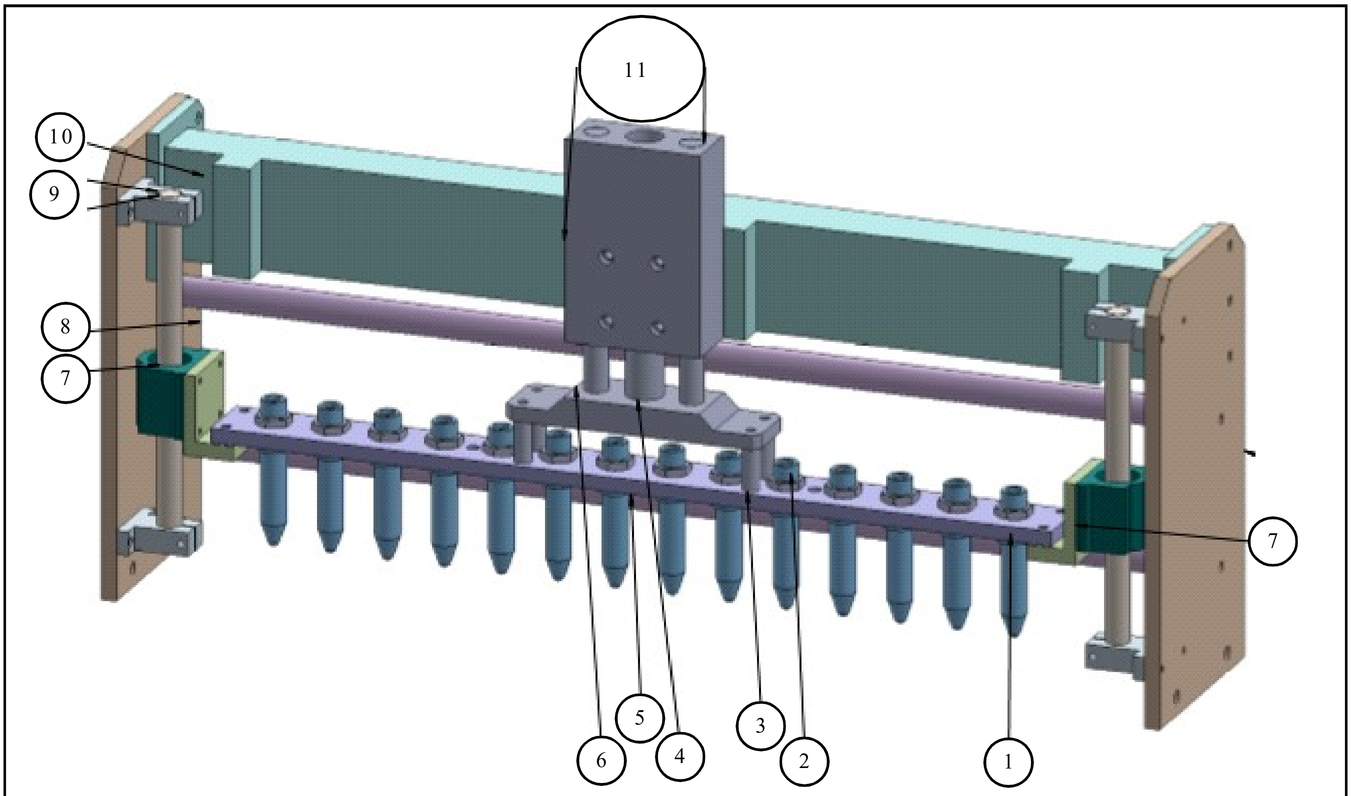
As per the design the chain with K-2 attachment and sprockets were fabricated. The carrier slat was fabricated for carrying the protrays on the top bed of machine.

Design considerations and construction of dibbling unit:

The function of dibbling unit was to make 5-10 mm deep depressions at the center of the each cavity of the growing media filled protrays. The dibbling system consisted of mounting/common bar, set of tubular pegs (14 Nos.), side plates and pneumatic compact guide cylinder (Fig. F). Common bar was fabricated out of aluminum and had dimension of 564 x 45 x 10 mm (LxWxT) (Fig. G). Dibbling pegs (14 Nos.) were fabricated out of aluminumand had dimensions as shown in Fig. H. A pneumatic compact guide cylinder was used to push the bar downwards to make the dibbling. This was done when the growing media protray reached the dibbling station and this was achieved using a proximity sensor. The guide cylinder has reed switches by which the movement of dibbling bar can be limited to the desired level. This action was synchronized with the chain conveyor indexing. The stroke and indenting of the operation weredesigned for 30 mm and 10mm, respectively.

Controls and PLCprogramme to control the operations of protray conveyor indexing and dibbling unit:

Control for the indexed movement of protray and cycle start of dibbling unit were done by stepper motor controlled by a PLC. The main conveyor shaft was driven by a stepper motor of 12 N-m, 3 phase to stop between each cavity in the protray. Motor was attached to the main shaft with a timer belt. Drive was configured to run with microstepping of 3200 pulse/rev to give smooth



1. Dibbling pegs, 2. Lock nut for dibbling pegs, 3. Front plate guide, 4. Main cylinder, 5. Mounting bar, 6. Support cylinder Spacer, 7. Housing for shaft, 8. Side mounting plate, 9. Shaft end support, 10. Mounting plate for guide cylinder, 11. Pneumatic compact guide cylinder

Fig. F : Dibbling unit

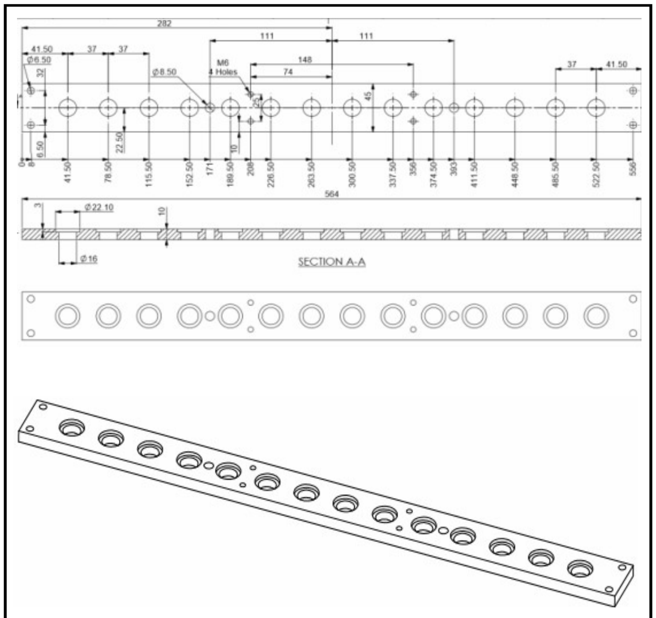


Fig. G : Mounting bar for dibbling pegs

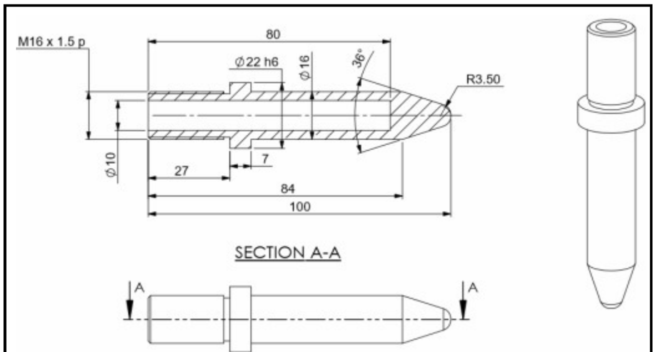


Fig. H : Construction details of dibbling peg

operation of the conveyor.

Each protray was detected by a sensor and total of 7 cavities were indexed by determined distance pre-programed. To facilitate the function of proximity sensor, metal pieces were glued on top of the protray carrying slats. PLC programming was done using ladder language.

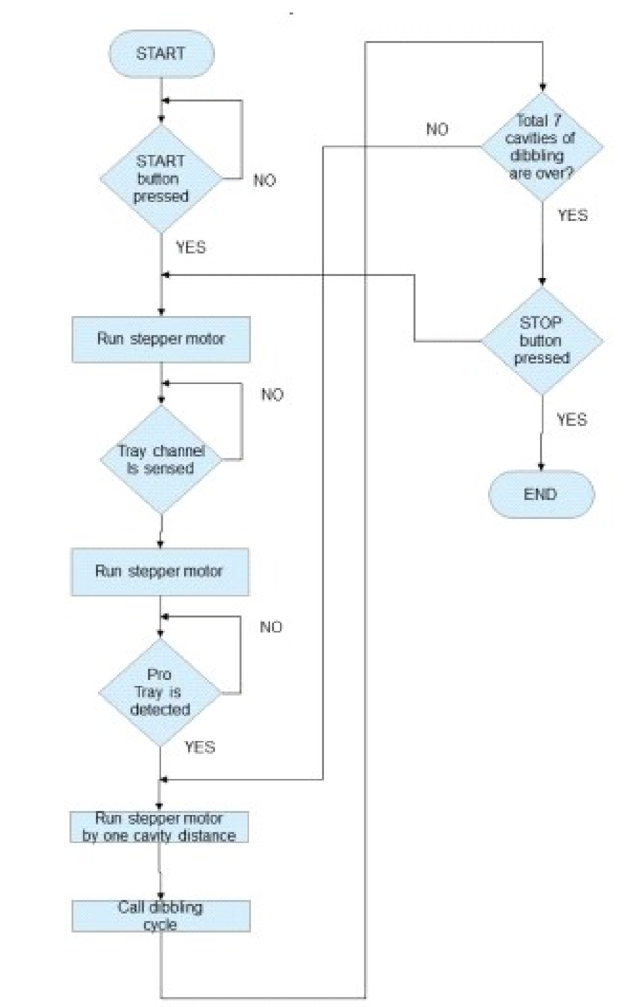


Fig. I (a) : Flow chart for cycle start

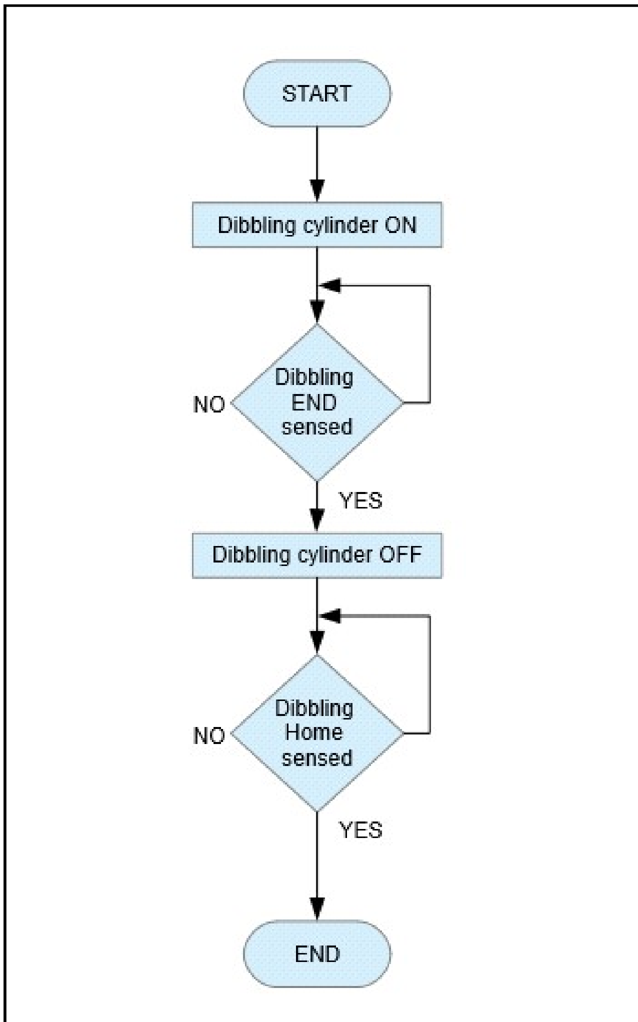


Fig. I (b) : Flowchart for dibbling cycle

The distance between the cavities were indexed by pre-programmed distance once a tray presence was detected. The sequence of operations are given in Fig. I (a and b).

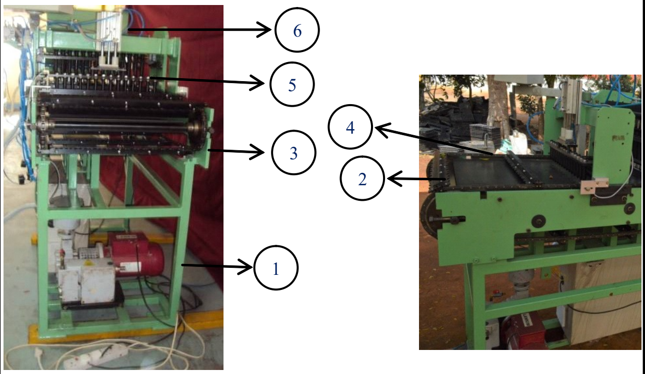
RESULTS AND DISCUSSION

The performance of the developed machine was evaluated for functions of mechanical components, pneumatic components, Controls and PLC programme.

Mechanical components:

The mechanical components were 1) base frame, 2) supporting platform for growing media filled protrays, 3) chain and sprocket with K-2 attachment, 4) protray carrier slat and 5) dibbling unit (Plate 1). The length of base frame was designed and fabricated to handle 5 protrays at a time. It was observed that the machine could handle 5 protrays satisfactorily as designed and developed. Supporting platform was fabricated and fitted to prevent sagging of growing media filled protrays while in operation. It was found that the protrays could be carried by the conveyor chain on this platform efficiently matching with the protray indexing.

The K-2 attachment chain and sprocket were considered to be used, designed as explained in previous section and fabricated. Every 12th pitch had a K-2 type attachment connected to it (Plate 2). The protray had cavities spaced at 37.0 mm in the direction of the conveyor movement. The conveyor chain inched at a distance of 37.0 mm continuously by using a stepper motor. The chains were guided using a hardened and ground slat



1)Base frame, 2) Supporting platform, 3) Chain and sprocket with K-2 attachment, 4) Protray carrier slat 5) Dibbling unit and 6) Pneumatic compact guide cylinder

Plate 1 : Automatic protray conveying and dibbling machine

from the bottom side.The K-2 attachment chain was able to carry the protrays as desired.

The protray carrier slat was another very important

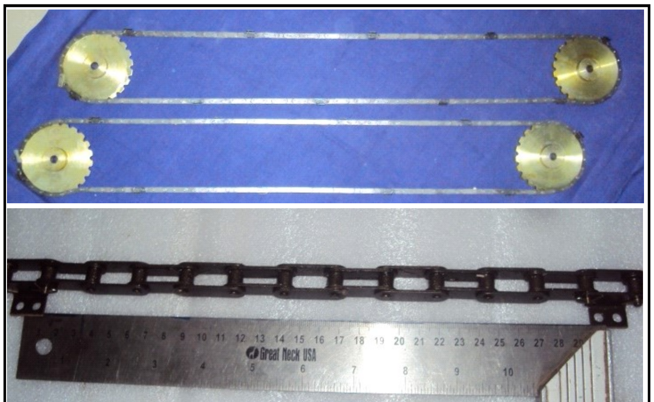


Plate 2 : Chain with K-2 attachment and sprocket

component designed and developed for loading the protrays. There are 10 carrier slats spaced at the interval of 12 pitches. The carrier slat was fitted with a profile matching to the protray in order to load the protray without any delay for positioning. It was observed that this component played very important role in positioning the protrays while loading, as precision function of dibbling unit depended on the position of the protray at dibbling station. The operator could load the growing media protrays without any judgement which otherwise could have reduced the performance of the machine.

The dibbling system was a set of conically shaped tubular pegs arranged in a common bar (Plate 3). Dibbling unit consisted of 14 conical shaped pegs and fitted on mounted bar with suitable lock nuts. The dibbling impression was measured and found to be 10 mm dia. and 10 mm deep in which the seeds could be placed properly for successful germination (Plate 4 and 5). The depth can be adjusted if required.

Pneumatic components:

The dibbling units up and down movement was provided by pneumatic compact guide cylinder (Plate 6). The guide cylinder had reed switches by which the

Plate 3 : Dibbler pegs and assembly

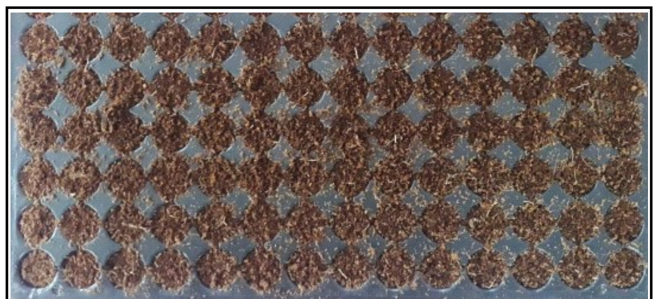


Plate 4 : Growing media filled protray

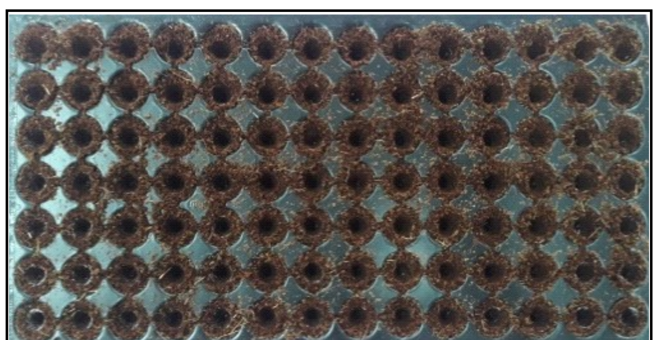


Plate 5 : Growing media filled protray dibbled by the automatic protray conveying and dibbling machine

movement of dibbling bar could be limited to the desired level. The stroke of the operation was 30 mm and indenting was 5 mm deep.

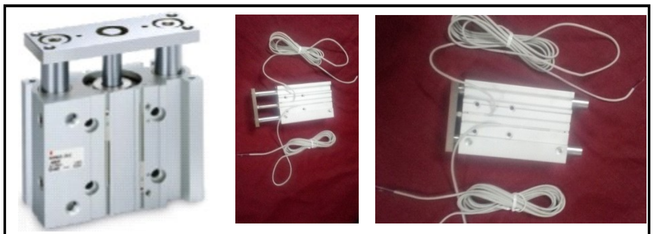


Plate 6 : Compact pneumatic guide cylinder

Controls and programmable logic control:

Control for the indexed movement of protray and cycle start of dibbling unit were by stepper motor controlled by a PLC. The main conveyor shaft was driven by a stepper motor (3200 pulse/rev) to stop between each cavity in the protray. Higher torque motor was chosen considering the friction and inertia of the load in the machine.Smooth movement of conveyor could be achieved by this configuration. Speon make proximity sensor of PNP type was used for the dead end limits of all motions and conveyor index and the inputs of sensors *viz.,* dibbling station home sensor, dibbling station lower sensor, main conveyor indexing sensor and tray detection sensor were connected to PLC.

The control for the seeder machine was based on Panasonic PLC FP0RC32MT. This was a dedicated PLC with motor control applications. PLC was connected to a Panasonic Human-Man-Interface and machine parameter values like speed and delay could be adjusted using this HMC. PLC programming was done using ladder language. The distance between the cups were indexed by pre-programmed distance once a tray presence was detected.

Conclusion:

An automatic protray conveying and dibbling system was designed and developed to be used in vegetable nursery. This machine was tested for performance of mechanical, pneumatic, electronic components and function of PLC. The machine could convey the growing media filled protray to match the indexing of the dibbling unit. The dibbling unit could dibble 10 mm dia. x 10 mm deep cavities in the protrays to achieve successful and uniform germination of seeds sown in these cavities. The capacity of the machine was found to be 300 protrays/h. An automatic protray sowing unit can be developed and can be integrated with this machine to mechanize the protray sowing operation.

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