Design Overview of Vegetable transplanter

SAEINDIA TIFAN 2024

6th Edition

‘Automated Multi-Vegetable Transplanter’
Focus on the term tractor mounted

Mastering the Basics: Three-Point Linkages

Understanding hitch categories

How to make our implement compatible with both hitch categories?

https://youtu.be/okclgUJ764Y?si=AHSc69ap_fjdFwiD
Hitch System Specification

✓ Compatibility CAT I/CAT II: Yes/No

✓ Pin hole diameter for CAT I:

✓ Pin hole diameter for CAT II:

The prime mover for tractor pulling the attachment would be in the range of 35-50 HP. Tractor will be provided by SAE TIFAN committee. Students need to make sure that the implement is compatible with 35-50 HP and 3-point linkage driven tractors.

I. The attachment should be compatible with both ISO-730 CATI and CAT II hitch geometry.
   a. CAT I:
      i. Mast height 460 +/-1.5mm,
      ii. Lower Hitch distance: 683 +/-1.5 mm,
      iii. Diameter of Top hitch pin 19mm,
      iv. Diameter of lower hitch pin 22mm,
      v. Clevis 65mm
   b. CAT II:
      vi. Mast height 610 +/-1.5mm,
      vii. Lower Hitch distance: 825 +/-1.5 mm,
      viii. Diameter of Top hitch pin 25.5mm,
      ix. Diameter of lower hitch pin 28mm,
      x. Clevis 65mm

II. Tractor wheels reactions: 20%:80% (Front: Rear) by mass

III. Turning radius: <2m

IV. Attachment should be transported through tractor 3-point linkage.

V. The sapling planting can be driven through ground wheel drive or PTO drive shaft.

Source: Adapted from ASAE Standards, 2001
Understanding Pickup System

- How can you pick a sapling from the tray?
- From which direction can you approach the sapling to pick it?
- Will it damage the sapling?
- Is it accurate?
- Is it fast?
The main function of this system is to pick up sapling cups from tray or buckets without any manual intervention. The pickup systems can be one or multiple depending upon the machine row configuration. Every team has its freedom to design and use any system that performs the intended function.

### Sapling Tray Dimension:
- Sapling cup diameter: 3.5cm
- Tray Length: 52.5 cm
- Tray Width: 27 cm
- Tray Depth: 4 cm
- Total Sapling in a tray = 7*14 = 98

### Sapling Size Considerations
- Teams are provided with Sapling (Chili, Brinjal or Tomato) that can range from 15cm to 25 cm in height.
- Compatible with specified crops?
  - Tomato, Chili, Brinjal*
- How many sapling trays can the implement hold?
- How are trays held on implement?
- Design of Mechanism for Sapling pick-up?
- Power source? Is it Hydraulic, Mechanical, Motors?

Source: MDPI Article: Design and Experiment of an Integrated Automatic Transplanting Mechanism for Picking and Planting Pepper Hole Tray Seedlings
Types of picking Mechanism

1. Pin type pickup
   - Pins will pick the sapling from the cup and drop that into the planting mechanism.

2. Push mechanism
   - Pushing mechanism push the sapling from the back side of the cup.
   - The dropped plant goes into the planting mechanism.

3. Gripper mechanism
   - Gripper mechanism plug out the plant with stem and the drop it into the planting mechanism.

Source: precision Agricultural science and technology: Automatic picking mechanisms
Design of Conveying System

✓ How saplings are being conveyed from Sapling trays to ground?

▪ Conveying maximum number of saplings, with no or minimum damage.
▪ Proper picking of saplings from tray/bucket and thus ensuring smooth transfer.
▪ Channelize the pickup saplings towards digging system.
▪ Choose an appropriate type of conveyor belt like a slat type belt, flat belt, metal rod with chains etc.
▪ Proper angle of the system to enable material movement.
▪ Speed of conveyor and liner speed of travel of material
▪ Saplings flow rate
▪ Power consumption for conveying unit
▪ Diameter and spacing of conveyer belts.
Hold and Conveying and planting system

• The main function of conveyor is to convey the saplings picked from trays/buckets to digging system. Conveyor unit/system is used. The system should be designed that it holds the saplings at predetermined spacing and then passes to the other end of digging unit.

• Wheel type
• Rotary Hopper Type
• Linkage Type
1. Wheel type transplanting mechanism

- The wheel method is a method in which a number of planting openers are installed on the wheel to formally match the wheel speed. And it is characterized by a uniform structure and simple structure even when the speed changes.

2. Rotary type transplanting mechanism

- The rotary method is the planting device that is most often used for planting vegetables by drawing power through the crankshaft and drawing the oval-shaped stop trajectory of the planting machine while the gear cases and planting machine rotate.

Source: research article: Analysis of mixed ratio of waste cooking-oils in biodiesel production process using near-infrared
Digging a hole in soil

✓ We need a sharp surface to dig a hole
✓ Think about objects which have sharp tips.
✓ Can we make a mechanism which digs and puts the sapling in the hole?
✓ Can we think of a shape like a cone?
✓ What if we make the cone hollow from inside?
✓ Blade depth should be adjustable (can be done by using top link of tractor also)
✓ Hole depth should be in range of 5-7cm.

Source: https://tse1.mm.bing.net/th/id/OIP.x1nVCySpbD_i8kAt-MNWgAAAA?rs=1&pid=ImgDetMain
3. Linkage type transplanting mechanism

- The both crank arms rotate counterclockwise with similar rotational speed around the fixed point respectively, as the result the seedling were picked by the duckbill planter at predetermined position and move downward to plant the seedling into the soil.

Source: MDPI Article: Optimization of Main Link Lengths of Transplanting Device of Semi-Automatic Vegetable Transplanter
Design of Digging and Covering of Soil

✓ Blade Shape and Geometry:
✓ Blade Material:
✓ Rack Angle, Throat clearance, Draft calculations:
✓ Blade depth adjustment:
✓ Soil Closing Mechanism:

Dig a hole in soil:
- Proper selection of blade shape and geometry
- Selection of appropriate blade material.
- Selection of proper rack angle.
- Throat clearance calculations
- Draft force calculations for the given soil
- Provision of depth change to adjust draft variation requirements.
- Choosing optimum machine travel speed to make best use of machine power and efficiency of system
2.4.1 Digging Force:

1. Cutting Blade shape: Conical
2. Blade Material: EN8
3. Rake Angle: 20°
4. Throat Clearance Calculation: 90 mm

Digging force is calculated by

\[ P = 0.0082 \left( \frac{V}{V_2y} \right) \left( \frac{C + C_a}{V_2y} \right) \times 0.84 \left( \frac{d}{w} \right) \	imes 1.4(sina) \]

\[ (1) \]

Where,
- \( V \): Velocity of tractor/blade, (mm)
- \( y \): Soil bulk density, (KN/m³)
- \( w \): Tool width, (m)
- \( \alpha \): Rake angle (degree)
- \( d \): Tool depth, (m)
- \( C \): Cohesion (kPa)
- \( C_a \): Adhesion (kPa)

**Draft Calculations**

\[ P = (y \times Z_1 + 2N_y) + (C \times Z_1 + N_C) \]

\[ (2) \]

For black cotton soil,
- \( N_y = 1.55 \) for \( \delta = 0 \) = Angle of shearing resistance of soil
- \( N_y = 1.75 \) for \( \delta = \phi \) = Angle of metal friction
- \( N_C = 1.65 \) for \( \delta = 0 \)
- \( N_C = 1.6 \) for \( \delta = \phi \)

\( y = 17.68 \) kN/m²
\( C = 30.18 \) kN/m²
\( Z_1 = \) Depth of operation = 10 cm = 0.1 m

\[ P = (17.68 \times 10^3 \times 0.1 \times 2 \times 1.75) + (30.18 \times 10^3 \times 0.1 \times 1.65) \]

\[ P = 5289.1 \text{ N For Black soil} \]

Source: MDPI Article: Optimization of Main Link Lengths of Transplanting Device of Semi-Automatic Vegetable Transplanter
Rack angle, throat clearance and Draft calculations

\[ D = k_0 \times w \times d \] (2) \( D \) (kgf) = draft force,
\( w \) (cm) = width of opener,
\( d \) (cm) = depth of opener,
\( k_0 \) ( ) = Specific soil resistance = 0.25 Taking,
\( w = 45 \text{ mm}, \)
\( d = 40 \text{ mm and} \)
\( k_0 = 1 \) considering factor of safety Total draft force for four furrow openers was obtained as kgf.

Source: MDPI Article: Optimization of Main Link Lengths of Transplanting Device of Semi-Automatic Vegetable Transplanter
Figure 1. Structural diagram of planting mechanism

Source: IOP Conference Series: Materials Science and Engineering article: Design and Analysis of Vegetable Transplanter Based on Five-bar Mechanism
What is it?

Is it already being used in some other machinery?

Which kind of machines are similar to transplanter?

Can we use the similar mechanisms present in those machines?
<table>
<thead>
<tr>
<th>Name</th>
<th>Schematic diagram</th>
<th>Dimension and works</th>
</tr>
</thead>
</table>
| Ring type Pressing Wheel            | ![Ring type Pressing Wheel Schematic](image1) | Diameter-200mm  
Thickness-5 mm  
After putting the seedling then, cover the soil and compact |
| Metering ruler                      | ![Metering ruler](image2) | Length- 40 cm  
Width- 5 cm  
Thickness-5 mm  
The metering ruler is very useful for accurately placing seedlings in the furrow opener. |

**Fig. 3.** Different views of the furrow opener vegetable seedling (FVS) transplanter: (a) top view; (b) perspective view; (c) front view; and (d) side view. All dimensions are in mm.

Source: ResearchGate: Article: Design and evaluation of a power tiller vegetable seedling transplanter with dibbler and furrow type
Range of angle of wheel shown in the video w.r.t vertical should be 25 degrees to 30 degrees.

Source: https://youtu.be/Eq8qHs9hcFo?si=u4bPukNEWQMKt_C
Design of Planting System

✓ Row spacing (mm) Min/Max:

✓ Plant spacing (mm) Min/Max:

✓ Planting Speed Min/Max:

✓ Supporting Calculation/Working principle:

Source: SAE TIFAN Rulebook
Figure 1. Structure of the pepper transplanter under development: (a) seedling picking manipulator, (b) seedling (c) conveying unit, (d) dibbling mechanism, (e) mathematical model of dibbling operations, and (f) soil-compacting

Source: article MPDI: Working Speed Analysis of the Gear-Driven Dibbling Mechanism of a 2.6 kW Walking-Type Automatic Pepper Transplanter
Belt for Holding pro-tray
Feed Rollers
Fork
Stepper Motor
Stepper Motor Shaft
Rotating Fingers
Pro-tray Guide
Chain & Sprocket Assembly
Ground Wheel

Source: ScienceDirect: Development of embedded automatic transplanting system in seedling transplaners for precision agriculture
### Performance parameter from Existing transplanter

#### Kubota Transplanter

<table>
<thead>
<tr>
<th>Model</th>
<th>KUBOTA SPV-6MD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drive Type</strong></td>
<td>4-wheel drive</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
</tr>
<tr>
<td>Overall length (mm)</td>
<td>3050</td>
</tr>
<tr>
<td>Overall width (mm)</td>
<td>2220</td>
</tr>
<tr>
<td>Overall height (mm)</td>
<td>2600</td>
</tr>
<tr>
<td>Minimum ground clearance (mm)</td>
<td>500</td>
</tr>
<tr>
<td>Weight</td>
<td>805 kgs</td>
</tr>
<tr>
<td><strong>Engine</strong></td>
<td></td>
</tr>
<tr>
<td>Engine Model</td>
<td>GA623-Diesel Engine</td>
</tr>
<tr>
<td>Engine Type</td>
<td>Water-cooled, 4-cyl, 3 cylinder diesel engine</td>
</tr>
<tr>
<td>Total Displacement (L (cc))</td>
<td>778</td>
</tr>
<tr>
<td>Output Revolution Speed (KW/PS)/rpm</td>
<td>14.4 KW (19.6 PS) @ 3200 rpm</td>
</tr>
<tr>
<td>Applicable Fuel</td>
<td>Diesel</td>
</tr>
<tr>
<td>Fuel Tank Capacity (L)</td>
<td>34 litres</td>
</tr>
<tr>
<td>Starting System</td>
<td>Starter motor</td>
</tr>
<tr>
<td><strong>Seedling Condition</strong></td>
<td></td>
</tr>
<tr>
<td>Seedling type</td>
<td>Seedling mat</td>
</tr>
<tr>
<td>Seedling height (cm)</td>
<td>8 to 25</td>
</tr>
<tr>
<td>Number of leaves (leaves)</td>
<td>2.0 to 4.5</td>
</tr>
<tr>
<td>Operation speed (m/s)</td>
<td>0.155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>KUBOTA SPV-6MD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steering System</strong></td>
<td></td>
</tr>
<tr>
<td>Wheel Type</td>
<td>Front wheel</td>
</tr>
<tr>
<td>No-punctur tire</td>
<td>No-punctur tire</td>
</tr>
<tr>
<td>Rear wheel</td>
<td>Rubber lug wheel</td>
</tr>
<tr>
<td>OD Front wheel (mm)</td>
<td>650</td>
</tr>
<tr>
<td>OD Rear wheel (mm)</td>
<td>950</td>
</tr>
<tr>
<td><strong>Shifting system</strong></td>
<td>Hydrostatic Transmission</td>
</tr>
<tr>
<td>No. of Shifting positions</td>
<td>HST, Main shift, Variable speeds for Forward and Reverse</td>
</tr>
<tr>
<td><strong>Planting Portion</strong></td>
<td></td>
</tr>
<tr>
<td>Planting system</td>
<td>Rotary, forced planting</td>
</tr>
<tr>
<td>No. of planting rows</td>
<td>6</td>
</tr>
<tr>
<td>Distance between rows (cm)</td>
<td>30</td>
</tr>
<tr>
<td>Hill space (cm)</td>
<td>10, 12, 14, 16, 18, 21, 24</td>
</tr>
<tr>
<td>Planting Depth (cm)</td>
<td>1-5.5 (7 positions)</td>
</tr>
<tr>
<td>No. of hills (mm)</td>
<td>110, 90, 80, 70, 60, 50, 45 (Seedling 3.3 sqm)</td>
</tr>
<tr>
<td>No. of seedlings per hill</td>
<td></td>
</tr>
<tr>
<td>Crossfeed distance</td>
<td>*11/26, 14/20, 18/16 (3 positions)</td>
</tr>
<tr>
<td>Vertical taking quantity</td>
<td>*8 to 18</td>
</tr>
</tbody>
</table>

Source: https://www.tractorjunction.com/implement/kubota/nsd8/
# YANMAR Full Automatic Vegetable Transplanter

<table>
<thead>
<tr>
<th>Model name</th>
<th>YANMAR Full Automatic Vegetable Transplanter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model number</td>
<td>PW20R</td>
</tr>
<tr>
<td>Type</td>
<td>- RS</td>
</tr>
<tr>
<td>Driving system</td>
<td>Four-wheel drive</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>3160</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>1725</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>1925</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>638</td>
</tr>
<tr>
<td></td>
<td>603</td>
</tr>
<tr>
<td>Engine</td>
<td>Engine model GB400</td>
</tr>
<tr>
<td>Steering system</td>
<td>Front wheel steering (power steering)</td>
</tr>
<tr>
<td>Wheel</td>
<td>Front (mm) Blowout-free tire ρE00ÅE0</td>
</tr>
<tr>
<td></td>
<td>Rear (mm) AG tire 8-18 ρE50ÅE90 Blowout-free tire ρE50ÅE0</td>
</tr>
<tr>
<td>Tread</td>
<td>Front (mm) 1200, 1270</td>
</tr>
<tr>
<td></td>
<td>Rear (mm) 1200, 1320 1200, 1270, 1320</td>
</tr>
<tr>
<td>The number of shift steps</td>
<td>Forward 2, backward 1 (HMT)</td>
</tr>
<tr>
<td>Speed</td>
<td>Forward 1 (m/s) 0 to 0.50</td>
</tr>
<tr>
<td></td>
<td>Forward 2 (m/s) 0 to 2.50</td>
</tr>
<tr>
<td></td>
<td>Backward (m/s) 0 to 0.81</td>
</tr>
<tr>
<td>Body control</td>
<td>Up/down Oil pressuring automatic following</td>
</tr>
<tr>
<td></td>
<td>Horizontal -</td>
</tr>
<tr>
<td>The number of planting rows</td>
<td>2</td>
</tr>
<tr>
<td>Row distance (mm)</td>
<td>2 rows on 1 ridge: 450, 500, 550, 600, 650</td>
</tr>
<tr>
<td></td>
<td>1 row on 1 ridge: 600, 650</td>
</tr>
<tr>
<td>Planting distance (mm)</td>
<td>260 to 800</td>
</tr>
<tr>
<td>Planting depth adjustment</td>
<td>10 steps x pin 2 steps (one-lever)</td>
</tr>
<tr>
<td>Ridge height (mm)</td>
<td>0 to 300</td>
</tr>
<tr>
<td>The number of cell trays</td>
<td>16 (planting table 4 + tray table 12)</td>
</tr>
<tr>
<td>Operating efficiency (hour/10a)</td>
<td>0.6 to 0.9</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Cabbage, Chinese cabbage, broccoli</td>
</tr>
<tr>
<td>Cell trays</td>
<td>30 - 128 holes, 25 - 200 holes</td>
</tr>
</tbody>
</table>

Source: https://japan-agritrading.com/products/yanmar-full-automatic-vegetable-transplanter-pw20r

- Video link
How to transmit power to our implement?

- By using ground
- By using PTO

Source:
- https://i.ytimg.com/vi/qosqMIn3Wwg/maxresdefault.jpg
How ground wheel can be used?

Source: https://youtu.be/qosqMIn3Wwg?si=9d87VOuhhYJeVhky
Let’s explore the advantages and drawbacks of ground wheel and PTO Shaft

Thank you