Development of Dibbile Mechanism for Two Row Operated Semi – Automatic Vegetable Transplanter

ABSTRACT

Vegetables play a crucial role in daily human nutrition, and India ranks second in vegetable production globally. Despite this, manual transplantation is prevalent in India, characterized by labor-intensive practices. The study aimed to address this by developing a tractor-operated linear dibble mechanism for tomato and chili seedlings, designed with seedling spacings of 45 and 60 cm. The evaluation for optimal operating conditions included varying engine speeds (700, 800, 900, 1000 rpm), gear positions (L1, L2), and power take-off positions (P1, P2). Among these, L1P1 and L1P2, with seedling spacings of 57.57 cm and 45.20 cm respectively, aligned with the designed spacings, while L2P1 was excluded due to excessive dibble spacing. Evaluation concentrated on 800 and 1000 rpm, with 700 rpm causing jerks. The preference for 1000 rpm was driven by higher field capacity, as exceeding 1000 rpm posed difficulties for workers. Selections were made with a focus on achieving desired dibble spacings while taking into account worker comfort and field capacity.

Keywords: Vegetables, manual transplantation, dibbler mechanism, seedlings

1. INTRODUCTION

India, the world's second-largest vegetable producer, cultivated approximately 588.26 million metric tons of vegetables in 2021, following China. According to the National Horticulture Database, in the 2021-22 period, the country's vegetable production reached an estimated 204.61 million tonnes, with West Bengal, Uttar Pradesh, and Madhya Pradesh emerging as the leading vegetable-producing states. Vegetables, being essential components of human nutrition, witnessed an increase in per capita consumption from 281 grams per day in 2005-06 to 397 grams per day in 2017-18. With growing demand, there is a necessity to enhance vegetable cultivation practices. Manual transplantation, a conventional method, remains widespread but is labour-intensive and time-consuming. Attempts to mechanize the process have led to the development of semi-automatic and fully-automatic transplanters. While fully-automatic transplanters offer efficiency, they are complex and require skilled labour, leading to higher initial costs. Semi-automatic transplanters, however, prove to be suitable for Indian conditions, striking a balance between time and labour efficiency and cost-effectiveness. The current study focuses on a low-cost, tractor-operated, two-row semi-automatic vegetable transplanter with linear operating dibblers, aiming to overcome challenges associated with furrow openers on mulches during seedling transplantation.

2. MATERIAL AND METHODS

The dibble mechanism in a vegetable transplanter is crucial for creating holes in the soil to accommodate seedlings during transplanting. Comprising sharp dibbling cups attached to a rotating shaft driven by a gear reduction box, this mechanism ensures proper seedling placement and spacing in the field. As the transplanter advances, the dibbling cups penetrate the soil at predetermined intervals, facilitating efficient and uniform transplanting. This core component directly influences key indexes like damaged plants and planting depth, making its rational design essential for enhancing transplanting quality and achieving optimal growth and productivity in the field.

2.1 Machine dimensions

The main shaft, an integral component of the dibble, with a circular cross-section, serves as the conduit for power transfer within the mechanism. Functioning as both the recipient and transmitter of initial motion, the 500 mm long and 35 mm diameter main shaft is equipped with rotating discs at each end, driven by a chain and sprocket. Design considerations include a maximum permissible shear stress of 42 MPa for torque in the shaft with keyways, a maximum permissible working stress of 84 MPa for bending in torque with keyways, and a maximum allowable shear stress of 56 MPa for shafts without keyways (Khurmi and Gupta, 2005).

The Scotch yoke mechanism, a mechanical linkage converting rotary to linear motion, utilizes a dibble disc with an off-centre pin, producing linear motion through the rotation of a disc with a slot and a sliding rod. The dibble disc, with a diameter of 210 mm and thickness of 11 mm, incorporates off-centre pin holes at spacings of 80 mm, 100 mm, and 120 mm. The yoke, a sliding block connected to the off-centre pin, facilitates linear motion through a crank-connected rod, with dimensions of 160 mm length, 40 mm width, and 10 mm thickness. The connecting rod, attached to the yoke and the disc, transforms rotary motion into reciprocating motion, driven by the off-centre pin's circular path. A 385 mm long crank with a 25 mm diameter is welded to the dibble pipe's extreme ends. Two bearing blocks with inner and outer diameters of 20 mm and 50 mm, respectively, and a height of 30 mm guide the yoke's reciprocating motion. In the dibble mechanism, two bearing blocks are employed for each mechanism, maintaining a distance of 120 mm between them. The dibbling pipes, with a diameter of 70 mm and an overall height of 60 mm, made of stainless steel, transfer seedlings at specific intervals into the soil for optimal spacing and depth.

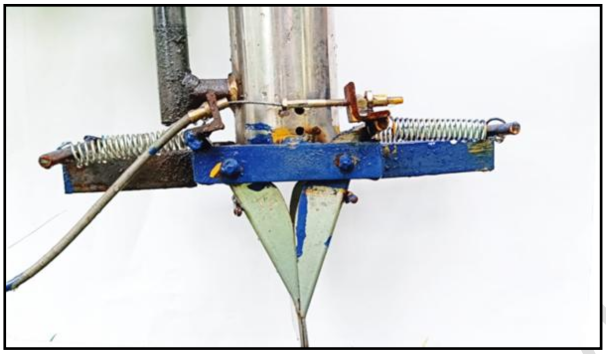
Planting cups, consisting of stainless-steel pipes with a 30 mm diameter and 300 mm length, attached to the dibble pipes through arc welding, guide seedlings into the soil with precise spacing and depth. The cups, housed within a rectangular frame (120×30 mm), penetrate the soil to a depth of 50 cm, opening to release the plant and closing upon reaching the uppermost tip, controlled by a cam mechanism. The cam mechanism, comprising a sector-shaped cam with a thickness of 11 mm and a radius of 40 mm, welded to the main shaft, operates with a lever pivoting on the main frame (200 mm length, 25.4 mm width). As the cam rotates, exerting pressure on the lever, it moves up and down, controlling the simultaneous opening and closing of two cups connected via a clutch wire and held by tension springs. This intricate system ensures efficient and reliable planting operations in the vegetable transplanter.

2.2 Calculation of plant to plant spacing

The rpm of two dibble discs of the transplanter at a known speed (V_m) and selected plant to plant distance between seedlings (Ag), is given (Narang *et al.,* 2011) by following relation and calculated values in showed in Table 2:

$$Ag = \frac{60 \times Vm}{n \times z} \qquad \text{...........} \qquad 2.1$$

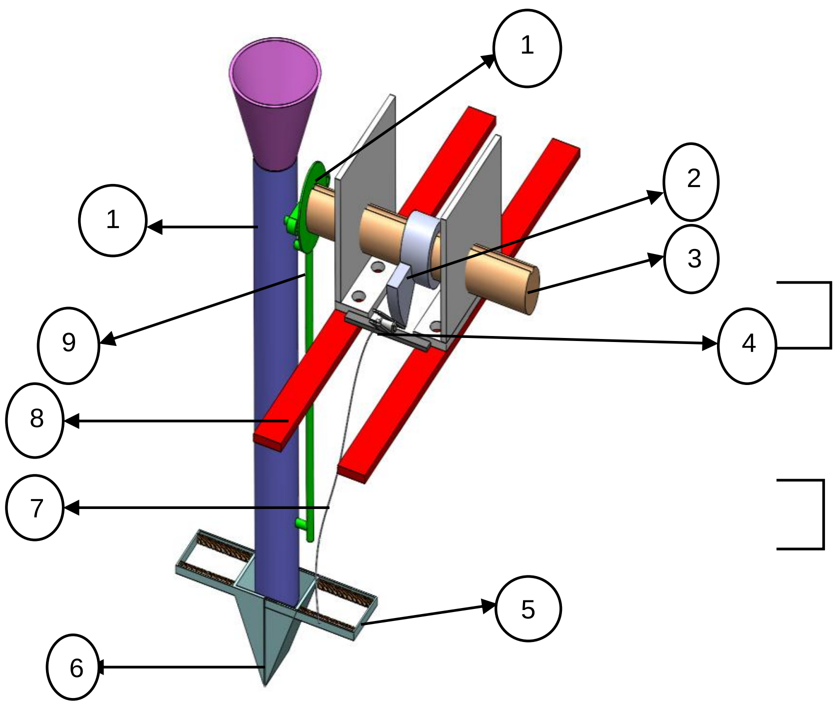
where,
Ag = Plant to plant distance between seedlings (cm)
n = Revolutions dibble discs per minute (rpm)
V_m = Forward speed of transplanter (m s^{-1})



Z = Number of dibbles

Fig. 1 Developed planting cup

Fig. 2 Developed cam and lever



1. Dibble disc	**6. Planting cups**
2. Cam	**7. Clutch wire**
3. Main shaft	**8. Supporting frame**

4. Lever	**9. Connecting rod**
5. Cups supporting frame	**10. Dibble pipe**

Fig. 3 Isometric view of planting mechanism

3. RESULTS AND DISCUSSION

The developed linear dibbling mechanism was driven from PTO of the tractor. Spacing between the seedlings or dibble to dibble may changes with the crank length, engine rpm, gear in which the tractor is running and PTO operated gear. As the machine was provided with fixed crank length, the effect of tractor operation conditions (engine speeds, gear positions and PTO positions) was studied. Four engine speeds (700, 800, 900, and 1000 rpm), two gear positions (L1 and L2) and two PTO positions (P1 and P2) were selected to observe the dibble spacing to match with the designed seedling spacings of 45 and 60 cm for both chilli and tomato seedlings. Dibble to dibble spacing was measured across all combinations of operating conditions by using the effect of operating conditions on dibble spacing was analysed using online statistical tool OPSTAT developed by CCS HAU, Hissar.

It was evident from Table 2, that the gear position, PTO position and interaction of gear and PTO positions were having significant effect at 1% level of significance and the combined interaction of engine rpm, gear position, PTO position was significant effect at 5% level of significance on the dibble spacing.

Table 1 ANOVA on the effect of operating conditions on dibble spacing

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Sig.**
Replication	2	6.031			
Engine speed	3	3.057	1.019	1.009	0.402
Gear position	1	7,969.63	7,969.63	7,890.18	0.000**
PTO position	1	3,341.67	3,341.67	3,308.36	0.000**
Engine speed x Gear position	3	3.557	1.186	1.174	0.336
Engine speed x PTO position	3	7.349	2.45	2.425	0.085
Gear position x PTO position	1	223.172	223.172	220.947	0.000**
Engine speed x Gear position x PTO position	3	11.182	3.727	3.69	0.022*
Error	30	30.302	1.01		
Total	47	11,595.95			

** Significant at 1% level, * Significant at 5% level

Table 2. Effect of all operating conditions on dibble spacings

Gear position	PTO position	Engine rpm	PTO rpm			Dibble spacing, cm			
			T1	T2	T3	T1	T2	T3	Avg.
		700	172.53	170.74	174.62	56.34	56.93	55.66	56.31
L1	P1	800	191.49	193.54	189.52	56.40	55.80	56.99	56.40
		900	201.86	198.52	204.01	57.78	58.75	57.17	57.90
		1000	228.4	225.8	230.8	56.22	56.86	55.63	56.24
		700	212.44	210.61	214.9	45.75	46.15	45.23	45.71
L1	P2	800	238.62	236.43	240.16	45.26	45.68	44.97	45.30
		900	258.12	260.25	262.32	45.19	44.82	44.46	44.82
		1000	287.65	283.46	284.31	44.64	45.30	45.16	45.03
		700	182.49	184.23	180.87	88.77	87.93	89.56	88.75
L2	P1	800	203.31	201.45	205.84	86.77	87.57	85.71	86.68
		900	222.47	220.16	224.86	87.4	88.3	86.46	87.39
		1000	250.65	252.84	248.66	89.04	88.27	89.76	89.02
L2	P2	700	248.42	246.52	248.65	65.21	65.77	65.15	65.38
		800	270.62	268.45	272.32	65.18	65.71	64.78	65.22
		900	294.65	292.81	296.4	65.98	66.39	65.58	65.98
		1000	322.96	321.82	320.25	69.13	69.36	69.70	69.40

3.1 Effect of gear position and PTO position on dibble spacing

The gear position and PTO position had significant effect on dibble spacing as presented (Table 2). The transplanter had average dibble spacings of 57.58, 45.20, 87.66 and 66.66 at L1P1, L1P2, L2P1 and L2P2 respectively presented in Fig 4. There is an increase in dibble spacing with increase in gear position at a particular PTO position. Whereas the dibble spacing was decreased from PTO position P1 to P2 at particular gear position. The decrease in spacing may be due to increase in the PTO speed from P1 to P2. The average decrease in spacing from L1P1 to L1P2 and L2P1 to L2P2 was observed as 14.55 and 21.0 cm respectively. The average dibble spacings were observed at L1P1(57.58 cm) and L2P2 (45.2 cm) were nearer to the designed spacings of 60 and 45 cm respectively.

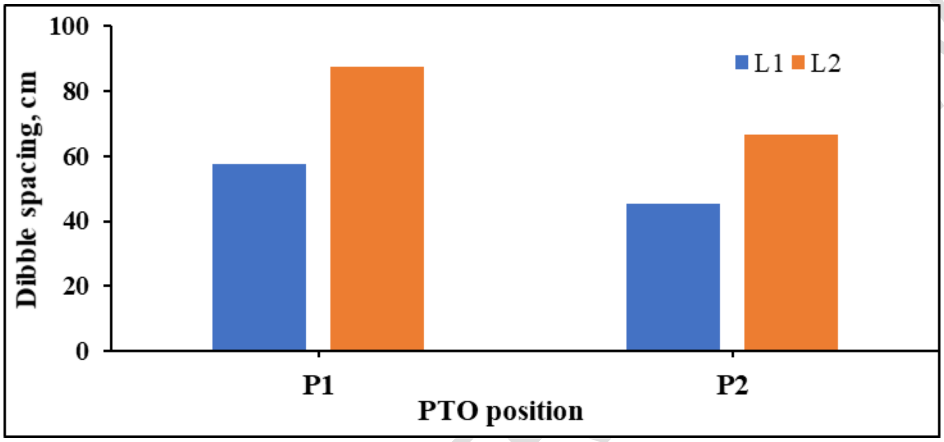


Fig 4 Effect of gear position and PTO position on dibble spacing

3.2 Effect of engine speed and gear position on dibble spacing

Dibble spacings of 51.3, 51.0, 51.6, 51.8 and76.6, 77.5, 77.7, 76.9 cm were observed at corresponding engine speeds of L1 and L2 respectively. Dibble spacing was increased with increase in the gear position from L1 to L2. The increase in the spacing was due to increase in the forward speed of the tractor when operated in gear position L2. Same trend was observed at all engine rpms. There observed no significant difference in the dibble spacings with increase in the engine speed as evident from the Table 2.

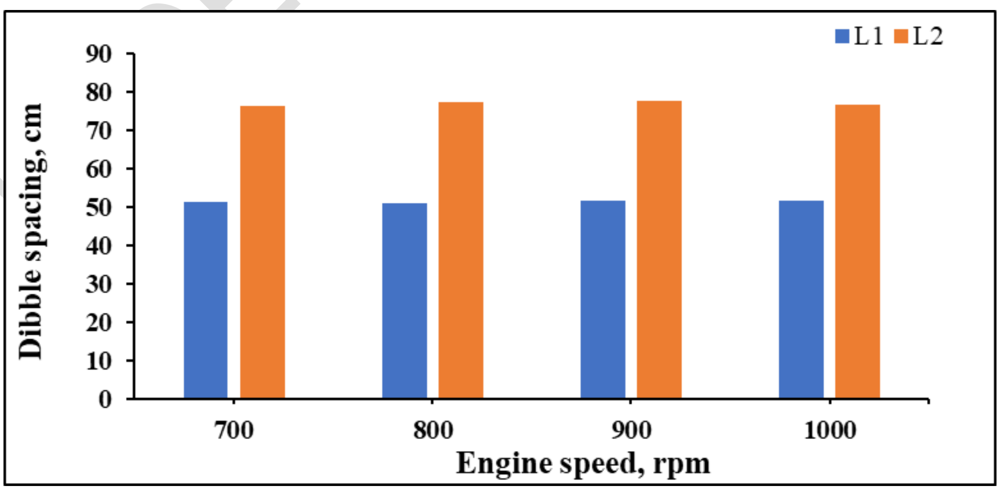
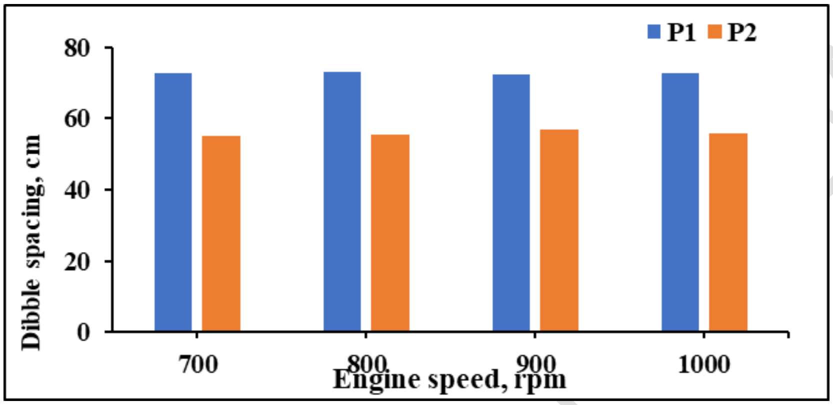


Fig 5 Effect of engine speed and gear position on dibble spacing

3.3 Effect of engine speed and PTO position on dibble spacing

The transplanter operated in PTO position of p1 and engine speeds of 700, 800, 900, and 1000 the observed the dibble spacings of 72.58, 72.91, 72.33, and 72.66 cm and in PTO position of P2, the dibble spacings were observed as 55.25, 55.58, 56.91, and 56 cm at all engine speeds respectively as shown in Fig.6. there was no significant change in the dibble spacing at all engine speeds when transplanter operated in particular PTO position. but, at different engine speeds the dibble spacing varied with change in the PTO position presented in Fig 6. it was observed that there was no significant difference between engine

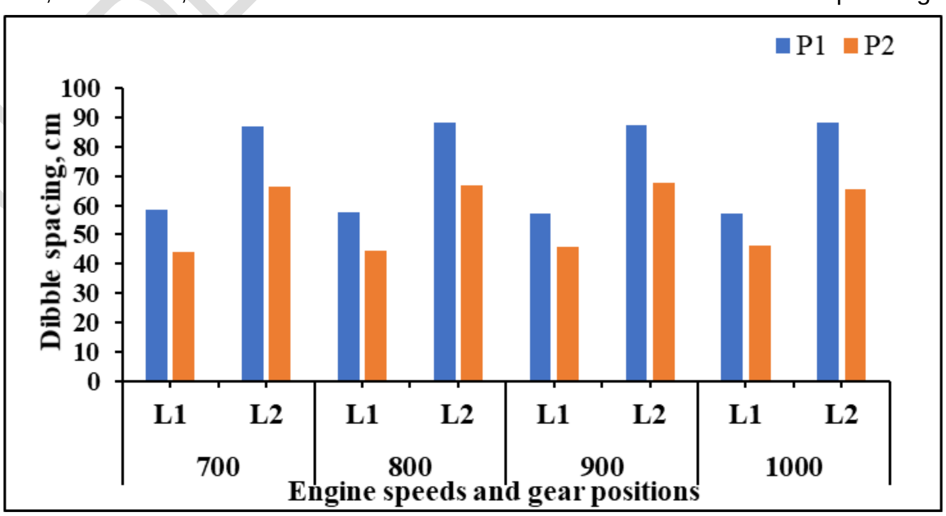


speed and PTO position shown in Table 2.

Fig 6 Effect of engine rpm and PTO position on dibble spacing

3.4 Effect of engine speed, gear position and PTO position on dibble spacing

There observed a significant difference in the dibble spacing with the interaction of engine rpm, gear position and PTO position at 5% level significance as shown in Table 2. The average dibble spacings of 58.33 cm, 57.66 cm, 57.16 cm, and 57.16 cm were observed at condition of L1P1 at all engine speeds of 700, 800, 900, and 1000rpms respectively. The dibble spacings were 44.16 cm, 44.33 cm, 46 cm, and 46.33 cm at L2P2, spacings of 86.83 cm, 88.16 cm, 87.5 cm, and 88.16 cm at L2P1 and spacings of66.33 cm, 66.83 cm, 67.83 cm, and 65.66 cm at L2P2 were observed at all corresponding engine



speeds.

Fig 7 Effect of engine speed, gear position and PTO position on dibble spacing

3.5 Optimization of operating conditions

The main objective of optimisation of operating conditions is to select the seedling spacing which is similar to the designed spacing. The study considered four engine speeds of 700, 800, 900, and 1000 rpm, two gear positions (L1 and L2), and two power take-off (PTO) positions (P1 and P2). Among these, three operating conditions were selected which suits for transplanting the seedlings the seedlings to 45 and 60 cm. At all the engine speeds and at gear position L1 and PTO position of P1 the average spacing was 57.57 cm (Fig 7) and observed no significant difference with the designed spacing of 60 cm. At all engine speeds and at gear position L1 and at PTO position P2, the observed average seedling spacing was 45.20 cm (Fig 7) and was on par with the designed spacing of 45 cm. Along with the two considerations of L1P1 and L1P2, the third consideration L2P2 was also selected to evaluate the transplanter in the field conditions.

The condition of L2P1 was excluded from field evaluation due to the average dibble spacing of 87.66 mm, which was exceeding the recommended spacing. Additionally, the evaluation focused solely on engine speeds of 800 and 1000, as the engine rpm of 700 for both L1 and L2 gear positions was disregarded. Based on observations that the tractor exhibited jerks at 700 rpm, negatively impacting the working conditions for both the driver and workers. Engine speed of 1000 rpm was chosen for its higher field capacity, allowing for increased transplanting rate rather than the 900 rpm. Engine speeds more than 1000 rpm led to difficulties for the worker in dropping seedlings into the dibble tube. The selection and exclusion of specific conditions were based on the achievement of desired dibble spacings and considerations for worker comfort and higher field capacity. Finally, three operating conditions were selected for evaluation of tomato and chilli in field conditions.

4. CONCLUSION

The study focused on selecting optimal operating conditions for seedling transplanting, considering engine speeds (700, 800, 900, 1000 rpm), gear positions (L1, L2), and power take-off positions (P1, P2). Three conditions were chosen: L1P1 and L1P2 had seedling spacings of 57.57 cm and 45.20 cm, respectively, aligning with designed spacings. L2P1 was excluded due to excessive dibble spacing. Evaluation focused on 800 and 1000 rpm, as 700 rpm caused jerks. The 1000 rpm was preferred for higher field capacity. Exceeding 1000 rpm led to difficulties for workers. Selections were based on achieving desired dibble spacings and considering worker comfort and field capacity. Three conditions were chosen for field evaluation with tomato and chili crops.

Table. 3 Operating conditions in the field evaluation

Operational conditions	Engine rpm	Forward gear position	PTO gear position	Forward speed (kmph)
S1	800	L1	P1	1.09
S2	800	L2	P2	1.25
S3	1000	L1	P2	1.55

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