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Mechanizing Small-scale Potato Farming: Development and Performance Evaluation of Power Tiller Operated Potato Planter cum Fertilizer Applicator

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***Abstract*:** Traditional potato planting methods are labour-intensive, time-consuming, and often lead to inconsistent planting, which reducing yield and quality. Animal-operated planters are slow and costly to maintain, while tractor-operated planters are designed for larger farms and are unfeasible to small farmers due to their high cost and technical requirements. A potato planter for use with a 9 hp power tiller has been developed. The performance of the developed planter was evaluated based on five key parameters: draft requirement, missing index, multiple index, effective field capacity, and fuel consumption. Results shows that the minimum draft was 0.79 kN at forward speed of 1.5 km/h and a depth of 80 mm. The lowest missing index (5.33%) and multiple index (4%) occurred at 1.5 km/h and 150 mm depth. The highest effective field capacity (0.124 ha/h) was achieved at 2.5 km/h and 80 mm depth, while the lowest (0.054 ha/h) was at 1.5 km/h and 120-150 mm depth. Fuel consumption was lowest at 13.96 l/ha when operating at 1.5 km/h and 80 mm depth.

***Keywords*:** Potato planter, Fertilizer applicator, Power tiller, Small scale farming.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important horticultural crops in the world and a cost-effective food that provides low-cost energy to the human diet (Pal and Chattopadhyay, 2020). Global potato production in 2022 was 375 million tonnes harvested in approximately 18 million hectares, with China and India are the leading producers, producing 96 million tonnes and 56 million tonnes, respectively (FAO, 2022). The potato production in India during 2023 was approximately 60.14 million tonnes from 2.3 million hectares. Although potatoes are grown in almost all states, major producing regions include Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Haryana, Assam, Jharkhand, and Chhattisgarh (Singh and Dutt, 2024). In the year 2022-23, overall potato production in Chhattisgarh was about 655.438 tonnes, contributing about 1.09 % to the country's total potato production. In developed nations, mechanized planting methods have replaced traditional practices, enabling uniform tuber depth, consistent planting, and improved crop yields (Anand et al., 2023). In many developing nations, traditional and semi-mechanized planting practices are still widely adopted (Bovas et al., 2022). India has seen a gradual shift from traditional planting techniques to mechanized methods, especially in major potato-producing regions such as Uttar Pradesh, West Bengal, and Bihar (Mehta et al., 2018). Despite these advancements, a significant proportion of Indian agriculture remains characterized by small and marginal farmers, where mechanization is less prevalent (Sarkar, 2020). In Chhattisgarh, almost 80 per cent of farmers fall into the small and marginal group, with average landholdings of 1.6 hectares (Chandrakar et al., 2021). These farmers predominantly rely on manual labour and animal-drawn implements for potato planting (Kosariya and Singh, 2022). Traditional planting involves manually placing tubers in furrows and covering them with soil using a spade, making the operation labour-intensive, time-consuming, and tedious, requiring approximately 1600-1700 man-hours per hectare (Issa et al., 2025). Furthermore, these result in uneven tuber placement and variable soil coverage, which adversely affect crop yields and quality (Mehta et al., 2018). Variations in planting depth may expose tubers to sunlight, leading to greening and increased solanine accumulation, making the potatoes unsuitable for human consumption (Rymuza et al., 2020). The use of animal power is growing increasingly expensive as it is necessary to be maintained throughout the year, even if there is no workaround on the farm. Moreover, the working rate of draft animals is quite slow, causing farm operations to be prolonged (Rajkhowa and Kubik, 2021). Although tractor-operated potato planters are available, their use is largely restricted to medium and large farmers due to high initial investment, limited utilization, and technical constraints (Zheng et al., 2021; Dhillon and Moncur, 2023). Therefore, a power tiller operated potato planter can offer a cost-effective and low maintenance solution for marginal and small farmers.

Moreover, several developed power tiller-operated potato planters were equipped with seed hoppers, metering mechanisms, furrow openers, and covering devices for effective planting. However, the earlier developed planters exhibited constraints in the capacity of the seed hopper. Most of the developed planters use chain and cup type, finger type seed metering mechanisms, that are significantly affected by power tiller vibration, leading to inconsistent seed distribution and reduced planting accuracy, which results in reduced crop yield (Kus, 2021). The earlier planters lacked integrated fertilizer applicators, preventing fertilizer application during planting and requiring extra field operations, which increased operational complexity, labour requirements, and fuel consumption. Therefore, this research aimed to evaluate the performance of the developed single row power tiller operated potato planter to address these challenges.

2. MATERIALS AND METHODS

The design and development of single-row potato planter operated by a power tiller was carried out in the Department of Farm Machinery and Power Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India. The main function of the developed is to place potato tubers into soil furrows at specified intervals and depths. The design and development of the planter's components were based on functional and ergonomic consideration to keep production costs reasonable.

2.1. Development of Potato Planter

The design criteria for the seed and fertilizer hopper were based on examinations and investigations of the physical characteristics of potatoes and fertilizer (Kosariya and Singh, 2022). The characteristics of potatoes for designing of planter hopper were bulk density of potatoes 750 kg/m^3, angle of repose 37°, seed rate 2000-2500 kg/ha, and the inter-row spacing in potato cultivation typically falls within the interval of 0.50-0.60 m, accompanied by an intra-row spacing of 0.15-0.25 m between individual tubers (Mandloi et al., 2018). Based on reviews and studies of fertilizer physical properties, the average bulk density of these fertilizers was about 800 kg/m^3, and the angle of repose was 38°, which were used for the design of the fertilizer hopper. Also, the potato crop requires a large amount of fertilizer mixture, varying from 700 to 900 kg/ha (Manikyam et al., 2022).

2.2. Design of Seed Hopper

The capacity of the seed hopper was designed to be sufficient to cover a 100 m length of operation. The area covered for a 100 m length of run with 0.6 m row-to-row spacing was calculated as 60 m^2, and the quantity of potato tubers required for this area was estimated to be 12 kg. Therefore, the volume of hopper was determined based on the average bulk density of potato tubers using Eq.1 (Singh et al., 2022).

$$\text{Volume of hopper} = \frac{\text{Weight of potato tubers}}{\text{Bulk density of potato tubers}} = 0.016\ \text{m}^3 \quad (1)$$

The seed hopper was designed as a cylinder with a perpendicular height of 0.16 m from the bottom and a radius of 0.18 m. The hopper with the above dimensions has a total volume of 0.0172 m^3, sufficient to carry 12 kg of potato tubers.

2.3. Furrow Opener and Transport/drive Wheel

A shoe-type furrow opener was mounted at the bottom of the seed delivery tube. A mounting plate was welded to the seed delivery tube, with drilled holes for mounting the furrow opener using a suitable nut-and-bolt arrangement. Moreover, the drilled holes in the mounting plate provide a means to adjust the e planting depth. The furrow opener has a point of share that cuts the furrow slice and inverts it with the help of wings (mouldboard) provided. Its purpose is to create a furrow so that the tubers can be planted at a specific depth. Two lugged wheels, each with a 270 mm diameter and a 65 mm rim width, serves as both transport and drive wheels, providing drive to the seed and fertilizer metering shafts through suitable gears arrangements.

2.4. Design of Power Transmission Unit for Seed Metering Mechanism

To ensure appropriate metering of potato tuber, a suitable bevel gear arrangement is selected. The driver gear, consisting of 10 teeth, is mounted on the transport/drive wheel shaft, and the driven gear, with18 teeth, is mounted on the perpendicular shaft to the drive wheel. The gear ratio between driver gear to driven gear is 1:1.8. This indicates that when the drive wheel rotates 1.8 times, the driven gear rotates the seed metering mechanism 1 time and caters to a suitable speed of seed metering plate that places the tubers at a specified distance and plants the tubers appropriately.

2.5. Ridger/Covering Device

A disc-type ridge former is provided for making ridges. The ridger are made from a 2 mm mild steel sheet. The former was mounted on the main frame using asuitable arrangement. Furthermore, there is a provision for adjusting the height of the ridge former according to the height of the furrow opener. In addition to creating the ridge, it also covers the loose soil over the potato tubers placed by the metering unit.

2.6. Design of Fertilizer Hopper

Considering the seed hopper capacity of 12 kg, the fertilizer hopper was designed to feed fertilizer once every two or three times as often as potato tubers are fed. The hopper was refilled after every 200 m of planting with a row-to-row spacing of 0.60 m. Therefore, the area covered in one operation was calculated as 120 m², and thus the fertilizer requirement for calculated area was determined using Eq. 2 (Madhusudan and Preetham, 2020):

$$\text{Fertilizer requirement} = \frac{\text{Area covered (m}^2\text{)} \times \text{Recommended fertilizer rate (kg ha}^{-1}\text{)}}{10000\ \text{m}^2} = 8.4\ \text{kg} \quad (2)$$

An additional 1.6 kg of fertilizer was provided as a buffer stock; therefore, the capacity of fertilizer hopper was kept to 10 kg. To ensure a smooth and continuous flow of fertilizer toward the metering mechanism under gravity, the hopper design was based on the angle of repose. The hopper's total capacity was kept at 10 kg of fertilizer, assuming an average bulk density of800 kg/m^3. Thus, the volume of fertilizer box was calculated using Eq. 3 (Kumar et al., 2017):

$$\text{Volume of fertilizer box} = \frac{\text{Weight of fertilizer, kg}}{\text{Bulk density, kgm}^{-3}} = 0.0125\ \text{m}^3 \quad (3)$$

Therefore, the fertilizer hopper dimensions were selected to accommodate the required storage volume. To ensure smooth material flow toward the centrally located metering device at the bottom, the hopper was designed with a trapezoidal cross-section, a common configuration for granular materials. The hopper geometry consisted of a bottom width of 0.16 m, a top width of 0.28 m, an upper section height of 0.50 m, a lower section height of 0.30 m, and a length of 0.28 m. Based on these dimensions, the total hopper volume was obtained by combining the volumes of the upper and lower sections, resulting in an overall capacity of 0.02232 m³. The hopper was fabricated from 20-gauge mild steel sheet, and the selected dimensions provided sufficient storage capacity for the fertilizer mixture required during potato tuber planting.

2.7. Fertilizer Metering Mechanism

The fertilizer metering device comprised a fluted roller arrangement integrated with a jack-type adjustment mechanism within the fertilizer hopper. The fluted roller shaft and the jack-type mechanism were mounted on a common shaft to ensure uniform and controlled fertilizer distribution. The jack-type mechanism consisted of a nut-and-bolt assembly mounted on the fluted roller shaft through a spring-tensioning system, which regulated the fertilizer application rate by varying the effective opening of the fluted roller. The fertilizer metering mechanism was driven by the transport wheel through a chain and sprocket transmission system. Fertilizer delivery to the furrow was facilitated using a PVC tube with an internal diameter of 30 mm, allowing smooth flow of fertilizer into the furrow formed by the furrow opener.

2.8. Design of Fertilizer Metering Drive Chain

The ground wheel shaft transmitted rotational motion to the 15 mm diameter fertilizer metering shaft through a chain-and-sprocket mechanism. A 19-tooth gear was mounted at one end of the fertilizer metering shaft. In contrast, the opposite end was fitted with a jack-type lever adjustment that regulated the fertilizer application rate by sliding the shaft along a keyed section. A 13-tooth gear mounted on the transport wheel shaft provided the driving input to the fertilizer metering shaft. The chain length between the transport wheel shaft and the fertilizer metering shaft was determined using Eq. 4 (Yunus et al., 2015):

$$L = 2C + 1.57\,(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4C} = 1170.25\ \text{mm} \quad (4)$$

Where; C = Centre to centre distance of two sprockets in mm D = Number of teeth of two sprockets. During continuous operation of the machine under undulating field conditions, the chain was subjected to tensile stresses, leading to an elongation of about 20 to 30 mm. Accordingly, the required number of chain links was determined using Eq. 5 (Kumar et al., 2017):

$$m = \frac{2C}{P} + \frac{Z_1 + Z_2}{2} + \frac{P\,(Z_2 - Z_1)}{4\pi^2 C} = 90\ \text{links} \quad ...(5)$$

Where, m represents the number of chain links, C denotes the center-to-center distance between sprockets (560 mm), Z_1

and Z_2 are the numbers of teeth on smaller and larger sprocket (13 and 19, respectively), and P is the chain pitch of 15 mm. Based on these parameters, it was determined that a chain length of approximately 1200 mm requires about 96 links, providing sufficient allowance for chain elongation and ensuring smooth, reliable power transmission during field operation.

2.9. Developed Single Row Power Tiller Operated Potato Planter

The developed power tiller operated potato planter consists of six major components: a seed hopper, cell feed type seed metering mechanism, fertilizer hopper, furrow opener, and ridger/covering device (Figure 1). Moreover, it allows uniform planting, ensuring that potato tubers were placed at consistent depths and spacings. The planter incorporates a fertilizer application system, allowing for simultaneous planting and fertilization. Table 1 presents the detailed specifications of the developed single-row power tiller-operated potato planter.

2.10. Experimental design and performance evaluation of developed potato planter

The experiment was laid out in two-factor randomized design for analysis potato planting. The experiments were conducted in the field to evaluate the performance of the potato planter (Figure 2). The statistical analysis was performed using SAS 9.4 Software. The field performance of the developed planter was assessed using following parameters with 5 replications. The experimental parameters used for the performance evaluation of developed potato planter presents in Table 2.

2.11. Draft Requirement

A spring balancing dynamometer was fastened to the front of the power tiller, to which the planter was attached, for

Table 1. Specification of developed single row power tiller operated potato planter

Specification	Values
Seed hopper	Height:160 mm, Dia.:370 mm,
Fertilizer hopper	Top width: 280 mm, Length: 280 mm, Bottom width:160 mm, Height: 350mm
Cell feed type seed metering	Number of cells: 9, Dia.: 360 mm
Seed delivery tube	Dia.: 90 mm, Length: 510 mm
Fertilizer tube	Dia.: 30 mm, Length: 290 mm
Furrow opener	Shoe type
Ridge former	Disc type
Ground wheel	Dia.: 270 mm
Overall dimensions	Length: 706 mm, Height: 850 mm, Width: 685 mm
Weight	45 kg
Power source	Power tiller 9 hp or above

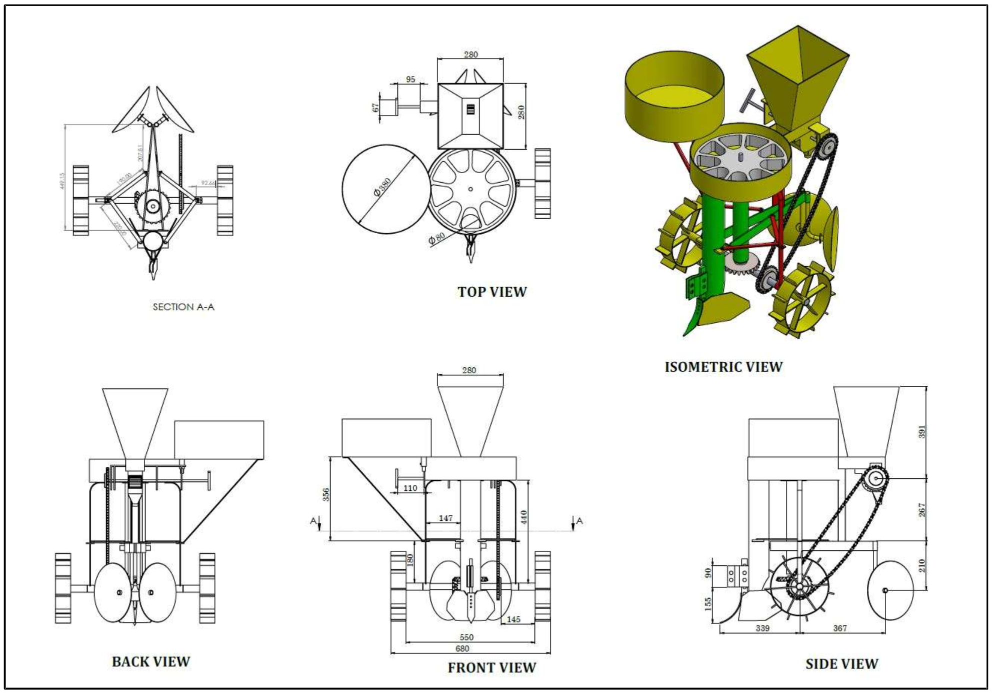

Figure 1. Developed single row power tiller operated potato planter

draft measurement. An auxiliary tractor pulled the power tiller (in neutral gear but with the planter in operating position) through the dynamometer over a 30-meter distance. The draft was recorded with and without the planter attached. The difference between these two readings determined the planter's draft. This process was repeated for each speed considered in the study (Hardik, 2014).

2.12. Missing Index

The planter was operated in the field, and the distance between two consecutive tubers was measured in a span of 5 m. If the distance between two consecutive tubers exceeded 1.5 times of the theoretical spacing, then this was considered as missing. A Missing index thus indicates how many times the labour failed to place the tubers in the cell of seed metering plate. The percentage of missing of tubers was calculated by using Eq. 6 (Gautam et al., 2019; Choudhary et al., 2024):

Missing index (%) = n/N …… (6)

Where, n = No. of spacings greater than 1.5 times the theoretical spacing in the given observation; N = Total number of observations

Figure 2. Field evaluation of power tiller operated potato planter

2.13. Multiple Index

It consists of two or more tubers dropped by the seed metering unit through a single hole in the metering plate. The multiple index indicates that more than one tuber has been dropped within the desired spacing. It is the fraction of the theoretical spacing that is less than or equal to half, and calculated using Eq. 7 (Thakur et al., 2020; Tsegaye, 2025).

Multiple index (%) = n_1/N ………… (7)

Where, n_1= number of spacings in the region less than or equal to 0.5 times of the considered spacing, N= total number of observations

2.14. Effective Field Capacity

The effective field capacity is the actual average rate of coverage by the planter. Effective field capacity is usually expressed in hectare per hour, and calculated using Eq. 8 (Parihar et al., 2022):

Effective field capacity (ha/h) = Area of plot (ha)/Time taken (h) ….. (8)

2.15. Fuel Consumption

Fuel consumption was measured in liters per hectare (l/ha) using top fill method (Devojee et al., 2019).

3. RESULTS AND DISCUSSION

3.1. Effect of Forward Speed and Planting Depth on Draft Requirement

The determination of draft is highly important for achieving an economical, energy-efficient potato planting operation. The maximum draft requirement (1.22 kN) occurred at a forward speed of 2.5 km/h and planting depth of 150 mm (Table 3). However, the minimum draft (0.79 kN) was observed at a forward speed of 1.5 km/h and planting depth of 80 mm. Moreover, it was observed that draft requirement increased with both forward speed and planting depth. This might be due to the furrow opener encountering greater soil resistance at greater depth and at higher speed. Aruna et al. (2020) observed that the draft requirement was significantly affected by forward speed and operating depth,

Table 2. Experimental parameters for performance evaluation of the developed planter

Parameters	Factors	Levels		
		Low (-1)	Middle (0)	High (+1)
Independent parameters	1. Forward speed (km/h)	1.5	2.0	2.5
	2. Planting depth (mm)	80	120	150
Dependent parameters	1. Draft requirement (kN) 2. Missing index (%) 3. Multiple index (%) 4. Effective field capacity (ha/h) 5. Fuel consumption (l/ha)			

as the volume of soil managed by the implement increased with both.

The LS-means of speed and planting depth at three different levels showed significant effect on the draft requirement (Figure 3A and Figure 3B, respectively). The interactions among operating parameters had non-significant effect on the draft requirement. The critical difference (CD) at the 5% level for draft requirement was 0.021 kN for forward speed and 0.027 kN for planting depth, while their interaction effect was non-significant, indicating that differences exceeding these values were statistically significant (Table 3). Similar trends have been reported by Okoko and Ajav (2020). The study emphasizes that through selecting suitable speeds and planting depths, draft requirements can be reduced, resulting in decreased fuel consumption and less wear on the planter.

3.2. Effect of Forward Speed and Planting Depth on Missing Index

The uniformity of tuber planting was affected by the missing index, which was observed during the performance evaluation of developed potato planter. The maximum value of missing index (12.66%) was observed at a forward speed of 2.5 km/h and planting depth of 80 mm, and the minimum missing (5.33%) was observed at a forward speed 1.5 km/h and planting depth of 150 mm (Table 4). The value of missing index increased with increase in forward speed; however, decreased as planting depth increased from 80 mm to 150 mm. No significant difference observed when forward speed increased from 1.5 km/h to 2.0 km/h; however, a significant effect on the missing index was observed when forward speed increased 2.0 km/h to 2.5 km/h. At higher forward speeds, the increased rotational speed of the metering plate reduces the time available to place tubers into the cups, leaving some cups unfilled and increasing the missing index. Conversely, greater planting depths increase soil resistance and reduce the planter's effective operating speed, allowing more accurate tuber placement, improved tuber retention, and better placement stability within the furrow. Similar

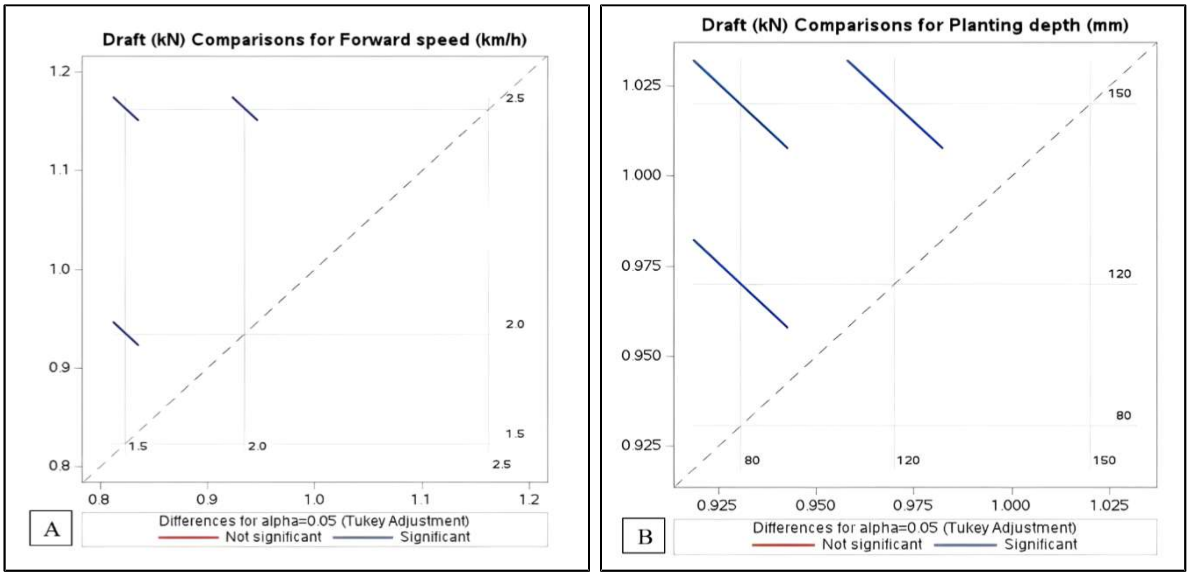

Figure 3. Effect of forward speed and planting depth on draft requirement

Table 3. Effect of forward speed and planting depth on draft requirement

Forward speed, km/h→ **Planting depth, (mm)↓**	**1.5 km/h**	**2.0 km/h**	**2.5 km/h**	**Mean planting depth**
80 mm	0.79	0.89	1.11	0.93
120 mm	0.82	0.92	1.15	0.96
150 mm	0.85	0.98	1.22	1.02
Mean Forward Speed	0.82	0.93	1.16	
Factors	**Forward speed**	**Planting depth**		**Forward speed × Planting depth**
Critical difference (5%)	0.021	0.027		NS

trends have been reported by Hardik (2014) and Khan et al. (2015).

The critical difference (5%) for missing index was 1.876% for forward speed, while planting depth and their interaction were non-significant (Table 4). The LS-means of forward speed had a significant effect on the missing index (Figure 4). However, neither planting depth nor interactions among operating parameters had a significant effect on the missing index, consistent with the result of Pandey and Sawant (2023). Additionally, the results show that optimizing planting depth and speed not only improves planting uniformity but also enhances overall crop yield.

3.3. Effect of Forward Speed and Planting Depth on Multiple Index

The maximum multiple index (9.33 %) was observed at a forward speed of 2.5 km/h, and planting depth of 80 mm, and minimum multiple index value (4%) was observed at forward speed of 1.5 km/h and planting depth of 150 mm (Table 5). The multiple index increased with forward speed; however, it decreased with increasing planting depth. This was because, as operational speed increased, labourers had less time to fill each cell accurately. This time constraint can lead to more frequent occurrences of multiple tubers or seeds being placed in the same cell, hence the slight increase in the multiple index. A similar result was reported by Hardik (2014) and Kosariya et al. (2023). This finding, highlights the importance of balancing speed and depth in mechanical planting operations to ensure precision and optimize crop yield.

The LS-means for forward speed and planting were non-significant on the multiple index. Furthermore, their

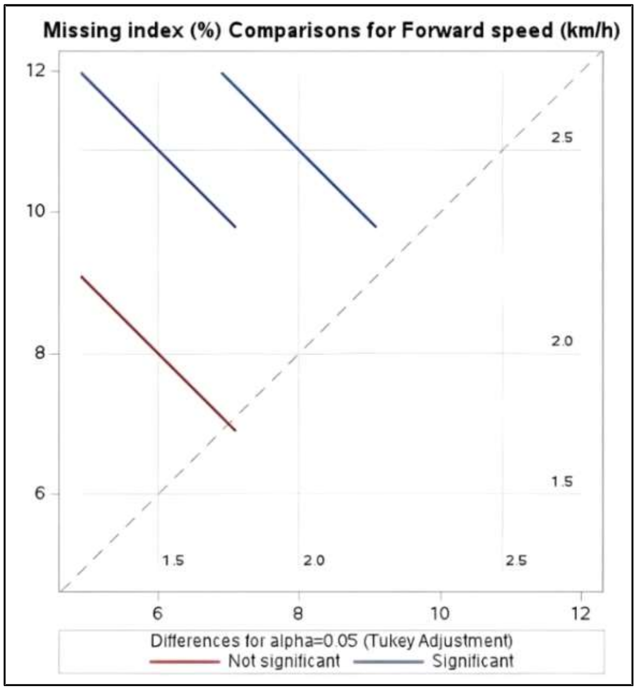

Figure 4. Effect of forward speed on missing index

Table 4. Effect of forward speed and planting depth on missing index

Forward speed, km/h→ Planting depth, (mm)↓	**1.5 km/h**	**2.0 km/h**	**2.5 km/h**	**Mean planting depth**
80 mm	6.66	8.66	12.66	9.33
120 mm	6	8	10.66	8.22
150 mm	5.33	7.33	9.33	7.33
Mean Forward Speed	6.00	8.00	10.88	
Factors	**Forward speed**	**Planting depth**		**Forward speed × Planting depth**
Critical difference (5%)	1.876	NS		NS

Table 5. Effect of forward speed and planting depth on multiple index

Forward speed, km/h→ Planting depth, (mm)↓	**1.5 km/h**	**2.0 km/h**	**2.5 km/h**	**Mean planting depth**
80 mm	7.33	8.66	9.33	8.44
120 mm	5.33	6.66	7.33	6.44
150 mm	4	5.33	8	5.78
Mean forward speed	5.55	6.88	8.22	
Factors	**Forward speed**	**Planting depth**		**Forward speed × Planting depth**
Critical difference (5%)	NS	NS		NS

interactions also had non-significant effect on the multiple index at 5% level of significance. As the effects were statistically non-significant, the observed differences among treatment means were within the critical difference (CD) at the 5% level (Table 5).

3.4. Effect of Forward Speed and Planting Depth on Effective Field Capacity

The minimum effective field capacity (0.054 ha/h) was observed at a forward speed of 1.5 km/h and planting depth of 120 and 150 mm; the maximum (0.124 ha/h) was observed at a forward speed of 2.5 km/h and planting depth of 80 mm (Table 6). The effective field capacity increased with forward speed, but decreased with planting depth. This might be due to as speed increased, the planter covered more area per unit time. The effective field capacity (EFC) was higher in larger fields than in smaller fields and in those with irregular shapes. Moreover, it can be enhanced through intensive operator training in machinery management, which improves operational skills. This finding aligns with the results reported by Kumar et al. (2017). The results accentuate that increasing forward speed can enhance the effective field capacity. However, it is crucial to ensure that the increased speed does not negatively affect the planter's performance.

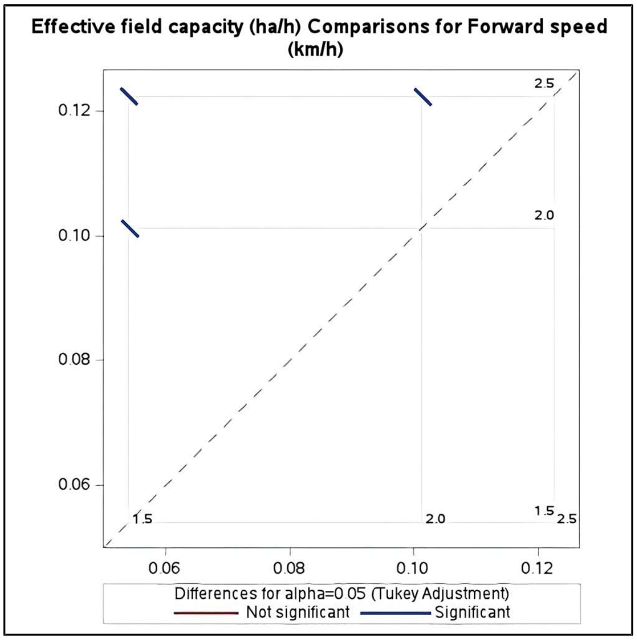

Figure 5. Effect of forward speed on effective field capacity

The LS-means of forward speed had a significant effect on effective field capacity (Figure 5). The critical difference (CD) at the 5% level for forward speed was 0.002 (Table 6), indicating that differences among mean values exceeding this limit were statistically significant. Furthermore, planting depth did not significantly affect the effective field capacity. Furthermore, their interactions also did not significantly affect the effective field capacity.

3.5. Effect of Forward Speed and Planting Depth on Fuel Consumption

The increase in fuel consumption was observed during the field evaluation of developed planter as forward speed and planting depth increased. The maximum fuel consumption (17.33 l/ha) was observed at a forward speed of 2.5 km/h and planting depth of 150 mm. However, the minimum fuel

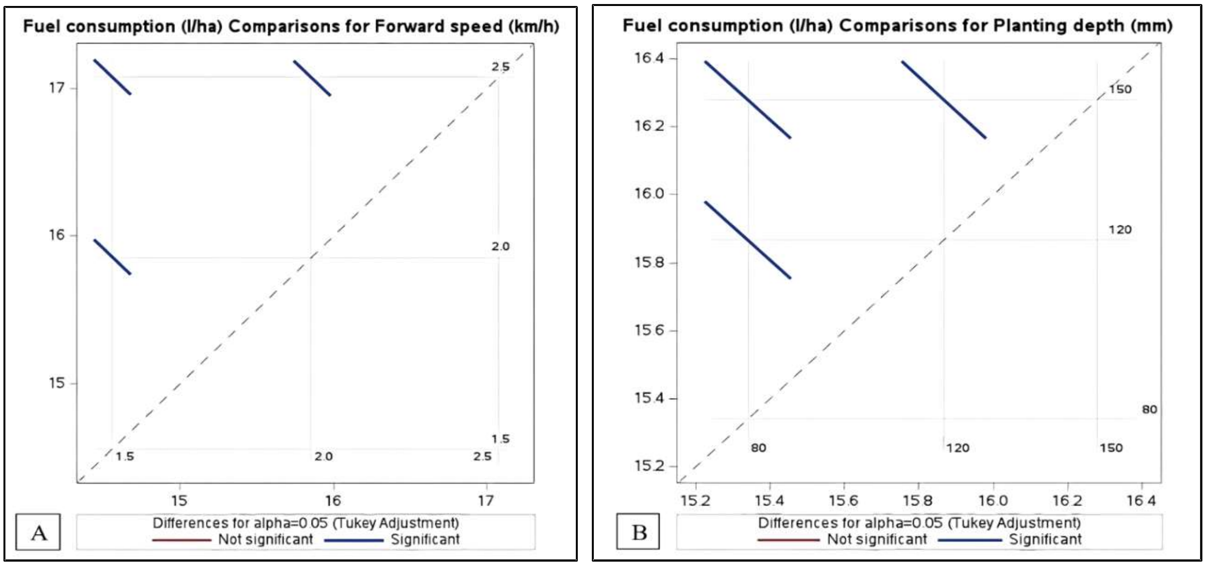

Figure 6. Effect of forward speed and planting depth on fuel consumption

Table 6. Effect of forward speed and planting depth on effective field capacity

Forward speed, km/h→ Planting depth, (mm)↓	**1.5 km/h**	**2.0 km/h**	**2.5 km/h**	**Mean planting depth**
80 mm	0.055	0.102	0.124	0.094
120 mm	0.054	0.101	0.122	0.092
150 mm	0.054	0.1	0.121	0.092
Mean forward speed	0.054	0.101	0.122	
Factors	**Forward speed**	**Planting depth**		**Forward speed × Planting depth**
Critical difference (5%)	0.002	NS		NS

Table 7. Effect of forward speed and planting depth on fuel consumption

Forward speed, km/h→ Planting depth, (mm)↓	**1.5 km/h**	**2.0 km/h**	**2.5 km/h**	**Mean planting depth**
80 mm	13.96	15.22	16.82	15.33
120 mm	14.76	15.79	17.06	15.87
150 mm	14.96	16.54	17.33	16.28
Mean Forward Speed	14.56	15.85	17.07	
Factors	**Forward speed**	**Planting depth**		**Forward speed × Planting depth**
Critical difference (5%)	0.192	0.213		0.333

consumption (13.96 l/ha) was observed at a forward speed 1.5 km/h and planting depth 80 mm (Table 7). Fuel consumption increased with increasing speed and planting depth. This is because at higher speeds and depths, it results an increased wheel slippage and a greater draft requirement, which requires more torque; i.e., the engine must exert more effort to sustain the required performance levels, thereby consuming more fuel, further contributing to elevated fuel usage. This result is consistent with the findings of Singh et al. (2024). Moreover, the results show that maintaining planting depth and forward speed during planting can significantly improve the planter's productivity and operational efficiency.

The LS-means of forward speed and planting depth for three different levels had significant effect on fuel consumption (Figure 6A and 6B, respectively). The interactions also had significant effect on fuel consumption. The critical difference (5%) for fuel consumption was 0.192 l ha^{-1} for forward speed, 0.213 l ha^{-1} for planting depth, and 0.333 l ha^{-1} for their interaction (Table 7). Similar findings have been reported in earlier studies indicate that increases in forward speed and operating depth lead to higher draft requirements and fuel consumption due to increased soil resistance and traction load (Nkakini et al., 2020; Pandey and Sawant, 2023).

4. CONCLUSION

Potato cultivation in Chhattisgarh is largely practiced by small and marginal farmers using traditional, labour-intensive methods. To address these constraints, a single-row power tiller-operated potato planter was developed and evaluated. The planter operated effectively with a 9 hp power tiller, maintaining recommended spacing and planting depth across tuber sizes. Performance evaluation showed that forward speed and planting depth significantly influenced planting quality, draft, and fuel consumption. Optimal performance was achieved at lower forward speed with moderate planting depth, ensuring improved planting uniformity, reduced draft and fuel consumption, and acceptable field capacity. Higher speeds increased field capacity but adversely affected planting precision and energy efficiency. Overall, the developed planter was suitable for small and marginal farmers, offering a balanced compromise between operational efficiency and planting accuracy.

CRediT Authorship Contribution Statement

Conceptualization: S. Jogdand, R. K. Naik, and Sajal Rahangdale. Data curation: S. Jogdand, R. K. Naik, and Sajal Rahangdale. Methodology: S. Jogdand, Gajendra Singh, Khilesh Dewangan, and Sajal Rahangdale. Project administration: S. Jogdand, R. K. Naik. Validation: Sajal Rahangdale, S. Jogdand, R. K. Naik and Gajendra Singh.

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Conflicts of Interest

The authors declare no conflicts of Interest.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors declare that no generative AI or AI-assisted technologies were used in the conception, design, data collection, analysis, interpretation, or writing of this manuscript.

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