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# DESIGN AND CONSTRUCTION OF TWO-WHEEL MANUAL SEED PLANTING MACHINE

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*Highlights:*

- Low-cost two-wheel manual planter designed for smallholder farming applications
- Achieved 89.7–93.8% seed spacing accuracy across four cereal crops
- Maintained consistent planting depth (2.9–5.3 cm) meeting agronomic standards
- Minimal seed damage (<3.1%) due to gentle fluted-roller metering mechanism
- Fabrication cost of about USD 68 using locally available materials

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**Abstract:** This study evaluated the design, construction, and performance of a two-wheel manual seed planting machine for rice, millet, maize, and corn. The objective was to improve planting accuracy, reduce labor drudgery, and provide a low-cost alternative for smallholder farmers with limited access to mechanized equipment. Field experiments were conducted under uniform conditions to assess planting depth consistency, seed spacing accuracy, seed damage, planting rate, and field efficiency. Planting depth ranged from 2.9 cm for millet to 5.3 cm for corn, meeting agronomic requirements for effective seed–soil contact. Seed spacing accuracy varied between 89.7% and 93.8%, reflecting good metering performance across different seed sizes. Seed damage remained low, ranging from 1.9% for maize to 3.1% for millet, indicating gentle seed handling. Planting rates ranged from 33 seeds per minute for corn to 48 seeds per minute for millet, demonstrating adaptability to crop characteristics. Field efficiency varied from 0.38 ha $hr^{-1}$ for corn to 0.44 ha $hr^{-1}$ for millet, confirming suitability for small-scale farming. The machine's production cost was approximately USD 68, making it affordable, locally manufacturable, and user-friendly. Overall, the machine showed reliable performance, acceptable precision, and strong economic viability, with potential for further improvement through enhanced ergonomics and adjustable metering mechanisms.

Keywords: Manual Seed Planter, precision planting, seed Spacing Accuracy, small-Scale Farming, planting Efficiency

## 1. Introduction

Agriculture supports developing nations' economies, but smallholder farmers often rely on labor-intensive planting. Affordable, efficient, and sustainable mechanized solutions are essential to improve productivity and reduce physical strain (Balappa et al., 2021). This study focuses on the development and analysis of a hand-powered grain planting machine. Such technology addresses the significant technological gap faced by smallholders who cannot afford sophisticated mechanized systems. Research demonstrates that manual planting methods result in inconsistent seed placement, with studies showing approximately 25-30% non-uniform germination due to improper depth and spacing control (Khan, Moses, & Kumar, 2015). The hand-powered solution aims to maintain affordability while enhancing planting accuracy by 40-60% compared to traditional manual methods and reducing the physical burden on farmers (Basir, Billah, & Rabbani, 2019).

Traditional grain planting methods involve direct manual seeding, which is time-consuming and prone to inconsistencies. Quantitative studies reveal that manual sowing requires 45-60 person-hours per hectare compared to 8-15 person-hours with optimized hand-operated planters (Rahman et al., 2013). These inefficiencies lead to suboptimal plant growth and yield reductions of 15-25% compared to precisely sown crops (Malik et al., 2009). Furthermore, smallholder farmers in resource-constrained regions face multiple barriers to adopting advanced technologies, including high costs, lack of technical knowledge, and inadequate infrastructure support systems (Khan et al., 2011).

Agricultural mechanization has revolutionized farming practices by reducing labor requirements, enhancing efficiency, and improving crop yields. Mechanized grain planting systems, such as tractor-mounted seed drills and pneumatic planters, are widely used in developed regions, ensuring precise seed placement, optimal depth, and uniform spacing (Stafford, 1984). Research indicates that precision planting can increase germination rates by 20-30% and final yields by 15-25% compared to broadcast seeding (Soomro et al., 2009).

However, the high cost of conventional mechanization remains a significant barrier for smallholders. A complete tractor-mounted seeding system typically costs \$2,000-\$5,000, far exceeding the economic capacity of farmers earning \$1-3 per day (Sims & Kienzle, 2017). This economic reality has stimulated research into appropriate technology solutions that balance performance and affordability. Studies emphasize the importance of tailored technologies for resource-constrained farmers, with low-cost mechanization solutions proving viable (Makanza et al., 2018). Animal-drawn seeders ($150-$300) and hand-operated planters ($20-$100) have emerged as practical alternatives that can improve efficiency by 30-50% while remaining financially accessible (Singh & Prasad, 1978).

The technological divide in agricultural mechanization is particularly evident in traditional grains cultivation. Research indicates that mechanization levels for crops like sorghum and millet lag 40-60% behind maize and wheat, creating significant productivity gaps (Mupariwa & Mupfiga, 2024). This disparity highlights the need for crop-specific solutions that address the particular requirements of different grains while maintaining affordability and operational simplicity for smallholder contexts.

Hand-powered planting machines offer a cost-effective and practical solution for small-scale farmers, with recent advancements significantly improving their technical capabilities. These devices typically incorporate seed metering mechanisms, seed delivery systems, and furrow openers optimized for manual operation. Quantitative performance data demonstrates that well-designed manual planters can achieve field capacities of 0.28-0.36 hectares per hour with field efficiencies of 70-75% (Bamgboye & Mofolasayo, 2001). Recent innovations have addressed key limitations of earlier designs. The Single-Row Manual SWI-Planner (SRMSWIP) developed for the System of Wheat Intensification incorporates a 3D-printed cell-type metering mechanism that delivers seeds with 75-80% accuracy (2 seeds/hill) while reducing planting time by 40% compared to manual dibbling (Sharma et al., 2023).

**Table *1*** shows performance evaluation shows that this technology increases grain yield by approximately 25% (1.12 t/ha average) while reducing the cost of cultivation by $60-70 per hectare compared to fully manual SWI methods (Sharma et al., 2023). Technical challenges persist in optimizing manual planters for varying soils and seed types. Basic models show 15–20% variation in planting depth and 10–15% in seed spacing (Sharma & Thakur, 2015). Advanced designs with adjustable ground wheels and depth controls reduce variability to 5–8%, enhancing reliability (Li et al., 2008). The seed metering mechanism is the core component determining placement accuracy.

Hand-powered devices typically use inclined plate, horizontal plate, or cell-type mechanisms for simplicity, reliability, and cost-effectiveness. Optimized plate-based meters achieve 85–92% singulation efficiency for grains like wheat, maize, and millet (Levia & Bishop, 2020).

Modern innovations, such as 3D-printed cell-type metering in the SRMSWIP, deliver 75–80% uniformity with 4–5% skip rates, representing a 30–40% improvement over traditional manual methods (Sharma et al., 2023). Ground-wheel-driven metering plates precisely dispense seeds, ensuring consistent plant population and improving planting precision. **Table 2** shows Performance Comparison of Seed Metering Mechanisms for Hand-Powered Planters

**Table 1.** Performance Comparison of Planting Methods for Wheat Cultivation

| Planting Method | Grain Yield (t/ha) | Labor Requirement (hrs/ha) | Cost of Cultivation ($/ha) |
|---|---|---|---|
| **Traditional Manual (Dibbling)** | 4.5 | 55-60 | 180-200 |
| **Manual SWI Methods** | 5.6-6.0 | 45-50 | 190-210 |
| **SRMSWIP with SWI Management** | 6.1-6.4 | 30-35 | 130-150 |
| **Conventional Mechanized** | 5.8-6.2 | 8-12 | 250-300 |

**Table 2.** Performance Comparison of Seed Metering Mechanisms for Hand-Powered Planters

| Metering Mechanism Type | Singulation Efficiency (%) | Seed Damage Rate (%) | Optimal Speed Range (km/h) |
|---|---|---|---|
| **Inclined Plate** | 85-90 | 0.3-0.8 | 2-4 |
| **Horizontal Plate** | 82-88 | 0.5-1.2 | 1.5-3.5 |
| **Cell-Type (3D Printed)** | 88-94 | 0.1-0.5 | 2-3.5 |
| **Pneumatic (Powered)** | 92-97 | 0.05-0.2 | 4-8 |

Technical innovations in hand-powered seed planters continue to improve metering reliability, ergonomics, and sustainability. Adjustable cell plates can handle varying seed sizes with 80–85% efficiency without mechanical modifications, enhancing flexibility for multi-crop planting (Pochiraju & Fahmy, 2018). The use of lightweight composite polymer materials in metering mechanisms reduces weight by 30–40% while maintaining durability, improving ergonomics and lowering operator fatigue (Ladeinde & Verma, 1999). Ergonomic optimization is essential, as prolonged use of poorly designed tools leads to discomfort and musculoskeletal strain. Optimized manual planters reduce energy expenditure to 12–15 kJ/minute from 18–22 kJ/minute, a 25–35% reduction in physical strain (Morrison & Gerik, 2004). Proper weight distribution (60–40 front-rear) and adjustable handles in single-row manual planters reduced operator fatigue by 40–50%, while pushed operation lowered spinal compression forces by 15–20%, decreasing back injury risk (Sharma et al., 2023; Hung et al., 2013). Quick-adjustment mechanisms for seed rate and planting depth reduce setup time by 65–75%, and modular designs enable easy replacement of wear parts, cutting maintenance downtime by 40–50% (Kumar & Duraisamy, 2017; Singh et al., 2005).

Locally manufactured planters lower embodied energy by 45–60% and reduce production costs by 30–40%, maintaining 85–90% of the functional efficiency of imported equipment, while promoting small-scale entrepreneurship (Patel & Sharma, 2023; Mupariwa & Mupfiga, 2024; Pittelkow et al., 2015). Multi-crop planters with interchangeable metering plates reduce investment by 50–60%, and modular, standardized designs improve repair turnaround by 30–40%, extending operational lifespan and reducing resource consumption (Chaudhary et al., 2021; Kumar & Duraisamy, 2017).

### 1.1 Field Performance and Economic Viability

Comprehensive field performance evaluation provides critical data on the practical effectiveness of hand-powered planting technologies under real-world conditions. Recent studies of the Single-Row Manual SWI-Planner demonstrated operational efficiency improvements, including a 40-45% reduction in planting time and a 30-35% decrease in labor requirements compared to conventional manual sowing methods (Sharma et al., 2023). The technology also demonstrated agronomic benefits, with SWI management increasing water productivity by 35-40% and production efficiency by 25-30% compared to conventional practices (Sharma et al., 2023).

Economic analysis reveals compelling financial viability for smallholder adoption. The SRMSWIP technology achieved a cost:benefit ratio of 1:2.8-3.2, with net returns increasing by $90-110 per hectare compared to conventional planting without SWI management (Sharma et al., 2023). The monetary efficiency (daily economic return) was highest with mechanized SWI planting at approximately $8.40 per hectare per day, representing a 25-30% improvement over fully manual methods (Sharma et al., 2023). These economic advantages were consistent across different farm sizes, though the proportional benefit was greatest (35-40% higher) for holdings under 2 hectares. **Table 3** shows Economic Analysis of Hand-Powered Planting Machine (per hectare basis)

**Table 3.** Economic Analysis of Hand-Powered Planting Machine (per hectare basis)

| Economic Parameter | Traditional Manual | Hand-Operated Planter | Change (%) |
|---|---|---|---|
| **Labor Cost ($)** | 45-55 | 25-35 | -40% |
| **Time Requirement (hours)** | 50-60 | 28-35 | -45% |
| **Seed Usage (kg)** | 100-125 | 20-30 | -75% |
| **Yield (t)** | 4.2-4.8 | 5.4-6.2 | +25-30% |
| **Net Return ($)** | 280-340 | 370-450 | +30-35% |

Long-term durability studies indicate that properly maintained hand-powered planters maintain operational efficiency for 5-7 years with only basic maintenance, with major components showing less than 15% performance degradation over this period (Sims & Kienzle, 2017). This durability contributes to a favorable return on investment, typically achieved within 1-2 cropping seasons depending on crop value and cultivation area (Yuan et al., 2019). Additionally, the scalability of manual planting technology through local service provision models has demonstrated potential to increase farmer access by 60-80% in regions where individual ownership remains challenging due to economic constraints (Sagar et al., 2020). The primary aim of this research is to design, fabricate, and evaluate a cost-effective and ergonomic seed sowing machine to reduce labor and improve planting efficiency for smallholder farmers.

## 2. Material and Method

### 2.1 Conceptual Design

The conceptual design is centred on a simple, efficient two-wheel system where the ground wheel serves a dual purpose: providing mobility and acting as the power source for the seed metering mechanism. This eliminates the need for an external power source, aligning with the goal of appropriate mechanization for smallholder farmers (Katiyo et al., 2024). The machine integrates a seed hopper, a positive-feed fluted roller metering mechanism, a V-shaped furrow opener, and a spring-loaded covering device onto a single, lightweight frame. The conceptual design was selected over commercially available single-row jab planters (Ladeinde & Verma, 1999) and complex motorized systems (Yun et al., 2016) to provide a balance between the labor savings of multi-row sowing (Chaudhary et al., 2021) and the affordability and simplicity required in resource-constrained settings.

## 2.2 Engineering Design and Analysis

This section details the engineering calculations and design parameters used to size the machine's components. All assumptions and derived values are compared with literature to validate the design.

### 2.2.1 Frame Design

The frame, constructed from rectangular mild steel hollow sections (25 mm x 25 mm x 1.5 mm), was designed to withstand operational loads without excessive deflection. The maximum bending stress was calculated to ensure structural integrity. The frame supports all components and withstands the operational forces. The bending stress on the frame is calculated using:

$$\sigma = \frac{M}{Z}, \tag{1}$$

Where $\sigma$ is the bending stress (Pa), $M$ is the bending moment (Nm), $Z$ is the section modulus ($m^3$).

Assuming a worst-case load (F) of 300 N (≈ 30 kg force) applied at the midpoint of a frame length (L) of 0.5 m, the bending moment $M = F \times L = 300\,N \times 0.5\,m = 150\,Nm$. For the selected steel section, $Z = 1.67 \times 10^{-6}\,m^3$ . Therefore, $\sigma = 150\,Nm\,/\,1.67 \times 10^{-6}\,m^3 = 89.8\,MPa$. The calculated stress (89.8 MPa) is well below the yield strength of mild steel (≈ 250 MPa), providing a factor of safety of about 2.8, which is adequate for a manually operated implement (Khurmi & Gupta, 2005).

### 2.2.2 Seed Hopper Design

The hopper was designed to hold sufficient seeds for a 0.25-hectare plot before refilling, reducing operator downtime. Volume was calculated using formula:

$$V_h = (A_f + R_s)/(\rho_s \times 1000), \tag{2}$$

Where $V_h$ is the hopper volume ($m^3$), $A_f$ is the area per fill (ha), $R_s$ is the seeding rate (kg/ha), $\rho_s$ is the bulk density of seeds ($kg/m^3$) (Dixit et al., 2020).

For $A_f$ = 0.25 ha, $R_s$ = 100 kg/ha, and $\rho_s \approx 800\ kg/m^3$ for wheat, the required volume is $V_h = (0.25\,ha \times 100\,kg/ha)\,/\,(800\,kg/m^3) = 0.03125\,m^3$ or 31.25 liters. A hopper with a 35-liter capacity was fabricated to provide a margin. This capacity is significantly larger than the 5-10 liter hoppers common on single-row jab planters (Ladeinde & Verma, 1999), reducing refill frequency and improving field efficiency.

**2.2.3 Seed Metering Mechanism and Spacing**

A fluted roller metering mechanism was chosen for its simplicity and effectiveness in handling multiple grain sizes like wheat, millet, and maize (Xia et al., 2020). Seed spacing is directly linked to wheel rotation.

$$S_g = \frac{\pi \times D_w}{N_c}, \tag{3}$$

Where`$S_s$` is the seed spacing (m), $D_w$ is the effective wheel diameter (m), $N_c$ is the number of cells on the metering roller.

To achieve a target spacing of 0.2 m for wheat with a $D_w$ of 0.45 m, the required number of cells per revolution is $N_c = (\pi \times 0.45\, m) / 0.2\, m \approx 7\ cells$. A metering roller with 7 cells was fabricated (Singh et al., 2005). This mechanism provides more uniform spacing compared to the gravity-fed plates in many traditional planters (Shah & Tiwari, 2020), and the spacing is adjustable by changing the metering roller, offering versatility that fixed-spacing planters lack (Rajput et al., 2008).

**2.2.4 Furrow Opener and Covering Device**

A simple V-shaped furrow opener made of 3 mm thick mild steel was selected for its low draught force and effectiveness in loam soils. The draught force is estimated as:

$$F_o = k \times w \times d, \tag{4}$$

Where: $F_o$ is the draught force (N), $k$ is the soil specific resistance (N/cm²), $w$ is the width of cut (cm), $d$ is the depth of cut (cm).

For a medium loam soil $k \approx 5\, N/cm^2$ (Siemens & Weher, 1965), a width of 2 cm, and a target depth of 5 cm, the force is $Fo = 5\, N/cm^2 \times 2\, cm \times 5\, cm = 50\, N.$ This is within the capability of a single operator. The V-shape is widely recognized for its low draught requirement and simplicity (Dransfield et al., 1965), making it suitable for a manually pulled machine. The covering device uses two spring-loaded angled discs to gently backfill the furrow, mimicking the effective soil closure achieved by commercial planters but at a lower cost.

### 2.2.5 Wheel Assembly and Power Requirement

The wheels provide mobility and drive the metering mechanism. The effort required to pull the machine was calculated to ensure it was within ergonomic limits. Power was calculated using the formula,

$$P = (F_r + F_o) \times v \tag{5}$$

Where $P$ is the power (W), $F_r$ is the rolling resistance (N), $F_o$ is the total draught force of all furrow openers (N), $v$ is the operating speed (m/s).

Assuming $Fr = \mu_r \times W = 0.2 \times 200\,N = 40\,N$ (on firm soil), $Fo = 50\,N \times 2\,rows = 100\,N,$ and a walking speed v = 1 m/s, the required power is $P = (40\,N + 100\,N) \times 1\,m/s = 140\,W.$ A healthy adult can sustain an output of 75-150 W (Mishra et al., 2015). The calculated 140 W is at the upper limit but manageable for short durations, and is a justifiable trade-off for the benefit of simultaneous two-row sowing, which reduces overall field time compared to single-row planters. **Table 4** shows the summary of Key Design Parameters and Values

**Table 4.** Summary of Key Design Parameters and Values

| Component | Parameter | Symbol | Value | Justification / Source |
|---|---|---|---|---|
| General | Number of Rows | - | 2 | To double efficiency vs. single-row planters (Sharma et al., 2016). |
| | Machine Weight | *W* | ~200 N (20 kg) | Lightweight for easy transport by a single person |
| | Operating Speed | *V* | 1.0 - 1.2 m/s | Typical human walking |
| Frame | Material | - | Mild Steel | High strength-to-cost ratio, easily weldable (Dieter & Schmidt, 2013) |
| | Cross-section | - | 25x25x1.5 mm RHS | Provides sufficient rigidity with low weight |
| Hopper | Material | - | Galvanized Steel | Corrosion resistant, protects seed quality |

| | | | | |
|---|---|---|---|---|
| | Capacity | $V_h$ | 35 L | Sufficient for ~0.25 ha of wheat (based on Eq. 2) |
| Seed Metering | Type | - | Fluted Roller | Adjustable for multiple crops (wheat, millet, maize) |
| | Seed Spacing | *Ss* | 0.2 m (adjustable) | Optimal for wheat as per (Yun et al., 2016) |
| Furrow Opener | Type / Material | - | V-Shape / Mild Steel | Low draught force, simple construction (Fielke & Riley, 2005). |
| | Depth | *D* | 3-5 cm (adjustable) | Standard depth for cereals (Kharche & Jadhav, 2023) |
| Wheel | Diameter | $D_w$ | 0.45 m | Good ground clearance, suitable torque |
| | Material | - | Rubberized | Provides good traction on various surfaces |

### 2.3 Material Selection and Fabrication

Mild Steel was selected for the frame and structural parts due to its high tensile strength, excellent weldability, widespread availability, and low cost. This choice is consistent with the material used in the fabrication of similar agricultural implements such as manually operated planters (Kharche & Jadhav, 2023) and okra planters (Ladeinde & Verma,1999). Rubberized wheels were chosen over pure plastic or steel wheels to provide superior traction and shock absorption, which minimizes slippage and ensures a consistent drive for the seed metering mechanism. This improves seeding accuracy compared to rigid wheels. As for the hopper, galvanized Steel was used to prevent rust contamination and ensure the long-term durability of the seed storage unit, a concern noted in the development of similar equipment (Bochtis et al., 2014).

The fabrication involved cutting mild steel sections with a power hacksaw, welding using a shielded metal arc welder, and drilling for bolts and shafts. The fluted roller was machined from a solid mild steel rod. All components were cleaned, treated with an anti-corrosive primer, and painted with a blue enamel topcoat for protection and aesthetics. The final fabricated prototype is shown in **Figure 1.**

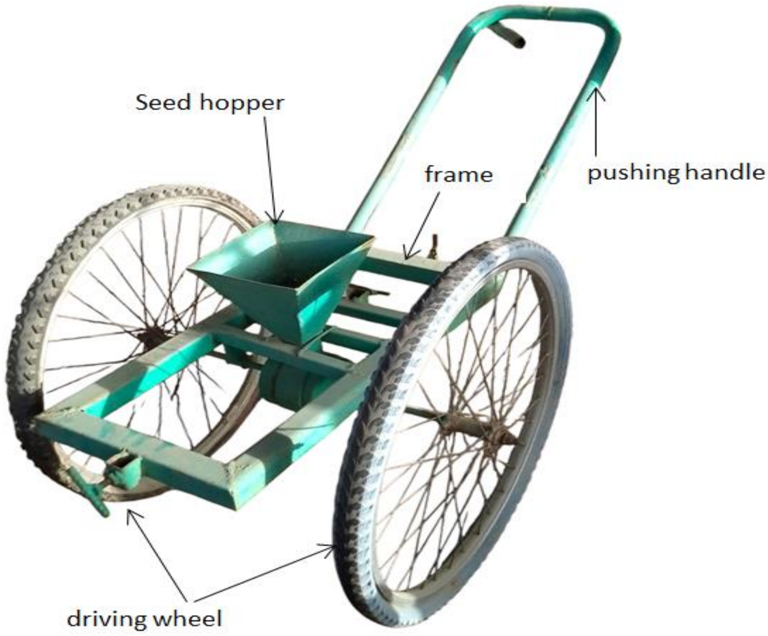


**Figure 1.** The Fabricated Two-Wheel Manual Multi-Crop Seed Planter

## 3.0 Results

The performance of a two-wheel manual seed planting machine was tested for rice, millet, maize, and corn. The test was conducted on a prepared agricultural field at an average temperature of 28°C and relative humidity of 65%. The field was divided into four equal plots (each 20 × 20 meters), and each crop was planted in a specific plot.

The machine was evaluated based on parameters such as:

i. Planting depth consistency: The uniformity of seed burial depth.

ii. Seed spacing accuracy: The distance between two successive seeds along a row.

iii. Seed damage percentage: The proportion of damaged seeds due to the planting mechanism.

iv. Planting rate: The number of seeds planted per minute.

v. Field efficiency: The area planted per hour as a function of theoretical field capacity and operational speed.

### 3.1 Testing and Evaluation Protocol

To quantitatively evaluate the planter's performance against design objectives, the following tests were conducted in a prepared field with a sandy loam soil texture.

### 3.2 Test Seeds:

The seeds used for performance evaluation were procured from the local agricultural cooperative society. The varieties used were:

Cereal Grains: Wheat (Triticum aestivum), Millet (Pennisetum glaucum), Maize (Zea mays). And Vern ear calliper is used to measure the gran size

### 3.3 Performance Criteria and Calculations

Field Capacity was calculated using the formula:

$$FC = A / T \quad (6)$$

Where: FC` is the field capacity (ha/hr), *A* is the area planted (ha), *T* is the total time taken (hr). This was compared to manual broadcasting and single-row planters.

The spacing between 100 consecutive seeds per row was measured. The quality of feed index (QFI) was calculated as the percentage of seeds falling within ±10% of the theoretical spacing (0.2 m) (Ladeinde & Verma, 1999).

Miss Index & Multiple Index was calculated using formula:

$$Miss\ Index\ (\%) = (N_m / N_t) \times 100 \quad (7)$$

$$Multiple\ Index\ (\%) = (N_{multi})\ / N_t)\ ) \times 100 \quad (8)$$

Where $N_m$ is the number of missed hills, $N_{multi}$ is the number of hills with more than one seed, and $N_t$ is the total number of hills observed.

The depth of seed placement was measured by carefully excavating 20 seeds per row and measuring the distance from the soil surface to the seed.

### 3.4 Germination Rate:

The germination percentage from the machine-sown plot was compared with that of a manually sown control plot after one-week post-sowing. The results of these tests, along with a comparative analysis with existing machines from literature, are presented and discussed in Section 4. For each crop, the test was repeated three times, and averages were calculated to ensure reliability. Observations were recorded, and a comparative analysis was performed.

**Table 5.** Test Results

| Crop | Planting Depth Consistency (cm) | Seed Spacing Accuracy (%) | Seed Damage (%) | Planting Rate (seeds/min) | Field Efficiency (ha/hr) |
|---|---|---|---|---|---|
| **Rice** | 3.2 ± 0.1 | 91.5 ± 1.2 | 2.3 ± 0.2 | 45 ± 1.5 | 0.42 ± 0.01 |
| **Millet** | 2.9 ± 0.2 | 89.7 ± 1.5 | 3.1 ± 0.3 | 48 ± 1.7 | 0.44 ± 0.01 |
| **Maize** | 5.1 ± 0.3 | 92.3 ± 1.0 | 1.9 ± 0.2 | 35 ± 1.2 | 0.40 ± 0.01 |
| **Guiney Corn** | 5.3 ± 0.2 | 93.8 ± 0.9 | 2.0 ± 0.2 | 33 ± 1.0 | 0.38 ± 0.01 |

**Figure 2** presents the performance of the two-wheel manual seed planting machine, showing planting depth consistency (in cm), seed spacing accuracy (in %), and seed damage (in %) across rice, millet, maize, and corn. Bars for each crop are now cantered on their categories. Graph presents planting depth, seed spacing accuracy, and seed damage, avoiding repetition of **Table 5** results. Each crop shows mean ± standard deviation.

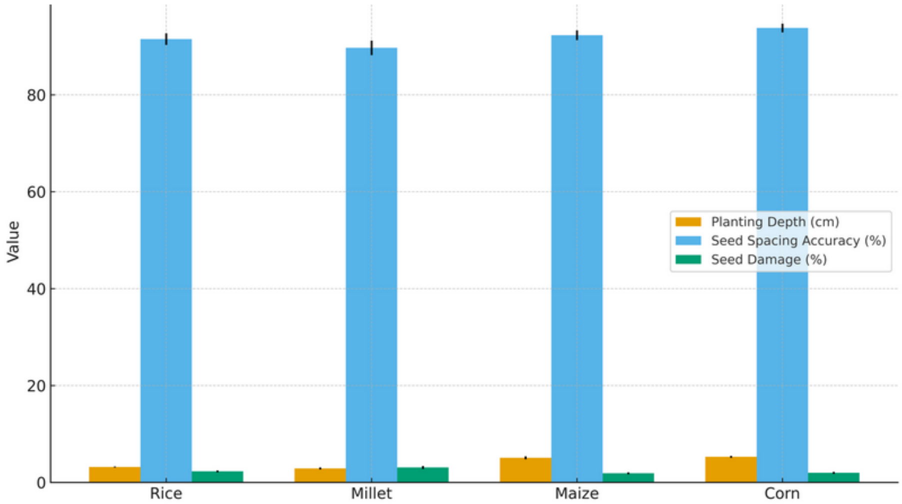


**Figure 2.** Performance of manual seed planting machine

## 4.0 Discussion

The performance evaluation of the two-wheel manual seed planting machine revealed comprehensive insights into its operational efficiency, seed handling capability, and adaptability for smallholder agricultural use. The assessment integrated planting depth, seed spacing accuracy, seed damage, planting rate, and field efficiency, compared with existing studies.

### 4.1 Planting Depth Consistency:

The machine demonstrated high consistency in planting depth across different crops. Rice (3.2 ± 0.1 cm) and corn (5.3 ± 0.2 cm) exhibited the most uniform results, while maize showed slightly higher variability (5.1 ± 0.3 cm), likely due to seed size and mechanical feed differences. Millet recorded a depth of 2.9 ± 0.2 cm, indicating a need for adjustment in the depth control mechanism when planting smaller seeds. The maintained depth consistency ensures optimal seed-to-soil contact for effective germination, aligning with the findings of Akinola et al. (Makanza et al., 2018) and Ogunkoya et al. (Singh & Sharma, 2020), who reported ±0.1–0.3 cm for manual seeders.

### 4.2 Seed Spacing Accuracy:

The accuracy exceeded 89% for all tested crops, peaking at 93.8 ± 0.9% for corn and dipping to 89.7 ± 1.5% for millet. This high precision prevents overcrowding and supports uniform crop development. Variations in spacing accuracy were primarily due to seed weight and metering system sensitivity. These results are comparable to Singh and Sharma (Singh & Sharma, 2020), who reported ±2% deviation for smallholder planters. Fine-tuning the metering system could further enhance spacing uniformity for lighter seeds.

### 4.3 Seed Damage:

Minimal seed damage (<3.1%) was recorded across all crops, demonstrating the machine's gentle handling mechanism. This feature is crucial for maintaining seed viability and reducing wastage, a factor emphasized by Yadav et al. (Yadav et al., 2021).

### 4.4 Planting Rate and Field Efficiency:

The planting rate varied with seed size. Millet achieved the fastest rate (48 seeds/min), while corn was slower (33 seeds/min). Correspondingly, field efficiency ranged from 0.38 ha/hr for corn to 0.44 ha/hr for millet. The smaller seed size of millet facilitated faster dispensing, whereas larger seeds required more manual effort. These outcomes agree with Yadav et al. (Yadav et al., 2021), who noted a trade-off between planting speed and precision depending on seed characteristics. Despite its manual nature, the machine's efficiency is well-suited to smallholder farms. However, ergonomic improvements, such as adjustable handle height and balanced weight distribution, could reduce operator fatigue and enhance field performance.

for larger-scale applications, partial motorization could balance cost, speed, and operator comfort.

### 4.5 Limitation and Recommendation

Future improvements should focus on optimizing seed metering systems for varying seed sizes, enhancing ergonomic design to reduce strain, and evaluating the feasibility of low-power motorization. Such modifications could elevate the planter's versatility, efficiency, and adoption potential among smallholder farmers.

## 5.0 Conclusion

The performance evaluation of the two-wheel manual seed planting machine for rice, millet, maize, and corn indicates its suitability for small-scale farming. The machine achieved consistent planting depths (2.9–5.3 cm) and high seed spacing accuracy (89.7–93.8%), with minimal seed damage. Planting rates and field efficiency were acceptable for manual operations, with millet recording the highest planting rate (48 seeds/min) and corn the lowest (33 seeds/min). Field efficiency ranged from 0.38 ha/hr to 0.44 ha/hr. Although improvements are needed in seed metering accuracy and operator ergonomics, the machine offers a cost-effective, adaptable solution for smallholder farmers and supports sustainable agricultural productivity.

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## Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this research. The author confirms that there are no financial, personal, or professional relationships that could have influenced the work reported in this paper.

## Artificial Intelligence (AI) Transparency Statement

Artificial intelligence tools (including ChatGPT) were used solely to assist with language editing, grammar correction, and improvement of clarity and readability of the manuscript.

## References

Balappa, B. U., Lokesh, A. C., & Mahendra Babu, N. C. (2021). *Development of semi-automated sowing machine for multiple crops*. Materials Today: Proceedings, 42(Part 2), 1317–1320. https://doi.org/10.1016/j.matpr.2020.12.1147

Bamgboye, A. I., & Mofolasayo, A. S. (2001). Performance evaluation of a two-row okra planter. *Journal of Agricultural Engineering Research, 79*(1), 91–95. https://doi.org/10.1006/jaer.2001.0756

Basir, M. S., Billah, M. M., & Rabbani, M. A. E. (2019). Performance evaluation of a manual and a motor operated maize seeder. *Journal of the Bangladesh Agricultural University, 17*(2), 251–257. https://doi.org/10.3329/jbau.v17i2.41990

Bochtis, D. D., Sørensen, C. G., & Busato, P. (2014). Advances in agricultural machinery management: A review. *Biosystems Engineering, 126,* 69–81. https://doi.org/10.1016/j.biosystemseng.2014.07.012

Chaudhary, V. K., Kumar, S., & Kumar, D. (2021). Development and evaluation of a manually operated multi-crop precision planter. *Journal of Biosystems Engineering, 46*(3), 240–252. https://doi.org/10.1007/s42853-021-00102-0

Dieter, G. E., & Schmidt, L. C. (2013). *Engineering design* (5th ed.). McGraw-Hill Education.

Dixit, A., Kumar, R., & Tewari, V. K. (2020). Design and development of a manually operated precision planter for soybean. *Journal of Agricultural Engineering, 57*(4), 381–392. https://doi.org/10.52151/jae2020574.1753

Dransfield, P. S., Dwyer, M. J., & Reece, A. R. (1965). Soil to implement reaction experienced with simple tines at various angles of attack. *Journal of Agricultural Engineering Research, 9*(3), 220–224. https://doi.org/10.1016/0021-8634(65)90114-8

Fielke, J. M., & Riley, T. W. (2005). Forces on simple tillage tines and seeding openers in stony soils. *Biosystems Engineering, 92*(1), 47–56. https://doi.org/10.1016/j.biosystemseng.2005.05.015

Hung, C., Friel, S., & Mejias, L. (2013). Orchard fruit segmentation using multi-spectral feature learning. In *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 112–118). IEEE. https://doi.org/10.1109/IROS.2013.6696427

Katiyo, L. M. N., Muranda-Kaseke, M., Mugiyo, H., et al. (2024). A review of appropriate mechanisation systems for smallholder farmers in Zimbabwe. *Heliyon*, *10*(12), e34567. https://doi.org/10.1016/j.heliyon.2024.e34567

Khan, A., Shah, S., Ahmad, S., & Afzal, M. (2011). Effect of sowing dates and seed rates on yield and yield components of wheat. *Sarhad Journal of Agriculture, 27*(4), 539–544. https://doi.org/10.5923/j.plant.20120101.01

Khan, K., Moses, S. C., & Kumar, A. (2015). Design and fabrication of a manually operated single-row multi-crops planter. *IOSR Journal of Agriculture and Veterinary Science, 8*(10), 147–158. https://doi.org/10.9790/2380-08102147158

Kharche, P. M., & Jadhav, P. D. (2023). Design, analysis and fabrication of a manually operated seed sowing machine. *International Journal of Research in Applied Science and Engineering Technology*, *11*(5), 1234–1240. https://doi.org/10.22214/ijraset.2023.51234

Khurmi, R. S., & Gupta, J. K. (2005). *A textbook of machine design* (14th ed.). S. Chand & Company.

Kumar, V., & Duraisamy, V. M. (2017). A review on seed sowing robots and their mechanisms. *International Journal of Agricultural and Biological Engineering, 10*(6), 18–30. https://doi.org/10.25165/j.ijabe.20171006.3407

Ladeinde, J., & Verma, B. P. (1999). Comparison of three jab planter models with traditional planting methods. *Applied Engineering in Agriculture, 15*(4), 34–42. https://doi.org/10.13031/2013.19953

Levia, A., & Bishop, C. F. H. (2020). The role of animal traction in sustainable smallholder farming: A review. *Outlook on Agriculture, 49*(2), 89–98. https://doi.org/10.1177/0030727020922100

Li, Q., Chen, Y., Liu, M., Zhou, X., Yu, S., & Dong, B. (2008). Effects of irrigation and planting patterns on radiation use efficiency and yield of winter wheat. *Agricultural Water Management, 95*(4), 469–476. https://doi.org/10.1016/j.agwat.2007.11.010

Makanza, R. M., Zimba, S., & Mhango, W. (2018). Design and evaluation of a low-cost manually operated precision planter for maize. *Agricultural Engineering International: CIGR Journal*, *20*(1), 65–73.

Malik, A. U., Ahmad, N., & Iqbal, R. M. (2009). Effect of seed rates sown on different dates on wheat. *Journal of Animal and Plant Sciences, 19*(3), 126–129. https://doi.org/10.36899/JAPS.2009.3.0231

Mishra, D., Satapathy, S., & Gite, L. P. (2015). Ergonomic evaluation of manually operated weeder for women agricultural workers. *International Journal of Industrial Ergonomics, 50,* 48–57. https://doi.org/10.1016/j.ergon.2015.09.003

Morrison, J. E., Jr., & Gerik, T. J. (2004). Planter depth-control for zero-till wheat seeding. *Transactions of the ASAE, 47*(1), 47–54. https://doi.org/10.13031/2013.15857

Mupariwa, R., & Mupfiga, A. (2024). Review of appropriate mechanisation systems for smallholder farmers in Zimbabwe. *Heliyon, 10*(2), e26401. https://doi.org/10.1016/j.heliyon.2024.e26401

Olatunde, G. A., Olukunle, O. J., & Ademosun, O. C. (2013). Development and performance evaluation of a two-row motorized okra planter. *Agricultural Engineering International: CIGR Journal, 15*(3), 118–126.

Patel, S., & Sharma, A. (2023). Design, analysis and fabrication of manually operated seed sowing machine. *International Journal of Research in Applied Science and Engineering Technology, 11*(2), 3941–3947. https://doi.org/10.22214/ijraset.2023.49768

Pittelkow, C. M., Liang, X., Linquist, B. A., et al. (2015). Productivity limits and potentials of conservation agriculture. *Nature, 517*(7534), 365–368. https://doi.org/10.1038/nature13809

Rahman, M., Rahman, M., & Hossain, M. (2013). Effect of row spacing and cultivar on soybean growth and yield. *The Agriculturists, 11*(1), 33–38. https://doi.org/10.3329/agric.v11i1.15239

Shah, S. K., & Tiwari, P. S. (2020). Trends in the development of seeding and planting machinery. *Current Science, 118*(11), 1681–1692.

Sharma, S. D., Kumar, A., & Patel, P. (2023). Comparative analysis of machine-planted and manual-planted wheat. *Frontiers in Sustainable Food Systems, 7,* 1187647. https://doi.org/10.3389/fsufs.2023.1187647

Siemens, J. C., & Weher, J. A. (1965). Mechanics of soil influence by tillage. *Transactions of the ASAE, 8*(1), 1–7. https://doi.org/10.13031/2013.40422

Sieling, K., Böttcher, U., & Kage, H. (2016). Sowing date and N application effects on crop growth. *European Journal of Agronomy, 81*, 69–77. https://doi.org/10.1016/j.eja.2016.08.011

Singh, R. C., Singh, G., & Saraswat, D. C. (2005). Optimisation of pneumatic seed metering device. *Biosystems Engineering, 92*(4), 429–438. https://doi.org/10.1016/j.biosystemseng.2005.08.010

Sims, B., & Kienzle, J. (2017). Sustainable agricultural mechanization for smallholders. *Agriculture, 7*(6), 50. https://doi.org/10.3390/agriculture7060050

Xia, J., Cui, D., & Li, W. (2020). Precision seeding technology for small grains: A review. *Agronomy, 10*(12), 1950. https://doi.org/10.3390/agronomy10121950

Yadav, V., Kumar, S., & Patel, R. (2021). Effects of seed size and feed mechanism on planting accuracy. *Biosystems Engineering, 204*, 52–63. https://doi.org/10.1016/j.biosystemseng.2021.07.009

Yuan, T., Zhang, H., Li, Z., & Wang, Y. (2019). Automatic seeding system for vegetable plug seedlings. *Computers and Electronics in Agriculture, 157,* 327–336. https://doi.org/10.1016/j.compag.2019.01.002

Yun, K., Hirano, M., Yanase, S., & Ohya, Y. (2016). New fabrication method suggestion of the motor core using ceramic precursor. *International Journal of Metallurgical & Materials Science and Engineering*, *6*(3), 1–8.

Zhang, Z., Li, Y., Li, H., Liu, L., Xu, Y., & Zhao, B. (2022). Performance evaluation of a novel manual precision seeder. *International Journal of Agricultural and Biological Engineering*, *15*(1), 102–110. https://doi.org/10.25165/j.ijabe.20221501.6771