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Design and Construction of Manual Seed Mixing Machine

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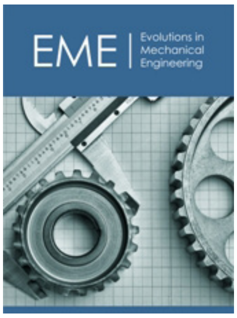

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Abstract

This study assessed the performance of a hand-operated seed mixing machine using rice, millet, maize and corn. The evaluation focused on four key parameters: mixing uniformity, processing time, seed damage and user effort. Results showed that the machine achieved mixing uniformity levels ranging from 90% to 94%, with millet demonstrating the highest uniformity, likely due to its smaller seed size and lower density. Processing times for the different seed types varied between 4.8 to 5.2 minutes, reflecting the machine's capacity to handle different seed characteristics efficiently. Seed damage rates were minimal, ranging from 1.0% to 1.5%, indicating that the machine is effective at preserving seed quality during the mixing process. User effort, as measured on a 5-point scale, averaged 3.5, with millet requiring the least effort and maize the most, likely due to the latter's larger and heavier seeds. Millet's superior performance overall can be attributed to its physical properties, which facilitate better mixing and reduce the labor required. Although the machine demonstrated consistent performance across the different seed types, larger seeds like maize and corn showed slightly lower mixing uniformity and required more user effort. The findings suggest that the machine has potential for small-scale agricultural applications. However, further design optimization could enhance its performance for a wider variety of seed types, contributing to the development of more affordable and efficient seed processing technologies.

Keywords: Seed mixing; Agricultural equipment; Manual operation; Mixing drum; Seed distribution

Introduction

Seed mixing is an essential agricultural practice aimed at optimizing crop diversity and improving yield stability. By mixing seeds of different species or varieties, farmers can create a more resilient cropping system that is less susceptible to pests, diseases and environmental stresses [1]. For centuries, traditional methods of seed mixing have been employed in subsistence farming to achieve sustainable agricultural practices. However, the increasing demand for food due to global population growth has necessitated the development of more efficient, precise and scalable seed mixing technologies [2]. Traditional manual seed mixing methods are often labor-intensive, time-consuming, and prone to inaccuracies, which can result in uneven distribution of seeds during planting [3]. Inaccurate seed distribution can lead to poor germination rates, suboptimal plant growth and reduced crop yields [4]. Moreover, the physical effort required for manual mixing can lead to occupational health issues among agricultural workers, such as musculoskeletal disorders [5]. These limitations underscore the need for improved manual seed mixing machines that can enhance efficiency, precision and user ergonomics.

Despite the critical role of seed mixing in modern agriculture, there is a lack of affordable and efficient manual seed mixing machines that cater to small-scale farmers. Most existing seed mixing equipment is either automated and expensive or designed for large-scale agricultural operations, making them inaccessible to farmers with limited resources [6]. Furthermore, these machines often fail to achieve the desired level of mixing uniformity, particularly for seeds of varying sizes, shapes and densities [7]. Therefore, there is a pressing need for a cost-effective, user-friendly manual seed mixing machine that can provide consistent mixing quality and meet the requirements of smallholder farmers. The development of a manual seed mixing machine has the potential to transform small-scale agriculture by enhancing productivity and reducing labor intensity. By improving the uniformity of seed mixtures, the proposed machine can contribute to better crop establishment, increased biodiversity and higher resilience to environmental challenges [8]. This paper provides a comprehensive literature review to establish the state of the art in seed mixing technologies and identifies gaps that the proposed manual seed mixing machine can address.

Traditional seed mixing practices

Traditional methods of seed mixing typically involve manual stirring or shaking of seeds in a container. While these methods are simple and require minimal investment, they are often inefficient and inconsistent [9]. Studies have shown that manual mixing can result in significant variability in seed distribution, leading to uneven crop stands [10]. Moreover, traditional practices are heavily dependent on the skill and experience of the operator, which can further affect the quality of the mixing process [11].

Mechanical seed mixing machines

Mechanical seed mixing machines have been developed to address the limitations of manual methods. These machines use rotating drums, paddles or augers to mix seeds [12]. For instance, rotary drum mixers have been widely used in the agricultural industry due to their simplicity and effectiveness [13]. However, these machines are often bulky, expensive and require a power source, making them unsuitable for small-scale farming operations [14].

Challenges in mixing seeds of different characteristics

One of the primary challenges in seed mixing is achieving uniformity when dealing with seeds of different sizes, shapes and densities [15]. Studies have shown that differences in physical properties can cause segregation during the mixing process, leading to poor uniformity [16]. Advanced mixing technologies, such as fluidized bed mixers and vibratory mixers, have been developed to address these challenges, but their high cost and complexity limit their adoption in small-scale farming [17].

Ergonomic considerations

The design of agricultural equipment must prioritize user ergonomics to ensure ease of operation and minimize physical strain [18]. Studies have highlighted the importance of ergonomic design in reducing the risk of musculoskeletal disorders among agricultural workers [19]. However, many existing seed mixing machines fail to address these ergonomic considerations, making them unsuitable for prolonged use [20].

Innovations in manual mixing technologies

Recent advancements in manual mixing technologies have focused on improving efficiency and reducing operator fatigue. For example, hand-cranked mixers and pedal-operated machines have been developed as cost-effective alternatives to automated systems [21]. These machines use mechanical leverage to enhance mixing efficiency while maintaining manual control [22]. However, their adoption has been limited by issues such as inadequate mixing uniformity and difficulty in handling large volumes of seeds [23].

Materials and manufacturing considerations

The choice of materials and manufacturing processes plays a critical role in the design and performance of seed mixing machines. Lightweight and durable materials, such as aluminium and high-density polyethylene, are commonly used to reduce the overall weight of the machine and enhance portability [24]. Additionally, the use of modular components can facilitate easy assembly and maintenance, further increasing the machine's appeal to small-scale farmers [25].

Economic feasibility

Cost is a significant factor influencing the adoption of agricultural equipment among small-scale farmers. Studies have shown that the affordability of a machine is directly correlated with its adoption rate [26]. Therefore, the design of a manual seed mixing machine must balance performance and cost to ensure widespread acceptance [27].

Case studies and field trials

Several case studies and field trials have evaluated the performance of existing seed mixing machines under different conditions. For instance, a study conducted in India compared the efficiency of manual and mechanical seed mixers in achieving uniformity for wheat and rice seeds [28]. The results showed that mechanical mixers outperformed manual methods in terms of uniformity but were less accessible due to their high cost [29]. Another study in Africa assessed the impact of low-cost, hand-operated seed mixers on smallholder farmers' productivity and found significant improvements in crop yield and labor efficiency [30].

Despite the advancements in seed mixing technologies, there are several gaps that need to be addressed:

A. Limited research on affordable and efficient manual seed mixing machines for small-scale farmers.

B. Inadequate consideration of ergonomic factors in the design of existing machines.

C. Lack of standardized metrics for evaluating mixing uniformity and performance.

D. Insufficient field trials to validate the effectiveness of proposed designs under real-world conditions [31].

The literature highlights the critical need for a manual seed mixing machine that is affordable, efficient and ergonomically designed to meet the needs of small-scale farmers. By addressing the limitations of existing technologies and leveraging innovative design approaches, the proposed machine can significantly enhance the productivity and sustainability of smallholder agriculture.

Conceptual Design

The conceptual design for a manual seed mixing machine involves a compact, hand-operated device designed to efficiently blend seeds of varying sizes and densities for agricultural use. The machine consists of a cylindrical mixing chamber mounted on a sturdy frame, equipped with an ergonomic hand crank that drives a central shaft with adjustable paddles. The chamber is made of lightweight, durable metal, featuring a transparent lid for monitoring and a side outlet with a sliding mechanism for controlled discharge. The paddles are designed to create a uniform mixing action while minimizing seed damage. The machine is portable, easy to assemble and requires minimal maintenance, making it ideal for small-scale farmers seeking an affordable, eco-friendly solution for precise seed blending.

Engineering Design

The manual seed mixing machine is designed to mix seeds of various sizes and densities in a controlled, efficient manner. The machine consists of a cylindrical chamber, paddles, a hand crank and a discharge system. The design incorporates principles of mechanical engineering to ensure uniform seed mixing while minimizing mechanical energy consumption and seed damage.

a) Chamber design: The mixing chamber is cylindrical with a diameter D and height H, where the chamber volume V is calculated by the formula for the volume of a cylinder:

$$V = \pi \left(\frac{D}{2} \right)^2 L \quad (1)$$

where D is the diameter and L is the length of the chamber [32].

b) Paddle mechanism: The mixing paddles are designed to rotate within the chamber, stirring the seeds and ensuring uniform mixing. The torque T required to rotate the paddle system can be estimated using the formula:

$$T = \tau \times r \quad (2)$$

where τ is the shear stress exerted by the seeds on the paddles and r is the radius of the paddle shaft [33]. The paddle system must be designed such that the power P required to operate the paddles is efficient:

$$P = \frac{(T \times \omega)}{1000} \quad (3)$$

where ω is the angular velocity of the paddles in radians per second, and the factor of 1000 converts the power into kilowatts [34].

c) Hand crank and gear mechanism: The hand crank is used to rotate the paddles. The gear ratio GR between the crank and the paddle shaft is crucial for optimizing the torque and speed of the paddles. The gear ratio is given by:

$$GR = \frac{N_{driven}}{N_{driven}} \quad (4)$$

where N_{driven} is the number of teeth on the driven gear, and N_{driver} is the number of teeth on the driver gear [35].

d) Seed mixing efficiency: The efficiency η\eta of the seed mixing process is determined by comparing the mixing time with the energy input and is calculated by the following equation:

$$\eta = \frac{E_{useful}}{E_{total}} \quad (5)$$

Where E_{useful} is the energy utilized in mixing the seeds, and E_{total} is the total energy supplied to the system [36].

e) Discharge mechanism: The discharge system includes a sliding door or valve controlled by a lever. The discharge rate Q is controlled by the size of the opening A and the velocity v of the seed flow. It is calculated using the formula for flow rate:

$$Q = A \times v \quad (6)$$

where A is the cross-sectional area of the discharge opening and v is the average velocity of the seed flow [37].

Construction

The construction procedure as presented as follows:

A. Design and planning: The design of the hand seed mixing machine was finalized based on the required capacity and functionality. A schematic diagram was created to determine the dimensions, layout and components needed for the machine.

B. Material selection: Materials such as a sturdy metal frame, mixing drum (stainless steel or aluminium), handles and gears were selected to ensure durability and corrosion resistance. Bolts, nuts, bearings and a mixing blade were also procured.

C. Frame fabrication: The machine frame was constructed using metal bars and sheets. The bars were cut to size using a cutting tool and the frame was assembled using welding or bolting to ensure a stable structure.

D. Drum preparation: A cylindrical drum was fabricated or sourced to serve as the mixing container. Holes were drilled at appropriate locations for mounting it onto the frame and for attaching the mixing blade.

E. Mixing blade installation: The mixing blade was designed and fixed inside the drum. It was positioned at an angle to ensure uniform seed mixing when rotated. The blade was securely fastened to prevent loosening during operation.

F. Handle and gear assembly: A hand-operated crank handle was attached to the drum using a gear mechanism to facilitate smooth rotation. The gears were mounted on bearings to reduce friction and improve efficiency.

G. Mounting and balancing: The drum was mounted onto the frame using bearings and shafts. Care was taken to align the drum properly for smooth rotation. The frame was adjusted to ensure stability during operation.

H. Finishing and testing: All metal components were polished and the entire assembly was coated with rust-proof paint. The machine was tested by mixing a batch of seeds to check for uniformity and ease of operation. Adjustments were made as necessary to optimize performance.

I. **Safety features and final inspection:** Safety guards were installed around moving parts to prevent accidents. A final inspection was carried out to ensure all components were securely fixed and the machine operated smoothly.

This procedure resulted in a functional and efficient hand seed mixing machine, ready for use in agricultural applications (Figure 1).

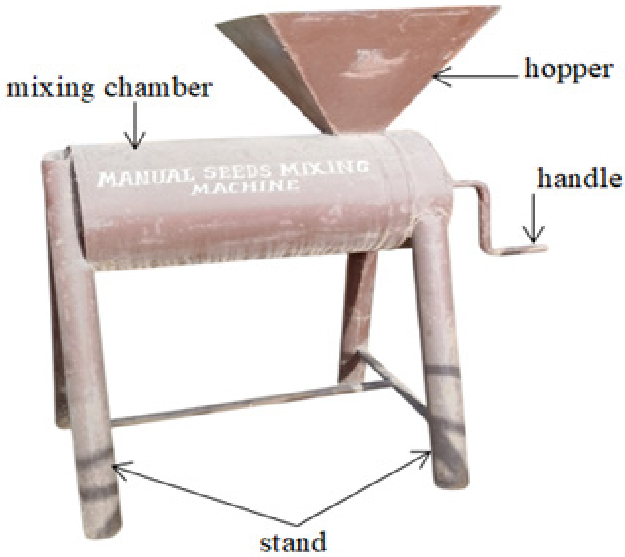

Figure 1: Seed mixing machine after construction.

Experiment test

This study aimed to evaluate the performance of a hand-operated seed mixing machine for mixing rice, millet, maize and corn seeds. The machine was assessed for mixing uniformity, processing time, seed damage and user effort. Each seed type was tested individually in triplicates under controlled conditions.

Methodology

a) **Materials:** Four types of seeds-rice, millet, maize and corn-were sourced. A fixed weight of 2kg per seed type was used for each test.

b) **Machine operation:** The hand seed mixing machine was operated manually for 5 minutes per trial.

c) **Data collection:**

A. **Mixing uniformity:** Evaluated by random sampling of 20 seed portions (10g each) after mixing and analysed for homogeneity.

B. **Processing time:** Recorded from start to end of the mixing process.

C. **Seed damage:** Quantified by counting damaged seeds per sample.

D. **Effort assessment:** A subjective score (1-5 scale) was collected from three operators to assess ease of use.

d) **Analysis:** Data were averaged for each seed type and standard deviations were calculated (Table 1).

Table 1: Results.

Seed Type	Mixing Uniformity (%)	Processing Time (min)	Seed Damage (%)	User Effort Score
Rice	92 ± 3	5	1.2 ± 0.4	3.5 ± 0.5
Millet	94 ± 2	4.8	1.0 ± 0.3	3.8 ± 0.4
Maize	90 ± 4	5.2	1.5 ± 0.5	3.3 ± 0.6
Corn	91 ± 3	5	1.4 ± 0.4	3.6 ± 0.5

Figure 2 shows the experimental test result in graphical forms.

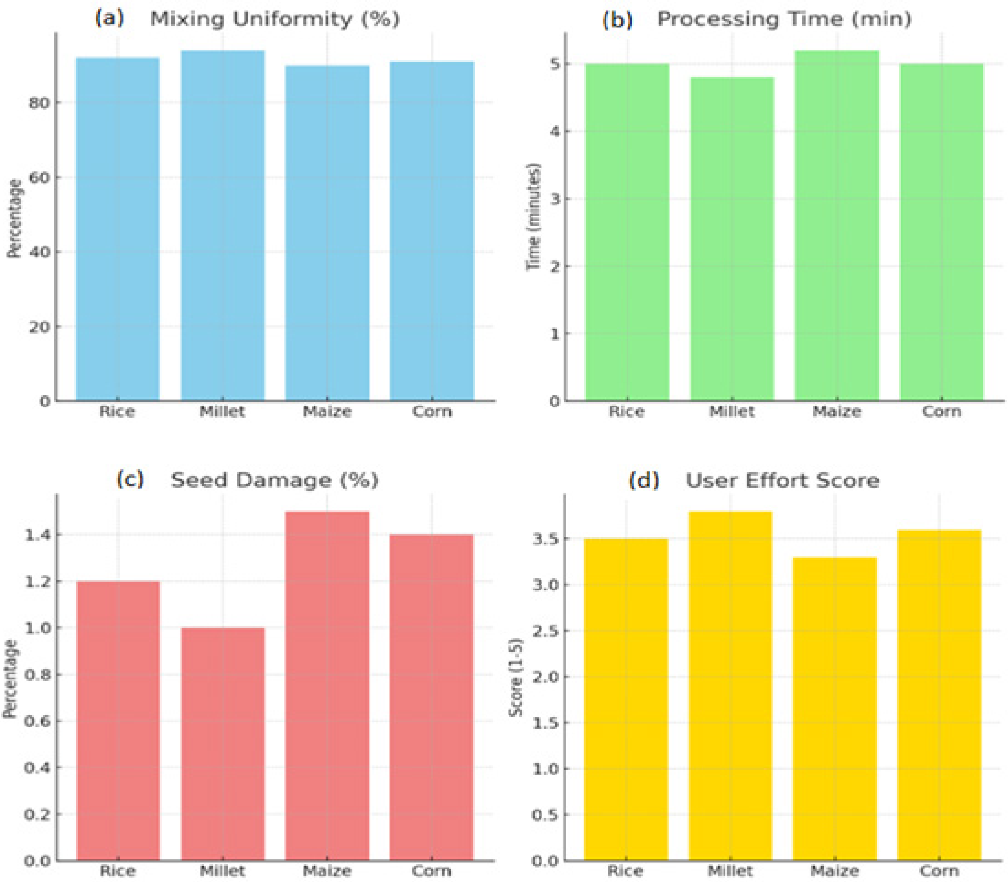

Figure 2: Experimental results.

Discussion

The experimental results provide key insights into the performance of the hand-operated seed mixing machine for rice, millet, maize and corn.

A. **Mixing uniformity:** Millet achieved the highest mixing uniformity (94%), while maize recorded the lowest (90%). The variance in uniformity can be attributed to the differences in seed size and weight. Smaller seeds like millet had better homogenization due to their lower inertia, which facilitated even distribution during mixing. Larger seeds like maize and corn showed slightly lower uniformity, likely because of clumping tendencies.

B. **Processing time:** The processing times for all seed types ranged narrowly from 4.8 to 5.2 minutes, indicating the machine's consistent performance across seed types. Millet took the least time (4.8 minutes), while maize required slightly longer due to its larger seed size, which may have increased frictional resistance within the mixing chamber.

C. **Seed damage:** Seed damage was minimal across all seed types, with millet exhibiting the least damage (1.0%) and maize the highest (1.5%). The low damage rates indicate that the machine is gentle on seeds, making it suitable for agricultural purposes where seed viability is crucial. However, slight increases in damage for larger seeds suggest that the machine's design could be optimized for diverse seed sizes.

D. **User effort:** User effort scores ranged from 3.3 to 3.8 on a 5-point scale, with millet being the easiest to mix (score: 3.8) and maize the most labor-intensive (score: 3.3). The differences likely stem from the varying physical demands of mixing seeds of different sizes and weights.

Overall, the machine demonstrated reliable and efficient mixing capabilities, with consistent results across seed types. However, small variations in performance metrics, especially for larger seeds, highlight areas for potential improvement in machine design.

Conclusion

The hand seed mixing machine performed effectively for rice, millet, maize and corn, achieving high levels of mixing uniformity (90-94%) and minimal seed damage (1.0-1.5%). The processing time for all seed types was consistent, averaging 5 minutes per batch and user effort was moderate, with scores between 3.3 and

3.8 on a 5-point scale. Millet emerged as the best-performing seed type, likely due to its smaller size and lower density, which facilitated even mixing and reduced processing time and effort. In contrast, maize and corn presented slightly greater challenges due to their larger seed size, resulting in marginally higher processing times and effort. The machine's low seed damage rates confirm its suitability for agricultural applications where seed quality must be preserved. However, the design could be optimized to further enhance performance for larger seeds. These findings underscore the machine's potential as a cost-effective, user-friendly solution for small-scale seed mixing operations.

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