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Research Article

DEVELOPMENT AND PERFORMANCE EVALUATION OF COTTON SEED COATING MACHINE

Rashid Mehmood[1], Zia Ul Haq[1*], Hira Bashir[1], Muhammad Ahmad[1], Aatif Naseer[1], Aksar Ali Khan[1], Syed Mudassir Raza[2], Asif Ali Mirani[4], Abu Saad[1], Muhammad Mohsin Ali[3], Tajwar Alam[5]

[1]*Faculty of Agricultural Engineering and Technology, PMAS Arid Agriculture University Rawalpindi*
[2]*College of Engineering, Huazhong Agricultural University, 430070, Wuhan, China*
[3]*Agricultural Engineering Institute, Pakistan Agricultural Research Council, 44000, Islamabad, Pakistan*
[4]*Agricultural Engineering Division, Pakistan Agricultural Research Council, 44000, Islamabad, Pakistan*
[5]*Institute of Hydroponic Agriculture, PMAS Arid Agriculture University Rawalpindi*
**Corresponding Authors: zia.ch@uaar.edu.pk*

Abstract

Mechanical seed coating has been globally adapted to protect them from fungus, soil-borne diseases, and other harmful substances. In crop production, attaining the potential yield is the main concern of farmers. Among the other problems of low yield, fungal attack is associated with germination stage. To avoid this problem, farmers are using fungicides with the help of bags or clothes. The traditional method is time-consuming, labor-intensive, costly as well as inefficient for uniform coating of seed. To address this challenge and to speed up seed coating process, a manually/motor-operated seed coating machine was designed at CAD/CAM Lab by using Auto CAD software and developed at Agricultural Engineering Workshop of Arid Agriculture University, Rawalpindi. The newly developed machine was tested at two levels, manually/motor-operated and compared with a traditional method. Its performance was evaluated using (metalaxyl + mancozeb) fungicide under three treatments levels: T1 (traditional coating method), T2 (manual coating method), and T3 (mechanical coating method). The data from the experiment on fully coated seed percentage, semi-coated seed percentage, and uncoated seed percentage were collected and statistically analyzed by using Statistix 8.1. Mechanical seed coating method T3 demonstrates superior results, achieving coating efficiencies of 79.2%, 85.4%, and 93.2% at 2-, 4-, and 6-minutes' intervals, respectively. The machine offers a cost-effective and efficient solution for cotton-seed treatment, significantly enhancing seed coating uniformity and reducing seed breakage compared to conventional practices.

Keywords: *Broken percentage, Cotton yield, Fungal attack, Fully-coated percentage, Semi-coated percentage, Un-coated percentage.*

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1. INTRODUCTION

Cotton is a vital cash crop in Pakistan, which subsidizing significantly to the country's economy and provides services to millions of people. Cotton is a remarkably important cash crop in Pakistan, providing food, fiber, and oil. It has the fundamental role in foreign exchange (55%), and production represents 1.5% in GDP and 7.1% in value-added agriculture (GOP, 2015). Cotton production is a central part of the national economy. Pakistan is the fifth largest fabricator of cotton and the third largest exporter of raw cotton in the world (International Cotton Advisory Committee, 2019).

Seed coating is the operation of covering seed with ingredients that might obscure the real shape and size of the kernel, consequential in a worthwhile weight rise and enhancing plant quality, preventing insects, boosting seed controlling properties, and modifying sprouting and sprig formation. This operation is used to change the corporeal features of seed (Avelar *et al*., 2012). Seed-coating skills could be a way to improve plantlet inception and plant development (Liu, 2010; Madsen, 2012). Seed coating has been used long time, specifically for vegetable seeds, to escalation its size, modify its shape and smoothness, to make it easy for straight sowing, and modify the relation among seeds and soil (Baudet and Peres, 2004; Levien *et al*., 2008).

Seed coating techniques in agriculture are not newly discovered. Coatings, caking, dry powder mixing, and other executions have been used to cover seeds (and seedlings) and increase the production of different ways of agricultural row crops for many years. The newly discovered innovations and most advanced techniques are being industrialized today for making farmers' lives easier. Numerous types of seed coatings that bring an extensive range of benefits and not just for coming up with pesticide/disease protection or easing planting regularity. Dry powder covered seed approach to seed coating can be considered a conventional way of coating seeds, though it still manages to be an effective way to improve seed germination and seedling health. All it involves is taking a dry powder made of desired bio-materials or bio-enhancements and mixing it manually with select seed for planting (Summit, 2023).

In the ancient years, seed improvement techniques, together with seed grooming and seed covering, have been engaged to improve seed staging bear from explicit state of affairs and rules. Seed inflation via seed coating dazed these problems. Seed coating terminologies have taken as an auspicious approach to reduce the duress of agricultural activities and conflict with abiotic and biotic stresses. Seed coating is a reliable approach to apply chemical materials in close proximity to sowing seeds, which eventually increases seed quality and production via modifying seed placement and performance. Also, the consumption of non-active or active materials into seeds during seed coating/covering modifies the original shape and size of seeds, therefore enhancing a build-up in seed weight, which simplifies seed handling and sowing (Zhang, 2022; Khan, 2025).

Seed treatment is essential for all crops, as it helps to manage and eliminate fungi, insects, and other pests that can harm seeds, seedlings, and plants. Employing cutting-edge technology and agricultural machinery is crucial for effective seed treatment, which ultimately increases producer profitability. The demand for seed treatment in Brazil has increased, particularly in terms of fungicide usage and application methods, and equipment. Seed treatment methods continue to evolve, encompassing changes in tools, chemicals, and biological materials used in the process (Madruga *et al*., 2023).

Different types of equipment are used for treating and coating seeds, including pelleting pans, rotary pans, and dry powder applicators. These machines can apply liquids, dry powders, or a combination of both to the seeds. Seed coating technology offers several potential advantages, such as improving crop establishment, enhancing seed performance, and providing early-season pest management for sustainable agricultural systems (Afzal *et al.*, 2020).

Non-natural covering of seed is hand-me-down to enhance seed handling and for the carriage of protectants, symbiotic microorganisms, micronutrients, soil adjuvants, germination promoters, growth regulators, and colors. Now, industry is concerned with protective techniques (e.g., insecticides and pesticides), seed bulking, and overdoing for marketing purposes. Seed coatings are mostly used for rapeseed and vegetables. (Pedrini *et al.*, 2017).

For the seed coating operation, the revolving drum sets the seed in stirring, and, in the recent machine system, seed rotation is improved by two outlets that combine at opposite to each other for regulated pressured air. The hinge with the spinning disc is lowered into the drum. The disc rotates at a fast speed. Spray the mixture with the dissolved coating chemical on the rotating disc using a nozzle with a narrow needle. By the strong centrifugal force, the applied drops are finely spread and thrown backward and forward by the moving seed. The rotational action also reduces the chance of having the seeds bond with each other as the coating seeds become dry. If the momentum is too fast, the flow of the action of machine becomes too disturbed, and some seeds may be thrown out of the drum or the coarse contacts among the seeds may become so enormous that the bid coating is lost in speck. If the speed is too slow, seeds may attach as the sue coating solution becomes dry (Zaim *et al*., 2023).

Traditional cottonseed coating methods, such as manual mixing using bags or cloths, are labor-intensive, time-consuming, and prone to inconsistent coating. These methods often result in uneven distribution of fungicides, increased seed breakage, and higher material wastage. In contrast, the proposed portable seed coating machine offers a controlled and automated environment for seed treatment. Its rotating drum mechanism ensures uniform application of fungicides across all seeds while minimizing physical damage. The closed system also reduces exposure to chemicals, enhancing operator safety. By significantly improving coating uniformity (up to 93.2 at 6 minutes) and reducing reliance on manual labor, the machine addresses the major drawbacks of conventional techniques and presents a scalable solution for small to medium-scale farmers.

2. MATERIALS AND METHODS

The 3D design of the cotton seed coating machine was made in CAD/CAM Lab of the Faculty of Agricultural Engineering & Technology. Design of the working machine was made on AutoCAD software as shown in Figure 1. Design in AutoCAD involves conceptualizing the structure, components, and assembly. Utilizing 2D and 3D drafting tools, precise measurements and detailing are employed to ensure accuracy. The iterative design process allows for modifications and improvements before finalizing the detailed technical drawings. For performance evaluation of the machine, an experiment was conducted at the Farm Machinery Workshop, PMAS Arid Agriculture University, Rawalpindi.

2.1 Selection of Materials

The required materials for the manufacturing of machine include stainless steel sheet, angle iron, shaft, pulleys, welding rods, bolts, drive gear, driven gear, and electric motor. The material selected was purchased from local market due to its cost-effectiveness and frequent availability. Consideration was given to initial material costs, maintenance, corrosion, and other potential cost savings. The use of both aluminum and stainless-steel results in significant life-cycle cost savings as compared to carbon steel. Furthermore, the combined economic and fire safety benefits that stainless steels offered were unequalled by the alternative materials (Gardner, 2005).

The machine consists of the following parts;

1. Frame **2.** Pulley **3.** Feeding pan/Coating unit **4.** Electric motor **5.** Gears

2.2. Fabrication of Cotton Seed Coating Machine

The designed coating machine was developed and tested at the Farm Machinery Workshop, PMAS Arid Agriculture University, Rawalpindi. The specifications of machine included height 1.37 m, width 0.58 m, depth 0.6 m, and total capacity of rotating drum 110 kg. The main parts of machine are shown in Figure 2.

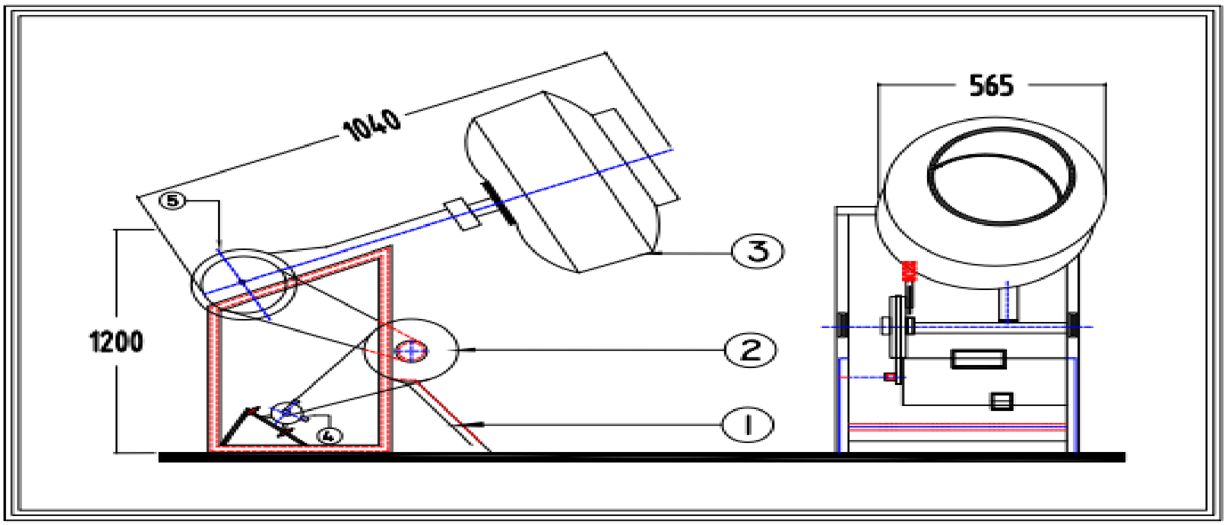

Figure 1: 3D design of cotton seed coating machine

Figure 2: Cotton seed coating machine

2.2.1. Frame

The frame of the machine was made of galvanized iron with dimensions of 1.37 m by 1.06 m, height of 1.37 m, width of 0.58 m and depth of 0.6 m.

2.2.2. Feeding Pan or Coating Unit

Cylindrical shape made up of stainless-steel sheet with a diameter of 0.97 m, depth of 0.6 m, and with a feeding opening with a 0.97 m diameter and 1.37 m height. Measured the thickness of the stainless sheet with the help of the vernier caliper. Welded the different angles (made of iron for making) to make the frame. Used a gas cutter machine for molding the angles into the handle, which enables drum to rotate.

2.2.3. Pulley

Pulleys are used to transfer power from the motor to the rotating drum, which involves a belt running between the motor pulley and the drum pulley, ensuring the drum rotates smoothly. By adjusting the size of the pulleys, the speed of the drum can be controlled. A larger motor pulley is paired with a smaller drum pulley, which increases the speed, while the opposite setup decreases it. Pulleys help maintain consistent rotational movement of the drum, which is essential for uniform seed coating. The circumference of the pulley is 2.23 m.

2.2.4. Electric Motor

The use of an electric motor in a seed coating machine is fundamental to the efficient operation of the seed coating process. The electric motor provides the necessary rotational force to the drum, ensuring that seeds are consistently and uniformly coated with the protective or nutritive materials. By driving the drum's rotation, the electric motor enables a controlled and continuous motion, which is crucial for the even distribution of coating materials over the seeds. The electric motor used for the machine was of 1.5 Hp with 1400 rpm.

2.3. Dimensions of Machine

The dimensions of cotton seed coating machine are 1.60 m x 0.7 m x 1.32 m. The weight would be approximately 110 kg, which can perform the desired function. Length of machine = 1.6 m.

- Height of machine = 1.32 m
- Width of machine = 0.71 m
- Capacity of rotating drum = 110kg
- Circumference of drum = 2.2 m
- Circumference of tyres = 0.05 m

2.4. Volume of Drum

The volume of a drum is the amount of space inside the drum, typically measured in units of cubic units such as cubic meter (m3), cubic feet (ft3), and liters (L) etc.

As drum consists of three parts so determine the volume one by one.

2.5. Volume of conical shape of the rotating drum (front)

The volume of the conical shape of the front side of the drum is calculated by the formula through equation (1) according to (Turmudi, 2019).

$$V_1 = 1/3\pi\ (R^2+r^2+Rr) \times h \ldots\ldots\ldots\ldots\ldots (1)$$

Where;

V1= Volume of conical shape of the drum (front)

R= Radius of the center of the drum to end side of the conical shape

R= Radius of the center of the drum to end side of the gate

H= Height of the conical shape of drum

By putting the values in the equation (1),

$$V1= 1/3\times 3.14\ (132+7.52+13\times 7.5) \times 3$$

$$V1= 16614.8\ cm3$$

2.6. Volume of conical shape of the rotating drum (back)

The volume of the conical shape of the back side of the drum is calculated by the formula through equation (2) according to (Turmudi, 2019).

$$V_2 = 1/3\pi\ (R^2+r^2+Rr) \times h \ldots\ldots\ldots\ldots (2)$$

Where;

V2= Volume of conical shape of the drum (back)

R= Radius of the center of the drum to end side of the conical shape

R= Radius of the center of the drum to end side of the gate

H= Height of the conical shape of drum

By putting the values in the equation (2), given;

$$V2= 1/3\times 3.14\ (132 + 9.52 + (13 \times 9.5)) \times 5$$

$$V2= 32801.9\ cm3$$

2.7. Volume of cylindrical part of drum

The volume of the circular part of the drum is calculated by the formula through equation (3) according to (Day, 2024).

$$V3= \pi r2h \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where;

V3= Volume of circular shape of the drum

R= Radius of the center of the drum to end side of the circular shape

H= Height of the circular shape of drum

By putting the values in the equation (3), given;

$$V3= 3.14 \times 132 \times 7$$

$$V3= 60902.5\ cm3$$

2.8. Total volume of drum

The total volume of the drum is calculated by the formula through equation (4).

$$V_{total} = V1+V2+V3 \ldots\ldots\ldots\ldots... (4)$$

Where,

V1= Volume of conical shape of front part of the drum

V2= Volume of conical shape of back side of the drum
V3= Volume of circular part of the drum
By putting the values in the equation (4), given;

$$V_{total} = 16614.8+32801.9+60902.5$$

$$V_{total} = 110319.2 \text{ cm3}$$

Here, this volume is in the cubic inch and convert it into the cubic meter as;

V_{total} = 0.11 m3

1 cubic meter = 1000 liters

V_{total} = 0.11 m3 × 1000 L

V_{total} = 110 liters

2.9. Statistical Analysis

Experimental data were analyzed by using RCBD (Randomized Complete Block Design) in “Statistix8.1” software at 5% level of probability as used by (Khan *et al*., 2025).

3. RESULT AND DISCUSSION

The performance of newly developed machine was evaluated in terms of fully, semi, uncoated, and breakage percentage for 2, 4, and 6 minutes of interval. Results of various parameters of different treatments are discussed as follows;

3.1. Fully Coated Seed (%)

Fully coated seed (%) is the number of seeds which was completely coated with chemical (metalaxyl+mancozeb) during coating operation. The mean value of fully coated percentage in treatment T1 (traditional coating method), treatment T2 (manual coating method) and treatment T3 (mechanical coating method) 65, 72.6 and 79.2% at 2 minutes’ time interval, 68, 81.8 and 85.4% at 4 minutes’ time interval and 75.4, 88 and 93. 2% at 6 minutes time interval as shown in Figure 3. The highest value of fully coated percentage was found in treatment T3, while the lowest value was observed in treatment T1. Statistical analysis showed that fully coated percentage in treatment T3 mechanical coating method, was significantly different from all other treatments (T1 & T2) at 5% level of probability. The data also reviews that coating percentage increases as time interval increases (from 2 to 6 minutes). These results are parallel to the findings of (Obaia *et al*., 2020), who found that the maximum value of fully coated seed (%) was observed when the experiment was conducted for 12 min coating time in comparison with 3,6 and 9 min. These findings also suggest that the mechanical method performed better as compared to traditional methods.

3.2. Semi Coated Seed (%)

Semi-coated seed (%) number of seed which was partially coated with chemical (metalaxyl + mancozeb) during coating operation. The values of semi coated percentage in treatment T_3 (mechanical coating method), treatment T_2 (manual coating method) and treatment T_1 (traditional coating method) 20.4, 16.4 and 11.6% at 2 minutes’ time interval, 18.2, 10.8 and 8.2% at 4 minutes’ time interval and 11.6, 3.8 and 2.2% at 6 minutes’ time interval as shown in figure 4. The highest value of semi-coated percentage was found in treatment $T_{3,}$ while lowest value was observed in treatment T_1. Statistical analysis showed that semi-coated percentage in treatment T_3 mechanical coating method, was significantly different with all other treatments (T_1 & T_2) at a 5% level of probability. The data also shows that coating percentage increases as time interval increases (from 2 to 6 minutes). These results are parallel to the findings of (Obaia *et al*., 2020), who found that the mechanical coating method performed better as compared to the conventional method.

3.3. Uncoated Seed (%)

Uncoated seed (%) is the number of seeds which was left uncoated with chemical (metalaxyl + mancozeb) during coating operation. The time interval between coatings significantly impacts the uncoated percentage of cotton seeds, with conventional methods showing a higher percentage of uncoated seeds over time due to uneven distribution. In contrast, manual and

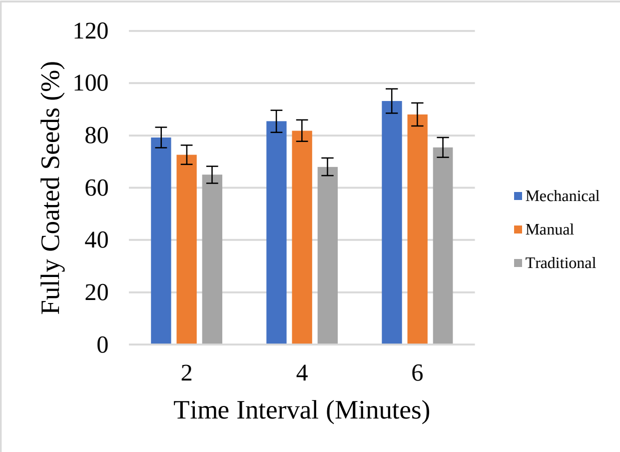

Figure 3: Fully coated seed (%) at different time intervals

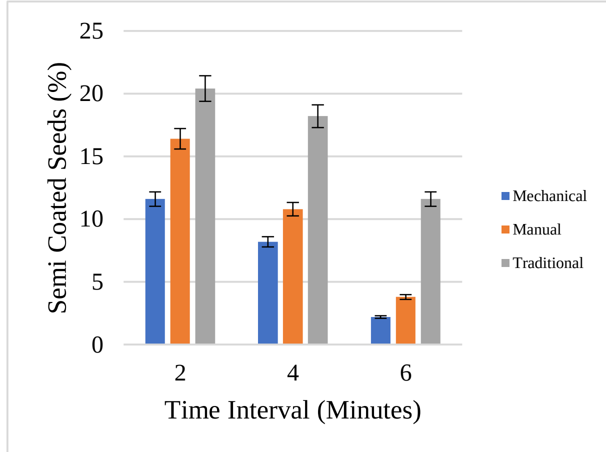

Figure 4: Semi-coated seed (%) at different time intervals

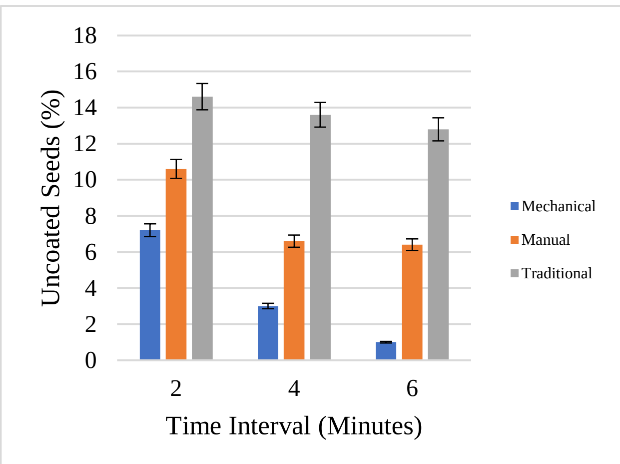

Figure 5: Uncoated seed (%) at different time intervals

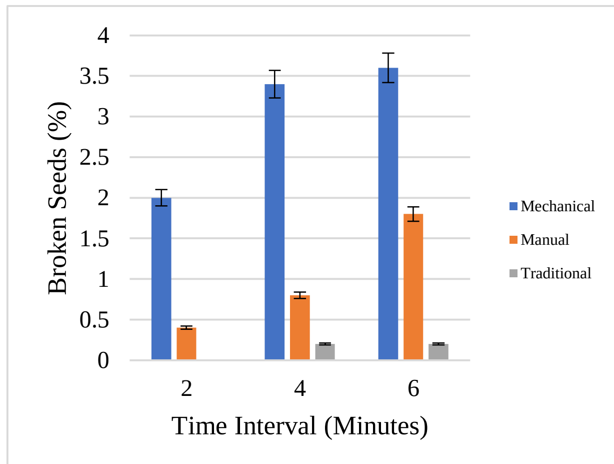

Figure 6: Broken seed (%) at different time intervals

mechanical methods maintain a lower percentage of uncoated seeds, even at longer time intervals, more precise application. The values of uncoated percentage in treatment T_3 (mechanical coating method), treatment T_2 (manual coating method) and treatment T_1 (traditional coating method) 14.6, 10.6 and 7.2% at 2 minutes' time interval, 13.6, 6.6 and 3% at 4 minutes' time interval and 12.8, 6.4 and 1% at 6 minutes' time interval as shown in figure 5. The highest value of uncoated percentage was found in treatment $T_{3,}$ while the lowest value was observed in treatment T_1. Statistical analysis showed that uncoated percentage in treatment T_3 mechanical coating method was significantly different with all other treatments (T_1 & T_2) at a 5% level of probability. The data also shows that coating percentage increases as the time interval increases (from 2 to 6 minutes). These results are in line with the findings of (Obaia *et al.*, 2020), who found that the minimum value of Uncoated seed (%) was observed in mechanical coating method as compared to conventional method.

3.4. Broken Seeds (%)

Broken seed (%) is the number of seeds broken during coating operation. The values of broken percentage in treatment T_1 (traditional coating method), treatment T_2 (manual coating method) and treatment T_3 (mechanical coating method) 0, 0.4 and 2% at 2 minutes' time interval, 0.2, 0.8 and 3.4% at 4 minutes' time interval and 0.2, 1.8 and 3.6% at 6 minutes' time interval as shown in figure 6. The highest value of broken percentage was found in treatment T_3, while lowest value was observed in treatment T_1. Statistical analysis showed that broken percentage in treatment T_3 mechanical coating method was significantly different from all other treatments (T_1 & T_2) at 5% level of probability. This may be attributed to the mechanical forces applied during the coating process, such as the speed of rotation and friction between seeds and the coating drum. The data also shows that coating percentage increases as time interval increases (from 2 to 6 minutes). These results are similar to the findings of (Zeybek, 2010; Khan, 2024), who concluded that the breakage seed (%) in the mechanical coating method had the highest percentage as compared to manual and conventional coating methods.

4. CONCLUSION

The indigenously developed cotton seed coating machine performed better for T3 (mechanical coating method) as compared to T1 (conventional coating method) and T2 (manual coating method). The best results were observed as 79.2% at 2 minutes time interval, 85.4% at 4 minutes time interval, and 93.2% at 6 minutes time interval at T3 (mechanical coating method).

Practical implications of this machine include its potential use by small- and medium-scale farmers for cost-effective, time-saving, and consistent seed treatment. It reduces manual handling of fungicides, thereby enhancing operator safety and ensuring better protection for seeds during germination. Potential applications extend beyond cotton-seed treatment to include other crops that require similar protective coatings. The compact and portable design allows for use in field conditions, seed centers, and rural farming communities. Future directions involve optimizing the machine to minimize seed breakage by refining the internal structure or reducing rotation speed, incorporating softer materials in the drum minimizing seed damage. Additionally, further optimization of the coating time could also reduce the mechanical stress on seeds, improving their integrity. Further, work could also explore automation, integration with seed drying systems, and testing with biological or organic seed treatments to widen its scope.

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6. AUTHORS CONTRIBUTION STATEMENT

Rashid Mehmood: Identification of research gap and design of machine. **Zia Ul Haq:** Supervised overall experiment and guideline during write up and finalizing manuscript. **Hira Bashir:** Results and discussion write-up. **Muhammad Ahmad:** Data collection, material and method write up, and design of machine. **Aatif Naseer:** Write up introduction of manuscript, Purchase material from local market, and helped in manufacturing process. **Aksar Ali Khan:** Methodology, conceptualization, formal data analysis and formatting of manuscript. **Syed Mudassir Raza:** Reviewing and editing. **Asif Ali Mirani:** Reviewing the manuscript. **Tajwar Alam:** Helped in finalizing the technical write-up. **Muhammad Mohsin Ali:** helped in finalizing the design of machine. **Abu Saad:** Statistical data analysis.

7. CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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