



Design and performance evaluation of an air-and-oscillating screen cleaning system for Ruzi grass seed

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Abstract

This study investigated the operational performance of a Ruzi grass seed cleaning unit by evaluating the effects of seed feed rate and airflow rate. The experimental variables included three seed feed rates (100, 200, and 300 kg/h) and three airflow rates (0.2, 0.3, and 0.4 m³/s). Analysis of variance (ANOVA) revealed that cleaning capacity increased with the seed feed rate, reaching a maximum of 195.03 kg/h at 300 kg/h, whereas the airflow rate showed no significant effect on this parameter. Impurity-removal efficiency increased with airflow rate, reaching a maximum of 99.56% at a feed rate of 100 kg/h and an airflow rate of 0.4 m³/s. Conversely, seed loss percentage increased with airflow rate but decreased as the feed rate increased, with a minimum value of 0.30% observed at 300 kg/h and 0.2 m³/s. Both factors exerted a statistically significant influence on impurity removal efficiency and seed loss. Within the tested ranges, a feed rate of 300 kg/h and an airflow rate of 0.3 m³/s were selected as a compromise operating condition, providing a cleaning capacity of 188.92 kg/h, an impurity removal efficiency of 87.40% and a low seed loss of 1.04%.

Keywords: Ruzi grass seed, Seed cleaning unit, Cleaning capacity, Impurity removal efficiency, Seed loss percentage

1. Introduction

Ruzi grass is an important forage crop in livestock production systems and for economically important animals because it grows rapidly, tolerates drought conditions, and provides high biomass yields. Consequently, it is widely cultivated as animal feed for dairy cattle, beef cattle, and buffaloes [1]. However, the production of high-quality Ruzi grass seed continues to face challenges related to contamination by impurities such as straw fragments, soil particles, unfilled seeds, and other foreign materials that are often mixed with the seed during the threshing and seed extraction processes. These contaminants directly affect seed quality and market value. Therefore, seed cleaning is a crucial step in standardized seed production systems [2-4].

In general, seed cleaning operations rely heavily on manual labor and utilize seed cleaning equipment that is not specifically designed for Ruzi grass seeds. Seed cleaning systems commonly separate materials based on their physical properties, including size, shape, weight, and aerodynamic characteristics. Air-screen cleaning systems are widely used because they can efficiently remove impurities that differ in size from the seeds as well as lightweight contaminants. Their operation is based on the combined action of oscillating screens and airflow generated by suction or blowing mechanisms [5].

Previous studies on seed cleaning machine design by Akinoso et al [6] reported that screen size, feed rate, and air velocity are critical factors influencing cleaning efficiency and seed loss. For example, the development of an air-screen cleaner for sesame seeds significantly reduced impurities and improved seed separation efficiency through a design optimized according to the physical properties and terminal velocity of the seeds [6-8]. Furthermore, studies on grass and cereal seed cleaning machines employing vibrating screens combined with fans demonstrated their effectiveness in reducing seed losses and improving post-harvest seed quality [9-10].

However, most seed cleaning machines currently available have been designed primarily for field crops or cereal seeds and are not suitable for Ruzi grass seeds, which possess unique characteristics such as small size, low weight, and the presence of many floral debris. Therefore, the design and development of a seed cleaning system specifically adapted to the properties of Ruzi grass seeds are essential for improving seed quality, reducing losses, and enhancing seed production efficiency at the farm level [11-15].

Accordingly, this research focuses on the design and performance evaluation of an air-screen seed cleaning system for Ruzi grass seeds. The study investigates the effects of seed feed rate and airflow rate on machine performance based on the physical characteristics of the seeds. The objective is to develop a prototype system capable of effectively reducing impurities, increasing seed cleanliness, and

minimizing the loss of sound seeds. The outcomes of this research are expected to contribute to the advancement of forage grass seed quality technologies for farmers in the future.

2. Materials and methods

2.1 Conceptual design of the cleaning system

The air-screen seed cleaning system was designed based on the principle of separating materials according to their size and aerodynamic properties. The oscillating screen unit functions to remove impurities that are either larger or smaller than the main seeds, while the air-cleaning system is used to eliminate lightweight materials such as leaf fragments and unfilled seeds. This process enhances seed cleanliness and minimizes the loss of viable seeds. The system operates on the principles of separation based on particle size, density, and aerodynamic characteristics through the combined action of an oscillating screen assembly for size grading and a fan unit for removing lightweight contaminants [16-17].

2.2 Conceptual design of the Ruzi grass seed cleaning system

Based on the cleaning system design concept, the Ruzi grass seed cleaning system was developed and divided into two main components: (1) the oscillating screen cleaning system, which consists of a feed hopper and an oscillating screen separator, and (2) the aerodynamic cleaning system, which consists of a fan unit responsible for generating airflow for the cleaning process. The details of each component are described as follows.

2.2.1 Feed hopper design

The feed hopper was designed to provide a continuous and uniform seed flow (Figure 1). The physical properties of Ruzi grass seeds were studied to minimize material accumulation on the hopper surfaces, which can adversely affect separation efficiency. The design utilizes a gravity-flow mechanism combined with a feed-rate control device to ensure a consistent seed supply during operation [18-20].

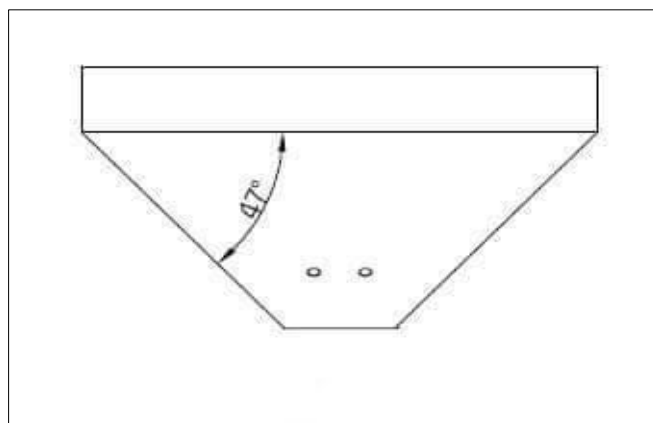


Figure 1 Feed hopper design

2.2.2 Oscillating screen design

The oscillating screen assembly was designed to incorporate a screening unit (Figure 2) for removing small debris and dust particles from the main seed fraction. The screen aperture size was determined based on the physical characteristics of Ruzi grass seeds. The oscillatory motion of the screen increases the probability of contact between seeds and screen openings, thereby improving separation efficiency and overall cleaning performance [20-24].

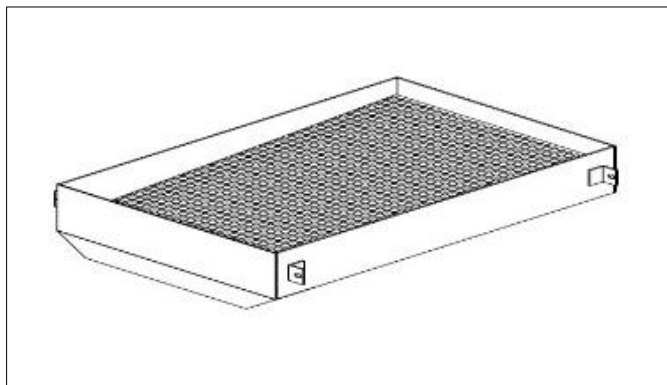


Figure 2 Oscillating screen design

2.2.3 Air cleaning system design

The air cleaning system was designed by considering the difference in terminal velocity between sound seeds and impurities. This allows the airflow to effectively remove lightweight contaminants from the system while minimizing the loss of viable seeds. A centrifugal fan (Figure 3) was selected as the airflow-generating device because its airflow rate can be adjusted according to the characteristics of the material being processed [25-27].

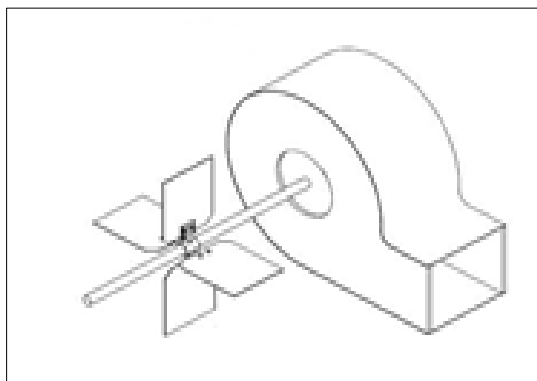


Figure 3 A centrifugal fan of cleaning design

2.3 Test methods

The primary objective of this research was to evaluate the performance of a Ruzi grass seed-cleaning unit by investigating the effects of seed feed rate and airflow rate on cleaning performance.

Uncleaned Ruzi grass seed containing non-seed material was obtained from farmers for the experiment. Random sampling and impurity separation before testing showed that the Ruzi grass seed contained, on average, 25% impurities.

A completely randomized design (CRD) was employed, and the data were analyzed using two-factor ANOVA with replication. Three seed feed rates (100, 200, and 300 kg/h), which were nominal feed-rate levels established through preliminary tests by adjusting the hopper feed-gate opening, and three airflow rates (0.2, 0.3, and 0.4 m³/s) were tested, with three replications for each treatment.

For each treatment, 3,000 g of Ruzi grass seed containing impurities was prepared. The sample was placed in the machine feed hopper, the seed flow was set using the hopper control gate, and the fan speed was adjusted to the specified condition. Timing began when seed entered the oscillating screen and ended when all material had discharged from the machine. The cleaned seeds and impurities were then collected, weighed, and analyzed.

2.4 Performance indicators

Performance was evaluated using three indicators: cleaning capacity, impurity removal efficiency, and seed-loss percentage as shown Equation 1-3, respectively. These were calculated using standard equations. The experimental results were compared to identifying the optimal operating condition, defined as the condition providing high cleaning capacity and efficiency with the lowest loss percentage. The indicators were calculated as follows:

2.4.1 Cleaning capacity (Q)

$$Q = \frac{W}{T} \quad (1)$$

where

Q = cleaning capacity (kg/h)
 W = weight of cleaned seed (kg)
 T = operating time (h)

2.4.2 Impurity-removal efficiency (E_i)

$$E_i = \frac{W_i + W_r}{W_i} \times 100 \quad (2)$$

where

W_i = initial mass of impurities before cleaning (kg)
 W_r = residual impurity mass after cleaning (kg)

2.4.3 Seed-loss percentage (L)

$$L = \frac{W_l}{W_c + W_l} \times 100 \quad (3)$$

where

W_l = weight of good seed discharged at the straw outlet (kg)
 W_c = net weight of separated good seed (kg)

3. Results and discussion

3.1 Results of Ruzi grass seed property analysis

Ruzi grass seeds used for testing were obtained from local farmers during the harvesting period. The initial moisture content was not measured, as it was not considered an experimental variable in this study. A random sample of 100 seeds was selected to measure seed dimensions, including width and length (Figure 4). The angle of repose was determined using Ruzi grass seeds at a sample mass of 100 g per test, with three replications. The measured average seed width and length were 1.50 mm and 5.18 mm, respectively, while the maximum seed width and length were 2.23 mm and 6.20 mm, respectively (Table 1). These physical properties were employed as design criteria for selecting the screen aperture.

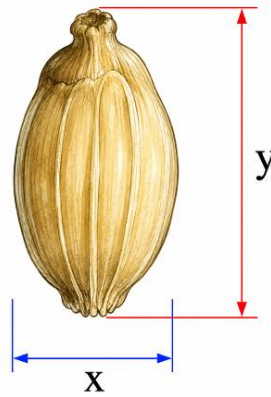


Figure 4 Ruzi grass seed; X = seed width; Y = seed length

Table1 Physical dimensions of the Ruzi grass seeds

Dimensions	Physical dimensions of the seed (mm)	
	x	y
Minimum	0.78	4.17
Maximum	2.23	6.20
Avg.	1.50	5.18

The average angle of repose was 27.83° , with values ranging from 25° to 30° , as shown in Table 2. The average angle of repose of the Ruzi grass seeds was 27.83° . This value was used as a design parameter for the feed hopper and deceleration gate to facilitate continuous seed flow and minimize clogging during operation (Figure 5).



Figure 5 Angle of flow test

Table2 Average angle of repose of Ruzi grass seed

Angle	Angle of Repose (degree)
Minimum	25
Maximum	30
Average	27.83

3.2 Cleaning-system design results

Physical-property analysis of Ruzi grass seed provided the basis for designing the cleaning system. The system consists of six components: (1) frame, (2) feed hopper, (3) separation screen, (4) impurity-extraction fan, (5) power-transmission unit, and (6) deceleration-gate separator, as shown in Figure 6. The design details are as follows:

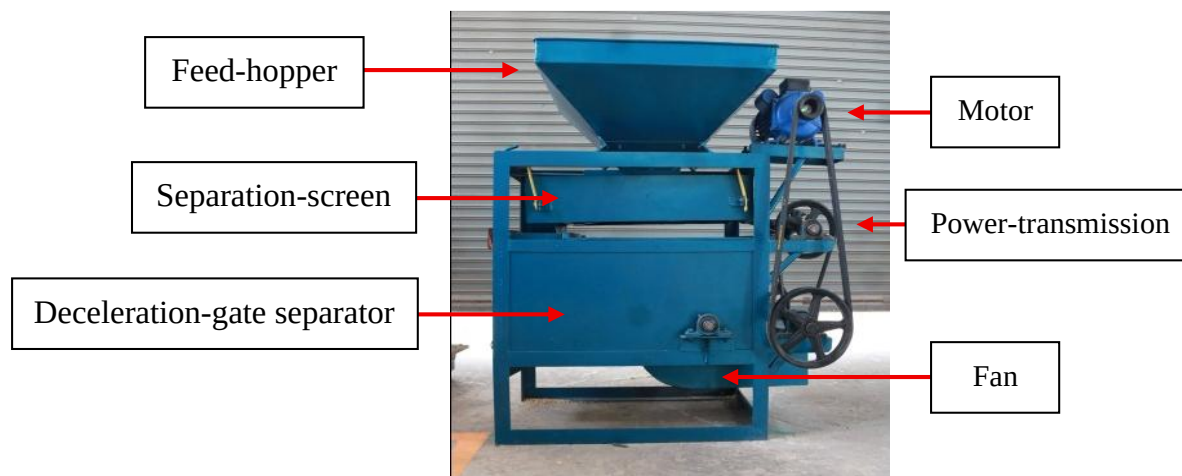


Figure 6 Ruzi grass seed cleaning system

- Frame design. The Ruzi grass seed-cleaner frame was designed and constructed for seed separation. Its width, length, and height were 560, 624, and 1,010 mm, respectively.

- Feed-hopper design. The optimum flow-angle value used in the hopper design was 47 degrees. The hopper angle of 47° was selected as the design flow angle to facilitate continuous movement of the Ruzi grass seed mixture through the hopper. The measured angle of repose of the Ruzi grass seed was 27.83°. Therefore, the selected hopper angle was intentionally greater than the measured angle of repose to provide a sufficient inclination for material flow and reduce the tendency of material to remain in the hopper. The 47° value should therefore be interpreted as a design parameter rather than as the angle of repose itself. We used a durable 1-mm galvanized sheet that was used. The hopper width, length, and height were 700, 800, and 400 mm, respectively.

- Separation-screen design. The maximum seed width and length were 2.23 mm and 6.20 mm, respectively. The 7-mm round-hole screen was selected based on the measured seed dimensions (average width 1.50 mm and maximum width 2.23 mm). The oscillating screen operated with an amplitude of 3 cm and a shaft speed of 162 rpm (2.70 Hz).

- Deceleration-gate separator design. The gate was designed using a 45° initial-flow angle and durable 1-mm galvanized sheet, that was width and length were 90 and 430 mm, respectively.

- Power-transmission design. A B-section V-belt transmitted power from a 2-hp motor to the oscillating-screen unit and the fan for aerodynamic separation.

- Fan design. A centrifugal fan was selected because it provides adequate airflow, is durable, and is easy to maintain. The fan produced a maximum air velocity of 20 m/s at a duct cross-sectional area of 0.0418 m². The experimental airflow rates were set at 0.2, 0.3, and 0.4 m³/s. The nominal feed rates of 100, 200, and 300 kg/h were established by preliminary adjustment of the hopper feed-gate opening.

3.3 Cleaning-system performance evaluation

3.3.1 Cleaning capacity

The cleaning-capacity results for the Ruzi grass seed cleaning unit are presented in Table 3.

Table 3 Effect of feed rate and airflow rate on cleaning capacity of the Ruzi grass seed cleaning

Feed rate	Airflow rate (m ³ /s)		
	0.2	0.3	0.4
100 kg/h	65.35	65.70	65.35
200 kg/h	109.98	113.67	114.56
300 kg/h	195.03	188.92	185.95

At a seed feed rate of 100 kg/h, cleaning capacities at airflow rates of 0.2, 0.3, and 0.4 m³/s were 65.35, 65.70, and 65.35 kg/h, respectively. At a feed rate of 200 kg/h, the corresponding capacities were 109.98, 113.67, and 114.56 kg/h. At 300 kg/h, they were 195.03, 188.92, and 185.95 kg/h, respectively. Cleaning capacity tended to increase as seed feed rate increased, whereas airflow rate had no effect. These results are illustrated in Figure 7.

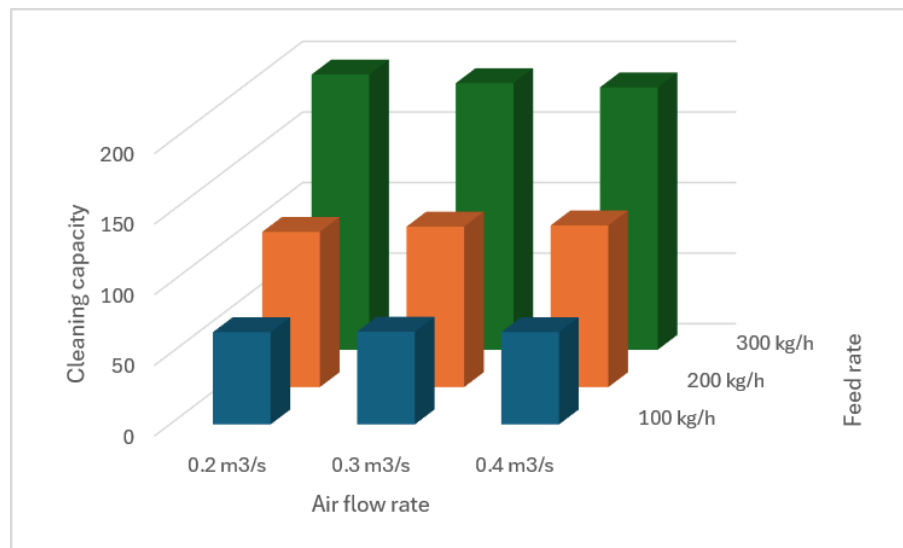


Figure 7 Relationship between factors affecting cleaning capacity

The Figure 7 shows that the Ruzi grass seed feed rate significantly affected cleaning capacity, whereas the cleaning airflow rate did not. Two-factor ANOVA with replication (Table 4) indicated that feed rate had a significant effect on cleaning capacity ($p < 0.05$), while airflow rate ($p > 0.05$) and the interaction between factors ($p > 0.05$) was not significant.

Table 4 ANOVA results for factors affecting cleaning capacity

Source of Variation	SS	df	MS	F	P-value
Feed rate	71096.68	2	35548.34	2637.577	< 0.001*
Air flow rate	10.15932	2	5.079661	0.376895	0.691 ^{ns}
Interaction	153.8983	4	38.47458	2.854695	0.054 ^{ns}
Within	242.5977	18	13.47765		
Total	71503.34	26			

3.3.2 Impurity-removal efficiency

The Impurity-removal efficiency results for the Ruzi grass seed cleaning unit are presented in Table 5.

Table 5 Effect of feed rate and airflow rate on impurity-removal efficiency

Feed rate	Airflow rate (m³/s)		
	0.2	0.3	0.4
100 kg/h	83.46	93.00	99.56
200 kg/h	79.44	88.85	99.17
300 kg/h	77.78	87.40	97.42

At a seed feed rate of 100 kg/h, mean impurity-removal at airflow rates of 0.2, 0.3, and 0.4 m³/s were 83.46%, 93.00%, and 99.56%, respectively. At 200 kg/h, the corresponding values were 79.44%, 88.85%, and 99.17%; at 300 kg/h, they were 77.78%, 87.40%, and 97.42%, respectively. Impurity-removal tended to increase with airflow rate but decrease as seed feed rate increased. These results are illustrated in Figure 8.

The Figure 8 shows that both Ruzi grass seed feed rate and cleaning airflow rate affected Impurity removal efficiency. Two-factor ANOVA with replication (Table 6) showed that both factors significantly affected Impurity removal efficiency ($p < 0.05$), and their interaction was also significant ($p < 0.05$). The result agrees with Afolabi et al. [28] who reported significant effects of feed rate and air velocity on impurity removal efficiency.

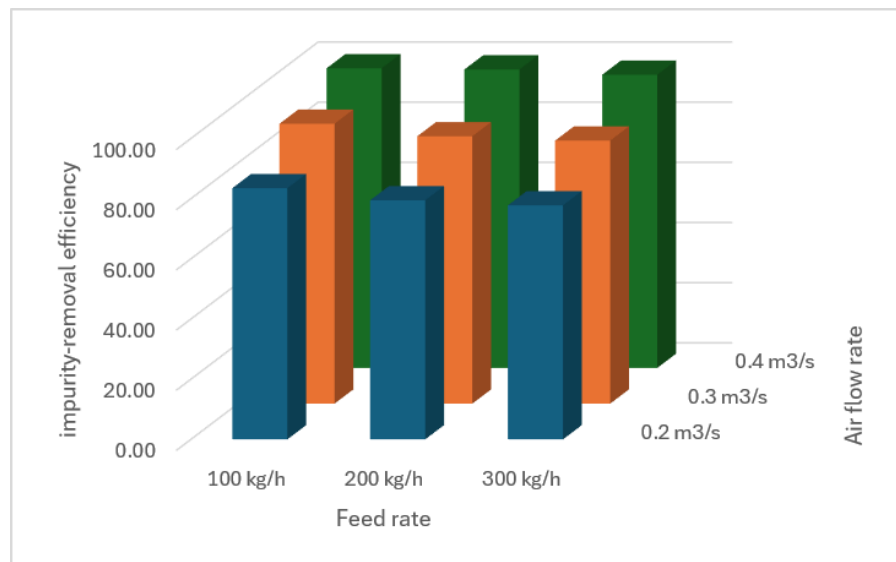


Figure 8 Relationship between factors affecting impurity-removal

Table 6 ANOVA results for factors affecting impurity removal efficiency

Source of Variation	SS	df	MS	F	P-value
Feed rate	92.4809	2	46.2404	246.5748	<0.001*
Air flow rate	1538.8137	2	769.4068	4102.8197	<0.001*
Interaction	17.3357	4	4.3339	23.1105	<0.001*
Within	3.3755	18	0.1875		
Total	1652.0060	26			

3.3.3 Seed-loss percentage

The seed-loss percentage results for the Ruzi grass seed cleaning unit are presented in Table 7.

Table 7 Effect of feed rate and airflow rate on seed-loss percentage of the Ruzi grass seed cleaning

Feed rate	Airflow rate (m³/s)		
	0.2	0.3	0.4
100 kg/h	3.53	4.16	10.49
200 kg/h	1.49	1.52	8.40
300 kg/h	0.30	1.04	5.59

At a seed feed rate of 100 kg/h, mean loss percentages at airflow rates of 0.2, 0.3, and 0.4 m³/s were 3.53%, 4.16%, and 10.49%, respectively. At 200 kg/h, the corresponding values were 1.49%, 1.52%, and 8.40%; at 300 kg/h, they were 0.30%, 1.04%, and 5.59%, respectively. Loss percentage clearly increased with airflow rate but decreased with seed feed rate. These results are illustrated in Figure 9.

The Figure 9 shows clear effects of Ruzi grass seed feed rate and cleaning airflow rate on loss percentage. Two-factor ANOVA with replication (Table 8) showed that both factors and their interaction significantly affected loss percentage ($p < 0.05$). This agrees with Afolabi et al. [28] who reported significant effects of material feed rate and air velocity on cleaning loss percentage.

The relation between impurity-removal efficiency and seed loss arises from the aerodynamic separation mechanism. Higher airflow enhances impurity removal by displacing lighter particles but can also entrain sound Ruzi grass seeds, increasing seed loss particularly at low feed rates. For instance, at 0.4 m³/s airflow, seed loss was 10.49% at 100 kg/h compared with 8.40% at 200 kg/h and 5.59% at 300 kg/h. Lower seed loss at higher feed rates reflects the reduced airflow-to-throughput ratio, which lessens the impact of airflow on individual seeds. Thus, while increasing airflow improves impurity removal, higher feed rates mitigate seed loss, highlighting the need to balance both parameters rather than maximize independently.

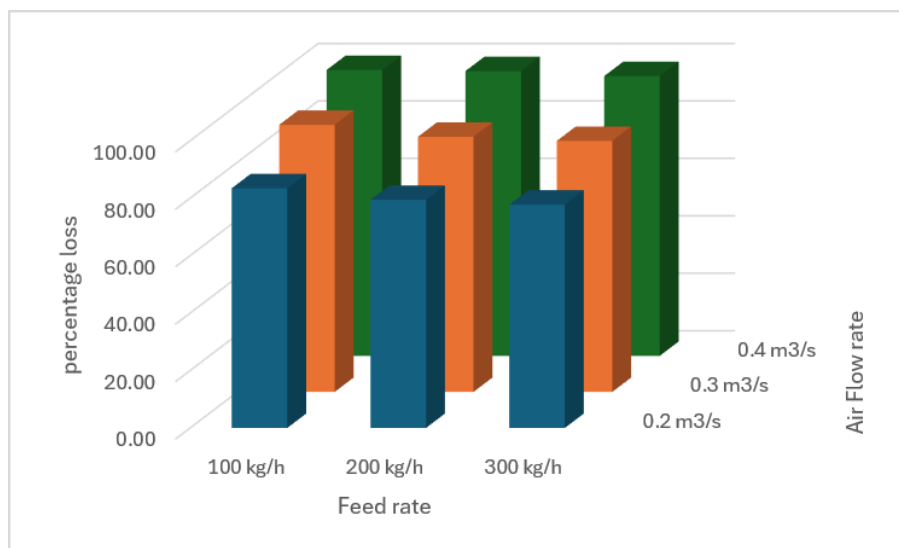


Figure 9 Relationship between factors affecting seed-loss percentage

Table 8 ANOVA results for factors affecting seed-loss percentage

Source of Variation	SS	df	MS	F	P-value
Feed rate	64.0923	2	32.0461	265.3833	<0.001*
Air flow rate	228.0129	2	114.0064	944.1200	<0.001*
Interaction	5.0889	4	1.2722	10.5358	<0.001*
Within	2.1735	18	0.1207		
Total	299.3677	26			

4. Conclusions

Physical-property analysis showed that Ruzi grass seed had average width and length of 1.50 and 5.18 mm, respectively, with maximum values of 2.23 and 6.20 mm. These data were used to select suitable screen apertures. The average angle of repose was 27.83°, which informed the design of the feed hopper and deceleration gate to maintain continuous flow and reduce clogging.

Cleaning-system design, the cleaning unit consists of a frame, feed hopper, separation screen, impurity-extraction fan, power-transmission system, and deceleration-gate separator. A 7-mm round-hole screen was selected based on the maximum seed dimensions. The hopper was designed with a 47° flow angle, while the deceleration gate used an initial angle of 45°. The system was powered by a 2-hp motor through a B-section V-belt, and a centrifugal fan was used for aerodynamic separation of impurities.

Performance evaluation, tests were conducted at seed feed rates of 100, 200, and 300 kg/h and airflow rates of 0.2, 0.3, and 0.4 m³/s. cleaning capacity increased as feed rate increased, reaching 185.95–195.03 kg/h at a feed rate of 300 kg/h. Airflow did not significantly affect cleaning capacity. Impurity removal efficiency increased with airflow at all feed rates. The highest efficiency, 99.56%, was obtained at 100 kg/h and 0.4 m³/s. However, seed loss also increased with airflow and was highest at this condition (10.49%). The lowest seed loss, 0.30%, occurred at 300 kg/h and 0.2 m³/s. Overall, the selected compromise operating condition was a seed feed rate of 300 kg/h and an airflow rate of 0.3 m³/s. At this condition, the cleaning capacity was 188.92 kg/h, the impurity-removal efficiency was 87.40%, and the seed loss was 1.04%.

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