Original Research Article

~~Design of Inclined Platefor seeder by Analyzing~~ Investigation of Physical and Frictional properties of Mustard Seed Varieties to Design Inclined Plate Metering Mechanism

Abstract

~~This study exploreds~~ds~~T~~The physical and frictional properties were studied for~~of~~ three distinct mustard seed varieties: RLC-1, GSC-7, and PBR-91, with the primary objective of designing an efficient inclined plate ~~for~~ seed metering mechanismfor ~~in~~ agricultural seeders. Mustard, a globally significant oilseed crop, plays a vital role in both agriculture and industry. Our comprehensive analysis encompassed various seed properties, including seed dimensions, test weight (1000 seed) ~~weights~~, moisture content, geometric mean diameters, surface area, bulk density, true density, sphericity, angle of repose, and coefficients of friction on plywood and GI sheet surfaces.

The results revealed significant variations among the mustard seed varieties. For instance, RLC-1 seeds exhibited lengths of 4.029 ± 0.37 mm, widths of 2.210 ± 0.31 mm, and thicknesses of 0.851 ± 0.19 mm, whereas GSC-7 displayed lengths of 4.110 ± 0.42 mm, widths of 2.300 ± 0.35 mm, and thicknesses of 0.910 ± 0.24 mm. Additionally, GI sheet surfaces exhibited a lower coefficient of friction compared to plywood.

This comprehensive dataset informs the design of tailored seed metering mechanisms, optimizing seed handling, minimizing seed damage and losses, and reducing blockage~~jamming~~ during ~~agricultural~~ seeding operations, thereby enhancing overall efficiency in mustard crop cultivation and seeding~~owing~~ technology.

Keywords: Engineering properties, Inclined plate, Mustard, Sowing, Sphericity.

Introduction

Seed planting is a critical stage in crop development and traditional manual methods are inefficient, labor intensive, and time-consuming (Ghosal and Pradhan, 2013). Mechanized sowing offers numerous benefits, including timely completion of field operations, reduced cost of cultivation, and greater precision (Grewal et. al., 2015, Badgujar et. al., 2020). However, existing planters often lack the necessary features to meet the specific requirements of mustard seed planting.

Mustard, a globally cultivated oilseed crop, ranks third in oil production after palm and soybean oil. The worldwide mustard yield surpasses 38 million metric tons, resulting in a total oil production of approximately 12-14 million metric tons. Mustard is an important oilseed crop in India, accounting for 28.6% of total oilseed production (Dayanand,and Mehta, 2014). The crop is primarily cultivated during the Rabi season, from September-October to February-March. India produces approximately 6.7 million metric tons of mustard annually, making it the second most important oilseed crop after China. The average oil content of mustard seeds is around 33-41.5% (Chauhan et al., 2020).

Mustard is predominantly cultivated as a cash crop in the states of Haryana, Punjab, Uttar Pradesh, Madhya Pradesh, and Himachal Pradesh. This crop is typically grown in regions characterized by temperate climates (Semwal et al., 2013). Successful cultivation of mustard relies on the availability of well-dried sandy-loam soil, which not only promotes the optimal germination of mustard seeds but also facilitates the overall growth of the mustard plants. The mustard plant is characterized by its lengthy tapering roots. Its stems reach a height of approximately 45 cm, and it produces vibrant yellow flowers. The seeds of the mustard plant are small and round, with their colors varying depending on the specific variety. Mustard thrives in subtropical climates, requiring a cool and dry environment for optimal growth. It typically flourishes within a temperature range of 10 to 25 °C. To support its growth, mustard necessitates lower temperatures, while slightly higher temperatures are ideal for germination. During the ripening stage, warmer temperatures are beneficial.

Mustard is a versatile crop with a wide range of applications. Mustard seed flour is a good source of antioxidants and has anti-microbial properties (Adegbeye et al., 2020). It can be used as a food additive to increase the shelf life and safety of food products. Mustard seeds can also be grown for biodiesel production (Singh, and Trivedi, 2017).In addition to the above, mustard seeds are also used in the production of mustard oil, which is a popular cooking medium and condiment. Mustard oil is also used in medicinal preparations, pharmaceutical products, and cosmetics.Mustard seeds are a valuable crop with a wide range of benefits (Semwal et al., 2020). They are a good source of nutrients, can be used to produce a variety of products, and have a number of industrial applications.

The study aims to investigate the physical and frictional properties of three mustard seed varieties: RLC-1, GSC-7 and PBR-91 for designing the inclined plate. The seed~~se~~ properties are important for designing efficient seed metering mechanisms in agricultural seeders (Gautam et. al., 2017, Badgujar et. al., 2018). The study measured the dimensions, 1000 seed weights, moisture content, geometric mean diameters, surface area, bulk density, true density, sphericity, angle of repose, and coefficients of friction on plywood and GI sheet surfaces for each variety.

Materials and method

In the design of a seeder, the critical components responsible for seed placement and conveyance are the seed metering disc. These elements play a pivotal role in ensuring that the seeds are transported to the furrow bottom without suffering damage or losses during the metering process (Yang et al., 2023, Badgujar et. al., 2022). Additionally, preventing the seeds from getting stuck or jammed in the seed hopper is equally important.

The metering mechanism is regarded as the core component of a sowing machine, responsible for the precise separation and uniform dispensing of seeds at the desired application rates. when assessing seed damage, the inclined plate mechanism consistently demonstrated significantly lower percentages of damage (Grewal et. al., 2015, Gautam et. al., 2017, Kumar et al., 2021, Badgujar et. al., 2017).

In the inclined plate metering mechanism, a metering plate with cells is used to individually pick and dispense seeds, with the number of seeds dropped depending on the design of the plate's cells. The shape of the grooves and the number of grooves are crucial design parameters that influence the seed dropping process from the plate. The design of these cells on the plate is tailored based on the physical properties of the specific seed variety being used. Consequently, different seed varieties require distinct types of plates.

In pursuit of these design goals, it becomes imperative to first ascertain the physical and frictional properties of the seeds. For our specific research, we have chosen to work with threedistinct varieties of mustard seeds: RLC 1, GSC-7 and PBR-91. The selection of these varieties was made randomly from bulk samples to ensure representativeness.

In summary, the design of the inclined plate, as explored in this study titled "Design of Inclined Plate for seeder by Analyzing Physical and Frictional Properties of Mustard Varieties," hinges on a thorough understanding of the physical and frictional characteristics of mustard seeds. This knowledge forms the foundation for crafting an efficient inclined plate seeder that minimizes seed damage, losses, and jamming while ensuring optimal sowing performance.

Selection of Seed Varieties

For this study, we selected three mustard seed varieties, namely PBR-91, GSC-7 and RLC-1, to investigate their physical and frictional properties.

Determination of Physical Properties

Physical Dimensions and test One Thousand Seeds Weight

To assess the average seed size, we randomly selected 100 seeds from each variety and measured their three linear dimensions, including length (l), width (w), and thickness (t), using a digital vernier caliper (model no, company, make is needed) with a precision of 0.05 mm. Additionally, we determined the weight of one thousand seeds (W1000) by manually counting one thousand mustard seeds from each variety and weighing them using an electronic balance with an accuracy of 0.01 g. (Adapted from Mohsenin, 1986).

Moisture Content of Seeds

The moisture content of the seeds was determined by initially weighing a sample of the seeds. Subsequently, the sample was dried at 105°C for 24 hours in a hot air oven, and the weight of the dried sample was recorded. The moisture content of the grains on a dry weight basis (%) was calculated using the formula:

Moisture content of grains (per cent, dry weight basis)

$$M = \frac{w_1 - w_2}{w_2} \times 100 \qquad \ldots(1)$$

Where,

M = Moisture content

w_1 = Weight of wet sample, kg

w_2 = Weight of the oven dried sample, kg

Geometric mean diameter

The geometric mean diameter of the seeds was determined using a Vernier caliper with a least count of 0.05 mm. The measurement process involved taking three mutually perpendicular dimensions of the seeds, specifically the maximum, intermediate, and minimum dimensions (Bahnasawy, 2007). The geometric mean diameter was calculated as follows:

$$D_g = (LWT)^{\frac{1}{3}} \quad ....(2)$$

Surface area

The surface area of the seeds, denoted as S, was calculated by drawing an analogy to a sphere with an equivalent geometric mean diameter (Sahay and Singh, 1994). This calculation was based on the following relationship:

$$S = \pi {D_g}^2 \quad ...(3)$$

Bulk Density

Bulk density plays a crucial role in designing the seed hopper and is influenced by the packing density of the seeds. To determine the bulk density, we filled a known volume of seeds in a cylindrical container to achieve the desired degree of packing. We performed 3 to 5 trials, measuring and recording the weight each time. The average weight per unit volume was then computed using the formula:

$$Bulk\ density = \frac{\text{weight of seeds (g)}}{\text{volume of cylinder (cm}^3\text{)}} \quad ...(4)$$

True density

True density is a fundamental parameter that reflects the actual density of a particle or material. It quantifies the ratio of a substance's mass to its true volume. The measurement of true density is crucial because it enables the calculation of the space occupied by individual seeds. In this study, true density was determined using the liquid displacement method, employing toluene as the displacing liquid.

The procedure involved filling a 100 ml measuring cylinder with seeds and recording the weight of the seeds in that volume. Toluene was then introduced into the cylinder containing the seeds, displacing some of the toluene. The volume of toluene displaced by the seeds was carefully noted (Karaj and Müller, 2010). True density was subsequently calculated using the following formula:

$$true\ density = \frac{mass\ \ of\ \ the\ seeds\ \ (kg)}{volume\ \ of\ toluene\ \ displaced\ \ by\ the\ seeds\ \ (m^3)} \qquad \ldots(5)$$

Sphericity

Sphericity is a factor affecting seed flow through various components of the planter. We calculated the sphericity of the seeds using the formula(Mohsenin, 1986):

$$sphericity = \frac{(l.b.t)^{1/3}}{l} \qquad \ldots(6)$$

Where,

l = Length of a seed, mm

b = Width of a seed, mm

t = Thickness of a seed, mm

Angle of Repose

To measure the angle of repose for mustard seeds, we placed a rectangular box filled with mustard seeds horizontally. The seeds were allowed to fall onto a horizontal circular disc positioned below the box. We measured the radius of the base of the seed heap and the height of the heap to calculate the angle of repose using the formula:

$$\theta = \tan^{-1}\left[\frac{2H}{D}\right] \qquad \ldots(7)$$

Where,

θ = Angle of repose

H = Height of cone, cm

D = Diameter of cone, cm

Coefficient of Friction

To determine the coefficient of external friction between mustard seeds and different surfaces, we used a box filled with seeds and measured the weights required for sliding the box on plywood and GI sheet surfaces(Sahay and Singh, 1994). The coefficient of external friction (μe) was calculated using the formula:

These methods were employed to comprehensively assess the physical and frictional properties of the selected mustard seed varieties for the purpose of designing the inclined plate metering mechanism.

$$\mu_e = \frac{(W_2 - W_1)}{W} \qquad \ldots(8)$$

Where:

μ_e = Coefficient of external friction

W1 = Weight required to slide the empty box

W2 = Weight required to slide the filled box

W = Weight of the mustard seeds

Result and discussion

The research was dedicated to the thorough analysis of various physical and frictional properties exhibited by three distinct mustard seed varieties: RLC-1, GSC-7, and PBR-91. These properties constitute pivotal factors guiding the design of efficient seed metering mechanisms essential for agricultural seeders. The dimensions of the seeds, encompassing their length, width, and thickness, were measured, revealing specific characteristics for each variety: RLC-1 displayed lengths of 4.029 ± 0.37 mm, widths of 2.210 ± 0.31 mm, and thicknesses of 0.851 ± 0.19 mm; GSC-7 exhibited lengths of 4.110 ± 0.42 mm, widths of 2.300 ± 0.35 mm, and thicknesses of 0.910 ± 0.24 mm; while PBR-91 showcased lengths of 3.981 ± 0.33 mm, widths of 2.114 ± 0.21 mm, and thicknesses of 0.762 ± 0.19 mm. Similar result were obtained by Grewal and Singh, 2016.

Further analysis unveiled 1000 seed weights, which were 6.74 ± 0.92 g for RLC-1, 6.80 ± 0.87 g for GSC-7, and 6.12 ± 1.1 g for PBR-91. Moisture content percentages were 15.43% for RLC-1, 16% for GSC-7, and 15.65% for PBR-91. Additionally, geometric mean diameters were calculated to be 1.90 ± 0.24 mm for RLC-1, 1.96 ± 0.26 mm for GSC-7, and 1.84 ± 0.23 mm for PBR-91 as shown in table 1. Similar trend is found by Damian, 2014.

These properties, along with surface area, bulk density, true density, sphericity, angle of repose, and coefficients of friction on plywood and GI sheet surfaces, showed distinctive characteristics for each variety. These findings are of paramount importance for designing tailor-made seed metering discs and related components, ensuring efficient seed handling, dispensing, and sowing, while minimizing damage and losses in agricultural practices.

Table1: Engineering properties of Mustard seeds

S.No.	**Parameter**	**Mustard seeds varieties**		
		RLC-1	**GSC-7**	**PBR-91**
1.	Length (mm)	4.029 ± 0.37	4.110 ± 0.42	3.981 ± 0.33
	width (mm)	2.210 ± 0.31	2.300 ± 0.35	2.114 ± 0.21
	Thickness (mm)	0.851 ± 0.19	0.910 ± 0.24	0.762 ± 0.19
2.	1000 seeds wt. (gm)	6.74 ± 0.92	6.80 ± 0.87	6.12 ± 1.1
3.	Moisture content (%)	15.43	16	15.65
4.	Geometric mean dia (mm)	1.90 ± 0.24	1.96 ± 0.26	1.84 ± 0.23
5.	Surface area (mm^2)	11.34	11.98	10.64
6.	Bulk density (g/cm^3)	0.835	0.847	0.829
7.	True density (g/cm3)	1.028	1.062	1.017
8.	Sphericity	0.65 ± 0.06	0.74 ± 0.07	0.59 ± 0.06
9.	Angle of repose (°)	29.03	28.79	27.65

10.	Coefficient of friction			
	Ply wood	0.364	0.370	0.350
	GI sheet	0.330	0.335	0.317

95% confidence limit

This study investigated the physical and frictional properties of three mustard seed varieties: RLC-1, GSC-7 and PBR-91. The results showed that the three varieties differ significantly in terms of their size, shape, weight, and surface properties. For example, RLC-1 seeds are slightly larger and heavier than PBR-91 seeds but lighter that GSC-7. GSC-7 variety has higher sphericity than other two varieties.

The study also found that the coefficient of friction between mustard seeds and plywood is higher than that between mustard seeds and GI sheet. This suggests that GI sheet is a more suitable material for inclined plates in mustard seed seeders, as it reduces the risk of seed jamming.

Physical properties: The physical properties of mustard seeds, such as their size, shape, weight, and surface properties, can affect their behavior in inclined plate seeders. For example, larger and heavier seeds may be more likely to jam or damage other seeds during the metering process. Seeds with a higher sphericity may also be more likely to roll and jam.

Frictional properties: The frictional properties of mustard seeds, such as their coefficient of friction with different materials, can also affect their behavior in inclined plate seeders. For example, seeds with a higher coefficient of friction are more likely to stick to the inclined plate and jam.

Implications for design: By understanding the physical and frictional properties of mustard seeds, engineers can design inclined plate seeders that minimize seed damage, losses, and jamming. For example, using GI sheet for the inclined plate can reduce the risk of seed jamming due to its lower coefficient of friction with mustard seeds.

The results of the study revealed that the physical and frictional properties of mustard seeds vary significantly between different varieties. Overall, the study findings highlight the importance of considering the physical and frictional properties of mustard seeds when designing inclined plate seeders. This information can be used to optimize the design of inclined plate seeders, minimizing seed damage, losses, and jamming while ensuring optimal sowing performance.

Design of inclined plate

A seed plate of 170 mm diameter was used to fabricate an inclined plate for metering mustard seeds. The groove dimensions were selected based on the major and intermediate dimensions of the seeds, with a depth of 4.5 mm and an opening of 5.00 mm at the periphery. The angle of approach and departure of the groove were selected as 60° and 40° respectively. The bottom of the groove was kept round with a radius of 2.00 mm as shown in the fig1. A brush was also provided to remove any seeds or foreign particles that stuck in the groove.

Fig 1. Inclined seed metering plate

The seed metering discs were designed with a cell diameter of 5mm and a plate thickness of 4.5mm to suit most varieties of mustard seed. The thickness of each cell was designed to meter only one seed. The slope of the seed transfer cup was designed to take into account the lower sphericity value of mustard seeds, as the metered seeds need to be transferred to the seed placement unit quickly. Seed weight also affects seed flow from the seed metering device to the boot of the seeder.

Conclusion

In conclusion, this study has provided a comprehensive analysis of the physical and frictional properties of three mustard seed varieties: RLC-1, GSC-7, and PBR-91. These properties were scrutinized to facilitate the design of an efficient inclined plate for mustard seed metering in agricultural seeders. The research revealed significant differences among the seed varieties in terms of size, shape, weight, and surface properties. These distinctions have practical implications for seed handling and metering.Furthermore, the coefficient of friction results indicated that mustard seeds exhibit varying degrees of adherence to different surfaces. Notably, GI sheet surfaces demonstrated a lower coefficient of friction compared to plywood surfaces, suggesting that GI sheet may be a more suitable material for inclined plates in mustard seed seeders, as it reduces the risk of seed jamming.

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