

Original Research Article

Engineering properties of onion seeds insight to mechanical plantation

Abstract:

Engineering properties of the crop is an important factor to effectively design agricultural machine. In terms of onion seeding or planting, various physical, mechanical and frictional properties play the crucial role in development of machine and performance assessment. This study focused to analysis the various engineering properties of onion seeds with respect to the different soaking time. Experiment was performed to assess the change in engineering properties of onion seeds (Gavran, Puna fursungi and KSP-117) by soaking in water with predefined duration (Dry seed, Day 1 and Day 2). Average moisture content of onion seeds was varied from 9.44 to 40.87 % (d.b.). Sphericity, aspect ratio, geometric mean diameter, and thousand seed weight were varied in the range from 0.72 to 0.77, 0.71 to 0.76, 2.05 to 2.18 mm, and 3.50 to 6.75 g, respectively. The bulk density of onion seeds was observed in the range of 489.64 to 526.24 kg/m³. It was observed that there was gradual increment in bulk density with increase in soaking time. However, gradually decreasing trend was observed in case of true density. True density of onion seeds was varied from 1127.14 to 1245.64 kg/m³. Coefficient of friction of onion seeds on a selected material (Wood, Plastic, Mild steel and Aluminum) showed gradual growth with respect to the soaking time. It was reported higher for wooden material (0.55 to 0.64), followed by mild steel, aluminum and plastic respectively. Thus, engineering properties can play a significant role in development of mechanical planting system for onion seeds.

Key words: Onion seeds, Engineering properties, Planting, Physical properties, mechanical properties, Frictional properties.

Introduction:

Onion is widely consumed as a vegetable in India and involve as a staple food. India is one of the largest producers of onions in the world after China. Due to continually increasing demand of onion in foreign market, onion export has jumped 64 % in volume. The country has exported 1.53 lakh MT of fresh onion to the world, worth Rs. 3.43 thousand crores during the year 2021-22. Major onion producing state are Maharashtra, Madhya Pradesh, Karnataka, Gujrat and Rajasthan, which contributed more than 75 % share in production of onion.

Cultivation area of the onion in 2022-23 was estimated to be 5.8 lakh hectares where production was found to 318 lakh metric tons.

Demand of onion is also increasing with increasing the population, labour scarcity is one of the major issues due to expansion of urbanization. Mechanization is one of the important tools to address the above said issues. Engineering properties of the crop is the important factor to design any machine effectively. Thus, the machine can perform effectively and enhance the productivity and production.

In order to design a machine for onion seeding or planting, various physical, mechanical and frictional properties play major role and influence in development of machines such as pneumatic planting machine, inclined plate planting system, seed cleaners, graders, sorting machines, transportation components etc. There are various researchers studied the properties of onion and similar seeds for design of various machine such as Punil *et al.* (2019) analyzes the engineering properties of onion seed (Gujarat white onion-1) in aspect of design of various agricultural equipment such as precision planter. Planting device need only one seed to place at pre-specified distance. Due to very small size of onion seed, it is difficult to maintain uniformity by metering device. Metering device is an important factor which should be design properly corresponding to the crop properties. Frictional, mechanical and aerodynamic properties of onion seeds were determined by Pandiselvam *et al.* (2013), in aspect of designing of onion thresher. All properties of onion seed were observed by varying the moisture content. Similarly, Yalcin *et al.* (2009) also evaluated the various properties of onion seedlings where moisture content varied from 7.81 to 23.99 % (d.b.). Study revealed that the thousand seed weight varied from 3.85 to 4.33 g, sphericity from 0.65 to 0.68. Bulk density and true density were lied in the range of 550.18 kg/m³ to 521.68 kg/m³ and 1096.49 to 1083.46 kg/m³, respectively. It was also reported that the coefficient of friction of onion seeds was increased linearly with the increase in moisture content. It varied from 0.16 to 0.23 and 0.15 to 0.19 for aluminum and galvanized material.

Jadhav *et al.* (2020) conducted the study to analyze the engineering properties of paddy and wheat, in aspect of designing of pneumatic planting device. Size and shape of seeds is an important factor. Based on size of the crop and its other properties, orifice sizes need to be optimized for efficient performance of the planter. A study was performed by Gautam *et al.* (2016) to study engineering properties of pelleted onion seed. Pelleted seeds were less stucked in mechanical planters, that allow growers too accurately and efficiently plant direct seeded crops. Evaluated properties were used to design the different component

of planter. Small and irregular seed size lead to affect the placement of the seed in the existing planting system. For effective mechanism development of onion seed, study of engineering properties is primarily important. These properties changes with change in location and variety. Thus, this study was focused to analyzed the various engineering properties of onion seeds for particular location and variety.

Materials and Methods:

This study was conducted for three different varieties *i.e.*, Light Red Gavran, Puna Fursungi and KSP-117 of onion seeds, which are most prevailed in different region of India. In order to assess the physical, mechanical and frictional properties of onion seeds study was conducted in the laboratory of ICAR-Central Institute of Agricultural Engineering, Bhopal. Different properties *viz.*, size, sphericity, aspect ratio, weight, bulk density, true density, coefficient of friction etc. were measured for dry, 1 day-soaked and 2 day-soaked seeds of all the three selected varieties.

Preparation of sample: Onion seeds of all the three varieties were taken in the laboratory. The seeds were separated in three parts, *i.e.*, one part is soaked for one day, second part for 2 days and third part was kept dry. Soaking process of seeds is an essential process, which break the dormancy of the seed, increase the germination process and provide uniform growth. Thoroughly hydrated seeds before planting mainly helpful for hard coated seed, as it helps to overcome any water-related germination barriers. Thus, all engineering properties were measured for dry, 1 day soaked and 2 day-soaked seeds of all the three varieties.

Moisture content of onion seeds:

Various properties of the seeds majorly depend of the moisture content of seeds (Jadhav *et al.*, 2020), such as, seed weight, sphericity, density of seed, coefficient of friction etc. The change in moisture content significantly affect these properties. Therefore, moisture content of onion seeds were determined by using hot air oven method by maintaining the temperature at 105 °C for 24 h (ASAE, 1997). Onion seed was measured before and after drying with the help of weighing balance (Model Citizen CY 304, least count of 0.0001 g). Moisture content was determined with the help of equation 1.

$$\text{Moisture content (db), \%} = \frac{M_1 - M_2}{M_2} \times 100 \quad \dots 1$$

Where, M_1 is Weight of sample before drying, g and M_2 is Weight of sample after drying, g

Size:

Size of onion seeds is prominent factor in deciding the metering mechanism which can influence the performance of planting system. In case of pneumatic planting, orifice size of pneumatic unit needs to be optimized to reduce the unnecessary losses and consequently reduced the germination due to breakage of seed. Thus, length, width and thickness of onion seed were measured by vernier caliper (make: Baker; model: SDN 30, least count: 0.01 mm).

Geometric mean diameter

Geometric mean diameter represents the size index of the seeds. It is a single representative of all the three linear dimensions. The geometric mean diameter can be determined by equation 2 (Mohsin, 1970).

$$\text{Geometric mean diameter} = (LBT)^{1/3} \quad \dots 2$$

Where, L is maximum length of onion seed, mm; B: width of onion seed, mm and T: thickness of onion seed, mm.

Sphericity

Sphericity is the representative of the shape of the seed. Sphericity of onion seed can be determined by dividing geometric mean diameter to the maximum axial length of seed (Mohsin, 1970).

Aspect Ratio

It is also representative of the shape parameter. It is the ratio of width to axial length of the seed (B/L).

Weight of seed:

Thousand seed weight is the significant parameter for seed quality assessment and, its commercialization and cultivation practices. It directly and indirectly influences the growth and yield of crop. Thousand seed weight of were calculated by collecting randomly 1000 seeds of onion and weighted using weighing balance (Model Citizen CY 304). It was replicated five times.

Bulk density:

Bulk density of seeds was calculated using circular container where volume of container was known. Circular container filled with seeds and gently tapped to compact it (Pandiselvam *et al.* 2014). The weight of filled seeds were measured and bulk density were measured by

taking the ratio of mass of seed to the volume of the circular container. It was replicated five times.

True density:

True density (ρ_t) of onion seed were calculated using toluene displacement method (Peng *et al.* 2022). Toluene was filled in measuring cylinder and selected quantity of seeds (fixed weight) were filled into the liquid. Displacement volume of liquid (true volume) due to pouring seeds were measured and true density was calculated by taking ratio of mass of the onion seeds and true volume of onion seeds. Each treatment was replicated five times.

Coefficient of friction:

The fictional force (F) to the normal force (N) ratio is used to express the coefficient of friction (Bajpai *et al.* 2019). It is expressed by ' μ '. The coefficient of friction varied with the material used to design the different components of the planting machine. Thus, coefficient of friction was measured for different selected platform namely, wood, plastic and mild steel sheet for all the three varieties.

Statistical Analysis:

SPSS software was used to perform the analysis of variance using full factorial in a completely randomized design. Tukey's (b) test was performed for pairwise comparison of the mean of variables (Narwariya *et al.* 2023). All data were assessed and examined at 5 % level of significance.

Results and Discussions:

Moisture content: Moisture content of onion seed is an important factor insight to healthy growth and better yield of onion. The level of moisture affects every aspect of physical characteristics of seeds. All the properties are affected by the moisture content (Pandiselvam *et al.* 2014; Yalçın *et al.* 2009).

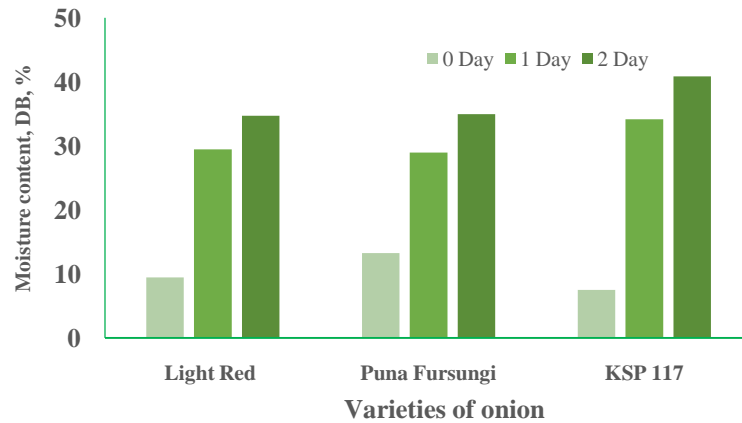


Figure 1: Variation of moisture content of onion seeds during soaking period

Figure 1 showed that moisture content (d.b.) of onion seeds for all selected varieties are varied from $9.44 \pm 0.57\%$ to $40.87 \pm 0.67\%$. Due to soaking process, moisture content of onion seeds was increased from zero days to second day. Moisture absorption percent was observed to be higher for KSP variety, however, the minimum moisture content for dry onion seed (7.50%) was also reported in the KSP 117 variety. Puna fursungi variety showed the higher moisture content (13.25%) for dry seed. In the same manner, maximum percent of moisture for two days-soaked onion seed was found for KSP 117 variety, whereas, for Light red and Puna fursungi variety this was observed to be similar at par as 34.71% and 34.34% respectively. Observed findings were in agreement with the study conducted by Pandiselvam *et al.* 2013.

Geometric mean diameter

Geometric mean diameter was determined using primary linear dimensions. Minimum value of GMD was observed as 2.05 mm for Gavran variety (dry seed), while maximum GMD was reported as 2.18 mm for 2 day-soaked seed for KSP-117 variety (Table 1). Gradual increase in geometrical diameter with respect to the soaking time was observed. The increase in GMD with the increase in soaking period might be due to absorption of moisture by the seeds leads to elongation of linear dimension. Due to the hygroscopic nature of the onion seed, water molecules were absorbed by the seed and hold in the cellular structure of the seeds. By the process of water absorption, seed were swelled and leads to increase in size of seeds. Similar results were reported by Sunitha *et al.* (2016) and Punil *et al.* (2019).

Sphericity

Onion shape was presented by using the sphericity and aspect ratio. The sphericity of seeds can impact their flow characteristics within a machine or conveyor system. Seeds with higher

sphericity tend to roll more easily, promoting smoother and more predictable material flow. Average sphericity of onion seeds under different soaking conditions were varied from 0.72 to 0.76 from zero day (Dry seed) to 2 days of soaking period. Punil *et al.* (2019) also reported average sphericity of 0.75 for GWO-1 onion variety, which was similar at par to the findings of the study. Table 1 showed that sphericity remained unaffected by sowing period.

Aspect Ratio

Based on the primary linear dimensions, aspect ratio of onion seed was determined of all selected varieties for dry, 1 days and 2 days of soaking period. Table 1 showed that aspect ratio of onion seeds varied from 0.71 to 0.76. Maximum aspect ratio (0.76) was observed for KSP-117 variety, whereas, minimum aspect ratio (0.71) was observed in Gavran variety. Punil *et al.*, 2019 reported that the average aspect ratio of onion seed was 0.74, It was in agreement with the finding of this study.

Table 1: Engineering properties of onion seeds for different varieties with soaking time

Particulars	Gavran			Puna Fursungi			KSP-117			
	Dry	1 Day	2 Days	Dry	1 Day	2 Days	Dry	1 Day	2 Days	
Sp	Mean	0.72	0.73	0.75	0.75	0.75	0.74	0.76	0.76	0.76
	SD	0.81	0.90	0.94	0.06	0.06	0.05	0.07	0.06	0.04
	CV, %	7.67	8.93	10.4	7.67	8.20	7.09	9.04	7.78	4.78
AR	Mean	0.71	0.74	0.74	0.74	0.76	0.72	0.75	0.76	0.76
	SD	0.07	0.07	0.09	0.08	0.08	0.08	0.09	0.08	0.07
	CV, %	9.64	9.15	12.65	10.91	12.40	10.85	12.84	10.44	9.20
GMD, mm	Mean	2.05	2.17	2.15	2.12	2.24	2.19	2.08	2.25	2.18
	SD	0.17	0.11	0.17	0.14	0.21	0.16	0.14	0.15	0.11
	CV, %	7.69	5.24	8.11	6.85	9.42	7.21	6.87	6.51	4.93
BD, kg/m ³	Mean	497.83	565.62	597.94	481.57	553.29	570.51	483.24	547.47	549.69
	SD	5.41	7.58	6.58	8.86	4.19	15.75	6.71	14.10	23.05
	CV, %	1.09	1.34	1.10	1.84	0.76	2.76	1.39	2.60	4.19
TD, kg/m ³	Mean	1245.64	1179.71	1195.98	1160.15	1127.14	1130.11	194.71	1113.96	1146.72
	SD	65.12	10.19	75.38	60.19	33.27	27.47	30.94	24.10	62.35
	CV, %	5.23	0.86	6.30	5.19	2.95	2.43	2.59	2.16	5.44

Thousand seed weight:

Thousand seed weight of onion seed sample were assessed. Thousand seed weight of onion seeds were gradually increased with respect to the soaking time. This was due to absorption of moisture by the seed with time. It was observed that thousand seed weight of onion seeds varied from 3.50 to 6.75 g. Thousand seed weight was minimum for dry seed of Puna

fursungi variety. It was revealed that thousand seed weight followed an increasing trend with the increase in soaking period. Table 2 showed that thousand seed weight was significantly affected by the variety and soaking period. It was also revealed that the interaction of variety and soaking period was also significantly affected thousand seed weight. It might be due to varietal effect and moisture absorption of onion seeds leads to change in linear dimensions. Table 3 showed that there was significant difference between the mean of thousand seed weight for variety Gavran and Puna fursungi with KSP-117. Whereas, thousand seed weight were significantly different for all the three soaking treatments. It might be due to the variation in moisture content in all the three soaking treatments.

Bulk density:

Gravimetric properties were a principal factor to theoretically design and effective calculation for optimum suction required to seed picking, holding the pneumatic metering unit and hopper size calculation for mechanized plantation (Rajaiah *et al.* 2016 and Singh *et al.* 2005). Thus, Bulk density for the selected varieties were recorded with respect to the soaking time and assessed the factor accordingly to the effect of moisture content. The bulk density varied from 481.57 to 597.94 kg/m³ (Table 1). Table 2 revealed that the bulk density was significantly affected by the variety and soaking period. The first order interaction of variety and soaking period was also found significant. The bulk density was significantly increased with the increase in Soaking period. Sunitha *et al.* (2016) and Pandiselvam *et al.* (2014) were also reported similar findings. Tukey's (b) analysis showed that there was significant difference in the bulk density of all the three varieties (Table 3). This might be due to variation in linear dimensions of all the three varieties and absorption of moisture. The bulk density was also significantly different for all the three soaking treatments. The increase in the bulk density by soaking treatments was might be due to reduction in intergranular pore space (Pandiselvam *et al.* 2014).

True density:

True density of onion seed was also evaluated with different soaking time for all the three varieties. Table 1 showed that the true density varied from 1113.96 to 1245.64 kg/m³. The true density was significantly affected by the variety and soaking period (Table 2). Tukey's (b) analysis showed that the true density of Gavraan variety had significant difference with the Puna fursungi and KSP-117 Variety. Whereas, there was no significant difference between the

true density of Puna fursungi and KSP-117 Variety. It might be due to variation in the linear dimensions of all the three varieties. The true density of dry seed was significantly different with the soaking period of one and two days. However, there was no significant difference in true density by soaking for one and two days (Table 3). It was observed that the true density decreased with the soaking of one day thereafter, it further increased for soaking of two days.

Observed trend was found to be similar to the study reported by Bajpai *et al.* (2020). When onion seeds absorb moisture, they tend to swell and increase in size. This swelling results in an increase in volume while the mass remains relatively constant, causing the true density to decrease. The soaking period of one or two days had no significant difference on true density might be due to less variation in the weight and volume of the seed as most of the pores filled with water after one day of soaking (Table 3).

Table 2: Analysis of variance for selected engineering properties of onion seeds

SOV	Bulk density	True density	1000 seed weight	Coefficient of friction			
				Wood	Plastic	Mild Steel	Aluminum
Model	<0.0001**	<0.002**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Variety	<0.0001**	<0.001**	<0.0001**	<0.0001**	<0.0001**	<0.019*	<0.0001**
Days	<0.0001**	<0.005**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Variety × Days	<0.033*	<0.846 ^{NS}	<0.004**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Mean	537.90	1166.02	5.55	0.54	0.42	0.51	0.52
R ²	0.93	0.96	0.94	0.99	0.98	0.97	0.97

** Significant at 1 % level of significance; * Significant at 5 % level of significance; NS Non-significant

Coefficient of friction:

The coefficient of friction (μ) of onion seeds were observed for the selected platform materials (Wood, Plastic, Mild steel and Aluminum) and depicted in figure 2. Study revealed that the ' μ ' was varied from 0.55 to 0.64, 0.25 to 0.56, 0.36 to 0.66 and 0.36 to 0.63 for wood, plastic, mild steel and aluminum material respectively. The coefficient of friction was gradually increased with respect to the soaking period. Pradhan et al. (2009) and Garnayak et al. (2008) also revealed that the coefficient of friction was increased by increasing the moisture content. Similar trend was observed for all the platform materials except plastic surface.

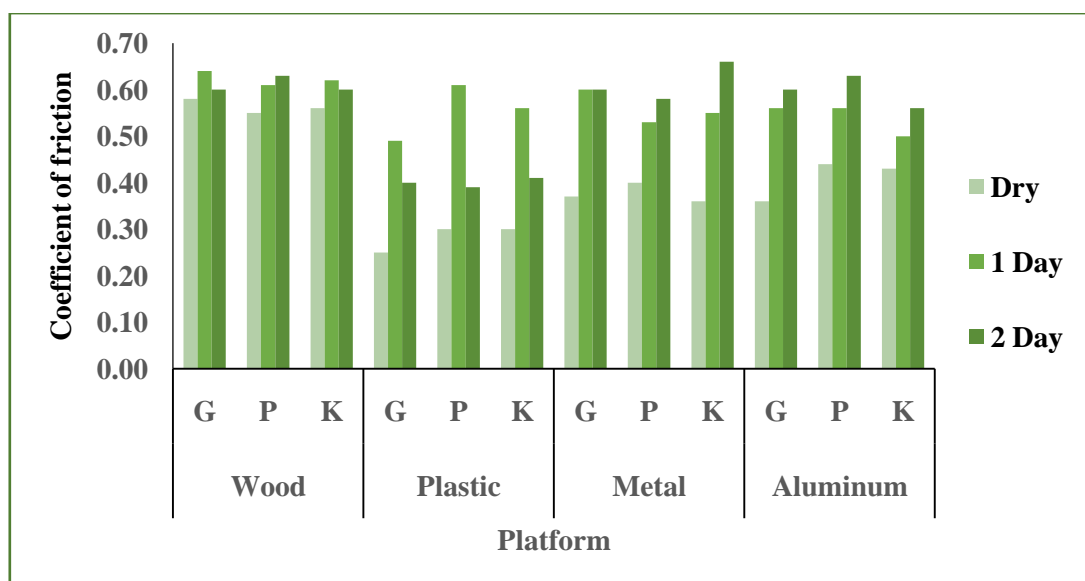


Figure 2: Coefficient of friction under different platform for different varieties (G- Gavran; P- Puna Fursungi; K- KSP-117)

However, in case of plastic material, μ was gradually reduced after first day of soaking time. Similar findings were reported by Pandiselvam *et al.* (2014). It might be due to more smoothness of plastic surface and less moisture absorption capacity. Plywood surface offered maximum coefficient of friction even in case of dry seed also. Jadhav *et al.* (2020) was also reported the μ for paddy and wheat on wood, plastic and mild steel material.

Table 3: Tukey's b comparison least squares mean (LSM) of dimensional properties

Particulars	Varieties			Soaking time		
	Gavraan	Puna fursungi	KSP-117	Dry	One day	Two days
LSM of BD, kg/m ³	524.80 ^a	535.12 ^b	553.79 ^c	487.54 ^a	553.46 ^b	572.71 ^c
LSM of TD, kg/m ³	1207.10 ^b	1139.12 ^a	1151.79 ^a	1200.16 ^b	1140.26 ^a	1157.60 ^a
LSM of 1000 seed weight, g	5.02 ^a	5.02 ^a	5.55 ^b	3.75 ^a	5.63 ^b	6.21 ^c
LSM of <i>CF Wood</i>	0.60 ^b	0.51 ^a	0.51 ^a	0.39 ^a	0.61 ^b	0.62 ^c
LSM of <i>CF plastic</i>	0.38 ^a	0.43 ^b	0.43 ^b	0.29 ^a	0.40 ^b	0.55 ^c
LSM of <i>CF MS</i>	0.51 ^a	0.53 ^b	0.53 ^b	0.37 ^a	0.56 ^b	0.62 ^c
LSM of <i>CF Aluminum</i>	0.51 ^a	0.52 ^b	0.54 ^c	0.41 ^a	0.56 ^b	0.59 ^c

Analysis of variance depicted that coefficient of friction was significantly affected by the variety and soaking period for all the platform materials. The first order interaction of variety and soaking period was also found significant at 1% level of significance (Table 2). For all of the platform materials selected, the coefficient of determination was also found to be higher than 0.90 which showed that the model predicted adequately. Tukey's (b) mean

comparison showed that there was significant difference in the coefficient of friction with the soaking treatment for all the platform materials. Whereas, coefficient of friction for Gavraan variety was significantly different from the Puna fursungi and KSP 117 variety for wood plastic and MS material. Whereas, in case of aluminum it was different for all the three variety.

Conclusions:

Engineering properties of onion seeds was highly influenced by the moisture content of onion seeds which was varied by soaking the seeds. It revealed that the moisture content plays an important role by which the other essential properties of seeds were also affected. All linear dimensions were gradually increased with the increase in moisture content. Gravimetric properties are an important factor in terms of design consideration of any machine development. Variation in the moisture was also influenced the gravimetric properties. Bulk density was linearly increased with respect to the soaking time and varied from 481.57 to 597.94 kg/m³. However, declining trend was observed for true density. Study also revealed that the coefficient of friction was also affected significantly by variety and soaking period for different platform materials. Thus, the variety and moisture content played significant role in engineering properties of onion seed. The study provides complete insight for variation in behaviour of onion seed properties with moisture content for three popular varieties of onion i.e., Gavraan, Puna fursungi and KSP 117, that can help in determining design factors for development of onion planting machinery.

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