Physical properties of soybean cultivated in NEH region of India

Hijam Jiten Singh, Dipankar De, P. K. Sahoo

(*Division of Agricultural Engineering, Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012, India*)

Abstract: This study was conducted to investigate physical properties of soybean cultivated in NEH region of India. Major, minor and intermediate mean diameters of soybean seeds were 8.88±0.55 mm, 4.68±0.32 mm and 6.46±0.36 mm, respectively. Geometric mean diameter was 6.45±0.35 mm. Mean roundness of the seeds was 0.66±0.02, while mean sphericity of the seeds in their natural rest position was 0.73±0.02. Bulk density, true density, porosity, thousand seeds weight and angle of repose were 749.50±1.59 kg/m^3, 1171.80±115.02 kg/m^3, 34.62±9.00 %, and 177.55±3.04 g and 25.82±1.88 °, respectively. The coefficient of static friction over aluminum, mild steel, and plywood surfaces were 0.46±0.03, 0.45±0.03 and 0.47±0.02, respectively. Statistical analysis indicated that the indigenous cultivar commonly found in NEH region was significantly difference from the cultivars found in the plains.

Keywords: soybean, physical properties, NEH region, India

Citation: Singh, H. J., D. De, and P. K. Sahoo. 2014. Physical properties of soybean cultivated in NEH region of India. Agric Eng Int: CIGR Journal, 16(3): 55−59.

1 Introduction

Soybean (*Glycine max*) is an important crop in India and it has been declared as a potential crop for north-eastern-hilly (NEH) region of India. The region offers scope for cultivation of a wide variety of agricultural crops because of its diversities in topography, altitude and climatic conditions. Soybean is one of the important major crops in the region. It is also being considered as a viable option in the region for enhancing food security and livelihood of rural households in the region (Baiswar et al., 2012). Soybean can be treated as oilseed as well as pulse crop with highest percentage of protein among all pulses. It is the only pulse crop that contains 20 % of oil in the seed, and also regarded as potential oil yielding crop. It contributes to 1/3rd of total oil produced in the world.

In hilly areas of NEH region, rice production is low and thus soybean is a profitable crop. Soybean is grown as a sole crop or it is intercropped with other suitable crops. With inter-cropping, the stability in production can be ensured and the control of pests and diseases can be done conveniently. Inter-cropping of maize and soybean, traditionally prevalent in the region, is a good practice. Inter-crops like orange-soybean, tapioca-soybean, etc. can also be practiced.

The best time for sowing of soybean in the region is June to July (kharif season). Varieties of products are prepared from soybean, such as soya milk, soya cheese, soya flecks for breakfast, fermented soybean as “Kinema” in Nepali or “Hawaijara” in Manipuri, soya biscuits as nuggets. It is also consumed in the form of boiled soybean pod or roasted beans, especially for the children. Its regular consumption helps to reduce cardiac disorders due to presence of abundant poly unsaturated fatty acid in soya oil (Anonymous, 2013).

The physical and engineering properties of seed are important in adoption and design of various handling equipment suitable for the region involved in, i.e. seeding, threshing, cleaning and sorting. Design-related physical properties of maize, sorghum, millet, groundnut, guava, orange, grape fruit and bitter lemon were studied (Waziri and Mittal, 1983). They reported that seed was placed in

Received date: 2014-05-30 **Accepted date:** 2014-07-11
Corresponding author: Hijam Jiten Singh, Division of Agricultural Engineering, Indian Agricultural Research Institute, Pusa Campus, New Delhi-110012, India. Email: hijam_jten@yahoo.co.in.

natural rest position and vertical position to obtain major, minor and intermediate diameters. A study on dimensions of agricultural product indicated that large number of measurements in various directions should be taken to determine the average diameter (Mohsenin, 1986). However, it was concluded that three major, intermediate and minor diameter were sufficient to determine the size of a material.

Jayan and Kumar (2004) conducted a study on physical properties of maize (CoH-3), red gram (APK-1), and cotton (MCU-5) seeds as design parameters for a planter. Thickness and cell diameters of the seed metering discs were designed with reference to the maximum breadth and length of seeds. Both roundness and sphericity affected seed flow through various components of the planter. Chukwu and Orhevba (2011) determined the selected engineering properties of two improved varieties of soybean (Samsoy 2 and Tas 1485-ID) grown in Oman. Studies indicated that the physical and engineering properties of seeds vary with the type of crop as well as their varieties.

This study was aimed to determine some physical and engineering properties of indigenous soybean cultivar (RAUS 5) commonly found in the NEH region of India. The properties are namely size, shape, thousand seeds weight, bulk density, angle of repose and coefficient of static friction on three different surfaces.

2 Materials and methods

The experiments to measure the physical properties of soybean cultivated in NEH region of India were carried out in the laboratory of the Division of Agricultural Engineering, IARI, New Delhi. The soybean variety 'RAUS 5' (S1) commonly found in NEH region was considered in the study. The soybean seed was collected from local market at Imphal, Manipur, India in the month of November, 2012. The relevant properties of seed of this crop were measured at 13.5 % moisture content. In order to check any variations with the varieties sown in plain areas of the country, soybean variety 'BRAGG' (S2) was also studied and its properties were also measured at the same moisture content. Statistical analysis was conducted to establish the significant difference between the two varieties. Size of the seed in terms of major, minor and intermediate diameters was measured using digital Vernier caliper (least count: 0.01). The dimensions of 50 randomly selected seeds for each variety were measured and their geometric mean diameter was determined. Geometric mean diameter was calculated as:

$$GMD = \sqrt[3]{a \times b \times c} \tag{1}$$

where, a = Major diameter, mm; b = Intermediate diameter, mm, and c = Minor diameter, mm.

Figure 1 Showing the measurement of major, minor and intermediate diameters

The shape of seed is expressed by its sphericity and roundness. Sphericity is a measure of shape character compared to a sphere of the same volume. Assuming that volume of solid is equal to the volume of tri-axial ellipsoid with intercepts a, b, c and the diameter of circumscribed sphere is the longest intercept of the ellipsoid, the degree of sphericity was calculated as follows (Mohsenin, 1986):

$$DS = \frac{\text{Geometric mean diameter}}{\text{Major diameter}} \tag{2}$$

$$DS = \frac{\sqrt[3]{(a \times b \times c)}}{a} \tag{3}$$

where, DS = Degree of sphericity; a = Major diameter, mm; b = Intermediate diameter, mm, and c = Minor diameter, mm.

The roundness was calculated as follows (Mohsenin, 1986):

$$R_p = \frac{A_p}{A_c} \quad (4)$$

where, R_p = Roundness; A_p = Projected area, mm^2, and A_c = Area of the smallest circumscribing circle, mm^2.

Bulk density of seed was measured using gravimetric methods. The measuring cylinder (250 ml capacity) was filled with seeds without compaction and then weighed. It was replicated 20 times. The bulk density was calculated as follows:

$$\rho_b = \frac{W}{V} \quad (5)$$

where, ρ_b = Bulk density, kg/m^3; W = Weight of seed, kg, and V = Volume of seed, m^3.

True density of seed was determined by toluene displacement method (Aviara et al., 2005; Ogunjimi et al., 2002). The volume and true density were evaluated for a sample of 100 seed. The weight of the sample was recorded. The sample was immersed in a jar containing toluene liquid (C_7H_8). The displaced volume of toluene was recorded for each sample, thus volume of sample was determined. True density was calculated using standard relationship as given in Equation (5) (Mohsenin, 1986). It was replicated 20 times.

$$\rho_t = \frac{W}{V_d} \quad (6)$$

where, ρ_t = True density, kg/m^3; W = Weight of seed, kg, and V_d = Volume of seed, m^3.

The porosity was calculated from the average value of bulk densities and true densities using Equation (6) (Thompson and Issac, 1967; Mohsenin, 1986).

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (7)$$

where, ε = Porosity; ρ_t = True density, kg/m^3, and ρ_b = Bulk density, kg/m^3.

A random sample of thousand seeds was selected and weighed on an electronic weighing balance having sensitivity of 0.01 g. The experiment was replicated for 20 such samples to determine average value of 1,000 seeds weight.

The apparatus used for measuring dynamic angle of repose consisted of a funnel with an adjustable throat opening mounted on a stand. A circular plate, with four centre arms, was mounted in the funnel above the adjustable throat. The funnel was filled with seeds by keeping its adjustable throat closed. The throat was fully opened to allow free flow of seeds over and around the plate mounted beneath the funnel. At the end of process, a heap-cone of the seed was formed on the plate. From the heap-cone, base diameter and height of cone were measured. The angle of repose was calculated using the following relationship:

$$\theta = \tan^{-1}(\frac{2h}{d}) \quad (8)$$

where, θ = Angle of repose, deg; h = Height of the cone, m, and r = Radius of the cone, m.

The coefficient of static friction for three surfaces i.e., plywood, aluminium and mild steel was measured for the seeds using incline plane method. The material was kept on horizontally placed surface and the slope was increased gradually. The angle (α) at impending slide was recorded. The coefficient of static friction was expressed by tan α. The procedure was repeated 20 times for each seed.

Statistically analysis of the measured properties was carried out using SPSS software. Independent sample t-test for equality of means for physical properties of soybean was done to establish the significant difference between the two varieties of soybean.

3 Results

3.1 Size of soybean

The size of soybean is defined by major, minor and intermediate dimension of maize seed. The observations recorded for soybean are presented in Table 1. The average major, minor and intermediate diameters of S1 were 8.88±0.55 mm, 4.68±0.32 mm and 6.46±0.36 mm, respectively. Whereas, the major, minor and intermediate mean diameters of S2 were found as 6.99±0.39 mm, 5.11±0.31 mm and 6.21±0.31 mm, respectively. The geometrical mean diameter (GMD) of S1 and S2 were 6.45±0.35 mm and 6.05±0.29, respectively. The GMD value of S1 was increased by 6.61% from S2. The coefficients of variation in all cases were less than 7%. Statistical analysis indicated that major, minor, intermediate and geometric mean diameters of S1 were significantly different as compared to S2 (Table 3).

3.2 Shape of soybean

The shape of soybean was determined in terms of roundness and sphericity, which is shown in Table 1. The average sphericity of S1 and S2 was 0.73±0.02 and 0.87±0.03, respectively. The mean roundness of soybean seeds were 0.66±0.02 and 0.81±0.03 for S1 and S2, respectively. The coefficients of variation in all cases were less than 4%. Both the sphericity and roundness of S1 was significantly lower than S2 (Table 3). The sphericity and roundness of S1 were reduced by about 16.09% and 18.52%, respectively compared to S2.

Table 1 Shape and size of soybean

Property	Descriptive statistics	Soybean variety	
		RAUS5 (S1)	BRAGG (S2)
Major diameter, mm	Mean±SD	8.88±0.55	6.99±0.39
	C.V., %	6.19	5.58
Intermediate diameter, mm	Mean±SD	6.46±0.36	6.21±0.31
	C.V., %	5.57	4.99
Minor diameter, mm	Mean±SD	4.68±0.32	5.11±0.31
	C.V., %	6.84	6.07
GMD, mm	Mean±SD	6.45±0.35	6.05±0.29
	C.V., %	5.43	4.79
Sphericity	Mean±SD	0.73±0.02	0.87±0.03
	C.V., %	2.74	3.45
And Roundness	Mean±SD	0.66±0.02	0.81±0.03
	C.V., %	3.03	3.70

Note: GMD = Geometric mean diameter; SD = Standard deviation; C.V. = Coefficient of variation.

3.3 Bulk density, true density and porosity

The physical properties of soybean, including bulk density, true density and porosity represents the volume of material involved in various handling operations, are shown in Table 2. The average bulk density, true density and porosity of soybean S1 and S2 were 749.50±1.59 kg/m^3 and 742.00±6.41 kg/m^3; 1171.80±115.02 kg/m^3 and 1132.15±110 kg/m^3; and 34.62±9.00% and 33.72±7.00%, respectively. Only the bulk density of soybean S1 and S2 were significantly different. Both the true density and porosity were not significantly different (Table 3).

3.4 Thousand seed weight

The average thousand seed weights were 177.55±3.04 g and 104.00±0.74 g for S1 and S2 seeds, respectively (Table 2). Seed S1 was 70.72 % larger than S2. The maximum thousand seed weight of 180.59 g was observed in case of the seed S2. The coefficient of variation of thousand seed weight for both the varieties was less than 2%. Table indicated that thousand seed weights of variety S1 and S2 were significantly different (Table 3).

Table 2 Bulk density, true density, porosity mass and angle of repose of soybean

Property	Descriptive statistics	Soybean variety	
		RAUS5 (S1)	BRAGG (S2)
Bulk density, kg/m^3	Mean±SD	749.50±1.59	742.00±6.41
	C.V., %	0.21	0.86
True density, kg/m^3	Mean±SD	1171.80±115.02	1132.15±110
	C.V., %	9.81	9.71
Porosity, %	Mean±SD	34.62±9.00	33.72±7.00
	C.V., %	25.99	20.76
1000 seeds weight, g	Mean±SD	177.55±3.04	104±0.74
	C.V., %	1.71	0.71
Angle of repose, (°)	Mean±SD	25.82±1.88	15±1.42
	C.V., %	7.28	9.47

Note: SD=Standard deviation; C.V.=Coefficient of variation.

Table 3 Independent sample test for physical and engineering properties of soybean

Properties	t-test for equality of means		
	t	d.f.	Sig. (2-tailed)
Major diameter	19.71	98	0.000*
Intermediate diameter	3.73	98	0.000*
Minor diameter	-6.67	98	0.000*
GMD	6.18	98	0.000*
Roundness	-29.33	98	0.000*
Sphericity	-26.85	98	0.000*
Bulk Density	4.94	38	0.000*
True Density	0.82	38	0.414
Porosity	0.28	38	0.780
1000 Seeds weight	101.11	38	0.000*
Angle of Repose	20.05	38	0.000*

Note: * Difference is significant at 5 % level of significance.

3.5 Angle of repose

Mean values of angle of repose of soybean S1 and S2 were found to be 25.82±1.88° and 15.00±1.42°, respectively. The mean angle of repose of S1 was increased by 72.13% compared to S2. The coefficient of variation of angle of repose for both the varieties was less than 10%. Table 3 indicated that angle of repose of S1 and S2 were significantly different.

3.6 Frictional properties

The frictional properties (coefficient of static friction) of soybean observed over different surfaces are summarized in Table 3. It was observed that the coefficient of static friction of soybean (S1) over the surface of aluminium, mild steel and plywood surfaces were 0.46±0.03, 0.45±0.03 and 0.47±0.02, respectively. Whereas, the coefficient of static friction of soybean (S2) over the surface of aluminium, mild steel and plywood surfaces were found as 0.37±0.03, 0.36±0.04 and

0.30±0.02, respectively. The maximum value for coefficient of static friction was on plywood surface for seed S1. T-test indicated significant difference in the mean value of coefficient of static friction for all cases, Table 5.

Table 4 Frictional property of soybean

Materials	Descriptive statistics	Soybean variety	
		RAUS5 (S1)	BRAGG (S2)
Aluminium	Mean±SD	0.46±0.03	0.37±0.03
	C.V., %	6.52	8.11
Mild steel	Mean±SD	0.45±0.03	0.36±0.04
	C.V., %	6.67	11.11
Plywood	Mean±SD	0.47±0.02	0.30±0.02
	C.V., %	4.25	6.67

Note: SD=Standard deviation; C.V.=Coefficient of variation

Table 5 Independent sample test for frictional property soybean

Friction surface	t-test for equality of means		
	t-value	d.f.	Sig. (2-tailed)
(a) Aluminium	8.888	38	0.000*
(b) Mild Steel	8.544	38	0.000*
(c) Plywood	18.051	38	0.000*

Note: * Difference is significant at 5 % level of significance.

4 Conclusions

The investigations on physical and engineering properties of soybean varieties 'Murli Makai' (S1) and HQPM5 (S2) revealed that the properties are largely dependent on variety, and were observed as followings:

1) The mean major, minor, intermediate and geometric mean diameters of S1 were 8.88±0.55 mm, 4.68±0.32 mm, 6.46±0.36 mm, and 6.45±0.35 mm, respectively. The GMD value of S1 was increased by 6.61 % from S2.

2) The average sphericity and roundness of S1 were 0.73±0.02 and 0.66±0.02, respectively. The sphericity and roundness of S1 were reduced by about 16.09% and 18.52%, respectively compared to S2.

3) The average bulk density, true density and porosity of maize seed S1 were 749.50±1.59 kg/m^3, 1171.80±115.02 kg/m^3 and 34.62±9.00 %, respectively.

4) The average thousand seed weights of S1 was 177.55±3.04 g. Seed S1 was 70.72 % larger than that of S2.

5) The mean value of angle of repose of soybean S1 was found to be 25.82±1.88º. The mean angle of repose of S1 was increased by 72.13 % compared with S2.

6) It was observed that the coefficient of static friction of maize seed (S1) over the surface of Aluminium, mild steel and plywood surfaces were 0.46±0.03, 0.45±0.03 and 0.47±0.02, respectively.

7) Statistical analysis indicated that the cultivar commonly found in NEH region was significantly different from the cultivars found in the plains.

Acknowledgements

Authors are highly thankful to the Indian Agricultural Research Institute, New Delhi, India for providing the financial and infrastructural supports for the experiment.

References

Anonymous. 2013. Available at: http://www.sikkimagrisnet.org/General/en/Soybean.aspx. (accessed on 20 January, 2013)

Aviara, N. A., E. Mamman, and B. Umar. 2005. Some physical properties of balanites aegyptiaca nuts. *Biosystems Engineering,* 92(3): 325-334.

Baiswar, P., N. T. Ao, D. N. Upadhyay, and S. Chandra. 2012. Screening of varieties against soybean rust caused by phakopsora pachyrhizi in mid-hills of Meghalaya. *Indian Journal of Hill Farming,* 25(1): 17-20.

Chukwu, O., and B. A. Orhevba. 2011. Determination of selected engineering properties of soybean (*glycine max*) related to design of processing machine. *Journal Agricultural Food Technology,* 1(6): 68-72.

Jayan, P. R., and V. J. F. Kumar. 2004. Planter design in relation to the physical properties of seeds. *Journal of Tropical Agriculture*, 42 (1-2): 69-71.

Mohsenin, N. N. 1986. Physical properties of plant and animal materials. 2nd Edition. *Gordan and Breach Science Publishers, Inc.* New York.

Ogunjimi, L. A. O., N. A. Aviara, and O. A. Aregbesola. 2002. Some engineering properties of locust bean seed. *Journal of Food Engineering,* 55: 95-99.

Thompson, R. A., and G. W. Issac. 1967. Porosity determination of grain and seeds with air compression pscynometer. *Transactions of ASAE,* 10(5): 693-696.

Waziri, A. N., and J. P. Mittal. 1983. Design related physical properties of selected agricultural products. *Agricultural Mechanization in Asia, Africa and Latin America*, 14(1): 59-62.