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Moisture Dependent Selected Engineering Properties of *Deenanath* Seeds in Relation to Development of Processing Machinery

Sanjay Kumar Singh[1]*, Sheshrao Kautkar[2], P. K. Pathak[3], Bholuram Gurjar[4], Sunil Swami[5] and Prabhu Govindasamy[6]

[1]Principal Scientist, [3]Principal Scientist and Head, [4]Scientist, Division of Farm Machinery and Post Harvest Technology, ICAR - IGFRI, Jhansi, India; [2]Scientist, ICAR- CIRCOT, Mumbai, India; [5]Scientist, Division of Seed Technology, ICAR - IGFRI, Jhansi, India; [6]Scientist, Division of Crop Production, ICAR - IGFRI, Jhansi, India. *Corresponding author email address: sksingh7770@yahoo.com

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ABSTRACT

Propagation of grasses through seeds is important in view of vigour and germination. Various grasses as *Pennisetum pedicellatum* Trin., *Cenchrus ciliaris* L., Chrysopogan fulvus have lower vigour and germination, due to which they need specific operations as defluffing, separation of true seeds, cleaning and grading by specific machines. In designing a machine for a specific use, physical properties and their behaviour with moisture play an important role. A study was conducted to assess the effect of moisture content at five levels [6.88 - 19.23 %, (d.b.)] on selected physical properties of defluffed *Deenanath* grass seed. The length, width, thickness, arithmetic mean diameter, and geometric mean diameter of defluffed *Deenanath* seed increased from 2.30 mm to 2.56 mm, 0.71 mm to 0.96 mm, 0.47 mm to 0.63 mm, 1.16 mm to 1.38 mm, and 0.90 mm to 1.15 mm, respectively, with increase in moisture content 6.88 % to 19.23 %. Bulk density, true density, and porosity decreased from 652.16 kg.m^{-3} to 585.78 kg.m^{-3}, 852.63 kg.m^{-3} to 792.71 kg.m^{-3}, and 25.62 % to 24.97 %, respectively, with increase in moisture content from 6.88 % to 19.23 per cent. The aspect ratio, sphericity, surface area, volume, and thousand-seed mass of the seed were in the range of 30.91 - 37.51 %, 0.39 - 0.45, 2.58 - 3.23 mm^2, 3.71 - 4.97 mm^3, and 0.480 - 0.523 g, respectively. Linear relationships with correlation coefficients higher than 0.90 were observed for the physical properties over the experimental range of moisture content.

Pennisetum pedicellatum Trin., commonly known as *Deenanath* (friends of poor) or *Desho* grass is an important fodder species of eastern and western states of Africa, South-east Asia, and Northern Australia (Chatterji *et al.,* 2014; Asmare *et al.,* 2017). It has ample scope under drought and marginal soil by providing nutritional security and a high quantum of quality forage to the animals (Kumar and Ghosh, 2018).

Apart from the animal feed, it is also used to reverse land degradation, rehabilitate degraded land, and to improve the physical and chemical properties of soil (Mandal *et al.,* 2017; Zhang *et al.*, 2020). In India, it is found growing in the natural grasslands on poor and marginal soils of Bihar, Odisha, West Bengal, Madhya Pradesh, and Uttar Pradesh (Roy *et al.*, 2019). Asmare *et al.* (2016) evaluated the *Pennisetum pedicellatum* as hay, and indicated its use as a basal diet for sheep with better performance than natural pasture hay- based diets. The grass has the potential to be used as source of some important nutrients (47.16 % carbohydrate, 19.3 % crude fibre, 7.7 % crude protein, 22.7 % ash) in alleviating potassium, phosphorus and calcium deficiencies in animals (Mustapha *et al.,* 2018). It is a profusely tillering annual variety with high leaf/ stem ratio of 0.44 to 0.83 (Yirgu *et al.*, 2017) and low oxalate content of 1.001 mg.100 g^{-1} dry weight (Suleiman *et al.*, 2020). Potential of green fodder yield (GFY) varies from 30.0 - 48.0 $t.ha^{-1}$, and dry matter yield (DMY) varies from 6.0 - 6.8 $t.ha^{-1}$ (Ahmed *et al.,* 2017). Highest CP (9.38 %) was observed at 90-day harvest, and lowest (7.33 %) at 150-day of harvest (Asmare *et al.,* 2016). The mineral contents (mg.100 g^{-1} dry weight) of *Pennisetum pedicellatum* Trin. grass was reported by Suleiman *et al.* (2020) as 11167 ± 3.82 sodium, 10850 ± 229.13 potassium, 108.3 ± 0.03 calcium, 28.3 ± 0.03 magnesium, 315.7 ± 0.03 phosphorus, 0.58 iron, 5.81 chromium and 4.07 nickel. It is a maintenance type forage with less than 4 % digestible crude protein and 50-52 % total digestible nutrients, and can be conserved as hay when harvested at 50 % flowering stage (Mahanta *et al.*, 2014). However, seed yields of grasses are very low, while demand for seed is high for rejuvenation of grasslands (Meena *et al*., 2019). *Deenanath* spikelets are about 4-6 mm long generally comes in clusters of 1-5**.** Germination of fluffy grass seeds are also less (<40 %). The light-weighed with 80 $kg.m^{-3}$ density (Vijay *et al.*, 2018), small size seed and fluff and hairs lead to difficulties in handling, transportation, and precise sowing in the field. Separation of fluffs and hairs from fluffy *Deenanath* grass seed, which contains 2-3 nucleus seeds, is difficult due to their minute size. It is separated manually by beating the fluffy *Deenanath* grass seeds with a wooden rod in order to get defluffed seed. Traditional method (manual) of defluffing *Deenanath* grass seed is time consuming, labour intensive, and includes foreign materials in the defluffed seed.

Several advances have been made towards development of processing machineries for cereals, pulses, oilseeds, fruits and vegetables, but proper machines are not available for defluffing, cleaning, and separation of fluffs and hairs from fluffy grass seeds. Defluffed seeds are sold @ ₹ 6000 per kg (year: 2021) by government owned institutions and purchased by the State Forest Departments, dairy industries, and animal rearing farmers. Traditional cotton-batting machine that is used for quilt making was tried for the separation of naked seed from fluffy *Deenanath* seeds by reducing the gap between the inner wooden cylinder and feeding rollers (Vijay *et al.,* 2018). The machine consisted of a pair of feed roller, wooden conveyer belt for pushing cotton into the feed roller, wooden cylinder having iron spikes on its periphery, 2.6 kW motor, belt and pulley system and gear mechanism. As reported by them, the fluff was passed thrice between the rollers to defluff the seed. Less true seed recovery of 5.6 % (450 g naked seed from 8 kg of fluff) was reported, which was obtained after sieving and cleaning. In this cotton-batting machine, there is no arrangement of sieve below the wooden cylinder and separate grading unit, and involves high processing time as fluffy seeds need to pass number of times through the machine. Also, this machine is not ergonomically suitable for the fluffy seeds as it does not provide safety of the worker, and there is a chance of pulling hand of the worker in between the feeding rollers. Few machines for the processing of grass seeds have been reported.

Hammer mill to reduce the hard seed content of the seca stylo (*Stylosanthes scabra*) seed (Hopkinson and Paton, 1993) was reported with 52 % dehulling efficiency and 20 % reduction in bulk weight when light materials aspired off**.** Loch (1993) used horizontal cone-shaped polishing chamber for dehulling of Chloris gayana and 50-70 % extraction of caryopsis was observed. The seed of Chloris gayana was rubbed against the surrounding mesh screen (0.83 mm apertures) by nylon brushes rotating at 945 rpm. In this machine, the gap between the abrasive roller and the concave is not suitable for fluffy seeds. Arude *et al.* (2018) developed a spike cylinder type single locking cotton feeder cum cleaner for double roller gin and observed 15 to 20 % increase in the output with improved fibre quality. Fulani *et al.* (2013) observed higher threshing efficiency at lower moisture content in case of cowpea. Maity *et al.* (2017) developed tyre type pelleting machine and observed 91% germination of seed pellets of dinanath grass. Roll mill separates the smooth clover seed on the basis of shape and surface texture. There is no other commercial machine suitable for defluffing (removal of hairs and fluff) is available. Still the defluffing operation is done manually. These machines are not suitable for defluffing, cleaning and grading of fluffy grass seeds. Therefore, potential exists for development of handling and processing equipment for *Deenanath* grass seed to address the problems of animal rearing farmers, forest departments and dairy federations.

For efficient processing operations, it is vital to have the information of moisture-dependent engineering properties of seed for better design of handling and processing equipment's and processes (Dawange *et al.,* 2019). The size, shape, porosity, and density play an important role in designing defluffing machines, grading systems, handling, transportation, and storage structure (Maunde *et al.,* 2007; Malik *et al.,* 2016; Kibar *et al.,* 2014; Rajaiah *et al.,*2020). Size and shape of *Deenanath* grass seed are important for the size reduction process during defluffing, selection of concave clearance and sieve size for the development of defluffing and grading systems of defluffing machine. Bulk density and true density of *Deenanath* grass seed decide the size of feeding chute of hopper of defluffing machine, and are also relevant for aspiration of lighter materials (fluff and hairs) from the heavier materials after defluffing the fluffy grass seeds. The knowledge of bulk density, true density, and porosity is also required during handling, transportation and storage.

A number of studies have been done on the determination of physical properties of different seeds (Zewdu, 2011 for *ajwain* seed; Pandiselvam *et al.,* 2014 for onion seed; Sangani *et al.*, 2014 for pigeon pea grain; Kudos *et al.,* 2016 for Buckwheat; Singh *et al.,* 2016 for *Anethum* sowa seed; Kumar *et al.,* 2016 for Chironji; Munder *et al.,* 2017 for sunflower seed; Bepary *et al.,* 2018 for rice-bean). Being biological materials, the physical properties of grass seeds are also affected by its moisture content. Togo *et al.* (2018) studied the physical and mechanical properties of alfalfa seed in moisture content range of 7.98–22.12 per sent. Singh *et al.* (2018) assessed the engineering properties of grain and kernel of Panicum miliaceum at moisture contents in the range of 6.5-26.5 % (d.b.). They observed length, width, thickness in the range of 2.22-2.36 mm, 2.08-2.24 mm, and 1.93-2.21 mm, respectively. Yelcin *et al*. (2004) studied the physical properties of vetch seed in the moisture range of 10.57-21.63 per sent. Literature review showed that there is lack of information on the moisture dependent physical properties of defluffed *Deenanath* grass seed. The present investigation, therefore, aimed at determining the physical properties of defluffed *Deenanath* grass seeds, and to establish the relationships with its moisture content as an aid to design of separating and grading equipment/ machineries for defluffing the fluffy grass seed.

MATERIALS AND METHODS

Experimental Material

The spikelets of fluffy *Deenanath* grass seed (variety: Bundel-II, Quantity: 500 g) were arranged from the Crop Research Farm, ICAR- Indian Grassland and Fodder Research Institute (IGFRI), Jhansi in the year 2019. The spikelets were defluffed (removal of fluff and hairs) manually to extract true seeds by beating it with 1-2 m wooden rod (Fig. 1) on threshing floor and then sieved. After defluffing the mixture of true seed and other foreign materials were subjected to cleaning using hand sieves of sizes 1.18 mm and 0.60 mm (square hole) in the Post Harvest Laboratory of Farm Machinery and Post Harvest Technology Division, ICAR-IGFRI, Jhansi. The seeds retained over 0.60 mm sieve were the true seed. Required quantity of true seed (100 in numbers for geometric properties, 1000 in numbers for thousand-seed mass, 150 g for bulk density, and 50 g for true density) were randomly selected and used for determination of moisture dependent physical properties.

Design of Experiment

The selected engineering properties of *Deenanath* grass seed were determined at five levels of moisture content (6.88, 10.21, 12.77, 16.19, 19.23 %, d.b.). This range of moisture content was taken as independent variable because harvesting, handling, defluffing, and storage operations of the seed are mostly done in this range of moisture content. Whereas, the geometric properties

a. Manual defluffing b. Spikelets (fluffy seed) c. Defluffed seed

Fig. 1: Defluffing of *Deenanath* grass seed

(length, width, thickness, arithmetic mean diameter, geometric mean diameter, volume and surface area), shape (sphericity and aspect ratio), 1000 seed mass, bulk density, true density, and porosity of *Deenanath* seed were taken as dependent variables. Hundred observations of geometric properties, and five observations of remaining dependent variables (thousand seed mass, bulk density, true density, porosity) of *Deenanath* seed were determined at each moisture level, and their averages with standard error were determined.

Measurement of Properties

Moisture content

The initial moisture content of defluffed *Deenanath* seed was determined using standard oven method in three replications by keeping the seeds at 105 °C ± 1 °C for 24 h (Gupta and Das, 1997). The initial moisture content of the seed was 10.21 % (d.b.).

Physical properties of defluffed *Deenanath* seed were assessed at moisture levels of 6.88, 10.21, 12.77, 16.19, and 19.23 % (d.b.). The levels of moisture contents were selected considering that generally followed during harvesting (14-19 %), handling (7-19 %), defluffing (7-10 %), and storage (7- 12 %) of the seed. The initial moisture of 6.88 % selected for the experimentation was obtained by drying the true seed samples in hot air oven till constant weight was achieved. The remaining levels of moisture content of test samples were achieved by incorporating measured quantity of distilled water based on following equation (Dursun and Dursun, 2005):

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad ...(1)$$

Where,
Q = *M*ass of water to be added, kg,
W_i = Initial mass of sample, kg,
M_i = Initial moisture content of sample, % (d.b), and
M_f = Final moisture content of seed sample, % (d.b).

True seed samples were subsequently properly mixed and packed in low-density polyethylene (LDPE) bags. The LDPE bags with conditioned samples were stored at 4ºC in a refrigerator for 7 days for moisture to distribute uniformly throughout the sample (De Figueiredo *et al.*, 2011).

Required quantity of conditioned seed was taken out from the refrigerator and kept at room temperature (28-35 ºC) for 2 h before conducting different tests (Singh, *et al.,* 2016). The technique of attending required moisture content in seeds and grains has frequently been used by many researchers (Sacilik, *et al*., 2003).

Geometrical Properties

The average size of defluffed *Deenanath* seed was determined in terms of linear dimensions, namely length, width, and thickness using a digital vernier calliper (Mitutoyo Corporation, Japan; Model: CD-12'' C; range: 0-150 mm; least count: 0.01 mm; accuracy: 0.001 mm). The arithmetic mean diameter and geometric mean diameter of seed were calculated by the Eq. (2) and (3), respectively (Konak *et al.,* 2002).

$$D_a = \frac{(L + W + T)}{3} \quad ...(2)$$

$$D_g = (L \times W \times T)^{1/3} \quad ...(3)$$

Where,
D_a = Arithmetic mean diameter, mm,
D_g = Geometric mean diameter, mm,
L = Length, mm,
W = Width, mm, and
T = Thickness, mm.

The measurements were repeated 100 times, and the average values considered for further analyses.

The volume (V) and surface area (A_s) of *Deenanath* seed were calculated using Eqs. (4) and (5), respectively (Singh *et al.*, 2016)

$$V = \frac{\pi X^2 L^2}{6(2L - X)} \quad ...(4)$$

$$A_s = \pi D_g^2 \quad ...(5)$$

Where,
X = $(WT)^{1/2}$,
V = Volume, mm^3, and
A_s = Surface area, mm^2

Shape

The criteria used to describe the shape of seed were sphericity (φ) and aspect ratio (R_a).

Sphericity of defluffed *Deenanath* seed is defined as the ratio of the surface area of a sphere having the same volume as that of the seed to the surface area of the seed. It was determined using the Eq. (6) (Dursun and Dursun, 2005).

$$\varphi = \frac{(L \times W \times T)^{1/3}}{L} \quad ...(6)$$

Aspect ratio which is the ratio of major diameter of the seed to its minor diameter was calculated using the Eq. (7) (Unal, 2009; Ghadge and Prasad, 2012):

$$R_a = \frac{W}{L} \times 100 \quad ...(7)$$

Thousand-seed mass

The thousand-seed mass of defluffed seeds was determined as mentioned by Selvi *et al*. (2006) by picking a random sample of thousand seeds from the lot. The weight of the sample was measured on a precision electronic balance (Name: Accuris; Model: EX225/AD; range: 0-220g; accuracy: 0.01 g)**.**

The procedure was repeated five times and the average of replicated values is reported.

Bulk density

Defluffed *Deenanath* seeds were filled in a 500 ml capacity measuring cylinder (Made: Borosil) up to a height of 150 ml. The excess seeds were removed using spatula and the seeds were not compressed with any means. Thereafter, the seed sample was weighed with an electronic balance.

Bulk density was determined as follows (Sharma *et al.*, 2013):

$$\rho_b = \frac{M}{V} \quad ...(8)$$

Where,
M = Weight of seed, kg, and
V = Volume of seed, m^3.

The average of values of five replications is reported.

True density

It was determined using toluene displacement technique. Weighed quantity of defluffed *Deenanath* grass seeds were poured into a 50 ml measuring cylinder containing toluene, and the difference in the level of toluene before pouring and after pouring of seeds gave the volume of toluene displaced with the seeds.

True density was calculated using the following equation (Unal, 2009):

$$\rho_t = \frac{\text{Weight of defluffed } Deenanath \text{ seed, kg}}{\text{Volume of toluene displaced, m}^3} \times 100 \quad ...(9)$$

Experiment trials were replicated five times, and the average value reported.

Porosity

Porosity is the ratio of the volume of the pores between seed grains to the total volume occupied by true mass of the seed grains. Porosity (ε) of the seed was determined at various moisture contents (6.88, 10.21, 12.77, 16.19, 19.23, % d.b.) from the calculated values of true density (ρ_t) and bulk density (ρ_b) using the equation (Pandiselvam *et al.*, 2014):

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad ...(10)$$

Experimental trials were replicated five times, and the average value reported.

Statistical Analysis

Experimental data of the parameters at different seed moistures were statistically analysed using SAS statistical software. The differences between the mean values of the physical properties of seed samples were tested for significance using t-test. Linear regression analysis was used to determine the relationships between moisture content and physical properties of the seed samples. The design of experiment consists of only one independent variable (moisture content) with unequal interval between its five levels (6.88, 10.21, 12.77, 16.19, and 19.23 %). Therefore, simple linear regression analysis was carried out to study the effect of moisture content i. e. the only independent variable on the dependent physical properties of *Deenanath* seed.

RESULTS AND DISCUSSION

Properties of Defloured *Deenanath* Grass Seed

Geometric properties

The mean values, standard error, and percent increase in physical characteristics viz. length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, and volume of the seed at moisture contents of 6.88, 10.21, 12.77, 16.19, and 19.23 % (d.b.) presented in Table 1.

The axial dimensions viz. length, width, thickness, arithmetic mean diameter, and geometric mean diameter increased significantly ($p<0.05$) with increase in moisture content in the range of 6.88 % to 19.23 %

Table 1. Moisture dependent physical properties of defluffed *Deenanath* seed

Sl. No.	Parameter	Moisture content (%, d.b.)				
		6.88	10.21	12.77	16.19	19.23
1.	Length, mm	2.30±0.02[d]	2.37±0.02[cd] (3.04)	2.44±0.02[cb] (6.09)	2.48±0.02[b] (7.83)	2.56±0.02[a] (11.30)
2.	Width, mm	0.71±0.02[c]	0.76±0.02[c] (7.04)	0.82±0.01[b] (15.49)	0.86±0.01[b] (21.13)	0.96±0.01[a] (35.21)
3.	Thickness, mm	0.47±0.01[d]	0.52±0.01[c] (10.64)	0.58±0.01[b] (23.40)	0.61±0.01[ab] (29.79)	0.63±0.01[a] (34.04)
4.	Arithmetic mean diameter, mm	1.16±0.01[d]	1.22±0.01[c] (5.17)	1.28±0.01[b] (10.34)	1.32±0.01[b] (13.79)	1.38±0.01[a] (18.97)
5.	Geometric mean diameter, mm	0.90±0.01[d]	0.97±0.01[c] (7.78)	1.05±0.01[b] (16.67)	1.09±0.01[b] (21.11)	1.15±0.01[a] (27.78)
6.	Aspect ratio, %	30.91±0.99[d]	31.92±0.83[cd] (3.27)	33.57±0.71[cb] (8.61)	34.63±0.65[b] (12.00)	37.51±0.68[a] (21.35)
7.	Sphericity	0.39±0.007[c]	0.41±0.006[c] (4.25)	0.43±0.006[b] (9.41)	0.44±0.006[ab] (11.70)	0.45±0.005[a] (14.78)
8.	Volume, mm^3	3.71±0.19[d]	4.02±0.28[c] (8.36)	4.46±0.42[b] (20.22)	4.79±0.44[b] (29.11)	4.97±0.35[a] (33.96)
9.	Surface area, mm^2	2.58±0.07[d]	2.81±0.09[c] (8.91)	3.01±0.11[b] (16.67)	3.11±0.10[b] (20.54)	3.23±0.07[a] (25.19)
10.	Thousand-seed mass, g[#]	0.480±0.005	0.491±0.004 (2.29)	0.502±0.006 (4.58)	0.516±0.002 (7.50)	0.523±0.005 (8.96)
11.	Bulk density, $kg.m^{-3}$[#]	652.16±4.0	635.47±4.1 (2.56)	613.63±3.9 (5.90)	601.22±3.9 (7.81)	585.78±4.0(10.18)
12.	True density, $kg.m^{-3}$[#]	852.63±5.0	836.15±4.9 (1.93)	819.87±4.8 (3.84)	804.45±4.8 (5.65)	792.71±4.9 (7.03)
13.	Porosity, %[#]	25.62±0.05	25.43±0.05 (0.74)	25.26±0.04 (1.40)	25.15±0.05 (1.83)	24.97±0.04 (2.54)

Note:
1. *Values followed with different superscript in a row are significant ($p<0.05$)*
2. *Values in bracket indicate the percentage increase/decrease in parameter values with respect to initial value of moisture content (6.88 %)*
3. *[#]indicates experiment replicated five times*

(d.b). The dimensional increases in length, width, and thickness were 11.30, 35.21 and 34.04 %, respectively with respect to the initial value of moisture content (Table 1). The trends of increased axial dimensions of defluffed seed against moisture content are depicted in Fig. 2. As shown in Table 1, the percentage increase in the dimensional values with respect to initial value of moisture content indicates that the seed was found to expand more along its width and thickness in comparison with its length. This behaviour was also reported by Singh *et al.* (2016) for *Anethum* sowa seed. The linear increase in all seed dimensions were due to the expansion resulting from increased moisture absorption by the seeds in their intercellular space. The decreased moisture content of the seed suggested that drying of defluffed *Deenanath* seed would result in shrinkage due to decrease in seed dimensions in terms of length, width and thickness (Table 1). The results of the dimensional values would be helpful to replace manual operation of *Deenanath* seed defluffing, cleaning, conveying and handling with mechanical operation by utilising the reported data for the development of machines and processing operations. Similar findings for ajwain seed, sunflower seed, dill seed were reported by Zewdu (2011), Munder *et al.* (2017), Singh *et al.* (2016), respectively.

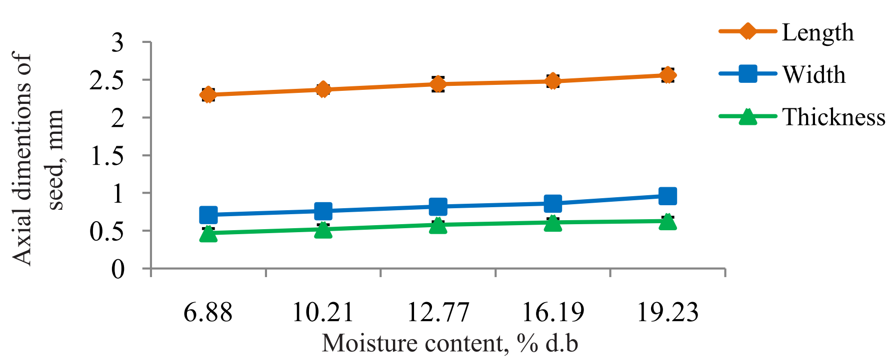

Fig. 2: Effect of increasing seed moisture content on seed axial dimensions

The variation of length, width, and thickness of defluffed *Deenanath* seed with increase in moisture content established a linear relationship expressed by the regression equations (Eqs. 11, 12 and 13) respectively.

$$L = (2.241 + 0.063m);\ R^2 = 0.992 \qquad ...(11)$$

$$W = (0.642 + 0.060m);\ R^2 = 0.976 \qquad ...(12)$$

$$T = (0.439 + 0.041m);\ R^2 = 0.961 \qquad ...(13)$$

Where,
L = Length, mm,
W = Width, mm,
T = Thickness, mm,
m = Moisture content, % (d.b.), and
R^2 = Coefficient of determination.

The average arithmetic means diameter and geometric mean diameter varied from 1.16-1.38 mm and 0.90-1.15 mm, respectively, in the experimental range of moisture content. The volume and surface area of *Deenanath* grass seeds also significantly increased ($p<0.05$) with increase in moisture content as shown in Table 1. The percent increase in volume was found to be 33.96 %, whereas the surface area increased by 25.19 % with respect to the initial value of moisture content. The ANOVA (analysis of variance) indicated that the differences among diameters of *Deenanath* grass seed, volume, and surface area were significant at 0.05 % level of significance. In other words, the geometrical parameters were significantly different for the moisture range from 6.88 % to 19.23 % (d.b.). The results were in agreement with the earlier findings for caper seed (Dursun and Dursun, 2005), onion seed (Pandiselvam *et al.*, 2014), and rice kernel (Ghadge and Prasad, 2012). The major differences in the dimensions of *Deenanath* grass seed and the above referred seeds were that Deenanath seed was the smallest one in the dimensions (including length, width, thickness) compared to other seeds. Therefore, the existing machines used for postharvest processing of other seeds could not be used for mechanical processing of *Deenanath* seed. Consequently, design and development of new machines would be possible for the processing of *Deenanath* seed based on the reported dimensional properties. The data would be useful in the selection of sieve size, inclination of sieve, power required for size reduction, etc.

Shape

The shape of defluffed *Deenanath* seed was investigated in terms of sphericity and aspect ratio. The data on linear dimensions and the major axis of the seed were used for the calculation of sphericity and aspect ratio and the results obtained are presented in Fig. 3 and Fig. 4, respectively. Sphericity of the seed increased from 0.39 to 0.45, and aspect ratio varied from 30.91 % to 37.51 % when the moisture content increased from 6.88 % to 19.23 % (d.b.). It is evident from Fig. 3 and Fig. 4 that both sphericity and aspect ratio displayed significant variations with change in moisture content of the seed. The slope (0.0049) of regression line shown in Fig. 3 predicts that the sphericity would increase by 0.0049 % with increase in moisture content by 1 per sent. Similarly, the slope of 0.5174 in Fig. 4 would result in increase of aspect ratio by 0.5174 with 1 % increase in moisture content. The increase in sphericity might have been caused by a proportional increase in the width and thickness of the seed with increase in moisture content. Similar findings have been reported by Dursun and Dursun (2005) for capper seed, Altuntas *et al.* (2005) for fenugreek seed, and Nimkar *et al.* (2005) for moth gram. However, Zewdu and Solomon (2007) found a decrease in the value of sphericity with an increase in moisture content for Tef seeds. The data on relatively lower values of sphericity (0.39-0.45 %)

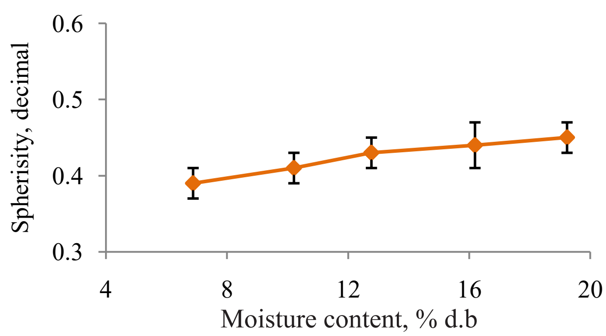

Fig. 3: Effect of increasing seed moisture content on seed sphericity

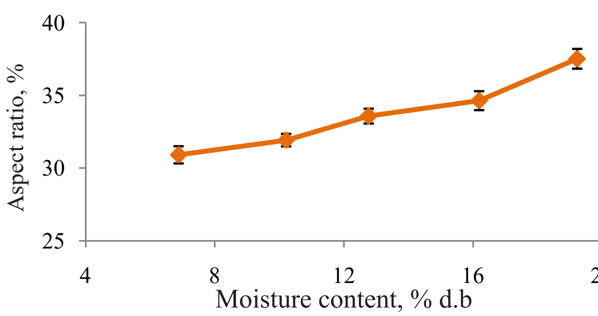

Fig. 4: Effect of increasing seed moisture content on seed aspect ratio

indicated that defluffed *Deenanath* seed would not rotate easily during handling, conveying, feeding in seed pelleting machine and feed hoper of different machines. This fact may be useful in designing feed hoppers, conveying systems, discharge outlet for seed processing, handling and packaging machines.

The relationship of sphericity (φ) and aspect ratio (R_a) with moisture content (m) of *Deenanath* grass seed are represented by the regression Eq. (14) and (15) respectively.

$$\varphi = (0.3605 + 0.0049\, m);\ R^2 = 0.962 \qquad ...(14)$$

$$R_a = (26.953+0.5174\, m);\ R^2 = 0.958 \qquad ...(15)$$

Thousand-seed mass

The experimental values obtained for thousand-seed mass of defluffed *Deenanath* seed at different levels of moisture contents are shown in Fig. 5. The thousand-seed mass significantly ($p < 0.05$) increased from 0.480 g to 0.523 g with the corresponding increase in moisture content from 6.88 % to 19.23 % (d.b.), which could be the result of moisture absorbed by the seed in its intercellular spaces. Similar trends of increased thousand seed mass with moisture content have been reported for moth gram (Nimkar, 2005), caper seed (Dursun and Dursun, 2005), onion seed (Pandiselvam *et al.*, 2014), vetch seed (Yalcin and Ozarslan, 2004), hulled wheat (Unal, 2009), and rice kernel (Ghadge and Prasad, 2012). The mass of any agricultural commodity is an important factor in designing air-cleaning and pneumatic conveying operations as it affects the acceleration of the seeds, thereby influencing the aerodynamic force exerted on the particle (Solomon and Zewdu, 2009).

The relationship between thousand-seed mass (M_t, g) and moisture content (m, % d.b.) of *Deenanath* grass seed was found to be linear function, and could be expressed by the following equation:

$$M_t = (0.4552 + 0.0036\, m);\ R^2 = 0.992 \qquad ...(16)$$

Bulk density

The experimental results for bulk density of defluffed *Deenanath* seed at various moisture levels are presented in Fig. 6. The bulk density was found to decrease linearly from 652.16 $kg.m^{-3}$ to 585.78 $kg.m^{-3}$ as moisture content increased from 6.88 % to 19.23 % (d.b.). This decrease in the value of bulk density might be due to the higher rate of increase in volume relative to the increase in mass of seed. This would cause the effect of greater compaction in dry seeds compared

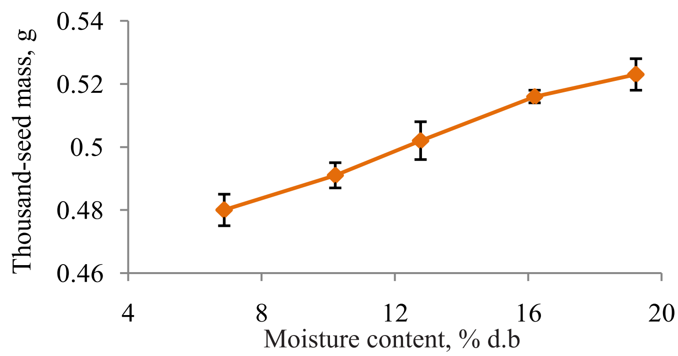

Fig. 5: Effect of increasing seed moisture content on thousand-seed mass

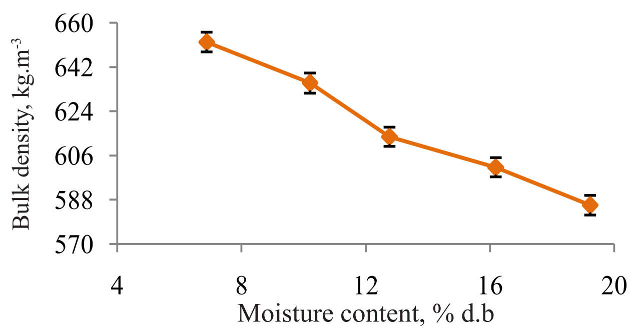

Fig. 6: Effect of increasing seed moisture content on seed bulk density

to wet seeds. The negative value of slope (-5.420) of regression line shown in Fig. 6 suggests that the bulk density of *Deenanath* seed would decrease by 5.420 kg.m^{-3} for each increment of 1 % in its moisture content. This would help in deciding the capacity of feeding chute (hopper) of defluffing machine, volume of packing bags, capacity of storage and transportation system, drying or processing of a definite quantity of *Deenanath* seed at particular moisture content.

These behaviour of bulk density of the grass seed are in accordance with those reported for *amaranth* seed (Abalone *et al.*, 2004), *dill* seed (Singh *et al.*, 2016), and moth gram (Nimkar, 2005). Bulk density of defluffed seed which ranged between 652.16 kg.m^{-3} and 585.78 kg.m^{-3} was comparable with bulk density of raw cashew (592 – 624 kg.m^{-3}: Balasubramanian, 2001). Bulk density of defluffed *Deenanath* seed was higher compared to bulk density of cumin (477 kg.m^{-3}: Singh and Goshwami, 1996), and guna seed (400 – 544 kg.m^{-3}: Aviara *et al.*, 1999).

The relationship between bulk density (ρ_b) and moisture content (m) of *Deenanath* grass seed can be represented by the following regression equation:

$$\rho_b = (688.42 - 5.4204m);\ R^2 = 0.985 \qquad ...(17)$$

True density

True density of defluffed *Deenanath* seed decreased from 852.63 kg.m^{-3}-792.71 kg.m^{-3} with an increase in moisture content from 6.88-19.23 % d.b. (Fig. 7). This decrease in true density might be due to a significant increase in seed volume, which was higher than the corresponding increase in the mass of the seed. Different types of variation in the trend of true density with moisture content for various agricultural seeds have been reported by researchers. An increase in true density with moisture content has been reported for Tef seed (Zewdu and Solomon, 2007), *Proso* millet (Singh *et al*., 2018), and sunflower seed (DeFigueiredo *et al.,* 2011). However, true density was found to decrease with increase in seed moisture content by Tunde-Akintunde and Akintunde (2007) for Beni seed and Zewdu (2011) for *ajwain* seed.

Deenanath being fluffy in nature occupies large volume due to presence of hairy structure on its outer fluffy layer. This generates empty pore spaces around every seed. This hairy fluffy outer layer when removed by defluffing can also remove the pore space between the seed, and the gap would be filled completely with other defluffed true seed. This would increase the overall weight of the seed in a measuring cylinder of same volume. Thus, true density of *Deenanath* seed was found to be higher than its bulk density at a given range of moisture contents. The increased true density would increase the overall capacity of a machine, as large quantity of true seed can be handled in the same component of the machine as compared to fluffy seed. The intercept (885.52) of regression line given in Fig. 7 suggests that the mean value of true density would at least remain 885.52 kg.m^{-3} even if moisture is not present in the seed. Overall, reported data, slope, and intercept values of true density of *Deenanath* seed would help to design of machine components as seed storage system, seed delivery system in pelleting machine, proper sized sieve in threshing machine, slope of feed hoper, and discharge chute of seed handling systems.

The relationship between true density (ρ_t) and moisture content (m) of *Deenanath* grass seed can be represented by the following regression equation:

$$\rho_t = (885.52 - 4.9294\ m);\ R^2 = 0.992 \qquad ...(18)$$

Porosity

Porosity of defluffed *Deenanath* seed decreased from 25.62 % to 24.97 % as the moisture content increased from 6.88 % to 19.23 % d.b. (Fig. 8). The trend of

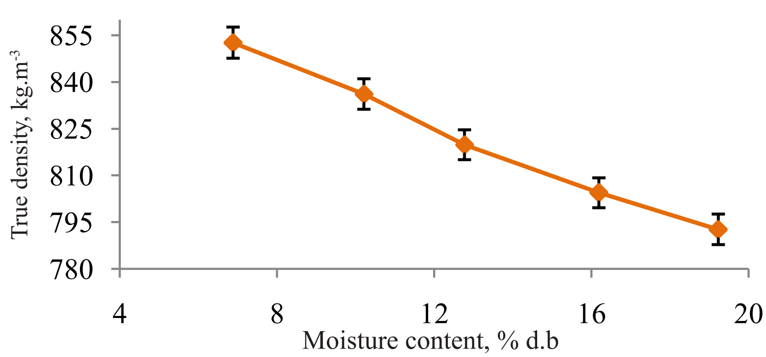

Fig. 7: Effect of increasing seed moisture content on seed true density

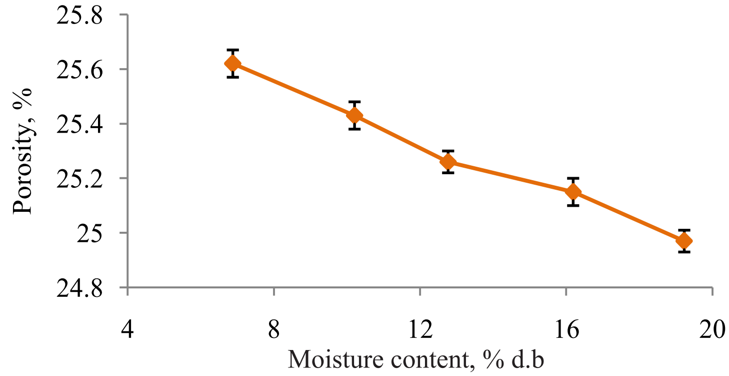

Fig. 8: Effect of increasing seed moisture content on seed porosity

decrease in porosity with increase in seed moisture content has been earlier reported by Sacilik *et al.* (2003) for hemp seed, and Singh *et al.* (2016) for *dill* seed**.** Porosity of defluffed *Deenanath* seed was lower than the porosity of *makhana* (29.4-48.9 %: Jha, 1999), onion seed (59.63-46.90 %: Pandiselvam *et al.*, 2014), and *dill* seed (61.92 %-60.24 %: Singh *et al.,* 2016).

Porosity data may be utilized for designing of aeration systems for deep bed dryer as higher porosity values provide better aeration and water vapour diffusion during deep bed drying (Singh *et al*., 2016). Grass seed like *Denanath* being very small in size than other crop seeds would face difficulty in deep bed drying due to less values of porosity compared to other seed. Less porosity would result in low space between the seeds for proper aeration and water vapour diffusion, which would result in non-uniform drying. Therefore, the reported data of porosity suggest that it would be logical to opt for thin layer drying method instead of deep bed drying for efficient drying operation of *Denanath* seed.

The relationship between porosity (**ε**) and moisture content (*m*) of defluffed *Deenanath* seed can be expressed by the following regression equation:

$$\varepsilon = (25.957 - 0.0514\, m);\ R^2 = 0.989 \qquad ...(19)$$

CONCLUSIONS

The average length, width, thickness, geometric mean diameter and arithmetic mean diameter of defluffed *Deenanath* seed increased linearly from 2.30 to 2.56 mm, 0.71 to 0.96 mm, 0.47 to 0.63 mm, 1.16 to 1.38 mm, and 0.90 to 1.15 mm, respectively, with corresponding increase in seed moisture content from 6.88 to 19.23 % (d.b.). Similar trend was demonstrated for sphericity, which increased from 0.39 % to 0.45 % with similar increase in moisture content. The aspect ratio, volume, surface area, and thousand-seed mass of the seed linearly varied from 30.91 to 37.51 %, 3.71 to 4.97 mm^3, 2.58 to 3.23 mm^2, 0.480 to 0.523 g, respectively. However, bulk density and true density decreased linearly from 652.16 to 585.78 kg.m^{-3}, and 852.63 to 792.71 kg.m^{-3}, respectively in the above seed moisture range. Porosity of the seed linearly decreased from 25.62 % to 24.97 % with increase in the above seed moisture. Postharvest processing and handling machines for fluffy grass seeds to defluff, clean, and grade are not available because of their tiny size and peculiar fluffy characteristics. Generated information on selected engineering properties of *Deenanath* seed would be useful to develop defluffing machine hopper, defluffing zone, concave clearance, discharge chute, sieve size of concave, sieve size of cleaning, as well as grading machines, seed storage, and packaging systems.

REFERENCES

Abalone R; Cassinera A; Gaston A; Lara M A. 2004. Some physical properties of amaranth seeds. Biosyst. Eng., 89 (1), 109 - 117.

Ahmed S; Sahay G; Sridhar K; Singh S; Saxena P; Roy A K. 2017. Improved forage crop varieties of IGFRI. Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India, Technical Bulletin, 1/2017, pp: 64.

Altuntas E; Ozgoz E; Taşer O F. 2005. Some physical properties of fenugreek (Trigonellafoenum-graceum L.) seeds. J. Food Eng., 71(1), 37 - 43.

Arude V G; Deshmukh S P; Patil P G; Shukla S K. 2018. Development of spike cylinder type single locking cotton feeder cum cleaner for double roller gin. Agric. Eng. Today, 42, 15-19.

Asmare B; Demeke S; Tolemariam T; Tegegne F; Wamatu J; Rischkowsky B. 2016. Evaluation of deshograss (*Pennisetum pedicellatum*) hay as a basal diet for growing local sheep in Ethiopia. Trop. Animal Health Prod., 48, 801-806.

Asmare B; Demeke S; Tolemariam T; Tegegne F; Haile A; Wamatu J. 2017. Effects of altitude and harvesting dates on morphological characteristics, yield and nutritive value of deshograss (*Pennisetum pedicellatum Trin*) in Ethiopia. Agric. Natural Resour., 51, 148-153.

Aviara N A; Gwandzang M I; Haque M A. 1999. Physical properties of guna seeds. J. Agric. Eng. Res., 73, 105-111.

Balasubramanian D. 2001. Physical properties of raw cashew nut. J. Agric. Eng. Res., 78 (3), 291 – 297.

Bepary R H; Wadikar D D; Patki P E. 2018. Engineering properties of rice-bean varieties from north-east India. J. Agric. Eng., 55(3), 32-42.

Chatterji A K; Das A P. 2014. Cytomorphological studies of the biotypes of *Pennisetum Pedicellatum Trin*. Int. J. Cyt. Cytosyst. Cytoge., 32(1), 5-14.

Dawange P S; Jha S K. 2019. Moisture dependent physical properties of quality protein maize. J. Agric. Eng., 56(3), 194-211.

DeFigueiredo A K; Baumler E; Riccobene I C; Nolasco S M. 2011. Moisture - dependent engineering properties of sunflower seeds with different structural characteristics. J. Food Eng., 102 (1), 58-65.

Dursun E; Dursun I. 2005. Some physical properties of caper seed. Biosyst Eng., 92 (2), 237-245.

Fulani A U; Kuje J Y; Mohammad M I. 2013. Effect of moisture content on performance of locally fabricated cowpea thresher. J. Eng. Appl. Sci., 5(2), 1-15.

Ghadge P N; Prasad K. 2012. Some physical properties of rice kernels variety PR-106. J. Food Process Technol., 3 (8), 1-5.

Hopkinson J M; Paton C J. 1993. Tropical pasture establishment treatment of Seca stylo seed to reduce hard seed content. Trop. Grasslands, 27, 327-334.

Jha S N. 1999. Physical and hygroscopic properties of makhana. J. Agric. Eng. Res., 72, 145-150.

Konak M; Carman K; Aydin C. 2002. PH - postharvest technology: Physical properties of chick pea seeds. Biosyst. Eng., 82 (1), 73-78.

Kibar H; Turgut Öztürk T; Temizel K E. 2014. Effective engineering properties in the design of storage structures of postharvest dry bean grain. Acta Sci., 36(2), 147-158.

Kudos S K A; Gupta R K; Mridula D. 2016. Moisture dependent physical properties of buckwheat. J. Agric. Eng., 53(1), 41-52.

Kumar J; Prabhakar P K; Srivastav P P; Bhowmick P K. 2016. Moisture dependent physical properties of chironji (buchanania lanzan) nut. J. Agric. Eng., 53(2), 45-54.

Kumar S; Ghosh P. 2018. Sustainable bio-energy potential of perennial energy grass from reclaimed coalmine spoil (marginal sites) of India. Renewable Energy, 123, 475-485.

Loch D S. 1993. Tropical pasture establishment 5. Improved handling of chaffy grass seeds: Options, opportunities and value. Trop. Grasslands, 27, 314-326.

Mahanta S K; Singh K K; Das K K; Das M M; Misra A K. 2014. Nutritional Profile of Improved Fodder Varieties for Livestock Feeding. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, pp: 26.

Maity A. Vijay D; Singh S K; Gupta C K. 2017. Layered pelleting of seed with nutrient enriched soil enhances seed germination in Dinanath grass (*Pennisetum pedicellatum*). Range Manage. Agrofor., 38(1), 70-75.

Malik M A; Saini C S. 2016. Engineering properties of sunflower seed: Effect of dehulling and moisture content. Cogent Food Agric., 2(1). https://doi.org/10.1080/23311932.2016.1145783

Mandal D; Srivastava P; Giri N; Kaushal R; Cerda A; Alam N M. 2017. Reversing land degradation through grasses: Asystematic meta-analysis in the Indian tropics. Solid Earth, 8(1), 217-233.

Maunde F A; Ali M A; Okene A E; Riji B B. 2007. Determination of physicomechanical properties of cowpeas to aid thresher design. Adv. Mat. Res., 18(19), 159-164.

Meena S S; Nagar R P. 2019. Seasonal effects on fodder yield and quality in cenchrus species under semi-arid climate. Indian J. Agric. Sci., 89 (8), 71 – 76.

Munder S; Argyropoulos D; Mueller J. 2017. Class-based physical properties of air-classified sunflower seeds and kernels. Biosyst. Eng., 164, 124 - 134.

Mustapha S; Safiya M Alhaji; Nasiru Y; Alhassan M; Sahabi Y M; Bello N; Khadijah A Y. 2018. Nutritional composition of *Pennisetum Pedicellatum* Trin grass. Int. J. Sci. Technol., 6 (10), 56-59.

Nimkar P M; Mandwe D S; Dudhe R M. 2005. Physical properties of moth gram. Biosyst. Eng., 91 (2), 183-189.

Rajaiah P; Mani I; Parray R A; Lande S D; Kumar A; Vergese C. 2020. Design and development of precision planter for paddy direct seeding. J. Agric. Eng., 57(4), 302-314.

Roy A K; Malaviya D R; Kaushal P. 2019. Genetic improvement of dominant tropical Indian range grasses. Range Manage. Agrofor., 40(1), 1-25.

Pandiselvam R; Pragalyaashree M M; Kailappan R; Thirupathi V; Krishnakumar P. 2014. Moisture dependent engineering properties of onion seeds. J. Agric. Eng., 51 (2), 36 - 43.

Sacilik K; Ozturk R; Keskin R. 2003. Some physical properties of hemp seed. Biosyst. Eng., 86 (2), 191-198.

Sangani V P; Patel N C; Davara P R. 2014. Physical properties of pigeon pea grains (BDN 2) as a function of moisture content. Agric. Eng. Today, 38 (4), 17 - 24.

Selvi K Ç; Pınar Y; Yeşiloglu E. 2006. Some physical properties of linseed. Biosyst. Eng., 95 (4), 607-612.

Sharma S C; Singh M P; Singh J. 2013. Determination of engineering properties of *Jatropha Curcas.* L. Agric. Mech. Asia Afr. Lat. Am., 44 (1), 19-26.

Singh K K; Goswami T K. 1996. Physical properties of cumin seed. J. Agric. Eng. Res., 64 (2), 93-98.

Singh K P; Chandel N S; Potdar R R; Jat D; Agrawal K N; Hota S. 2018. Assessment of engineering properties of *Proso* millet (*Panicum miliaceum*). J. Agric. Eng., 55(2), 42-51.

Singh R K; Vishwakarma R K; Vishal M K; Goswami D; Mehta R S. 2016. Moisture dependent physical properties of dill. J. Agric. Eng., 53 (1), 33-40.

Solomon W K; Zewdu A D. 2009. Moisture-dependent physical properties of niger (Guizotiaabyssinica Cass.) seed. Ind. Crops Prod., 29 (1), 165-170.

Suleiman M; Khadija A Y; Nasiru Y; Safiya M A; Alhassan M; Bello H J. 2020. Mineral and anti-nutrient composition of *Pennisetum pedicellatum* Trin. grass. Res. J. Food Sci. Nutr., 5 (4), 78-84.

Togo J M; Wang D; Ma W; He C. 2018. Effect of moisture content on selected physical and mechanical properties of alfalfa seeds. J. Biol. Agric. Healthcare, 8(14), 8-18.

Tunde-Akintunde T Y; Akintunde B O. 2007. Effect of moisture content and variety on selected physical properties of beni seed. Agric. Eng. Int.: CIGR J., 9, 1 - 14.

Unal H G. 2009. Some physical and nutritional properties of hulled wheat. J. Agric. Sci., 15 (1), 58-64.

Vijay D; Gupta C K; Malaviya D R. 2018. Innovative technologies for quality seed production and vegetative multiplication in forage grasses. Current Sci., 114 (1), 148-154.

Yalcin I; Ozarslan C. 2004. Physical properties of vetch seed. Biosyst Eng., 88 (4), 507-512.

Yirgu T; Mengistu S; Shanku E; Ijara F. 2017. Desho grass (*Pennisetum pedicellatum*) lines evaluation for herbage yield and quality under irrigation at Wondogenet. Am. Eur. J. Agric. Environ. Sci., 17(5), 427-431.

Zewdu A D. 2011. Moisture-dependent physical properties of ajwain (*Trachyspermumammi* L.) seeds. Philipp. Agric. Sci., 94 (3), 278-284.

Zewdu A D; Solomon W K. 2007. Moisture-dependent physical properties of tef seed. Biosyst Eng., 96 (1), 57-63.

Zhang N; Zhang Q; Li Y; Zeng M; Li W; Chang C; Xu Y; Huang C. 2020. Effect of groundcovers on reducing soil erosion and non- point source pollution in citrus orchards on red soil under frequent heavy rainfall. Sustainability, 12(1146), 1-16.