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Defluffing machine for dinanath grass seeds (*Pennisetum pedicellatum*)

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ABSTRACT

Traditionally, defluffing (separation of nucleus seeds from fluffy seed) of dinanath grass seeds (*Pennisetum pedicellatum*) is cumbersome and time consuming. Hence, a defluffing machine consisting of feeding chute, feed rollers, serrated cylinder assembly, grading unit and power transmission unit was developed considering the physical properties of the dinanath seed and evaluated its performance at ICAR-Indian Grassland and Fodder Research Institute, Jhansi (2019). The mean values of seed dimensions (length × width × thickness) for fluffy seed and nucleus seed were computed as 6.20×2.77×1.83 mm^3 and 2.44×0.82×0.58 mm^3 respectively. The average bulk densities of fluffy and nucleus seeds were 7.65 kg/m^3 and 613.63 kg/m^3 respectively. The optimum machine performance like defluffing capacity (4.9 kg/h), defluffing efficiency (92.1%) and nucleus seed recovery (22.82%) were found at 7 % moisture content and 545 rpm of serrated cylinder speed about 76 % processing cost saving using the machine could be done as compared to traditional manual defluffing. Drastic reduction (99.7%) in volume of fluffy seed was achieved after defluffing.

Keywords: Dinanath, Defluffing capacity, Defluffing efficiency, Nucleus seed

Grasses are the best propagating material for marginal and uncultivable wastelands, forest and rangelands, but non-availability of quality seed is one of the obstacles in the green fodder production. Availability of good quality seed is only 25–30% in cultivated fodder and <10% in range grasses and legumes in India (Anonymous 2011). Among annual range grasses, dinanath (*Pennisetum pedicellatum*) is an important fodder species, because of high early vigor, adaptability to poor soils and high productivity. However, during seed production, the light weight small seed enclosed in voluminous fluff leads to difficulties in precise sowing in the field. Reducing the volume and extracting nucleus seed (true seed) is the requirement for large scale adoption of the dinanath grass. If the fluff and hairs are removed, it is better to embed the seed with pelleting technology to ensure maximum germination (Maity *et al.* (2017). Defluffing (removal of fluff and hairs from fluffy seeds) is an important post harvest operation in grass seed processing. Traditionally, defluffing of fluffy dinanath grass seeds is done manually by beating the harvested and dried crop. This process is time consuming, labor intensive and recovered nucleus seed includes foreign materials and damaged seed.

Various developments in the determination of physical properties of seeds and post harvest separation machineries have been made (Aradwad *et al.* 2018, Dewange and Jha 2019, Mishra *et al.* 2019 and Singh *et al.* 2020). Arude *et al.* (2018) developed a spike cylinder type single locking cotton feeder cum cleaner for double roller gin and observed 15–20% increase in the output with improved fibre quality. Higher threshing efficiency has been reported for cowpea (Fulani *et al.* 2013). Togo *et al.* (2018) studied the physical properties of alfalfa seed. Very little information is available about defluffing of fluffy grass seeds. Thus, developing machine for the separation of fluff of dinanath grass seeds is essential for getting nucleus seed for effective fodder production. This study, therefore, presents the development and evaluation of the defluffing machine for dinanath grass seeds.

MATERIALS AND METHODS

The development of defluffing machine and its evaluation was undertaken at ICAR-Indian Grassland and Fodder Research Institute, Jhansi during 2019. The required physical properties of dinanath grass (variety BD-II) seeds for developing the prototype of defluffing machine were determined. The moisture content was determined by heated air oven method at 105±3 °C for 24 h (AOAC, 1980). Length (L), width (W), thickness (T), arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (ϕ), surface area (A_s), volume (V), bulk density (ρ_b) and 1000 seed mass were determined using the relationship given by Dursun and Dursun (2005) and Singh *et al.* (2016).

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The average size of fluffy dinanath seeds and nucleus seeds of dinanath were determined by randomly selecting 100 seeds and were measured using a digital vernier caliper (Mitutoyo Corporation, Japan; Model No: CD-12" C; least count 0.01 mm). Thousand seed mass was determined by picking the sample of thousand seeds randomly from the lot and the mass of each sample were measured on a precision electronic balance having accuracy of 0.01 g. Bulk density of seeds was measured using AOAC method, in which a 500 ml cylinder was filled with dinanath seeds to 15 cm of height and calculated as the ratio between the seed weight and the volume of the cylinder.

Development of defluffing machine: The defluffing machine (DM) consisted of serrated cylinder (SC) assembly, feeding chute (FC), feeding rollers (FR), grading unit (GU) and power transmission unit (PTU). The SC was made of wood (360 mm diameter, 580 mm long) with serrated iron teeth at equal distances on its outer periphery. SC was mounted on the rotating shaft fixed on angle iron frame and powered by 0.75 kW electric motor through belt pulley drive mechanism. SC speed of 600 rpm was decided through trial runs on the existing cotton batting machine which is used for quilt making. The SC was covered with upper casing and perforated lower casing. On inner surface of the upper casing, sand paper was fixed. Concave clearance and sieve size were decided on the basis of size of dinanath grass seeds.

Size of FC was decided based on the bulk density of fluffy dinanath seed. Feeding chute was placed tangential to the feeding rollers to facilitate the feeding of fluffy grass seed. Two feeding rollers each of 60 mm diameter, 615 mm long were provided in FC. Power from main shaft of SC was transmitted to the upper feeding roller through chain sprocket system which was placed in opposite side of main pulley. Lower FR was connected to upper FR through meshed gear mechanism. A grading unit comprised a sieve at the top and a MS tray at the bottom was attached below the SC assembly with the provision of crank shaft and belt pulley system to provide reciprocating action to the sieves. Size of pulleys and the lengths (L) of belts used in the design of the machine were determined using the equation (1) and (2) respectively (Khurmi and Gupta 2007).

Ergonomic considerations were used in the design for safety of the worker. The length of the feeding chute was kept 950 mm as per IS: 9020–2002. Height of the machine was kept 950 mm as per average waist height (natural indentation) of the worker for comfortable working. The machine consisted of all safety guards over power transmission system. The conceptual design and drawing of DM was prepared with the help of PTC Creo Parametric 3.0-2014 software (Fig 1, 2).

Testing procedure of defluffing machine: The prototype of DM was tested for defluffing of fluffy dinanath grass seeds. Experiments were conducted by taking 9 samples each of 500g of feed mass of fluffy dinanath grass seeds at three levels of moisture content (7%, 9%, 11%) using Randomized Block Design (RBD) having 3 replications. On start of the motor, the SC along with FR start rotating and GU start moving to and fro. The bunch of fluffy seed was fed in the FC and the seed materials were slightly pushed towards FR by a person. Simultaneously, the SC pulled the mass through the gap between the iron teeth and the upper casing. The experimentation on the machine was started after 2 minute of start when steady state of inflow and out flow of the materials occurred. The rotational speed of cylinder was 545 rpm during operation. The defluffed nucleus (true) seeds alongwith the separated hairs and powdery dust particles passed through the openings of the upper screen of the GU and dropped down on the bottom tray during the reciprocating motion of the grading assembly. The time taken in defluffing the selected mass of the fluffy seeds were measured using a quartz stop watch and the samples retained on the top sieve and bottom tray of GU were collected separately. The top screen (1.8 mm round) of the GU contained the seed cover materials such as hairs and appendages without the true seed and few non-defluffed seeds. Further, separation of nucleus seed, dust particles and bigger chaffs from the mixture of seeds retained on the bottom tray of GU was done separately

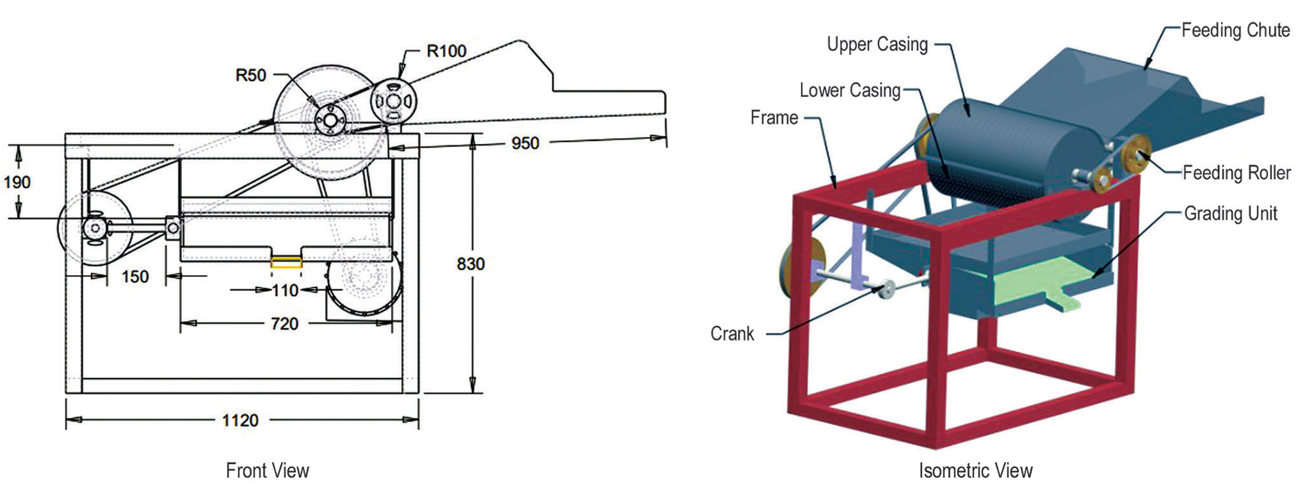

Fig 1 Front and isometric views of the CAD design of defluffing machine.

using two square opening test sieves of sizes 1.18 mm and 0.60 mm. The material retained on 0.6 mm sieve was the desired nucleus seed.

Computation of machine performance parameters

Defluffing capacity, D_c: It is the ratio of mass of fluffy seed fed to the defluffing time. Defluffing capacity (kg/h) was estimated as:

$$D_c \text{ (kg/h)} = \frac{F/1000}{D_t/60} = \frac{3F}{50\, D_t} \quad (1)$$

where, F is mass of fed seed sample (g) and, D_t is time of defluffing (min).

Traditional method of defluffing of dinanath seeds includes drying of harvested crop followed by beating manually with wooden stick (1 to 2 m length) on threshing floor and sieving. This process has less defluffing output (6 kg/day/women).

Defluffing efficiency, D_e: It is the ratio of mass of defluffed seed to the total mass of fed seed sample expressed in percentage. Preliminary tests on prototype indicated that the material passed through top sieve of GU and retained on bottom plate of GU do not have any fluffy seed. Chances of non-defluffed seeds were only on the samples retained on the top screen. Therefore, the D_e was calculated using 5 g random sample from the material retained on the top screen of grading unit and following formula was derived to calculate the D_e.

$$D_e\,(\%) = \frac{\text{Mass of defluffed seed} \times 100}{\text{Total mass of fed seed}} = \left(\frac{\text{Mass of non defluffed seed}}{\text{Total mass of fed seed}}\right) \times 100$$

$$= \left(1 - \frac{M_{ND} \times M_t}{SF}\right) \times 100 \quad (2)$$

where, F is mass of fed seed sample (g); M_{ND} is mass of non defluffed seed from 5 g random sample taken from top screen (g) and, M_t is mass retained on top screen of grading unit (g).

Nucleus seed recovery, M_n: It is the ratio of quantity of nucleus seed obtained from sieving of the mixture retained on bottom tray of GU to the mass of fed seed sample expressed as a percentage and is given as;

$$M_n\,(\%) = \frac{\text{Mass fraction retained on 0.6 mm sieve} \times 100}{\text{Total mass of fed seed}} = \left(\frac{M_f}{F}\right) \times 100 \quad (3)$$

RESULTS AND DISCUSSION

The mean values of physical properties of both fluffy and nucleus dinanath seeds were determined for designing the machine. The mean values of seed dimensions (L×W×T) for fluffy seed and nucleus seed were 6.20×2.77×1.83 mm^3 and 2.44×0.82×0.58 mm^3 respectively. Similarly, D_a and D_g for fluffy seeds were 3.6 mm, 3.11 mm respectively and for nucleus seeds, the respective values were 1.28 mm and 1.05 mm. D_g value was found more than that of its width and thickness. The sizes of fluffy and nucleus seed were taken into considerations to design the concave clearance, sieve sizes of lower casing and GU. Ten millimeters concave clearance was selected considering the maximum length of fluffy seed (6.20+0.97 mm) in view of one thin layer of fluffy material lodged onto the rotating SC while in operation, whereas 2.6 mm round sieve size of lower casing was taken so that all the material which are crushed passed through it on GU. Similarly, 1.8 mm round opening sieve was selected for the top screen of GU so that the nucleus seeds and smaller dust particles pass through the openings of top sieve.

The mean value of sphericity for fluffy and nucleus seeds were 50.57% and 43.01% respectively. According to Singh *et al.* (2020), such seeds having lower value of sphericity may not be considered as spherical. The mean value of ρ_b of fluffy and naked seeds was 7.65 kg/m^3 and 613.63 kg/m^3. This indicates that the bulk density of nucleus seed was 80.21 times the fluffy seeds. Data on ρ_b was used for the design of size of FC. Similarly, the volume of fluffy seed and nucleus seeds were 10.97 mm^3 and 6.62 mm^3

Table 1 Specifications of the defluffing machine

Items	Specification
Main Frame	Dimension: 1120 × 700 × 950 mm^3 Material: angle iron (45 × 45 mm^2)
FC	Dimension: 950 mm length, 600 mm breadth Material: MS sheet, 18 gauge
SC Assembly	Wooden cylinder: 360 mm diameter and 580 mm long with serrated iron teeth on periphery; Cylinder shaft diameter: 30 mm ; Upper casing: 380 mm diameter; Lower casing: 380 mm diameter, 2.6 mm round sieve; Abrasive material on inner surface of the upper casing: sand paper (0.5 m^2); Clearance between upper casing and SC: 10 mm
FR	Feed roller: 2 (Nos.); 60 mm diameter, 615 mm long; Feed roller shaft: 20 mm diameter
GU	Dimension: 730 mm length × 600 mm width × 360 mm front height and 285 mm back height; Vertical gap between top sieve and bottom plate: 150 mm; Inclination of bottom plate: 10 degree; Top sieve: 1.8 mm round opening and a MS tray at the bottom
PTU	Electric motor: 0.75 kW, single phase A.C. motor (1440 RPM). V-Belt and pulley system: (i) between motor pulley and SC pulley; (ii) between SC pulley and GU pulley Chain and sprocket system between SC shaft and FR shaft Cam shaft and belt pulley attachment: between GU and SC

Table 2 Recovery of nucleus seed, defluffing capacity and defluffing efficiency for fluffy dinanath seeds

F (g)	M_c (%wb)	M_t (g)	M_b (g)	Mass fractions through sieves			M_{ND} (g)	D_t (min)	Performance parameters		
				Retained on 1.18 mm sieve	Retained on 0.60 mm sieve	Passed through 0.60 mm			M_n (%)	D_c (kg/h)	D_e (%)
500	7.0	295.20	203.80	55.20	114.10	34.00	0.6690	6.12	22.82[a]	4.90[a]	92.10[a]
	9.0	310.51	187.48	62.32	98.40	25.86	0.9170	7.18	19.68[b]	4.18[b]	88.63[a]
	11.0	325.40	172.50	49.71	78.55	44.24	1.4981	10.0	15.71[c]	3.02[c]	80.50[b]
Coefficient of variation (CV)									0.669	4.798	2.214
Critical difference (CD)									0.294	0.439	4.370
Mean sum of square (MSE)									0.017	0.037	3.716
F value									1140	36.35	14.52
Level of significance (p-value)									<0.01	<0.05	<0.05

a, b, c: the letters at superscript indicate whether the treatment means are at par or different. M_c, Moisture content of fed seed sample; M_t, Mass retained on topscreen of GU; M_b, Mass retained on bottom plate of GU.

respectively. Average 1000 seed mass of fluffy and nucleus seeds were 0.819 g and 0.478 g respectively. Kushwaha *et al.* (2007) studied selected physical properties of okra pod and seed for application in designing seed extractor. Based on the physical properties of dinanath grass seeds and as per design considerations, the specifications of prototype were developed (Table 1).

Performance evaluation: The prototype was evaluated for defluffing of dinanath grass seeds and M_n, D_c and D_e were measured. The operating speed of SC was 545 rpm. The data were analysed using generalized linear model (GLM) procedure of SAS (V-9.3) to assess the suitability of the machine. The experimental results on performance parameters are presented in Table 2. ANOVA was conducted for M_n, D_c and D_e (Table 2).

The ANOVA shows high F value (1140.1) for M_n at 1% level of significance. The linear effect of M_c was highly significant on M_n. Similarly, F values of 36.35 and 14.52 were observed for D_c and D_e at 5% level of significance, therefore, the effect of M_c on D_c and D_e were highly significant. Results indicated that the defluffing at 7.0% M_c and 545 rpm produced highest capacity of 4.9 kg/h and lowest D_c of 3.02 kg/h was observed at 11.0% M_c with the same speed. Increased D_c at 7 % M_c was the result of more dryness of the fluffy seed. The results of D_e of the machine (Table 2) indicates that the highest value of D_e was 92.10% at 7 % M_c which was at par to the seed having 9% M_c because the critical difference (CD=4.370) is more than the difference of average values of D_e at 7.0% M_c and 9.0% M_c. The lowest value of D_e was 80.5% at 11.0% M_c which is significantly different. Kamble *et al.* (2003) conducted the study on pearl millet thresher and got the reduced threshing efficiency with increase of M_c because high moisture content increased the plasticity of the grain. Bansal and Lohan (2009) obtained higher threshing efficiency at lower M_c during threshing of seed crops. Kushwaha *et al.* (2005) developed an okra seed extractor and evaluated at different M_c and found that extracting efficiency decreased with increase in M_c.

Fulani *et al.* (2013) observed higher threshing efficiency at lower M_c in case of cowpea. The M_n decreased from 22.82–15.71% with increase in M_c from 7–11%. The quantity of nucleus seed obtained from 500 g fluffy seed was 22.82% at 7% M_c. This shows 77.2% decrease in bulk weight and 99.7% reduction in bulk volume of fluffy seeds after defluffing in the form of nucleus seed. This will be helpful in easy handling, transportation and storage. Vijay *et al.* (2018) conducted study on traditional cotton batting machine for defluffing of dinanath grass seed and got 5.6% M_n. They also observed 94% decrease in mass and 98% reduction in V of nucleus seed as compared to fluffy seed.

Cost economics: Cost of defluffing using the prototype of machine was determined considering the fixed cost and variable cost of the machine (Dabhi and Davara 2017). It was compared with traditional manual defluffing cost. Total cost was considered as the sum of fixed and variable costs. Following assumptions were made:

Life of machine, year: 10; Total working days per year : 150; Total working hours per day ; Depreciation cost of defluffing machine, ₹/yr : 10% of initial cost; Rate of interest on capital investment per year, % : 12; Housing, insurance and other expenditures, ₹/yr : 1% of initial cost; Repair and maintenance cost, ₹/yr : 5% of initial cost; Capacity of defluffing machine: 4 kg/h; Labour charges, ₹/day : 400; Electricity charges @ ₹ 6 per unit: 0.75kW * 8h * 6 = ₹ 36/day

The machine defluffing cost was determined as ₹ 16.05 per kg, while traditional defluffing cost was ₹ 66.66/kg considering manual defluffing @ 6 kg/day. This indicates 75.92% saving of cost as compared to traditional (manual) defluffing cost. The main aim of defluffing was justified with cost saving and also in labour saving for the farmers.

It was concluded that the developed defluffing machine had highest defluffing capacity (4.9 kg/h), defluffing efficiency (92.1%) and nucleus seed recovery (22.82%) at 7.0 % moisture content. The lowest defluffing capacity of

3.02 kg/h and defluffing efficiency of 80.5% were recorded at 11.0% moisture content. It was observed that DM could save 76% cost of defluffing as compared to the manual defluffing. The mean value of seed dimensions (L×W×T) for fluffy seed and nucleus seed were 6.20×2.77×1.83 mm^3 and 2.44×0.82×0.58 mm^3 respectively. Similarly, the mean values of bulk densities of fluffy and nucleus seeds were 7.65 kg/m^3 and 613.63 kg/m^3 respectively. Transportation cost of voluminous fluffy seeds may be reduced drastically as its volume reduced up to 99.7% after defluffing in the form of nucleus seed. The defluffed dinanath seeds, not only aid in easy storage and transportation but also in sowing either through broadcasting or pelleting. The defluffing machine may also provide an opportunity to defluff other grass seeds of similar nature.

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