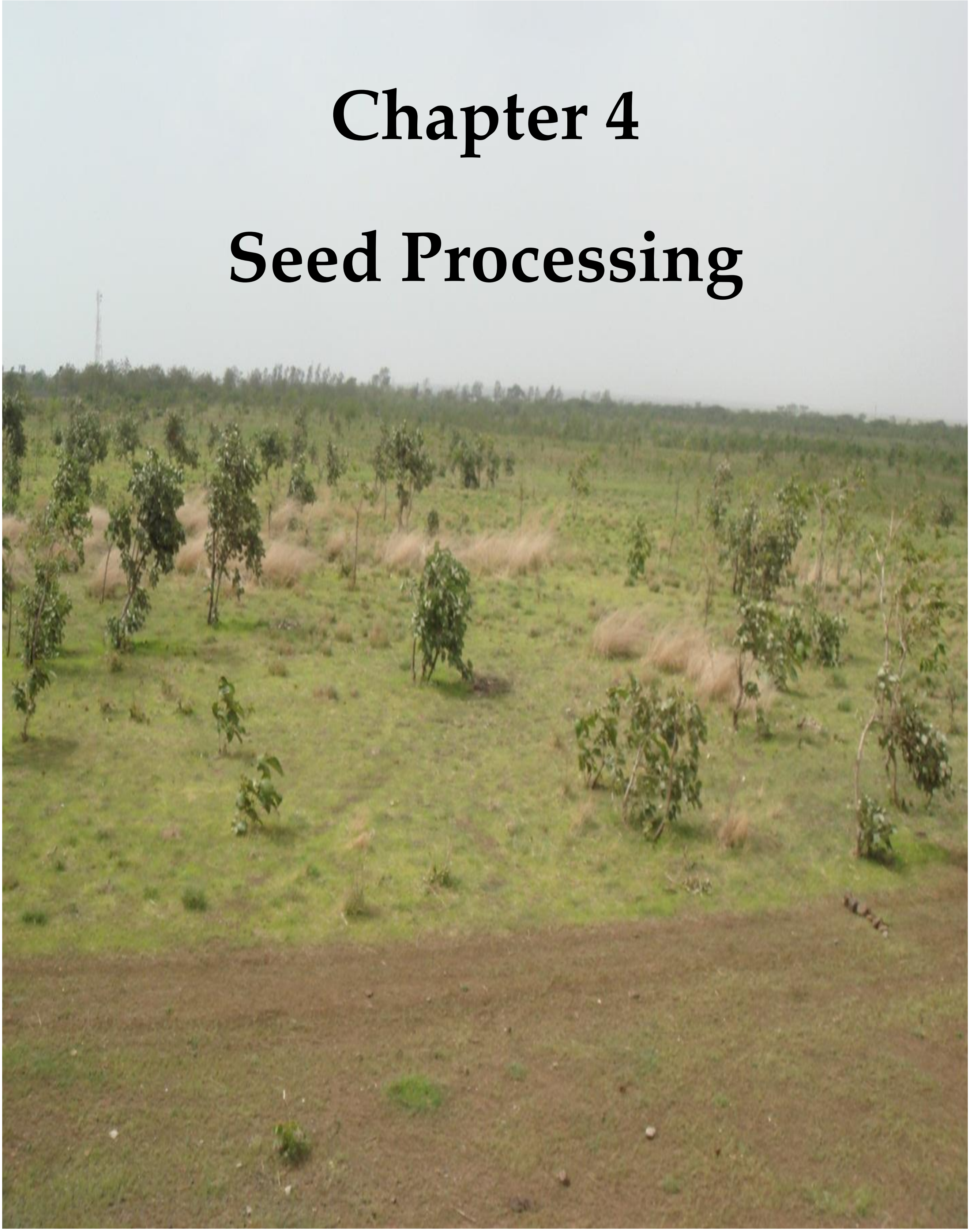
Chapter 4

Seed Processing



Chapter 4

Seed Processing

Successful revegetation relies on the use of high quality seed. Several techniques have been designed to evaluate the quality of seed. The primary emphasis of the seed quality is for physical purity. Pasture establishment or renovation will be only as good as the seeds that are planted. The separation of the seed sample into different portions such as pure seeds, inert matter, other crop seeds, weed seeds, etc. are the types of manual separation involved in purity analysis. As seed production and the seed trade broaden and become international, the seed industry and governments have made issues surrounding seed quality a top priority. Insuring a quality product, stopping the spread of noxious weeds, and providing accurate labeling are top of their concerns.

Pure seed refers to the species under consideration and in addition to mature, undamaged seed includes undersized, shriveled, immature and germinated seeds, provided they can be definitely identified as the species under consideration; and pieces resulting from breakage that are more than one-half of their original size (ISTA, 1976). Seeds of Leguminosae with the seed coats entirely removed are regarded as inert matter.

A seed lot is defined as a specified quantity of seeds that is physically identifiable and of reasonably uniform quality from a particular geographic source. Seed lots received from the field are often at high moisture content and contain trash and other inert material, weed seeds, deteriorated and damaged seeds, off-size seeds, etc. Seed processing is necessary in order to dry the seeds to safe moisture level; remove or reduce to the extent possible the various undesirable material, weed seeds, other crop seeds, deteriorated or damaged seeds; uniform size grading and seed treatment to upgrade the overall seed quality. In its common usage in India, seed processing refers to all the steps necessary for preparation of harvested seed for marketing namely Harvesting, Seed Collection, Post-harvest seed conditioning, Seed Drying, Seed Cleaning, Seed Extraction and Seed storage.

Seed processing is involvement of various methods and techniques used to obtain clean, high quality seeds. It refers to all the steps necessary for preparation of harvested seed for marketing like handling, drying, shelling, preconditioning, cleaning, size grading, treating packaging, etc. In the present study, seed processing involved different steps by which the seeds of good quality were obtained and were efficiently stored, they are harvesting, seed collection/gathering, post-harvest seed conditioning, seed drying, seed cleaning, seed extraction and seed storage.

According to Lodge and Peterson (1987) and Dowling and Garden (1990) many grasses among the native ones have been identified for different purposes such as fodder, shelter, as ornamental purposes and also for different situations as revegetation as well as stabilization of degraded land and roadsides, etc. From more than past decade, interest in plantation of these useful grasses has increased by pastoralist as well as by farmers. Usage of these species and their commercial availability mainly depends on easy access of supply of good quality seeds which gives satisfactory and reliable establishment, and this all further depends on the appropriate seed harvesting and processing techniques.

Materials and methods

The present study deals with recent advances in seed harvesting and processing and gives outline about the quality seed production for the selected grasslands. The steps followed were:

- Harvesting and Seed Collection
- Post-harvest seed conditioning
- Seed Drying
- Seed Cleaning

- Seed Extraction
- Seed storage

Harvesting and Seed Collection

Manual harvesting was done, the processes applied were:

- For grasses **:** Combing, Plucking, Shaking, Swathing and Sweeping was done. Combing was done for awned species
- For legumes : The dried pods were plucked.

Post-harvest seed conditioning was done by threshing and winnowing.

Seed Drying

- Harvested material was spread on the cloth in shade in well ventilated room.
- Direct sunlight was not applied to grass seeds as it may affect the viability of seeds.
- Legume pods were dried in direct sunlight, as the pods split opened then the seeds were dried in shade. (Legumes can withstand some exposure due to their harder seed coats.)

Seed Cleaning

Assortment of species

Prior to going for the cleaning, the collected grass species were classified according to their dispersal units. For this classification we used the classification of Loch et al. (1996) and then modified it according to our requirements. The main purpose of this classification was for selection of appropriate sieve size for the cleaning objective. On basis of range of seed size and other essential features, two seed cleaning equipments were constructed, a sieve stand and a seed thresher, using them the cleaning procedure was performed

Experimental procedure

Sieve stand (Geometric separation)

- About 1 kg of harvested and properly sun-dried sample was fed onto the sieve with mesh size of 3 and 4 which removed inert material like bigger straws, dried leaf particles, etc. through manual rubbing.
- By using sieves with the mesh size of 6, 8 and 10 smaller particles of trash were removed.
- While with sieves of mesh size of 12, 14 and 16 separation of different size of florets was done.
- The cleaned florets along with associated chaff were collected in the seed container while bigger trash remained on the sieve within the sieve holder.
- The seeds in the seed container with associated chaff were further applied to seed thresher.

Seed thresher (Mechanical separation)

- The cleaned material obtained from sieve stand was inserted to seed thresher from the feed which directly falls in the sieve drum. Minimum amount of feed was standardized as 500 gms.
- The rubbing process was initiated by moving handle in a clockwise or anticlockwise direction, due to which rubber blades attached to the central shaft rubbed the fed material with the sieves. The rubbing separated chaff material from the caryopses which fell into the seed container.
- The remnants of bigger trash (if present) fell into the trash container through the outlet.
- The pure caryopses and particles of chaff then were further applied for winnowing.
- Cleaned caryopses were weighed with electronic weighing balance and stored in polyethylene bags and labeled for further analysis.
- The chaff particles as well as trash captured from the outlet were also weighed for determination of cleaning loss.

- The difference between the weight of caryopses and the trash / chaff material gave cleaning efficiency as well as cleaning loss.
- The values obtained from caryopses separation and physical properties were evaluated using frequency distribution (Table 4.4).

Cleaning Steps were as follows:

Harvested and proper sun dried sample applied to the sieve stand

Rubbing process

Inert material removed

Separated caryopses along with the associated chaff were further applied to the seed thresher

Loading of samples to the thresher

Pure caryopses + remnants of chaff particles (Seed container)

Remnants of bigger trash (Trash container)

Winnowing

Pure caryopses

Minor waste

Parameters measured (Simonyan and Yiljep, 2008)

i. Cleaning efficiency (Purity)

$$\eta = \frac{G_o \; x \; 100}{G_o + C_{cg}}$$

Where, η= cleaning efficiency %, G_o= weight of pure caryopses in seed container, (g) and C_{cg}= weight of contaminant in cleaned caryopses (g)

ii. Cleaning loss

$$C_L = \frac{G_i \; x \; 100}{G_w}$$

Where, G_i= weight of caryopses at chaff outlet (g) and G_w = weight of caryopses at input (g)

Seed Storage

Seeds were stored in air tight plastic bottles, thus the moisture content and temperature outside the bottles could not affect the contents (**Plate 4.5 b**).

Results and Discussion

Harvesting and Seed collection / gathering

It is the process of gathering/collecting mature seeds from the fields. It marks the end of the growing season or growing cycle of a particular species, and also focuses on seasonal celebrations in many religions.

The timing of harvesting for any species is a very critical decision which exhibits the balance between weather conditions and the degree of maturity. Weather conditions such as frost, rain and unseasonably warm or cold periods can affect the seed yield and its quality. The harvesting before maturity i.e. early harvest can avoid damaging conditions but it results in poorer yield and quality. While delayed harvesting i.e. after the seed maturity, may result in better harvesting but can increases the risk of weather problems. This timing, along with the surrounding environment is also important for the seed quality as it directly affects the germinability of seed and hence the growth of the seedling. Generally grasses need 20-30 days after flowering for seeds to properly mature and it will vary because the period of flowering and seed development lasts from several days to two weeks. As a result, seed heads emerge at different times, which cause uneven seed ripening and thus grasses generally do not mature uniformly. In the grasses, seed ripening begins at the panicle tip and moves downward. This is the stage where moderate to hard pressure with a thumbnail will make a mark on the seed (Ehlke and Undersander, 1990).

There are mainly three methods of harvesting grass seed: direct combing, swathing and combing and seed stripping (Najda et al., 1994). For almost all grass species, harvesting was done manually, while for few awned species; other harvesting methods were also applied. For legume seeds, the pods were plucked manually.

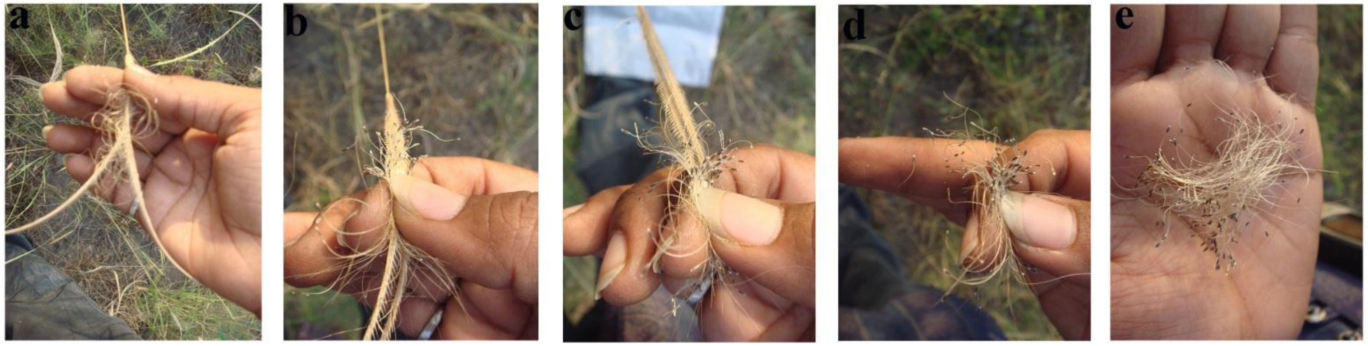
In the present study the main harvesting method used was swathing, in which the grasses were cut from the particular height. In some species only inflorescences were cut down, while in dominant awned species direct combing was applied and manual collection (florets gathering) was done. Harvested material was kept in paper bags, paper envelops, large plastic bags, etc. The harvesting procedure was done during the day time and care was taken to achieve maximum maturity of the seeds. Harvesting was done when the inflorescence seemed dried. After completion of the harvesting procedure; the harvested plant material was subjected for differentiation into seed heads and other unwanted plant parts by manual plucking.

Seed collection/gathering, is basically a part of harvesting which requires good planning regarding the collection equipment, packing and labeling of collected material, maintenance of records (e.g. field diary), transportation facilities from field to laboratory, etc. The other important points regarding collection of seeds are:

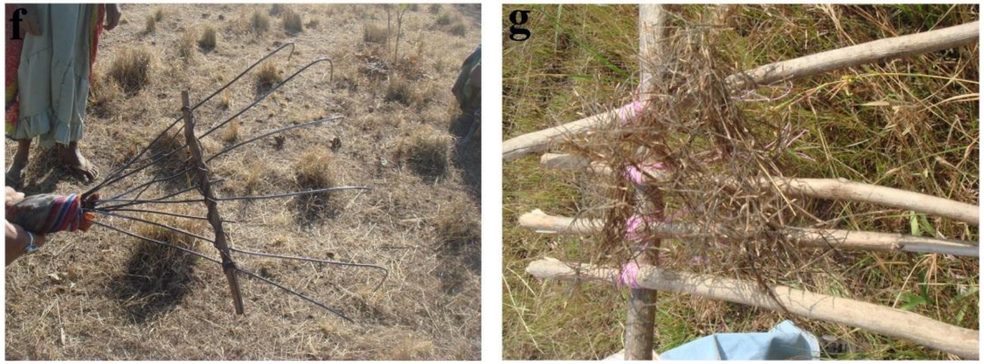
- Information about the location, time of flowering and fruiting for particular species
- Information about the periodicity of seed maturation
- Avoidance of poorly formed stands, excessively flimsy, off-color, abnormal or diseased plants
- Information about topography and meteorological parameters along with attack of pests which greatly affects the seed quality, yield and periodicity.

In our study area, we observed the differences in seed quality between early and delayed harvest, and the main reason behind it was differences in weather conditions at the time of seed maturity. Thus, it is necessary that the time as well as date of harvesting should be appropriate so that moisture content of harvested seed remains at minimum level which again helps in keeping good seed quality. Such study was done by Biddle and King (1978) on Peas and their results have shown that the moisture content more than 35 % significantly reduced both, the germination and the seed size and increased the amounts of leachate as measured by the electrical conductivity.

The exact timing of ripening of seeds in grasses may vary according to the rainfall pattern and fluctuating temperature of the preceding spring. In the study area also, both of these factors worked during the harvesting and seed collection period of successive years. Generally the seed of most of the species (and plants) throughout the study area ripen from October to November.. Another emphasis was given on the color change of plant parts especially of leaf and inflorescence and for few grass species, it was seed color also. While for legumes, pod color i.e. from green to pale yellow (for almost all species) was the main indicator and along with it change in seed coat color i.e. from green to pale yellow, red or



a, b, c, d, e: Mannual harvesting of awned species (*Schoenefeldia gracilis*)



f & g: metal and wooden comb prepared by tribals for harvesting of awned species

Plate: 4.1 Harvesting methods

a, b, c: Harvesting of awned species (*Schoenefeldia gracilis*) with ordinary comb

d, e, f: Harvesting of awned species (*Heteropogon contortus*) with ordinary comb

Plate 4.2 Harvesting processes

brown was another confirmatory indicator. Thus color identification was used as primary indicator for collecting mature seeds. Harvesting for grass species was done when the leaf color turned from green to golden yellow, inflorescence color turned from green to yellowish brown or reddish brown and finally, florets appeared brittle and color changed from green to pale or golden yellow.

For grasses, collection was done by removing seed from the seed heads i.e. by the use of secateurs (plucking whole inflorescence) and combing was used for awned species. While for legumes, directly dried pods were plucked.

Plucking of whole inflorescences involved the cutting of an inflorescence, keeping it in a paper bag, drying it in the lab and then shaking it. Due to shaking the mature seeds fell down. The seeds were gathered in paper bags to decrease the moisture level. While combing was used mainly for the awned species (*Heteropogon contortus, Schoenefeldia gracilis,* etc.). In this method the common hair comb was used. Sometimes sweeping was also done to gather the mature seeds which had already fallen down. The collection methods which we used are exhibited in **Plate 4.1 and 4.2**.

Post-harvest seed conditioning

After harvest and collection, seeds must be threshed, cleaned and dried for storage. Seed threshing, seed cleaning and seed drying are the main component of post-harvest seed conditioning. Newly harvested grass and legume seeds contain husk, straws, soil particles and dried leaf particles as unwanted materials. Sometimes they also contain seeds of other species. These foreign materials must be removed through appropriate cleaning process to obtain seeds of good quality. Following the cleaning of seeds, seed drying is necessary for the seed health. Seeds are often harvested at higher moisture contents than those recommended for storage. And the seeds with high moisture content are more susceptible to damage during cleaning because they are relatively soft. Drying reduces seed moisture to a safe level for both cleaning and later storage.

Threshing involves separating the seeds from panicles and straw and winnowing of chaff material from the seeds. Seed materials can be threshed by hand or machine. In Manual threshing which we followed, a simple stick or beat is used to separate the seed from the inflorescence and straw by beating the harvested repeatedly on the floor or by beating it through stick. In all the techniques care was taken to minimize physical damage which can affect germination or allow disease infestation.

Seed drying

The longevity of seeds in long-term seed storage is strongly dependent on their maturity at the time of harvest. In most of the species, maximum longevity occurs when the collection is done at the time of natural dispersal. Immature seeds are significantly short lived and seeds that have not attained mass maturity may be killed by drying. Thus the international standards recommend drying, as soon as possible after harvest, which helps in the enhancement of seed longevity.

Newly harvested seed is quite moist and has moisture content. Therefore, the seeds must be dried to a safe moisture content to prevent loss of germination, heating and infestation during storage. Leaving the seed to dry on the mother plant is best since the seeds continue to mature and are shed naturally. However, if the crop remains in the field for too long, yields may be lowered, especially in wet windy areas and also shows increase in diseases and pests which may again lower quality and remain a problem during storage.

The rate at which a seed dries is a function of how fast the moisture evaporates from its surface. This in turn depends on the temperature and relative humidity (RH) of the drying air, and the rate at which moisture moves from inside the seed to the seed surface (i.e. permeability of the seed to moisture). During drying seed moisture evaporates into the surrounding air. Evaporation, using heat from the seed, occurs until the amount of water in the seed is equivalent to or in equilibrium with the amount in the air (relative humidity). This is termed as the equilibrium moisture content of seeds and varies from crop to crop

(Anonymous, 1994). There is a relationship between safe drying temperature and initial seed moisture content. The general recommendation for field crops is to dry the seed at temperatures of no more than 32, 37 and 43°C for moisture contents of more than 18%, 10 to 18%, and less than 10% moisture, respectively Seed viability is decreased by drying at temperatures above 40°C. If drying is too rapid there is a tendency for the seed coat to split or harden which may prevent the interior of the seed from drying (Anonymous, 1994).

Seeds are dried to a safe moisture limit by sun drying and forced air drying in order to maintain the viability and vigor for a very long time. Generally, there are three methods used for drying seed viz: sun drying, natural forced air drying and artificial drying. For present study we applied only sun drying.

Seed cleaning

Seed cleaning is basically a process that involves the removal of inert matter (Straws, dried leaves, etc.), other crop seed (including weeds) and damaged seed from harvested, threshed and dried material which ensures good seed quality. If cleaning is done with the right equipment and appropriate methods, it increases purity and germinability by removal of unsuitable materials. It can also decrease the number of diseased seeds and improve the visual, commercial and planting quality of the seed lot.

Cleaning consists of three main stages: pre-cleaning, basic cleaning and grading. Pre-cleaning removes materials other than seed which can hinder the seed flow and also minimize the cleaning accuracy. During the basic cleaning, materials other than the seed of required species are removed. While grading process enhance the quality of the seed by separation and removal of uneven, immature, diseased seeds.

Seed cleaning can be done manually for small seed lots by sorting out unwanted material. While mechanical cleaning is more useful for bigger seed lots which also minimize the labor costs of manual cleaning. The graders can be used to separate the seeds according to the size for large seed lot. The gravity separators can be used to separate the seeds based on the density while cylindrical separator are used to maintain the uniform shape and size of seeds. The seed blower is used to separate heavy and light fractions for small sized seeds and seed brushing machine is used to remove the hairiness of the seeds. By this way the undesirable fractions namely inert matter, weed seeds, other crop seeds, light and chaffy seeds are removed or separated from the desirable seed lots. However, machines are not as perfect as traditional manual systems as their capacity is far greater and cannot facilitate a final hand selection of seeds for a single species.

Seeds have three major characteristics by which they can be separated from non-seed material or other seeds (Anonymous, 1994). They are:

- Geometric: size (width and thickness), length and shape.
- Mechanical: resilience, shape, size, surface texture and density.
- Physical: surface texture, specific gravity and affinities.

In present study, prior to going for the cleaning, the collected grass species were classified according to the nature / type / structure of their dispersal units. For this classification we used the classification of Loch et al. (1996) as a base and then classified our grasses accordingly. The main purpose of this classification was selection of appropriate sieve size for the cleaning objective.

Classification based on Loch et al. (1996).

DISPERSAL UNIT

1. COMPLEX: Dispersal along with intact inflorescence or part of it (spikelet cluster).

2. SIMPLE: Dispersal units having rachis internode and 2 attached spikelets.

3. FASCICLE: Dispersal units having clusters of spikelets (1-3) surrounded by an involucre with 2 rows of wavy bristles.

COMPLEX

<u>Awned</u>

Andropogon pumilus

Iseilema laxum

Themeda laxa

Themeda quadrivalvis

Themeda triandra

<u>Awn less</u>

Dactyloctenium aegyptium

Desmostachya bipinnata

Eleusine indica

FASCICLE

Cenchrus biflorus

Cenchrus ciliaris

Cenchrus setigerus

Melanocenchris jacquemontii

Pennisetum setosum

SIMPLE

Awned

Awn less

Rigi1d Awn

(Non hygroscopic Awn)

Lax Awn

(Hygroscopic Awn)

<u>Papery Husk</u>

Arthraxon lanceolatus
Chloris barbata
Chloris virgata
Schoenefeldia gracilis

<u>Tough Husk</u>

Aristida adcensionis
Aristida funiculata

<u>In Singles</u>

Apluda mutica
Bothriochloa pertusa
Capillipedium hugellii
Chrysopogon fulvus
Cymbopogon martinii
Dicahnthium annulatum
Dichanthium caricosum
Ischaemum sp.
(*I. indicum, I. molle, I.pilosum, I. rugosum*)
Sehima sp.
(*S. ischaemoides, S. nervosum, S. sulcatum*)
Sorghum bicolor
Sorghum halepanse
Thelepogon elegans
Themeda cymbaria

<u>In Clusters</u>

Heteropogon contortus
(all varieties)

SIMPLE

Awned

Awn less

With Surface hairs

Alloteropsis cimicina
Oplismenus burmanii
Digitaria adscendens
Digitaria granularis
Echinochloa colonum
Echinochloa crusgalli
Echinochloa stagnina
Eragrostiella bifaria
Imperata cylindrica
Panicum antidotale
Panicum trypheron
Paspalidium flavidum

With stiff surface bristles

Brachiaria reptans
Brachiaria cruciformis
Chionachne koeginii
Coix lachryma-jobi
Cynodon dactylon
Dinebra retroflexa
Eragrostis sp.
(E. cilianensis, E. ciliaris, E. Japonica,
E. nutans, E. tremula, E. tenella,
E. unioloides, E. viscosa)
Hackelochloa granularis
Isachne globosa
Ophiorus exaltatus
Sporobolus sp.
(S.diander, S. fertilis, S. halvolus,
S. marginatus)

Without surface hairs and bristles

Pterotis indicum
Setaria glauca
Setaria tomentosa
Setaria verticillata

Any kind of seed lot can be separated geometrically or mechanically. In geometric separation emphasis is given on the size and shape of the seed. This method is applied by passing the seed lot over the sieve. The holes of the sieve may be square or they may be slots which are oblong. These square holes separate seeds according to their width while oblong slots separate seeds according to their thickness. Whenever the shape of seeds differs, then the rolling ability of the seed is used to separate the seeds with differing size in the same seed lot. In mechanical separation the main emphasis is given on the density of seed lot and along with it the size and shape of the seeds is also taken into the consideration.

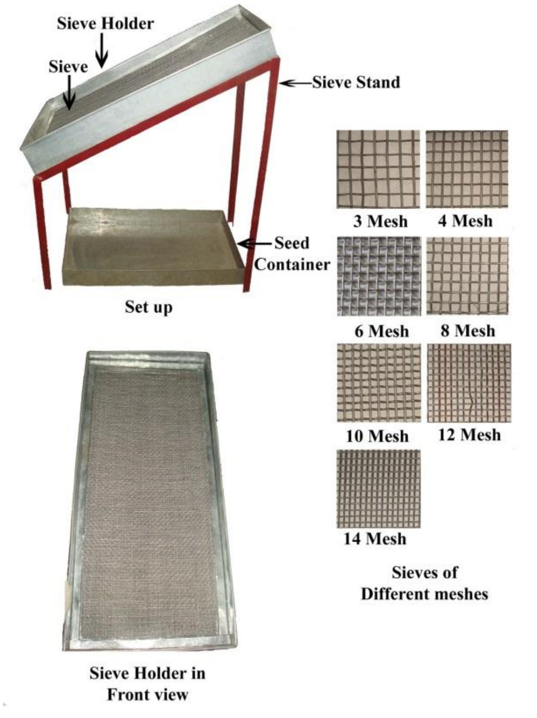
Harvesting and post-harvesting introduce many foreign materials as contaminants into the seed lot. Hopfen (1969) pointed out that threshed caryopses require considerable additional cleaning before it can be used as food, whole or ground and even as seed. For this, sieving is considered as an appropriate technique in which lot of modifications are being tried till the date (Dreesen, 2004; Schmidt, 2000; Simonyan and Yiljep, 2008). Picket and West (1988) defined sieving as a process in which material mixture moves over a perforated surface with openings of a specified shape and size having one or more oscillating sieves and a fan delivering air through the sieves.

In the selected study area high diversity of grasses is found, and almost all are being used as forage. Many among them are having very small sized caryopses and much attention had not been given on proper harvesting, efficient cleaning and separation of these seeds, as a result germination output is not up to the mark when these seeds are sown in the field. To obtain quality grass seeds (caryopses) of such a minute dimensions, it is desirable that they must be cleaned at the proper maturity stage. It will not be possible to separate the caryopses of different fodder grasses with a single sieve of the machine. During the caryopses separation, a series of operations were performed in which all these functional elements are put together to form a successful equipment. In the selected study area, the available conventional machines for cleaning the grass seeds are very large, requiring a high capacity power source besides requiring large fields, highly skilled operators and technicians to use and maintain them. On the other hand, they were not handy as well as their maintenance is also not affordable. Thus there was an urgent need to have small, handy and affordable equipment for such kind of caryopses separation for successful grassland establishment. In the present study an effort was made to develop an indigenous simple machine for the same purpose.

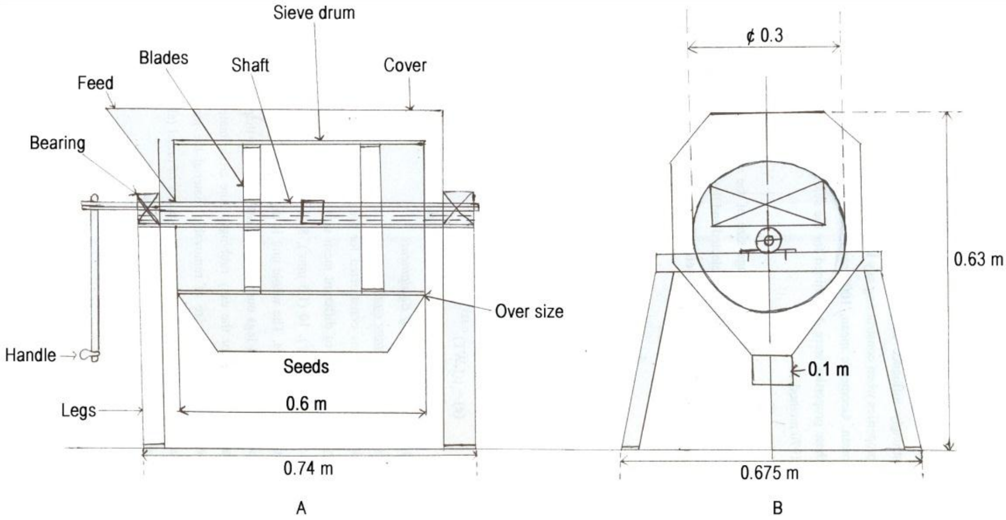
Constructions of Equipment

1. Sieve stand – a rubbing equipment

The sieve stand was constructed for the purpose of geometric separation. This stand has replaceable sieves of different mesh size **(Plate 4.3)** ranging from 16 mesh (0.8 mm^2), 14 (1 mm^2), 12 (1.2 mm^2), 10 (1.5 mm^2), 8 (2 mm^2), 6 (3 mm^2), 4 (6 mm^2), 3 (8 mm^2) and all having square holes. The whole unit is made up of iron. The shape of the unit is rectangular, and the stand has 4 legs out of which two are shorter than the other two. This maintains the slanting position for the easy rubbing of the crude material, rubbing was done manually. Depending upon the size of removable material the mesh size was chosen. The rubbed material was collected into a metal (aluminum) seed container placed below the stand.

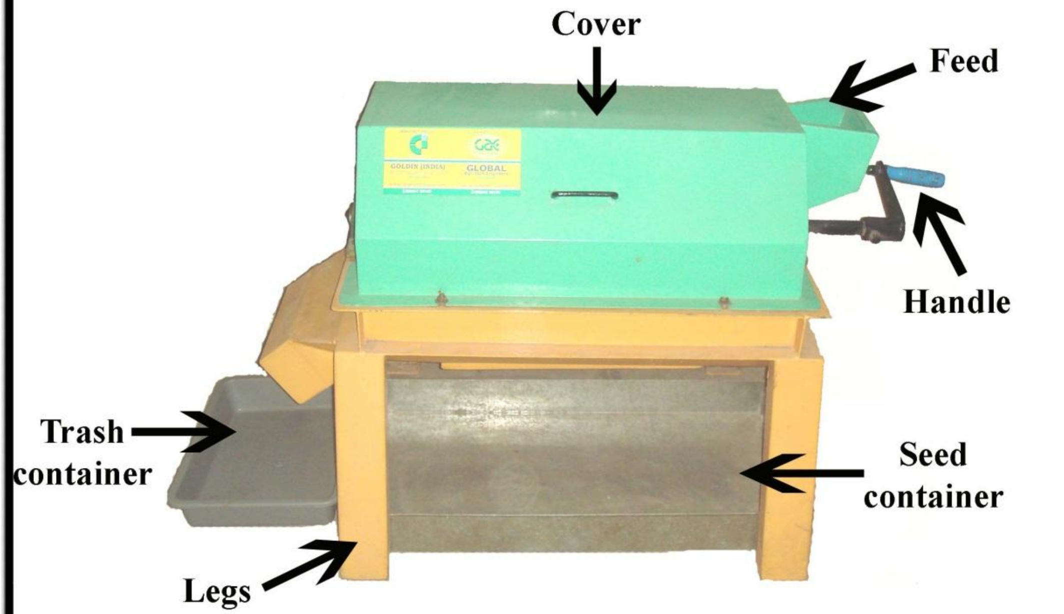


Sieve stand

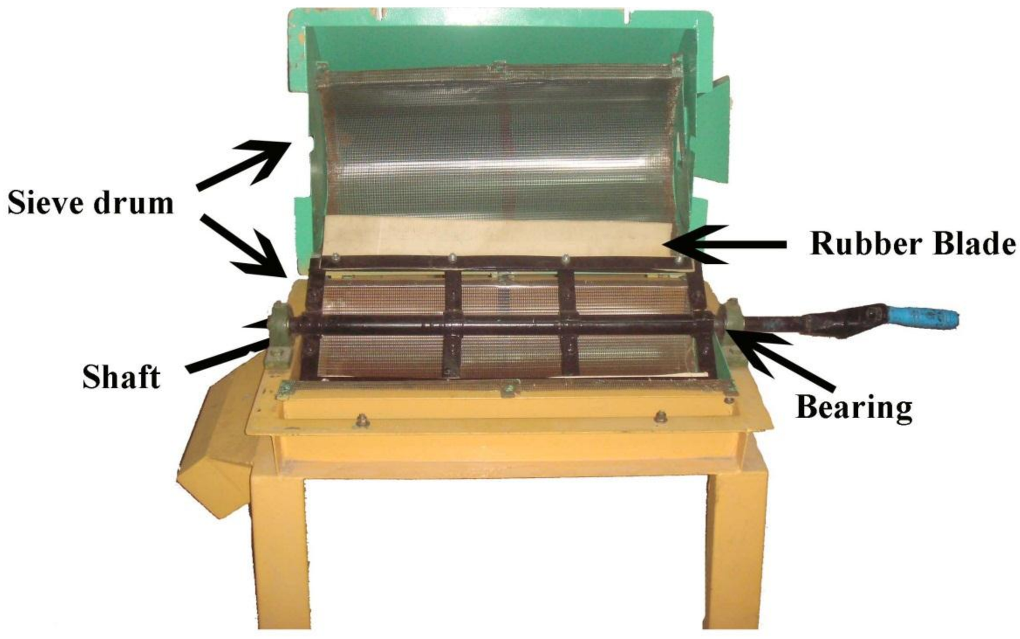


Basic schematic design of seed thresher
A - Side view B - Front view

Plate 4.3 Seed cleaning units



a. Seed thresher closed



b. Seed thresher opened

Plate 4.4 Seed thesher

2. *Seed thresher*

The seed thresher was constructed for the purpose of mechanical separation having simple mechanism. Here also the whole unit is made up of iron and almost rectangular in shape. The basic design of apparatus was approved by Mr. G.D. Karhadkar, workshop superintendent at Department of Mechanical Engineering, Faculty of Technology, The M. S. University of Vadodara **(Plate 4.3)**. The machine was then got constructed at Globtech, BIDC, Vadodara after discussion with Mr. L. D. Patel, about selection of material to be used **(Plate 4.4)**. Table 4.1 represents the dimensions of sieve stand as well as seed thresher.

3. *Principle of Operation*

Basic cleaning refers to actual cleaning and grading of seeds. In cleaning process, the separation of undesirable material, from desirable material is done on the basis of differences in various physical properties of both. The geometric separation was done with sieve stand based on the size (width and thickness), length and shape of the seed. Mechanical separation was done through a thresher based on the resilience, shape, size, surface texture and density of the seed.

Through appropriate technology, an attempt was made to design and create a modified model of a manual grass seed cleaner. It consisted of two units; the sieves stand and seed thresher. The sieve stand was used for the removal of bigger trash and seed thresher for the removal of minute chaff particles. Both of these equipments were designed based on basic sieving process and considering the physical properties of seeds. Instead of conventional large machines with high power consumption, these two manual handy ones are affordable and is a new attempt to get quality seeds in forage reestablishment i.e. mainly for minute forage grass seeds. The sieving process of the sieve stand separates bigger trash while thresher separates associated chaff. Obtained results for each species along with their desired physical properties are presented in table 4.2 and 4.3. Table 4.2 presents the mean values of axial dimensions, Mass of 1000 seeds, Arithmetic mean, Geometric mean and Sphericity of selected grass species (Mohsenin, 1970). Arithmetic mean and geometric mean can be used to determine the average diameter of seeds. This is useful in determining the diameter of sieve hole.

Table 4.1 Parameters of the sieve stand and seed thresher

Parameter	Dimensions	
	Sieve stand	Seed thresher
Overall length	1.2 m	0.74 m
Overall width	0.37 m	0.675 m
Overall height	1.42 m	0.63 m
Effective threshing cylinder diameter	-	0.40 m
Effective concave diameter	-	0.30 m
Sieve dimension	0.35x1.0 m	0.673x0.72 m
Sieve inclination	30^0	0^0 (horizontal)

Table 4.2 Physical characteristic of selected grass species

Sr. No.	Species Name	Shape	Seed size LxTxW (mm)			Mass of 1000 s eed(gm)	Arithmetic mean diameter (mm) *Da*	Geometric mean diameter (mm) *Dg*	Sphericity (%) ¢
Sp.1	*Apluda mutica*	Ovate	2.1	0.6	0.9	0.67	1.14 ± 0.065	0.33 ± 0.052	0.39 ± 0.020
Sp. 2	*Arthraxon lanceolatus*	Oblong	1.8	0.25	0.3	0.04	0.79 ± 0.018	0.04 ± 0.005	0.16 ± 0.008
Sp. 3	*Cenchrus ciliaris*	Oblong	1.9	0.8	0.5	0.88	1.06 ± 0.010	0.25 ± 0.009	0.35 ± 0.005
Sp. 4	*Chloris barbata*	Fusiform	1.4	0.5	0.4	0.20	0.76 ± 0.006	0.09 ± 0.004	0.25 ± 0.004
Sp. 5	*Chloris virgata*	Ellipsoid	1.5	0.4	0.5	0.14	0.80 ± 0.007	0.10 ± 0.005	0.25 ± 0.005
Sp. 6	*Chrysopogon fulvus*	Oblong to elliptic, linear	4.6	0.5	0.9	0.60	2.00 ± 0.012	0.68 ± 0.026	0.41 ± 0.007
Sp. 7	*Dactyaloctanium aegyptium*	Squarish to ovoid	0.9	0.9	0.5	0.24	0.76 ± 0.008	0.13 ± 0.005	0.28 ± 0.004
Sp. 8	*Desmostachya bipinnata*	Ovate	0.95	0.3	0.4	0.11	0.55 ± 0.008	0.04 ± 0.002	0.19 ± 0.004
Sp. 9	*Digitaria adscendens*	Oblong	2.2	0.8	0.4	0.75	1.13 ± 0.006	0.23 ± 0.005	0.33 ± 0.003
Sp. 10	*Echinochloa colonum*	Ovoid to ellipsoid	1.6	1.2	0.7	0.80	1.17 ± 0.006	0.45 ± 0.008	0.44 ± 0.002
Sp. 11	*Echinochloa crus-galli*	Ellipsoid	1.8	1.66	0.9	1.06	1.45 ± 0.005	0.89 ± 0.019	0.54 ± 0.004

Sr. No.	Species Name	Shape	Seed size LxTxW (mm)			Mass of 1000 s eed(gm)	Arithmetic mean diameter (mm) *Da*	Geometric mean diameter (mm) *Dg*	Sphericity (%) ¢
Sp. 12	*Eleusine indica*	Ovate, ellipsoid to Subglobose	1.2	0.6	0.5	0.23	0.77 ± 0.006	0.12 ± 0.003	0.28 ± 0.003
Sp. 13	*Eragrostis tenella*	Oblong to obovate	0.5	0.2	0.2	0.10	0.30 ± 0.009	0.007 ± 0.001	0.11 ± 0.004
Sp. 14	*Eragrostis unioloides*	Ovoid	0.7	0.2	0.4	0.12	0.43 ± 0.005	0.018 ± 0.001	0.15 ± 0.003
Sp. 15	*Ischaemum pilosum*	Oblong	2.4	0.8	0.6	0.71	1.27 ± 0.003	0.39 ± 0.007	0.40 ± 0.004
Sp. 16	*Ischaemum rugosum*	Ovate	2.2	0.9	0.8	0.55	1.30 ± 0.006	0.53 ± 0.010	0.46 ± 0.003
Sp. 17	*Panicum trypheron*	Ovoid to orbicular	1.6	1.2	0.4	0.71	1.06 ± 0.008	0.25 ± 0.010	0.36 ± 0.005
Sp. 18	*Paspalidium flavidum*	Ovoid to orbicular	1.2	1.2	0.4	0.64	0.93 ±0.004	0.19 ± 0.005	0.33 ± 0.003
Sp. 19	*Schoenefeldia gracilis*	Fusiform to obovate	2.0	0.5	0.35	0.16	0.92 ±0.088	0.11 ± 0.016	0.25 ± 0.007
Sp. 20	*Sehima ischaemoides*	Oblong	1.8	0.4	0.5	2.13	0.90 ± 0.005	0.12 ± 0.003	0.26 ± 0.002
Sp. 21	*Sehima nervosum*	Fusiform to lanceolate	4.3	1.0	0.3	1.86	1.87 ± 0.025	0.43 ± 0.041	0.34 ± 0.015
Sp. 22	*Sehima sulcatum*	Oblong to fusifom	2.6	0.9	0.6	0.80	1.37 ± 0.004	0.47 ± 0.006	0.42 ± 0.002
Sp. 23	*Sorghum helepanse*	Ovate	2.8	1.7	1.1	3.71	1.87 ± 0.003	1.75 ± 0.015	0.69 ± 0.002
Sp. 24	*Thelepogon elegans*	Oblong	3.6	1.4	0.5	2.48	1.84 ± 0.008	0.84 ± 0.023	0.49 ± 0.006
Sp. 25	*Themeda cymbaria*	Ellipse to fusiform	2.3	0.9	0.3	0.50	1.17 ± 0.006	0.21 ± 0.006	0.31 ± 0.004

Table 4.3 Efficiency parameters of the thresher

Sr. No.	Species Name	Amount of material after processed in sieve stand (gms)	Amount of cleaned Pure caryopses (gms)	Amount of contaminant in cleaned caryopses (gms)	Cleaning efficiency (Purity) %	Cleaning loss %
1	*Apluda mutica*	**800±5.1**	**630±2.7**	**170±2.3**	**78.75±4.5**	**21.25±4.4**

Sr.		Amount of material after processed in	Amount of cleaned Pure caryopses	Amount of contaminant in cleaned	Cleaning efficiency	Cleaning
2	*Arthraxon lanceolatus*	**330±2.2**	**280±4.2**	**50±4.1**	**84.85±6.3**	**15.15±1.4**
3	*Cenchrus ciliaris*	**600±±3.2**	**534±2.5**	**66±4.5**	**89±7.7**	**11±4.8**
4	*Chloris barbata*	**800±7.0**	**687±6.4**	**113±9.0**	**85.88±7.2**	**14.13±2.6**
5	*Chloris virgata*	**820±6.4**	**789±2.3**	**31±1.5**	**96.22±4.4**	**3.78±0.4**
6	*Chrysopogon fulvus*	**680±6.0**	**567±5.3**	**113±4.5**	**83.38±1.8**	**16.62±1.3**
7	*Dactyaloctanium aegyptium*	**910±5.1**	**750±6.0**	**160±7.6**	**82.42±5.5**	**17.58±5.3**
8	*Desmostachya bipinnata*	**870±5.3**	**630±7.0**	**240±8.5**	**72.41±7.4**	**27.59±9.4**
9	*Digitaria adscendens*	**480±4.2**	**270±3.2**	**210±9.3**	**56.25±3.4**	**43.75±5.2**
10	*Echinochloa colonum*	**880±6.4**	**410±2.9**	**470±9.5**	**46.59±2.4**	**53.41±5.1**
11	*Echinochloa crus-galli*	**860±7.0**	**565±5.3**	**295±9.7**	**65.7±7.7**	**34.3±5.0**
12	*Eleusine indica*	**770±3.2**	**590±6.4**	**180±2.5**	**76.62±9.4**	**23.38±7.4**
13	*Eragrostis tenella*	**720±2.9**	**645±2.9**	**75±4.5**	**89.58±7.3**	**10.42±4.8**
14	*Eragrostis unioloides*	**710±2.3**	**670±7.0**	**40±4.5**	**94.37±5.5**	**5.63±5.5**
15	*Ischaemum pilosum*	**640±3.2**	**490±4.2**	**150±3.5**	**76.56±5.7**	**23.44±2.5**
16	*Ischaemum rugosum*	**820±6.0**	**730±5.1**	**90±4.8**	**89.02±7.4**	**10.98±1.3**
17	*Panicum trypheron*	**740±5.1**	**534±2.9**	**206±9.6**	**72.16±4.8**	**27.84±9.4**
18	*Paspalidium flavidum*	**810±2.9**	**625±5.3**	**185±4.5**	**77.16±5.5**	**22.84±6.1**
19	*Schoenefeldia gracilis*	**950±6.4**	**610±3.0**	**240±9.1**	**71.76**	**28.24±5.2**
20	*Sehima ischaemoides*	**430±2.9**	**335±3.2**	**95±4.2**	**77.91±4.7**	**22.09±2.2**
21	*Sehima nervosum*	**220±6.0**	**190±6.0**	**30±1.2**	**86.36±5.3**	**13.64±6.4**
22	*Sehima sulcatum*	**350±5.1**	**275±5.3**	**75±4.1**	**78.57±5.2**	**21.43±5.9**
23	*Sorghum helepanse*	**810±4.2**	**695±2.9**	**115±1.5**	**85.8±7.0**	**14.2±1.5**
24	*Thelepogon elegans*	**100±2.9**	**110±2.9**	**70±4.9**	**61.11±9.1**	**38.89±5.3**
25	*Themeda cymbaria*	**260±2.3**	**125±5.1**	**135±2.5**	**48.08±4.1**	**51.92±5.7**

Table 4.4 Frequency distribution of cleaning efficiency through different ranges of *Dg*

	Range of *Dg*	No. of species	Name of the species	No. of species shows cleaning loss >50%
Class 1	0.5	20	*Apluda mutica*	2
			Arthraxon lanceolatus *Cenchrus ciliaris* *Chloris barbata* *Chloris virgata*	*Echinochloa colonum* *Themeda cymbaria*

	Range of *Dg*	No. of species	Name of the species	No. of species shows cleaning loss >50%
			Dactyaloctanium aegyptium	
			Desmostachya bipinnata	
			Digitaria adscendens	
			Echinochloa colonum	
			Eleusine indica	
			Eragrostis tenella	
			Eragrostis unioloides	
			Ischaemum pilosum	
			Panicum trypheron	
			Paspalidium flavidum	
			Schoenefeldia gracilis	
			Sehima ischaemoides	
			Sehima nervosum	
			Sehima sulcatum	
			Themeda cymbaria	
Class 2	1	4	*Chrysopogon fulvus*	0
			Echinochloa crus-galli	
			Ischaemum rugosum	
			Thelepogon elegans	
Class 3	2	1	*Sorghum helepanse*	0

Table 4.3 shows efficiency parameters of the thresher. Maximum cleaning efficiency of the designed seed thresher was 96.22% where successful separation of *Chloris virgata* caryopses could be achieved, while it was minimized for *Echinochloa colonum* i.e. 46.59%. The largest caryopses were of *Chrysopogon fulvus* having dimension of 4.6x0.5x0.9 mm with the sphericity of 0.41% .While caryopses of *Eragrostis tenella* had minimum dimension i.e. 0.5x0.2x0.2 mm with the sphericity of 0.11%. Cleaning of both the spp. could be done efficiently using the designed thresher, 83.38% and 89.58% cleaning efficiency was reported for these spp. respectively. Table 4.4 shows the dependency of separation rate on Geometric diameter which graphically is also represented in Fig. 4.1.

It has been reported that the thickness and looseness of the grain mog (material other than grains) layer on the sieve influences separation (Rothaug et al., 2003). Thus the material which would be applied to the machine as feed was properly dried so that the husk layer of the caryopses could be separated easily. The general observations' regarding sieving says that there is a decrease in cleaning efficiency with increasing sieve oscillation frequency. The decrease in cleaning efficiency with increasing sieve oscillations may be due to less resident time of materials to be separated on the sieve. Harrison and Blecha (1983) described in their study that the transport of particles along oscillating sieves, which is a function of sieve oscillation frequency, affects the efficiency of the process and affects metering of particulate substances along the sieve. While Feller and Foux (1975) indicated that these frequency affects the passage of particles through the sieves.

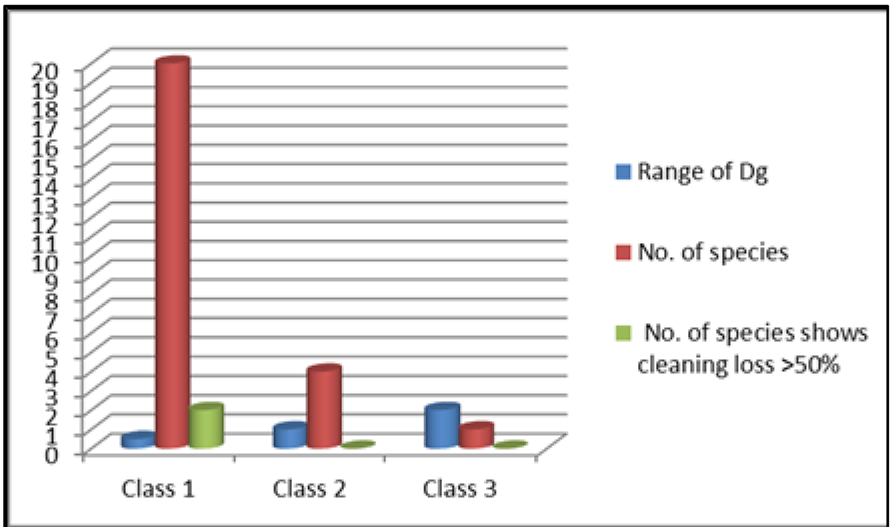


Figure 4.1 – Frequence distribution of cleaning efficiency according to Dg range

Sieving is one of the basic techniques which conventionally is used since long. Thus, its efficiency and ability of separation of bigger and smaller particles or heavier and light material is used in number of researches regarding the sieving. Some of such researches say that there was a decrease in cleaning efficiency with increasing feed rate, while cleaning loss increased with increasing feed rate. According to Rothaug et al., (2003) overloaded sieve decreases seriously the performance of the cleaning unit and lowers the grain separation rate. As the feed rate increases, it increases the load intensity on the sieve as a result multiple particles of feed act as obstructions to flow. Conventionally air is used to remove light materials from mixtures, assist the position of particles over sieve opening and also moves particles along the sieve surface if they do not pass easily through the openings. Hollatz and Quick (2003) reported that at low feed rates, aerodynamic separation of grain from the straw and chaff took place over the sieve and at a higher feed rate, material particles were no longer supported aerodynamically, which forms a mat on sieve, increasing grain losses. Due to some of such reason, Miu (2003) modeled vibratory cleaning sieve stochastically and divided overall movement of grain within the chaff layer as segregation movement to the top of the sieve in which diffusion created by the sieve vibration, transport movement along the sieve and passing through sieve openings. Elfverson and Regner (2000) said that the transport of particles along an oscillating sieve influences the efficiency of the process and also affects metering of particulate substances along an oscillating pan while Picket and West (1988) mentioned that particles caught in the opening reduce the sieving efficiency. Likewise, Zhao et al., (1999) also reported that grain conveyance on the sieve is influenced by air velocity, which leads to initial segregation of grain from materials other than grain.

Such investigations were also made by Beck and Kutzbach (1996) on the initial distribution of grains in the cleaning unit which depends on degree of pre-segregation of grains achieved during threshing, on grain pan and by stepping to the cleaning sieve. While Grift (2000) reported the spread pattern as a good tool for evaluating material distribution and on the basis of that Joshi et al., (2006) determined the quality of the distribution pattern and the effective width. Adewumi (2006) studied the distribution and spread pattern of grains, relative to the distance from the plane at which materials are discharged, as an approach to investigate the separation of grain from materials other than grain in a horizontal air stream. On mentioned basis the present study was undertaken to investigate caryopses separation and cleaning efficiency distribution in the cleaning unit of a conventional stationary sieve stand.

There is a range of equipment that can be used to process chaffy grass seeds, removing inert appendages and even the husk surrounding the caryopsis and these equipment can be broadly grouped according to the method applied like threshing, sizing, rubbing, etc. (Loch, 1993). Different methods, however, suits different seed structures and much of the previous work had not focused on the local forage species, especially on such small sized seeds.

Most chaffy seeds can be sown through specialized planters with varying degrees of difficulty, but their distribution has invariably been uneven and the seeding rate can fluctuate considerably. Alternatively, the chaffy seeds should be processed to remove some or all of their appendages, so that they flow more freely and can be sown uniformly. But the fact is that, if all the appendages are removed then the attack of soil microbes may desiccate seeds that are sown without any kind of appendages attached. Thus care should be taken at the time of sowing or seed sowing should be done at appropriate time when the environmental conditions support the seed to be germinating and gain enough strength against any kind of infestation.

Obtained results show that the species like *Chloris viragta, Eragrostis unioloides,* etc. exhibits the simple nature of their floret structure. This simple nature helps the whole floret in easy drying and thus in easy detachment from the caryopses. Thus they show higher percent of cleaning efficiency i.e. 96.22% and 94.37% respectively. And opposite to it, species like *Echinochloa colonum* and *Themeda cymbaria* shows considerable complex nature of their floret structure. This complexity may hinder the efficiency of separation of the caryopses from the surrounding covering layer i.e. floral husk. As a result these species showed lower cleaning efficiency i.e. 46.59% and 48.08% respectively. Another reason behind the lower efficiency may be the proportion of immature seeds which might be higher in the harvested material due to the acropetal manner of seed maturation. Though this manner is almost same in all kinds of grasses, the time taken for maturation of all seed (after the seed setting) at the same time might be slower than the other grasses. Thus we cannot get all the seeds mature at the same time. While in other species the floral husks become papery or loose on proper drying and the separation become easy for such small sized grass seeds. The constructed machine can easily clean the seeds of awnless grass species.

The species which shows negative results are mainly due to their smaller size. But some kind of rubbing must be accomplished thus the florets were separated to some extent. But instead of a single sized sieve, the replaceable sieves of different mesh size can overcome the negative result of such smaller sized species. In species like *Aristida adscensionis, Aristida funiculata, Heteropogon contortus, Themeda triandra,* etc. there are chances to breakage of caryopses due to their tight bounding of outer layers which could not be separated easily. While in species like *Cenchrus biflorus* and *Cenchrus setigerus* negative result is due to their hard involucres. In *Chionachne koenigii* and *Coix lachryma-jobi* negative result is due to the hard outer layer.

Seed processing should be done at a sufficiently high rate per hour to minimize the cost and make it commercially viable. The basic aim of seed processing is to remove appendages that interfere with the separate and independent movement of seeds. Leaving protective husks around the caryopses reduces the risk of physical damage during processing, especially where caryopses are tightly held within the surrounding floral husk (Loch, 1993) and also any kind of infestation. It also improves the reliability of field establishment under marginal moisture conditions because naked caryopses are more likely to germinate on a small false start rainfall event. Current work is evaluating various processing options to streamline the handling of chaffy seeds of grasses.

From the present investigation, we could divide the caryopses separation by sieves into three divisions i.e. increasing, peak and decreasing and these divisions were based on sieve length for the sieve stand and feed amount for seed thresher. During the sieving process in both the equipment, segregation and separation take place along the sieve length as caryopses and chaff are being transported over the sieve. Though, at higher feed rate, it takes a longer time for the caryopses to be separated from the chaff, and this may be due to the denseness of the chaff.

The process of caryopses / florets harvesting can be described as recovering caryopses from the field and separating them from the rest of the trash material with a minimum loss and a predefined quality level of the end product. The entire harvesting process may be divided into cutting, threshing, separation and cleaning functions therefore, the present study focused on the cleaning mechanism of a simple, conventionally equipped sieve stand and seed thresher. The performance of the cleaning mechanism is expressed in terms of (1) grain losses, (2) cleaner capacity and (3) grain purity. In total about 50% of collected forage grass species could be efficiently cleaned up to pure caryopses level. Even though, these species shows minor dimensions of their seeds whose manual separation is next to impossible. For better field establishment, separation of such small sized forage grass seeds through such sieve stand and handy, conventional seed thresher might be so promising for future revegetation programs. Our work has highlighted alternative methods of harvesting and processing that will go a long way towards coping with stand establishment problems of a diverse range of the grasses found in the study area. Prepared seed thresher and sieve stand can be used for other grass species based on its mentioned performance. Obtained pure caryopses will be more helpful in pasture regeneration program.

Seed storage

In practical consideration, deterioration during storage is mainly associated with elevated temperature and seed moisture levels. Quantitative relationship between these variables and seed longevity have been established for some species and similar relationships can be qualitatively applied for all seeds. Such effects of temperature, moisture, etc. on storability were investigated for different crops, which include effect of seed moisture, packaging material and storage temperature on storability of three varieties of papaya (Yogeesha et al., 2008). Sometimes harvesting time may also affect the seed storability by affecting its physiological quality and chemical composition as it is one of the most critical steps in seed production (Marcos-filho et al., 1994); likewise the effect of temperature during seed development on weight, germinability and storability of lettuce seeds was determined by Contreras (2009). Beside the environmental factors, Sing et al. (2009) showed that seed coat color also affects the storability of horse gram seeds while desiccation tolerance of seed may also affect its storability (Tang et al., 2008).

a: Harvsted material collected in cloths bags

b: Airtight storage of cleaned florets

Plate 4.5 Storage of harvested material

Seed storage is broadly termed as the preservation of viable seed until their sowing or their use. It is essential to balance the uncertainty of seed production or their availability during bad seed years. It delays deterioration, maintains viability and protects seed from rodent and insect damage. The longevity of seeds is a species-specific characteristic. The seed of most of the species must be stored at low temperature and low moisture content in sealed containers. It is important to dry the seed uniformly to prevent fluctuation in moisture content during storage. During the storage, the respiration continues at low temperature, which is necessary to keep the embryo alive. Polythene bags make good containers because they are impermeable to water. Seeds are stored from harvest to the next planting, which may be in the next season or after several seasons. A number of factors influence the viability and maintenance of seed quality during storage and among them most important are seed moisture and temperature.

Generally, there are two major types of storage facilities: Open naturally ventilated (or unconditioned) storage and conditioned storage. In present study, for collected cleaned seeds we used air tight plastic bottles, thus the moisture content and temperature outside the bottles could not affect the contents **(Plate 4.5)**.

In all areas of tropics, much of the harvested food is lost during storage because of worms, beetles and other infestations. Not only the food but any kind of seed material is susceptible to them. In pasture, mainly the legume seeds are more susceptible then the grass seeds. In our study, depending upon the storage facility, the grass seeds showed best performance, even after two years of storage, their viability was not affected and they show good germination results. There was no insect attack or any other problem with the seed health, but the legume seeds were attacked by insects due to which there was damage to seeds. To protect these seeds, we used the bio-insecticides having no side effects on the germinative capacity. As we know that chemicals insecticides may change the chemical constituents of the future generations, we did not prefer it and used Neem leaves (*Azadirachta indica* Juss.) and Seetafal/Custard apple leaves (*Annona squamosa* L.) as their insecticidal properties for food storage are well known. We tried these biopesticides on two species i.e. *Cassia tora* and *Crotalaria leptostachya* during the storage. These two species showed highest insect infestation. The results shown that, there was no effect on the germination % and even the time of germination was also not differing. There was no insect / pathogen attack after the treatment. This exhibits that both of these bio insecticides can be efficiently used for the storage.

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