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Seed Quality in Forage Crops: Current Status and Gaps in Ethiopia

Gezahagn Kebede[1, *], Getnet Assefa[2], Fekede Feyissa[3], Mulisa Faji[1], Mengistu Alemayehu[4], Alemayehu Mengistu[5], Kedir Mohammed[1]

[1]*Holetta Agricultural Research Center, P. O. Box 31, Holetta, Ethiopia*
[2]*Livestock Specialist, Addis Ababa, Ethiopia*
[3]*Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia*
[4]*Ethiopian Agricultural Research Council Secretariat, Addis Ababa, Ethiopia*
[5]*Forage and Rangeland Scientist, Urael Branch, P.O. Box 62291, Addis Ababa, Ethiopia*
**Corresponding author: gezk2007@yahoo.co.uk*

ABSTRACT

This paper summarizes forage seed quality attributes, stages to be considered for quality seed production, current status, and gaps of forage seed quality in Ethiopia. Seed quality is one of the main factors affecting crop production potential. Seed quality such as genetic quality, physiological quality, physical quality, and pathological quality should be considered during seed production. The pre-planting stage is the first stage to be considered for the production of good quality seed. The environmental conditions under which the forage crop is grown and the cultural practices used for production can affect seed quality. Several environmental factors such as soil conditions, nutrient deficiency, water stresses, extreme temperatures, and pest infestation may affect seed quality by reducing its viability and vigor by the time the seed reaches physiological maturity. Besides, identification of suitable sites, use of proper seedbed preparation, sowing time, seed rates, and planting methods are also considered to affect quality forage seed production. The post-planting stage such as weeding, pest and disease control, time of harvest, and field inspections at different stages is the second stage to be considered for quality seed production. Determination of seed harvesting stage of some forage species is more complex compared to food crops due to unsynchronized seed maturity and seed shattering problems so that identification of optimum seed harvesting stage for species which have indeterminate growth habit is very important. The post-harvesting stage such as drying, threshing, cleaning, packing, storing, transporting, and marketing is the third most important stage to be considered for quality seed production. Forage plants are cultivated mostly for herbage utilization so that seed production does not virtually exist in the country. The price of small-seeded perennial forage species and their cost of production are very high globally due to low seed yield performance, unsynchronized seed maturity, seed shattering problem, and difficulty in post-harvesting and handling processes compared to most annual forage species. Some of the beneficial qualities of forage seeds can be stored for a longer time, relatively free of disease, and not attacked by pests like weevils compared to food crops. Some forage seeds have a problem of seed dormancy but the problem can be solved by mechanical, chemical, and hot water scarification. Generation of different forage seed production technologies which are feasible for different agro-ecologies are extremely important for higher and quality seed production but the technologies are not yet well known for most forage species.

Keywords: Forage seed, Seed shortage, Seed quality, Field inspection, Storage condition

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1. INTRODUCTION

Livestock is the integrated component of the Ethiopian farming systems and performs multiple functions at different levels of aggregation. This sector of agriculture plays a vital role in the livelihood of the majority of people in the country. The principal objective of farmers engaged in mixed farming is to gain complementary benefits from an optimum mixture of crop and livestock farming and spreading income and risks over both crop and livestock production (Solomon, 2004). Ruminant livestock is a major component of the agricultural systems in the tropics. At the individual smallholder level, livestock is an important source of food (meat and milk), cash income, and services like transport and traction and manure for soil fertility management and fuel (Berhanu *et al.,* 2006). Although Ethiopia holds the largest livestock population in Africa, estimated at 43.1 million heads of cattle, 23.6 million sheep, 16.8 million goats, 0.62 million camels (CSA, 2008), the total national milk production remains among the lowest in the world. Inadequate supply of quality feed is the major factor limiting livestock productivity. But the use of improved nutrition through the adoption of cultivated forage and better crop residue management can substantially raise livestock productivity.

Livestock feed resources are classified as natural pasture, crop residue, improved pasture, and forage, agro-industrial by-products, other by-products like food and vegetable refusal, of which the first two contribute the largest feed type (Alemayehu, 2004; Firew, 2007). Animals depend mainly on natural pastures and crop residues for their feed requirements. Natural pastures which provide more than 90% of the livestock feed are generally very poorly managed. Due to poor management and overstocking, natural pastures are highly overgrazed resulting in severe land degradation, loss of valuable species, and dominance by unpalatable species (Alemu, 1998). In the highlands, the human population is increasing rapidly, forcing farmers to use grazing areas for arable farming. Crop residues contribute less in providing quality feed for animals due to high fiber content and low digestibility. In general, feed shortages and nutrient deficiencies become more acute in the dry season in both the highlands and lowlands (Alemayehu, 2005). Integration of improved forage crops into the farming systems through different methods such as under-sowing, intercropping, planting on fallow land, rely cropping and others have a substantial contribution to mitigating feed problem. The major limitation for the cultivation of forage crops is the lack of quality planting materials.

The availability, access to, and use of quality seeds of adaptable forage crops are important in increasing forage production and productivity. Quality in seeds embraces all the physical, biological, pathological, and genetic characteristics which contribute to the final yield of forage crops. The seed is a living biological product, which requires special attention and care to ensure its all quality attributes. High-quality seed is a major factor in obtaining a good crop stand and rapid plant development even under adverse conditions although other factors such as rainfall, agronomic practices, soil fertility, and pest control are also crucial. The quality of seeds alone is known to account for an increase in productivity of at least 10-15% depending upon the species and it can be further raised to 45% with efficient management of the other inputs. Seed production should be strictly monitored throughout the crop growth period, from planting through to harvesting, drying, threshing, cleaning, packaging, storage, and marketing. Hence, Seed producers should understand the principles and procedures for growing a forage crop for seed, and ensure that all operations are carried out at the right time and the right place. Therefore, this paper attempts to briefly review forage seed quality attributes, stages to be considered for quality seed production, current status, and gaps of forage seed quality in Ethiopia.

2. Seed Quality Attributes

The seed is alive, and it can change over time under varying conditions. It can also vary from year to year and so do planting conditions. Forage seed quality is critical in the establishment of a uniform forage plant stand, the first step in producing a successful crop, but good planting conditions are also critical since high-quality seed can fail under too much stress. So, seed quality is a multiple concept comprising several components divided into four major groups that include genetic quality, physiological quality, physical quality, and pathological quality (Huda, 2001).

2.1 Genetic Quality

The genetic quality is determined by the genetic information contained in the seed. The important factors are the inherent genetic information contained in the seed which provides the potential for higher yield, better seed quality, and greater tolerance to biotic and abiotic stresses; and varietal identity specifically the transfer of seed of desired variety from the breeder to the farmer through successive generations of seed multiplications. A seed with poor genetic composition will not grow well in the field. Quality seed is expected to have the superior inheritable quality to produce the expected biomass and seed yields. When forage crops are grown under different soil and fertility conditions, climatic conditions, photoperiods, and elevation for several consecutive generations, the developmental variation may arise sometimes as differential growth response. To minimize the opportunity for such shifts to occur in forage species it is advisable to grow them in their areas of adaptation and growing seasons. Mechanical mixtures are the most important source of variety deterioration during seed production. It may often take place at the time of sowing if more than one variety is sown with the same seed drill; through volunteer plants of the same crop in the seed field, or different varieties grown in adjacent fields. Often the seed produce of all the varieties is kept on the same threshing floor, resulting in a considerable varietal mixture. To avoid this sort of mechanical contamination it would be necessary to rogue the seed fields and practice the utmost care during the seed production, harvesting, threshing, and further handling. In sexually propagated crops, the natural crossing is another most important source of varietal deterioration due to introgression to genes from unrelated stocks which can only be solved by prevention.

2.2 Physiological Quality

It refers to aspects of the performance of the seed. It is the viability, germination, and vigor of seed, which determines the potential germination and subsequent seedling emergence and crop establishment in the field. Viability is the potential to germinate. A nonviable seed will not germinate under any conditions. Viable and nonviable seeds may look the same. Germination is the emergence from the seed and development of those essential structures that under favorable conditions produce a normal plant. Requirements for initiation of germination include a favorable moisture level in the seed; a favorable temperature in the environment around the seed; and a favorable oxygen supply to the seed. Some seeds may require specific light. Also, the seed's dormancy must be broken for germination to proceed. At the field level, seed vigor means the ability to germinate, to emerge, and to produce healthy seedlings rapidly, uniformly, under a wide range of environmental conditions, and to maintain this ability for a long period. Many factors, such as maturity level at harvest, age of the seed, mechanical injuries, disease infection, and storage environment, can influence seed vigor. Genetic factors also influence vigor. Seeds low in vigor generally produce weak seedlings that are susceptible to environmental stresses. Seeds high in vigor generally provide for early and uniform stands that give a competitive advantage for seedlings against environmental stresses. Seed lots that have low germination are also less vigorous due to seed deterioration. As seeds deteriorate, loss of vigor precedes loss of viability, so seeds with low germination usually will be less vigorous. Hence, in seed lots with poor germination, those seeds that do germinate often produce weaker seedlings with reduced yield potential. However, some species have inherently low germination potential and cannot be assumed to have poor vigor due to low germination. Seed vigor usually cannot be assessed by the consumers. Germination and seed size often are good indicators of seed vigor.

2.3 Physical Quality

It denotes the physical characteristics of the seed lot. Physical qualities of the seed in a seed lot are characterized by a minimum of damaged seed, minimal weed seed or inert matter, minimum of diseased seed, and near-uniform seed size. Damaged (broken, cracked, or shriveled) seed may not germinate and is more likely to be attacked by insects or micro-organisms. Good quality seed should be free of weed seeds (particularly noxious types), chaff, stones, and seeds of other crops. Discolored or stained seeds are symptoms of seeds that may carry micro-organisms that already have attacked the seed when it starts to grow. The plant may live and spread the disease to other plants. The mature, medium and large-size seed will generally have higher germination and vigor than immature and small-sized seed. Generally, in the conditioning of seed lot, broken, shriveled, weed seeds, chaff, stones, the seed of other crops, discolored seeds, undersized seeds, and light seeds are normally eliminated.

2.4 Pathological Quality

It refers to the presence of disease and pests within a seed lot. It includes the absence of infection/infestation with seed-borne pests such as fungi, bacteria, viruses, nematodes, insects, etc. Seed health is an important attribute of quality, and seeds used for planting should be free from pests. Seed infection may lead to low germination, reduced field establishment, severe yield loss, or a total crop failure. Seed productions in disease-free areas, or under effective disease control and field inspection schemes, are very important for obtaining healthy seed. Thus, understanding the disease epidemiology, its transmission rate, and economic threshold, combined with seed health testing, could help define the need for seed treatment. Chemical seed treatment is one of the most efficient and economical plants protection practices and it can be used to control both external and internal seed infections. It also protects young seedlings or adult plants from attack by seed, soil, or air-borne pests. It disinfects seeds of pathogens, checks the spread of harmful organisms, promotes seedling establishment, improves seed quality, and minimizes yield losses. Seed treatment is preferable over other conventional methods because it is easy to apply, safer to handle, cheaper, better targeted against the organism, and less influenced by the environment.

3. STAGES OF QUALITY SEED PRODUCTION

3.1 Pre-planting stage

There are variations in agricultural lands in terms of altitudes, soil types, topography, etc., and these influence the geographic distribution of forage species and varieties. Apart from agro-ecological and climatic adaptation, the area selected for seed production should be free from natural hazards like floods, drought, frost, salinity, diseases and insect pests, etc., to prevent any damage to forage seeds quality. Most cultivated forage crops can be successfully produced on soil types that are well-drained and productive. Areas with dry and cool weather conditions during ripening and harvesting are ideal for maintaining seed quality. Accessibility and proximity of the land for supervision and suitability for transporting the seed quickly and economically is also essential. The fields must be also suitable for the specific forage crops management practices required for high-quality seed production. Selection of fields with the right cropping history and suitable crop rotation is necessary, and if possible these two should be combined. The right previous cropping history is necessary to avoid genetic, mechanical, and pathological contamination in seed production, whereas crop rotation is mainly practiced to maintain soil fertility and control soil and/or seed-borne diseases. The land selected for forage seed production should be free from varieties of the same crop species for at least one or two years before planting unless the previous crop is of the same variety. Moreover, the seed production field should be properly isolated from other cultivars of the same species to avoid mechanical admixture and cross-pollination. A larger isolation distance is required for cross-pollinated forage crops than self-pollinated crops. Although the field size, topography of the site, wind speed and direction, insect type and population, and cropping patterns influence the risks of contamination, standard isolation distances (Table 1) are usually recommended for different forage crops.

Land should be prepared as early in the season as possible. Land preparation begins with slashing and burning any previously growing bush on the selected forage seed field. This should be followed by plowing and harrowing so that, at the time of planting, the seed field will be clean and free of weeds. The seedbed should be thoroughly prepared and leveled to ensure that sufficient moisture is available in the soil. Generally, deep plowing and harrowing once or twice will provide good root growth that enables plants to get moisture from the soil. The time of sowing depends on the variety and area of adaptation. Forage crop must be planted at its recommended time, otherwise, growth and development may be affected, thus reducing seed quality. Matching cultivar maturity to the sowing date is a key element for maximizing seed quality in different agro-ecologies, and it helps in reducing risks. In general, late planting is not recommended because it can lead to substantial reductions in seed yield and quality. Early planting, on the other hand, is beneficial but may increase risks of early dry spells, frost damage, and weed infestation. The optimum seed rates vary with the type of forage species, biotic and abiotic factors and may also differ among varieties depending on seed size and the method and time of sowing. The recommended seed rate should be used when a crop is sown at the normal time to achieve the right plant population for adequate competition with weeds and better seed yield and quality. Planting at a higher rate (more than the recommended) is not encouraged because of its negative impact on seed quality, particularly on seed size and weight. Instead of using higher rates, farmers must pay close attention to all recommended seed production practices. In seed production, planting in rows has an advantage over broadcasting, as it requires less seed, facilitates, mechanical weed control, pesticide spray, access for rouging and field inspection, and produces better yield and quality. The depth of sowing should be also considered and it depends on the seed size, large seeds being buried more deeply than small seeds.

A well-balanced supply of nitrogen, phosphorus, and potassium is essential for seed production, as it influences seed development, seed quality, and yield. Fertilizer application to seed crops should be based on local recommendations. High nitrogen levels may promote vegetative growth, cause delayed maturity, predispose the crop to foliar diseases, lead to severe lodging and reduced yield and seed quality. Phosphorus is essential for enhancing seed maturity, and potassium for enhancing seed development. Improved forage crops are reasonably responsive to fertilizers and the seed yield potential cannot be fully realized without inorganic fertilizers application. Because of the general deficiency of nitrogen and phosphorus in most soils, balanced use of these nutrients is essential. Apart from the type of fertilizer, the time and method of application of the fertilizer are very important. Phosphorus and potassium are relatively stable in the soil and can be applied at the time of planting.

However, nitrogen fertilizers are volatile, a minimum of two split applications is necessary, i.e., one at planting and the second during crop growth.

Table 1. Field standards of breeder/pre-basic, basic, and certified seeds of different forage crops grown in Ethiopia

S/N	Species	Breeder/pre-basic seed			Basic seed			Certified seed		
		RMY	IMM	OMP	RMY	IMM	OMP	RMY	IMM	OMP
A	**Grasses**									
1	*Avena sativa*	3.0	5.0	0.03	2.0	5.0	0.05	2.0	3.0	0.10
2	*Chloris gayana*	3.0	200.0	NS	3.0	200.0	0.10	2.0	100.0	0.20
3	*Panicum coloratum*	3.0	10.0	NS	3.0	10.0	0.02	2.0	10.0	0.05
4	*Phalaris grass*	3.0	200.0	NS	3.0	200.0	0.02	2.0	100.0	0.05
5	*Panicum maximum*	3.0	10.0	NS	3.0	10.0	0.02	2.0	10.0	0.05
6	*Pennisetum glaucifolium*	3.0	200.0	NS	3.0	200.0	0.02	2.0	100.0	0.05
7	*Pennisetum purpureum*	3.0	200.0	NS	3.0	200.0	0.02	2.0	100.0	0.05
8	*Bracharia grass*	3.0	200.0	NS	3.0	200.0	0.02	2.0	100.0	0.05
9	*Setaria sphacelata*	3.0	200.0	NS	3.0	200.0	0.02	2.0	150.0	0.05
10	*Cenchrus ciliaris*	3.0	50.0	NS	3.0	50.0	0.10	3.0	50.0	0.02
B	**Legumes**									
1	*Vicia species*	3.0	100.0	NS	3.0	100.0	0.10	3.0	50.0	0.20
2	*Trifolium species*	3.0	150.0	NS	3.0	150.0	0.05	2.0	100.0	0.50
3	*Desmodium species*	3.0	100.0	NS	3.0	100.0	0.50	2.0	50.0	0.50
4	*Vigna unguiculata*	2.0	10.0	0.20	2.0	10.0	0.20	1.0	5.0	0.50
5	*Lablab purpureus*	2.0	10.0	NS	2.0	10.0	0.10	2.0	10.0	0.20
6	*Lupinus angustifolius*	3.0	100.0	NS	3.0	100.0	0.10	3.0	50.0	0.20
7	*Medicago sativa*	4.0	400.0	NS	4.0	400.0	0.05	3.0	300.0	0.10
8	*Stylosanthes*	3.0	10.0	NS	3.0	10.0	0.10	3.0	5.0	0.2
C	**Tree/shrub**									
1	*Chamaecytisus palmensis*	NS	200.0	NS	NS	200.0	NS	NS	100.0	NS
2	*Sesbania sesban*	NS	200.0	NS	NS	200.0	NS	NS	100.0	NS
3	*Sesbania marcanta*	NS	200.0	NS	NS	200.0	NS	NS	100.0	NS
4	*Leucaena leucocephala*	NS	200.0	NS	NS	200.0	NS	NS	100.0	NS
5	*Cajanus cajan*	3.0	100.0	NS	3.0	100.0	0.10	2.0	50.0	0.20
D	**Root crop**									
1	*Beta vulgaris*	2.0	1000.0	NS	2.0	1000.0	0.10	2.0	1000.0	0.20

[**RMY**= Rotation minimum year; **IMM**= Isolation minimum meter; **OMP**= Off types maximum percent; NS= Not Specified [Source: Extracted from Ethiopian standard draft 1st edition, 2012]

3.2 Post-Planting Stage

Seed production is one of the most important means of introducing common, noxious, and parasitic weeds into agricultural lands. Moreover, increased use of fertilizers, inadequate rotations, and ineffective control practices are major factors encouraging weed infestation. Hence, freedom from weed seeds is a very important seed quality attribute. In forage seed production, contamination of the seed crop with other crop or weed seeds of similar physical characteristics must be reduced to the barest minimum because cleaning alone will not sufficiently remove such contaminants. A well-designed integrated weed control package combining crop rotation, inter-row cultivation, and hand pulling, coupled with herbicide application, is commonly used. In case of heavy weed infestation, herbicides may be applied. The herbicide must be selected for the weeds infesting the forage crop and applied at the recommended rate, growth stage, and method of application using the right equipment. Effective crop rotations, properly prepared seedbeds, and planting at a time that allows rapid and uniform crop establishment can increase the effectiveness of the herbicides. Rouging, the act of removing undesirable plants is another fundamental aspect of quality seed production. Forage seed fields should be rouged before undesirable plants cause genetic or physical contamination because during crop growth stages the rogues can be identified visually. These growth stages vary with the crop, the undesirable species, stage, and condition of growth. Rouging can be performed at various stages of crop growth, but the most effective stages are flowering, post-flowering, or maturity when it is easier to see important morphological characteristics that will help differentiate between the variety and the rogues.

Freedom from pathogens, especially seed-borne diseases, is one of the most important seed quality attributes and standards. Lack of proper disease management in quality seed production may adversely affect the productivity, quality attributes, and standards of the harvested seed. The standard for field inspection varies from country to country based on the forage crop, the susceptibility of the cultivar, seed class, and environmental factors. Seed treatment plays a crucial role in a well-designed plant protection program. Isolation, field inspection, rouging of infected plants, and application of chemical treatment are crucial for the production of healthy seeds.

Each type of plant has an optimal time for the seeds to be harvested, but factors such as climate, weather, disease, insects, birds, or predatory mammals may require that the seeds are harvested before that time. When a large number of maturing seeds are present, any color changes in individual seeds are reflected in the overall appearance of the forage crops. This method is more useful when crops are reasonably well synchronized. Maturation may be uneven within the pod, cob, or panicle, or uneven on the plant, and uneven within the stand of plants. It is more difficult to determine the optimum harvest dates for indeterminate plants because of the longer flowering period. For that reason, the pods of many plants are harvested individually. Seed quality depends on the position of seeds in the plant, maturity, seed size, vigor, etc. (Khatun *et al.,* 2008). Early harvested seeds will be immature and less developed and as such perform poorly in store compared to seed harvested at the right physiological maturity (Singh and Lachanna, 1995). Physiological maturity is the stage at which translocation of food materials to the seed stops and represents the highest quality level but moisture is too high for storage. But harvest maturity occurs 7-10 days following physiological maturity and is an important process where moisture is lost from the plant and is safe for storage. Grasses and legume seeds reach physiological maturity between 35 and 45% and 45 and 50% moisture content, respectively. Attainment of physiological maturity is a genotypic character that is influenced by environmental factors (Mahesha *et al.,* 2001a). Low seed moisture content, resulting from delayed harvesting, increases shattering losses and excessive seed injuries. The moisture content of the seed can be used as an indicator of when the crop is ready for harvesting. The crop characteristics or electric moisture meters can be used to decide the time to harvest.

Field inspection is a systematic procedure to verify the levels of contamination with off-types, other crops, seed-borne diseases, and noxious weeds in forage seed multiplication fields. During the inspection, by comparing the results against the prescribed set of standards (Table 1), the seed fields can be approved to be harvested for use as seed or discarded. Continuous and rigorous supervision is needed in quality seed production. The first thing is to verify the suitability of the site and field for seed production. The second is to check on plant density and the need for weed control during seedling emergence and establishment. The third is to inspect the field to certify or discard the seed crop at full maturity. Regular field visits are necessary for proper forage crop management and monitoring. Field inspection is one of the practices that differentiate quality seed production from biomass production. It is a measure to ensure that the seed produced will meet the seed quality standards. It assesses the potential risks of contamination and remedial actions required. Failing to inspect seed production fields may adversely affect all quality attributes and standards of the harvested seed.

3.3 Post-Harvesting Stage

After harvest, seeds must be threshed, cleaned, and dried ready for storage. Cleaning includes the removal of inert matter; the seed of weeds, other crops, other varieties, and seeds of the same variety which are shriveled, damaged, deteriorated, or diseased, to improve and upgrade seed quality. These must be removed through the threshing and cleaning process to obtain good quality seeds of the required cultivar. Traditionally, winnowing follows threshing, to remove chaff, straw, and other light materials from the seed. Generally cleaning is the process of physically removing undesirable elements in a given seed lot, leaving only the pure seed component.

Most forage seed is stored for some time. During this time, the seed may deteriorate considerably. Deterioration means the loss of some key physiological functions, with ultimately leads to loss of essential seed quality attributes like viability, germination, and vigor. The rate of deterioration varies among forage crops. Starchy seeds, such as grasses generally have a slower rate of deterioration compared to oily and high protein seeds such as legumes, when all other factors such as temperature, humidity, and moisture content of the seed are the same. Differences also exist in deterioration rates among varieties of the same forage species. Seed deterioration cannot be put off indefinitely. Germination remains unchanged for some time during storage and then declines rapidly. As seeds age, both germination and vigor decline, slowly at first and then more rapidly at the end of the seed's useful life is reached. Seed vigor declines faster than germination. Keeping the store clean, cool, and dry is the best forage seed management practice because this reduces physiological processes, fungal and insect activities.

The storability of forage seeds is mainly a genetic character that might be influenced by the pre-storage condition of seed, seed maturation, and environmental factors during pre and post-harvest stages (Mahesha *et al.,* 2001b). Newly produced forage seeds must be stored in new bags because old bags can be a source of contaminants and insect infestation. Most forage crops, with few exceptions, have a medium to long-term storage period with minimum loss of viability. Generally, grasses store better than legumes, and legumes store better than oilseed crops. During storage, seed quality can remain at the initial level or decline to a level that may make the seed unacceptable for planting purpose which is related to many determinants: environmental conditions during seed production, pests, diseases, seed oil content, seed moisture content, mechanical damages of seed in processing, storage longevity, package, pesticides, air temperature and relative air humidity in storage, biochemical injury of seed tissue (Guberac *et al*., 2003; Heatherly and Elmore, 2004).

Forage crop seeds are orthodox type, i. e. they are not sensitive to low moisture and temperature, hence can be dried to very low moisture content and stored at very low temperatures. The moisture content of the seed is the most critical factor affecting the rate of deterioration. According to Yadav *et al*. (2005), harvesting at high moisture content increases the chances of mycofloral infection on seed while harvesting at low moisture content increases mechanical damage to the seed. The level of seed moisture content is one of the key factors that determine when farmers can start harvesting the crop. After harvest, the seed can be further dried by spreading the seed on drying floors through exposure to the sun. Particular attention is given to seed moisture content after harvest to ensure that seed can be handled and stored and processed so that it retains high germination. The seed is hygroscopic; it will absorb moisture from the surrounding air or release moisture into the air depending on the moisture content of the seed, temperature, and relative humidity of the air. After the initial drying and during storage the seed can absorb moisture from the air or releases moisture to the air until it comes into equilibrium with the relative humidity of the air. So, seed drying is important to prolong shelf life and protect seeds from easy attack by insects and pests during storage.

The optimum moisture percentage of forage seed depends on the type of species and the temperature. Some legumes seed can be easily damaged if the seed is too dry. The lower the seed moisture percentage is, the slower the rate of seed respiration. A slower rate of seed respiration results in a slower rate of deterioration. Therefore, proper drying of the seed is critical for minimizing deterioration during storage. So, most seeds are dried to a safe moisture level, between 10 and 12%, before processing and storage.

Temperature and relative humidity of the storage environment are the two most critical factors to pay attention to when a longer seed storing period is considered without losing its viability. The lower the temperature and relative humidity, the longer the seeds can be safely stored. In general, the seed crop should be dried only at a recommended temperature level. The too high temperature will damage seeds by reducing their vigor or can result in death and too low temperature may also cause heating and molding which can also result in the death of seeds.

The general effect of temperature on longevity is that longevity increases as temperature decreases. The relative humidity and temperature of the store are controlled by mechanical means. This is usually used for processed, packaged, and high-value seeds because of the high cost of controlling the environment. Conditioned stores are required in humid tropical conditions if ambient temperatures exceed 30°C and relative humidity is 70% or more.

4. STATUS AND GAPS OF FORAGE SEED QUALITY

4.1 Status of Forage Seed Quality

In the development of forage and pasture crops, the quality of the seeds used has a profound effect on the expected output. This is usually expressed in terms of the yield produced, the quality of the forage, and its subsequent use as a seed. If seeds are not desired quality the possibility of getting weeds, diseases and pets are expected. This generally will result in a reduction of the overall yield, affecting other fields and the overall environment at large. Though forage crops are introduced more than 5 decades ago, their adoption by farmers is still not very well developed due to various factors. Seed availability is one of the major reasons.

There are no private farmers producing forage seeds in the country. Very few private forage seed producers are currently starting the business. Some research institutes and others are trying to produce some forage seeds. But these are also constrained with the expertise, facilities, finance, and many more. Under these situations the status of forage seed quality both produced locally and imported from abroad has been given very little attention. However, seed growers are encouraged to consider and understand seed quality components to produce quality seeds that can save time and money during forage production (Table 2).

Table 2. Laboratory standards of basic seed of different forage crops grown in Ethiopia

		Basic seed						
SN	**Species**	**PSM**	**OSM**	**WSM**	**ISM**	**IMM**	**GPM**	**MCM**
A	**Grasses**							
1	*Avena sativa*	97.0	0.20	0.01	0.02	2.0	85.0	12.0
2	*Chloris gayana*	75.0	0.20	0.05	NS	0.50	40.0	10.0
3	*Panicum coloratum*	95.0	0.10	0.05	NS	0.50	70.0	10.0
4	*Phalaris grass*	95.0	0.10	0.05	NS	50.0	70.0	10.0
5	*Panicum maximum*	95.0	0.10	0.05	NS	0.50	70.0	10.0
6	*Pennisetum glaucifolium*	NS	NS	NS	NS	NS	NS	NS
7	*Pennisetum purpureum*	NS	NS	NS	NS	NS	NS	NS
8	*Bracharia grass*	NS	NS	NS	NS	NS	NS	NS
9	*Setaria sphacelata*	95.0	0.10	0.05	NS	0.50	60.0	10.0
10	*Cenchrus ciliaris*	80.0	0.20	0.05	NS	0.50	50.0	10.0
B	**Legumes**							
1	*Vicia species*	98.0	0.10	0.10	0.50	0.50	90.0	10.0
2	*Trifolium species*	95.0	0.10	0.05	NS	0.50	75.0	12.0
3	*Desmodium species*	95.0	0.10	0.05	NS	0.50	75.0	12.0
4	*Vigna unguiculata*	98.0	0.10	0.10	0.05	1.00	87.0	12.0
5	*Lablab purpureus*	98.0	0.05	0.05	NS	0.50	80.0	10.0
6	*Lupinus angustifolius*	98.0	0.10	0.10	0.50	0.50	90.0	10.0
7	*Medicago sativa*	98.0	0.10	0.05	NS	0.50	80.0	10.0
8	*Stylosanthes*	95.0	0.05	0.1.	NS	0.50	70.0	10.0
C	**Tree/shrub**							
1	*Chamaecytisus palmensis*	98.0	0.10	0.10	NS	0.50	70.0	10.0
2	*Sesbania sesban*	97.0	0.10	0.10	NS	0.50	70.0	10.0
3	*Sesbania marcanta*	97.0	0.10	0.10	NS	0.50	70.0	10.0
4	*Leucaena leucocephala*	97.0	0.10	0.05	NS	0.50	75.0	8.0
5	*Cajanus cajan*	98.0	0.05	0.05	NS	0.50	80.0	12.0
D	**Root crop**							
1	*Beta vulgaris*	98.0	0.05	0.05	NS	0.50	80.0	10.0

PSM= Pure seed minimum %; **OSM**= Other seed maximum %; **WSM**= Weed seed maximum %; **ISM**= Infected seed maximum %; **IMM**= Inert matter maximum %; **GPM**= Germination percent minimum; **MCM**= Moisture content maximum]; NS= Not Specified [Source: Extracted from Ethiopian standard draft 1st edition, 2012]

Physical and genetic impurity can cause substantial problems with quality forage seed production. Physical impurity is the presence of foreign materials, weed seeds, etc. It is common in perennial forage grasses and some legumes seed such as Rhodes, Stylosanthes, alfalfa, and others. This is due to the growers' poorly identify forage seeds from other foreign materials, lack of availability of seed threshing and cleaning facilities, and presence of seeds of different weeds could also be problems in some cases. Most of the forage crops are recommended at species level so that genetic purity is less important, but for cross-pollinating forage crops such as alfalfa, and some browse trees like tagasaste and species which have many varieties like oats, the genetic purity is crucially important (Getnet *et al*., 2012). There are a lot of interrelated forage seed production problems which may result physical and genetic impurity at field and storage conditions. According to Getnet *et al*., 2012), some of the reasons for genetic impurity are: 1) lack of skills and awareness on varietal differences and on management of pure seed production especially at smallholder farmers' level; 2) lack of seed quality control system including official variety release, control of genetic purity at the field level, seed certification; and 3) absence of enough seed-producing enterprises.

Physiological purity is another important seed quality parameter for the successful establishment and production of forage and pasture crops. Almost all the research activities in seed quality conducted at the Ethiopian Institute of Agricultural Research (EIAR) and regional research centers are mainly on seed germination. Seed viability (germination) test is very important before planting forage crops to get optimum plant population at field conditions. Seed production managements at different growth stages and post-harvest handling, treatment, and conditioning have a great effect on the physiological quality (viability, germination, and vigor) of forage seeds. Seeds of many forage species could be stored for a longer period especially in the cooler highland areas like Holetta. Loss of viability of seeds of different forage crops after five years of storage period is very minimal for some selected forage crops. A study on the shelf life of some forage seeds is shown in Table 3. The result indicated that the mean germination percentage of different forage seeds has a decreasing trend over years but the rate is very low indicating that they have longer storage life. It is also observed that seeds of some forage crops such as alfalfa and vetch can be stored more than ten years under cool room temperature conditions in the highland areas like Holetta.

Table 3. Germination (%) of seeds of different forage crops at different storage durations under room temperature and humidity conditions at Holetta in the highlands of Ethiopia.

	Germination over years of storage (%)				
Forage species	**1st year**	**2nd year**	**3rd year**	**4th year**	**5th year**
Phalaris tuberosa	64	51	34	39	31
Lolium perenne	46	33	14	20	21
Festuca arundinacea	68	43	51	26	36
Setaria anceps	7	4	2	2	3
Chloris gayana	28	23	19	17	17
Panicum coloratum	61	45	26	18	19
Panicum antidotale	20	9	11	7	9
Avena sativa	93	77	73	-	-
Medicago sativa	95	87	86	89	72
Vicia species	89	91	91	93	93
Mean	**57**	**46**	**41**	**35**	**33**

Most forage seeds are not seriously affected by disease and storage pests such as weevil are also other beneficial qualities of most perennial forage species. However, seeds of some forage crops have low viability (germination) potential due to biotic and abiotic factors. Identification of the right seed harvesting stage for each forage species is one of the great problems for quality seed production. This is due to the indeterminate growth nature of most forage crops such as *vicia spp*. *Trifolium spp*., alfalfa, Rhodes, phalaris, Panicum, browse trees, etc. Research experience showed that harvesting stages after full flowering have a great effect on the germination of some perennial forage species (Table 4). The result showed that the highest seed germination percentage was obtained after four weeks of full flowering for Rhodes (88%) and Panicum (33%), but phalaris grass gave better germination (63%) at six weeks after full flowering. Moreover, lack of appropriate skills for post-harvest handling viz, drying, threshing, cleaning, winnowing, packing, storing, transporting and marketing have also an effect on the quality of forage seeds. Selection of the right niches also to be considered to produce viable forage seeds. Some forage crops such as fodder beet (*Beta vulgaris*), alfalfa (*Medicago sativa*), etc., are site-specific for the production of viable seeds. Though fodder beet gives seed at Holetta, the seeds are not viable because the crop needs some chilling temperature at flowering and seed setting stages, but this crop gives viable seed at Meraro. Due to the presence of high frost and rainfall at flowering, seed set, and seed maturity stages, the production of good quality seeds from late maturing forage crops is a great problem in the highland areas. After the flowering stage, low soil moisture content and high temperature can also cause a critical problem on seed quality of late-maturing forage crops in the lowland areas. Therefore, environmental stresses such as frost, extreme temperatures, soil moisture, soil acidity, and soil salinity should be considered before the selection of sites and forage species for the production of quality seeds. Seed dormancy is most common in wild flora for survival purposes under unfavorable environmental conditions (Askin and Baskin, 2004). Some forage species are dormant when harvested, and the dormancy period may last for a few weeks to several months. When seeds are dormant, they are still viable but will not germinate when placed in the proper germination environment. Some improved forage crops still carry genes for seed dormancy. Forage crops such as phalaris, Rhodes, Panicum, Setaria, clovers and browse trees have got dormancy problems due to inherent (mechanical and physiological) dormancy, chemical dormancy, and enforced dormancy (Getnet *et al*., 2012). Most *Fabaceae* seeds such as alfalfa (*Medicago spp.*), clovers (*Trifolium spp*.), etc., have a hard seed coat due to the thickness and biochemical composition of their testa, which limits the inhibition of water. Thus, special seed pre-conditioning treatments must be used to break or overcome seed dormancy.

Table 4. Effect of harvesting stage after full flowering on the germination percentage of grasses at Holetta

Harvesting stage (Weeks after full flowering)	**Phalaris**	**Rhodes**	**Panicum***
1	13	77	3
2	18	72	9
3	36	82	13
4	45	88	33
5	51	80	23
6	63	78	24

*****Germination % was doubled when storage is prolonged to 2 years

Three common scarification techniques are used to soften or break the seed coat. These are mechanical, chemical, and heat scarification. Mechanical scarification is simple, cheap, and safe and is recommended for the majority of forage legume seeds. Variations in hard seediness in annual clovers are affected by both genetic and environmental conditions during plant growth, seed development, and maturation. Hard seediness varies within and between species. It is affected considerably by the pre- and post-harvest conditions. A small number of clover seeds can be scarified manually using sandpaper. Care should be taken to damage the seed coat at the end furthest away from the embryo to avoid killing the seed. The seed coat may also be damaged by immersing the seeds in concentrated sulphuric acid for 7-20 minutes (depending on the species and thickness of the seed coat) followed by washing and drying. However, this treatment can damage the seeds and different species have a different degree of resistance. Generally, this is an expensive and dangerous method and is therefore considered unsuitable for seed scarification. Some seeds, especially those with waxy or oily seed coats, can be effectively scarified using boiling water. A good practical way of doing this is to soak the seeds in boiling water for a few seconds, followed by overnight drying. Table 5 indicates that the germination potential of tagasaste seeds can be improved from 1.5 to 80.5% by treating the seeds with hot water. According to Getnet *et al*. (2012), soaking the seed of tagasaste in boiling water for 9-11 minutes is used to decrease the hardness of the seed coat, and thereby increase the germination percentage from 3% (untreated seed) to 75%. The plant growth regulator, ethrel was effective in dormancy breaking in some forage crop seeds (Globerson, 1978). Smoke is also an effective agent in breaking seed dormancy of many species (Minorsky, 2002).

Table 5. Effect of hot water treatment on the germination of tagasaste seeds

Length of boiling water treatments in minutes	% Germination
1	63.5
2	68.5
3	74.5
6	76.5
9	80.5
12	68.5
15	63
18	67.5
21	55.5
24	28.5
Control	**1.5**

4.2 Gaps of Forage Seed Quality

There is a need to design strategies to maintain the physical and genetic purity of forage seeds at all levels. Different forage species need suitable seed production sites when compared to forage (biomass) production sites. There is a great gap exists in the identification of suitable seed production sites for recommended forage crops which has a substantial contribution to good quality seed production. Forage seed production technologies such as harvesting management, seed cleaning, processing, and conditioning should be developed and extended to producers for the production of quality seed. Government and private forage seed production, seed cleaning, and processing centers are weak so they should be strengthened. There is no forage seed certification in the country and all stakeholders should support the establishment of a seed certification system. Seed quality is an important aspect for successful forage establishment, conservation, and exchange of forage genetic materials. In Ethiopia, forage seed quality research and its application in various development activities are highly undermined and do not have much attention. Seed quality is not also virtually considered in the extension activities of forage crops. If things are continuing like this, its impact and consequences could be very risky. Different forage species are introduced from many countries by federal and regional research centers for improvement of the livestock sector of the country. The establishment of an effective and strong quarantine system is the first and most important step in the production of quality seeds in the country. However, for introduced germplasm, there are no strong laboratory quartine services and no well-established quartine fields for assessments of forage seed quality in the country. Therefore, strengthen the proper quartine service of the country is very important to protect the ecology from various pests, diseases, and weeds.

5. CONCLUSIONS

In the development of forage and pasture crops, the quality of the seeds used has a profound effect on the expected output. The demand for forage seed in Ethiopia is increasing at an alarming rate from time to time but a substantial gap exists in satisfying the demand for quality seed. Most forage seed supplied by research centers lacks the standard quality attributes. This is mainly attributed to a shortage of qualified personnel in seed technology, lack of adequate facilities for internal quality control and short-term storage, lack of appropriate breeder seed maintenance storage facilities to keep the quality standard; and inadequate budget for source seed multiplication. Production of genetically pure and good quality seed is a cost-demanding task that requires high technical skills and comparatively huge financial investment. During seed production, strict attention must be given to the maintenance of genetic purity and other quality parameters to fully exploit the genetic potential of the forage crops under production. This is usually expressed in terms of the yield produced, the quality of the forage, and its subsequent use as a seed. If seeds are not the desired quality, weeds, diseases and pests are expected. This generally will result in a reduction of the overall yield, affecting other fields and the overall environment at large. Forage seeds have some specific characteristics when compared to seeds of food and horticultural crops. Long longevity period, resistance to field and storage pests and diseases, are some of the beneficial qualities of most forage seeds. Generally, improving all seed quality attributes through proper management at pre-and post-harvesting stages are critically important for the promotion of the livestock feed sector in the country.

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