Chapter Eight

Forage Development for Sheep and Goats

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Objectives

1. To discuss alternative strategies and techniques for feed resource development and improvement available for the smallholder farmer.
2. To explain important activities which integrate the various sub-sectors, namely food crops, forage crops, ruminant livestock and environment conservation especially soil and vegetation.
3. To discuss promising forage and pasture species, their establishment techniques and their suitability to different agro-ecological zones.
4. To explain practical procedures of forage seed production.
5. To explain improved forage conservation and storage techniques.
6. To list methods of improving the productivity of natural pasture in both highland and pastoral grazing areas.

Expected Outputs

Knowledge of alternative forage development strategies for different agro-ecological zones.

8.1. Forage Development Strategy Options

There are two important factors that should be considered in forage development strategies for sheep and goats. First, their ecological distribution in the country is closely associated with either of climatic extremes — sheep mostly concentrated in the highlands while goats in the arid and semi-arid lowlands. Second, the feeding habit of sheep is grazing herbage close to the ground while goats predominantly browse diverse flora. Therefore, the type of forage to be introduced and its favored climate and soil, system of development and utilization at the farmer level, need to be viewed in relation to the ecological situations and feeding behavior of sheep and goats.

There are several strategies of forage development introduced with widely varied results into Ethiopian farming systems, especially in the highlands. Permanent pasture technologies have had limited success in spite of three decades of research and development endeavors. The lack of success is due to several constraints including low farmer resources, causing a low adoption rate of high-input technologies that take long periods of time for realization of benefits, and fragmented land with continually decreasing land holdings. Promising strategies that have shown some initial successes of improved forage development in the country are briefly discussed below.

8.1.1. Improving forage productivity of grazing lands on marginal areas

In the mixed crop–livestock (the central highland) and cash crop (the south-western highland) areas, the natural pasture from marginal lands is an important source of livestock feed. Natural pastures provide about 50% of the total annual feed supply depending on availability of alternative feed resources such as crop residues. These marginal-land grazing areas are located mostly on both extremes of topography — steep slopes and bottomland not suited for normal crop production. These grazing lands can be improved in yield and quality through methods like over-sowing. They can alternatively be made more productive through replacement of the sward with adaptable improved forage species.

Waterlogged areas

These consist of poorly drained or flooded areas dominated by black clays (*Vertisols*) or riverbed deposits eroded from various land-forms (alluvial). The *Vertisols* cover a huge area of land (12.6 million ha) estimated to cover about 12% of the country. These waterlogged areas are not suited for normal crop production due to poor drainage, so in most highland areas they are mainly utilized as bottomland communal grazing lands or for pasture deferred as standing hay for use in the driest part of the year.

Currently, the only species identified for over-sowing highland pastures are vetches (*Vicia* species), which unfortunately do not perform well under poor drainage. Some native grass species that showed considerable promise as water logging tolerant at Debre Zeit are listed in Table 8.1. Other commercial forage species recognized for their tolerance to excess moisture are listed in Table 8.2. Such aquatic and semi-aquatic grasses and legumes available commercially may be considered for salvaging marshy areas located on the peripheries of major rivers and lakes.

Table 8.1. Herbage yield and quality of native grass species grown under rain-fed conditions for three months on bottom lands at Debre Zeit.

Species	Herbage yield (DM t/ha $^{-1}$)	Nutritional analysis		Tolerance to water logging
		CP%	IVOMD%	
Pennisetum sphaceletum	10.5	10.1	53.6	Excellent
Pennisetum trachyphyllum	10.3	7.5	64.5	Excellent
Panicum maximum	14.4	11.5	59.3	Good
Chloris gayana	8.7	9.5	57.5	Fair
Pennisetum unisetum	8.1	9.3	50.2	Fair

Table 8.2. Selected commercial grass and legume forage species with potential adaptability to water-logged areas.

Potential species	Common name	Excess water tolerance
GRASS SPECIES		
*Brachiaria mutica**	Para grass	Excellent
Echnochloa polystachea	Aleman	Very good
Hymenache amplexicaulis	Hymenachne	Good
*Paspalum dilatatum**	Paspalum	Good
Phalaris aquatica	Phalaris	Good
LEGUME SPECIES		
*Macroptilium lathyroides**	Phasey bean	Excellent
Aeschynomene americana	Joint vetch	Very good
*Desmodium intortum**	Green leaf	Good
*Desmodium heterophyllum**	Hetero	Good
BROWSE TREES/SHRUBS		
Sesbania sesban	Sesbania	Excellent
Salix subserata	Willow tree	Excellent

*Also well-adapted to black-cracking heavy clay soils (Vertisols) (*Koticha, Merere, Walka*)

Steep slopes

Sloping land features like gullies, escarpments and peaks are unsuitable for cultivation and are thus generally utilized as communal grazing lands. They serve as the sole source of feed when all cultivable lands are cropped, and waterlogged areas become inaccessible due to flooding during the rainy season. Various forage-development strategies potentially applicable in these areas are discussed below.

Agroforestry

Agroforestry involves a close association of trees or shrubs with crops, animals and/or pasture. Specifically, it is the deliberate combination of trees with crop plantation or pastures, or both, in an effort to optimize the use of accessible resources to satisfy the objectives of the producer in a sustainable way.

Alley cropping

Alley cropping is an agroforestry practice in which leguminous browse trees or shrubs are planted widely apart so that grain crops are sown in the alleys between rows of trees. The trees are pruned

heavily during the cropping season in order to reduce shading, and the pruning is used for fodder, green manure and mulch. Unlike the case with other herbaceous intercrops, competition between the trees and cereal crop for moisture and nutrients is minimal since the deep roots of the tree utilize nutrients from deep layers of the soil that the cereal plant roots do not reach. In this system, the legume trees provide feed to stock, improve the nitrogen status of the soil through biological nitrogen fixation, and make available nutrients from the subsoil to the surface.

In soil conservation programs, steep slopes are planted with narrow lines of forage intercropped with arable crops. This system is referred to as *forage strip* or *strip cropping*. Herbaceous forages such as elephant grass, vetiver grass, *Panicum*, stylos, desmodium, siratro as grass/legume mixtures or pure stands are established on soil conservation terrace lines (Figure 8.1) for multiple uses, including:

- providing both bulk and quality feed for a cut-and-carry feeding system;
- preventing soil erosion;
- providing fuel wood;
- providing shelter and green manure for crops; and
- improving soil fertility.

Species suitable for the alley cropping system are listed in Table 8.3.

Table 8.3. Forage species suited for planting on sloping areas.

Herbaceous species	Tree and shrub species
Stylosanthes guyanensis	*Chaemacytisus palmensis* (tagasaste, tree lucerne)
Stylosanthes scabra	*Leucaena pallida*
Stylosanthes hamata	*Sesbania sesban*
Stylosanthes humilis	*Calliandra calothyrsus*
Stylosanthes fruitcosa (native)	*Cajanus cajan*
Desmodium intortum	*Gliricidia sepium*
Desmodium uncinatum	
Pennisetum purpureum	
Panicum maximum	
Phalaris tuberosa	

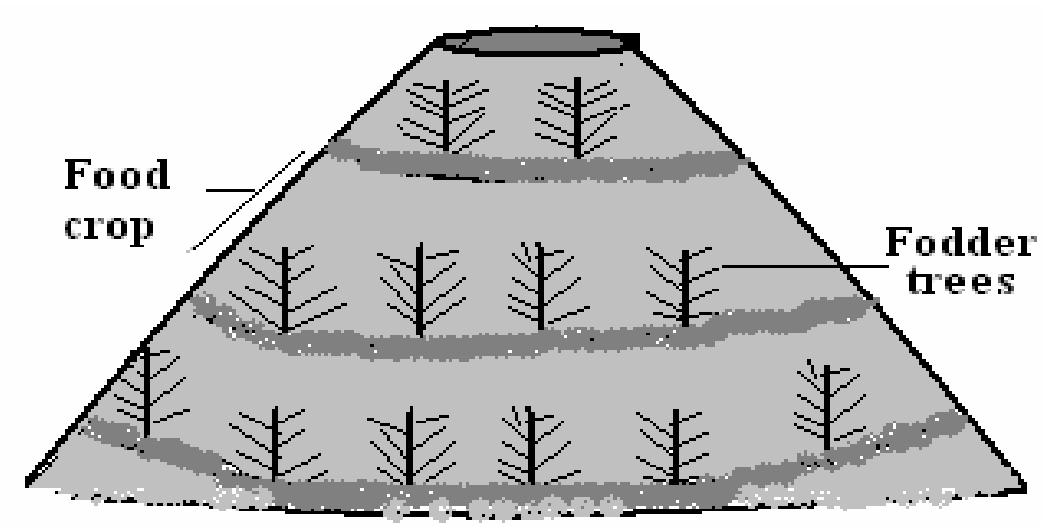

Figure 8.1. Alley cropping.

8.1.2. Integration of forages with food and cash crops

Forage legumes and grasses can be integrated into cropping systems through a number of methods such as intercropping, relay or sequential crops, fodder banks and alley farming. There are better chances for these technologies to be acceptable to the smallholder farmers than the more expensive conventional pastures. This is because, in all of the above-mentioned methods, the land is tilled for the sake of the food crop and so there is no need for special input for pasture establishment. The farmer is often reluctant to sacrifice arable land for sole pasture production. In this system, however, the farmer is likely to accept production of food and forage crops together. This will increase the net production per unit area of land.

Intercropping

Intercropping is a method in which two fairly compatible crops, often a leguminous forage species and a cereal crop, are grown together at a given planting pattern during a season. Competition between the cereal and the intercrop is minimized through selection of lines with different growth rate, rooting pattern and adaptation to light intensity. The intercrop, being leguminous, fixes nitrogen and thus avoids competition with the cereal for nitrogen, which is often scarce in tropical soils. Different forage legumes have different intensity of reaction with cereal crops. ***Relay cropping*** is the practice of intercropping a cereal planted within or between the rows of forage by offsetting the planting time of the cereal crop and the intercrop by two to three weeks to reduce competition.

The advantages of such an intercropping system are:

- the possibility of nitrogen accretion from the legume to the cereal;
- maintenance of continuity of feed supply during the dry season;
- more efficient utilization of low-quality cereals through the addition of high-protein forages;
- possibility of returning manure from livestock to the field; and
- increasing crop productivity.

Cereal/forage crop rotation

This system involves introducing annual forage legumes into the traditional cropping pattern. In the central highlands, to which the system is more applicable, the cropping sequence is cereal-cereal-pulse. In between any two cereal crop phases, annual fodder crops like clovers, medics or lablab may be sown, harvested and conserved as hay for strategic feeding during the dry season.

The advantages of this system are primarily to provide high-quality fodder and maintain soil fertility. Interspersing a legume in the crop rotation enhances soil fertility, prolongs the cropping period and reduces the normal fallow time traditionally used to replenish soil fertility. Legume crops also reduce the use of high amounts of chemical fertilizers. Thus, the method minimizes expenses for commercial fertilizers, especially nitrogen, which is fixed from atmospheric sources through *Rhizobial* fixation (Figure 8.2).

Sequential cropping

Sequential cropping is practiced when two crops (forage and pulse) are grown during a season, one after the other. The essential feature of this system, known as sequential or double cropping, is that the two crops do not overlap, the second being sown only after the first crop is harvested. This cropping is incorporated between any two cereal crop phases according to the traditional crop rotation.

For example, at the Debre Zeit Agricultural Research Center (DZARC), short-duration native clovers were successfully grown in sequence with chickpea on a *Vertisol* to exploit the advantages of:

1. producing a double crop of food grain (chickpea or grasspea) and high quality fodder, and
2. improving the nitrogen content of the soil through *Rhizobial* nitrogen fixation by both crops (Figure 8.3).

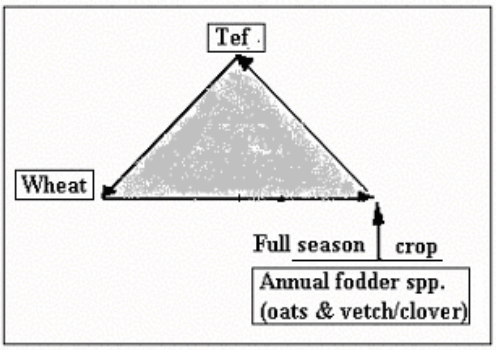

Figure 8.2. Modified cropping cycle with a replacement of the pulse phase with annual fodder legumes grown as full-season crop in the Ethiopian-highland cereal-based farming system.

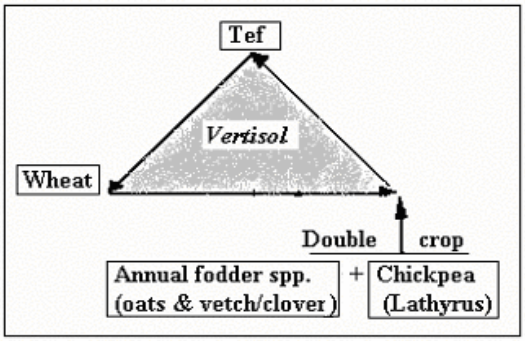

Figure 8.3. Modified cropping cycle without affecting the traditional crop rotation practice on the Ethiopian highland *Vertisols* through sequentially growing annual fodder crops with off-season pulses (chickpea/grasspea).

Fodder bank/lay pastures

This is a system whereby fallow land is sown to leguminous perennial forages or self-seeding annuals for production of high quality dry-season fodder and at the same time rebuilding the nitrogen content of the soil through biological nitrogen fixation. The system is like forage/crop rotation except that the forage phase may last for three or more years until the desired soil fertility level is attained.

Backyard forage crops

Backyard forage/fodder crops include highly productive species grown around a farmer's homestead under intensive management conditions. The objective is to produce high-quality fodder as supplementary feed to highly productive dairy cows and young animals. The system has gained popularity among smallholder farmers since it does not compete with food crops for arable land.

Recent forage innovation surveys undertaken nationwide indicate that most forage technologies successfully introduced to the farming community are based on this strategy. The quantity of produced fodder can be increased through the use of irrigation (from wells or surface water ponds), making multiple harvests possible. For instance, where water is abundant multiple harvests of high quality alfalfa fodder are possible every 3 to 4 weeks (12 cuts per year) (e.g., Debre Zeit Research Center Dairy Farm). Highly productive fodder species recommended for this system are listed in Table 8.4.

Table 8.4. Forage species suited for backyard forage production system.

Herbaceous species	Tree and shrub species
Pennisetum purpureum (Elephant grass)	*Chaemacytisus palmensis* (tagasaste)
Medicago sativa (Alfalfa)	*Leucaena pallida*
Desmodium intortum (Green leaf desmodium)	*Leucaena leucocephala*
Desmodium uncinatum (Silver leaf desmodium)	*Sesbania sesban* (Sesbania)
Beta vulgaris (Fodder beet)	*Calliandra calothyrsus*
	Gliricidia sepium
	Desmanthus virgatus
	Cajanus cajan (Pigeon pea)

Transferable Messages

- Determine the ecology and terrain of your *kebele* and take the choice of alternative approaches appropriate for the area.
- Make the appropriate choice of forage species.
- Select progressive farmers to demonstrate your choice of interventions.
- Organize demonstration visits by other farmers and encourage discussions on the practice and advantages of the introduced forage species and the approach.

8.2. Establishment and Management of Sown Pastures

8.2.1. Important considerations

Permanent pasture establishment can be an expensive venture so one has to take certain fundamental considerations before attempting such a venture.

Adequate soil moisture: For most productive pasture species, there is better chance of success where annual rainfall is about 600 mm or more.

Soil fertility: Improved forages can behave as food crops in soil-fertility requirements.

Topography: Must be convenient for easy farm operation (cultivation, fertilizing, spraying, harvesting, etc), and convenience for grazing animals (if grazed pasture).

Cost-effectiveness of undertaking ecological changes

- Consider whether clearing, cultivation, fertilizing and drainage operations are all justified and cost-effective.
- Check for the possibility of controlling the established pasture to implement management measures, including: better stock distribution, better systems of grazing, reduced stocking, and closing to stock until recovery.

8.2.2. Procedures of establishing sown pastures

Selection of pasture mixtures

Mixed pastures composed of grasses and legumes are preferred to solid stands for the following agronomic and nutritional advantages:

Agronomically

- More rapid establishment of the sward and better land use.
- Better seasonal distribution of growth by the inclusion of both early- and late-maturing species.
- Increased production with greater palatability.
- Leguminous components increase the nutritive value of the sward.
- Legumes play an important role through symbiotic N fixation, and the cycling of this nitrogen into the pasture system.

Nutritionally

- Legumes have high protein content. They improve the palatability of a mixed grass–legume pasture by keeping the crude protein level above the critical level of 7%, below which voluntary intake declines.
- Dry-matter digestibility and voluntary intake of legumes is generally higher than that of grasses. The fiber content increases at a later stage of maturity as compared to grasses, thus ensuring quality feed supply over the dry season.
- Legumes have high contents of the minerals: calcium, sulphur and phosphorus; therefore, they provide stock with more balanced diets.

Number of components

Pastures can be established as a mixture composed of up to five grass-plus-legume species depending upon specific situations.

Examples of some recommended mixtures and seeding rates are outlined as follows.

(a) Two components

Mixture options	Component A	Component B
Option 1	Rhodes grass	Lucerne
Seed rate	11 kg/ha	2 kg/ha
Option 2	Guinea grass	Centrosema
Seed rate	4–6 kg/ha	2–3 kg/ha
Option 3	Rhodes grass	Siratro
Seed rate	3–4 kg /ha	1 kg/ha

(b) Three components

OPTION 1:		
Component A	Component B	Component C
Para grass	Centro	Tropical kudzu
Root splits 60–90 × 90–120cm	4–5 kg/ha	1 kg/ha
OPTION 2:		
Component A	Component B	Component C
Guinea grass	Molasses grass	Stylo
3 kg/ha	1–2 kg/ha	1–2 kg/ha

Seedbed preparation

It should be realized that grass seeds are very small in size (most grass seeds are equal to or less than teff seeds), and thus one has to prepare a seedbed favorable for seed germination, seedling emergence, and growth.

Procedures

- **Clearing trees:** Consider ecological impacts, i.e., hazards of soil erosion and watershed destruction. Methods of clearing are:
  - ♦ Mechanical: Manually, using axe or slashers ('gejera').
  - ♦ Ring-barking: Removing a strip of surface bark 10 cm wide around the trunk.
- **Ploughing:** First deep-ploughing, then shallow-ploughing to a fine, firm, even, and level seedbed.
- **Rolling:** Done after sowing to consolidate the soil and provide better soil–seed contact.

Fertilizing and manure application

Improved pastures require fertile soils for optimal herbage production. Basal applications of the macronutrients, especially nitrogen (100–150 kg/ha urea) and phosphorus (50 kg/ha triple superphosphate) are helpful for successful establishment. However, considering the economic status of farmers, use of farmyard manure, as much as possible, is advisable at the rate of 5–10 tons/ha (t/ha). If the pasture to be established contains a good proportion of adapted and readily nodulating legumes, the nitrogen application may be ignored or reduced to a starter dose (10–25 kg urea/ha) in anticipation of atmospheric nitrogen fixation after some weeks by the legume component.

Propagation by seed

Seed considerations

True variety: Check that the seed is the right variety recommended for the target area. The best way to do this is to obtain seed from a reliable source.

Seed quality: There is a need to use high quality seed to establish the pasture. Quality is measured in terms of purity and germination. If commercial seed is considered, it is fair to request for a recent seed analysis statement for the seed to be sown, since this will show the quality details. Purity is expressed in terms of the percentages of seed of the sown variety, other crops and weeds, of inert matter (including pieces of straw, soil etc.), and of broken seed. Special attention must be given to the weed seed in the sample so as not to introduce new, potentially serious weeds into the pastureland.

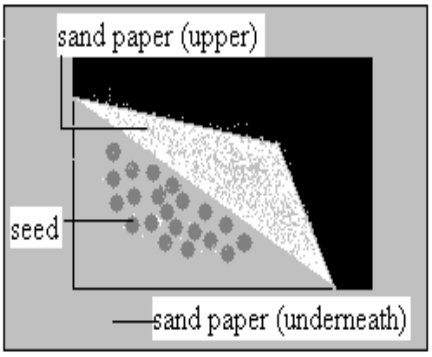

Figure 8.4. Seed scarification by rubbing the seed in between two pieces of sandpaper.

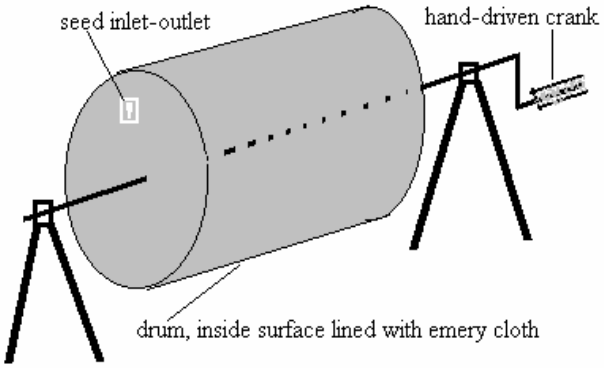

Figure 8.5. Scarifying seed by using a drum scarifier.

Seed dormancy

Seed dormancy is a natural protective phenomenon which prevents premature germination of seed to ensure long-term survival of species.

Two types of seed dormancy

1. **Embryo dormancy:** The embryos are physiologically inactive due to intrinsic germination inhibitors, inactive enzyme systems. These need a period of dormancy after ripening.

2. **Dormancy due to seed coat characters:** Occurs due to a) seed coat mechanisms constricting the expansion and growth of the embryo, b) prevention of the entry of gases and moisture, or c) chemicals in seed coats which inhibit germination.

Methods of breaking seed dormancy

Storage: Holding freshly harvested seed in storage will overcome dormancy problems since dormancy declines with time. Storage is often applied to grass seeds.

Scarification: Scarification treatments are employed prior to sowing to abrade the seed coat and improve permeability, e.g., most legume and some grass seeds such as *Cenchrus, Melinis,* and *Paspalum notatum* require scarification.

Methods of Scarification

Mechanical scarification: The seed coat is abraded by passing over abrasive surfaces or rubbing with sandpaper if sowing small quantities (Figure 8.4). For large quantities, use drum scarifiers. These are seed-mixer drums with an inner surface lined with abrasive material (Figure 8.5).

Hot-water treatment: Immersion of seed in hot water, the temperature and duration of treatment depending on species (Figure 8.6). For example:

- *Chaemacytisus palmensis* at 100 °C for 9 minutes.
- *Leucaena leucocephala* at 75°C for 6 minutes.
- *Phaseolus atropurpreus* at 55°C for 20 minutes.
- *Stylosanthes guyanensis* at 55°C for 20 minutes.

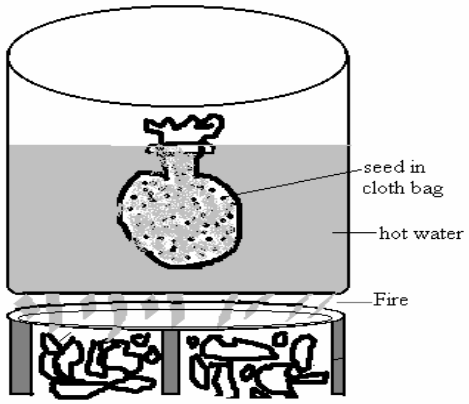

Figure 8.6. Scarifying seed by immersing in hot water.

Inoculation

Inoculation is treating legume seeds with *Rhizobium* bacteria carried in peat medium. The inoculum is usually sold along with the seed. Inoculation is recommended, particularly when introducing new forage species into new areas, to ensure that the species are nodulated by the most effective and efficient *Rhizobium* bacteria strains.

Most native legume species do not require inoculation since they can be infected by bacteria strains living in the soil. An effective nodule is pink on the inside while ineffective nodules are either white or green.

A simple method of inoculation:

- Make slurry of inoculant in water and mix the seed thoroughly to make all seeds wet.

- Add a small quantity of sugar solution (10%) to the slurry to make it sticky. For inoculating 1 kg of seed, a half teacup full of sugar is sufficient.
- Inoculation and drying should be done in the shade.
- Inoculated seeds should be sown within 24 hours of inoculation.

Seed rate

Seed rate depends primarily on the viability and purity of the seed. Furthermore, seed rate depends on seed size, pure stand or mixture, amount of rainfall and soil fertility. As a general guideline, for row planting, sow grasses at 6–8 kg/ha, legumes at 3–4 kg/ha, and fodder shrubs at 10–15 kg/ha. When broadcasting seed, sow at double the rate recommended for row planting.

Sowing practice

Timing: The most desirable time to seed non-irrigated areas is immediately before the season of the most reliable rainfall, and when temperature is favorable. Sow perennial species at the onset of the longest wet season when the soil has received sufficient moisture to support germination and establishment.

Spacing: Generally, spacing between rows should not exceed 25–45 cm and within-row plant spacing should be 5–15 cm.

Depth: Generally, the smaller the seed the shallower the depth of planting. Usually, grasses are sown at the depth of 1–1.5 cm, while medium-sized legume seeds are sown at a 2.5 cm depth.

Method of sowing

Two ways:

1. **Row-sowing**
2. **Broadcasting**

Row-sowing is preferred because it offers the following advantages:

- Low seed rate is required, which is important in view of seed scarcity and cost.
- Better establishment than by broadcasting in case of poor weather conditions.
- Easy weeding and fertilizer application.
- Better exposure of plants to sunlight.

When planting in rows manually, mark the rows with a stick or a row marker that has adjustable spikes. Sow the seeds in the row and cover with a thin layer of soil pressed down by feet (men or animals) to ensure good soil–seed contact.

When row-planting is not possible, broadcasting should be done, in which case the sowing rate should be doubled to compensate for poor seedling survival. To cover surface-sown seeds, drive animals back and forth, or drag a spiny tree branch devoid of leaves. Both methods give good results (Figure 8.7).

Propagation by vegetative parts

Vegetative propagation is necessary for establishing sterile plants, erratic-seeders and for plants giving seed of low genetic stability (hybrid varieties; segregating populations). Some examples:

- Sterile: *Digitaria decumbens (pangola grass).*
- Erratic-seeder: *Pennisetum purpureum* (elephant grass).
- Low genetic stability (bred variety): *Pennisetum clandestinum* (kikuyu grass).

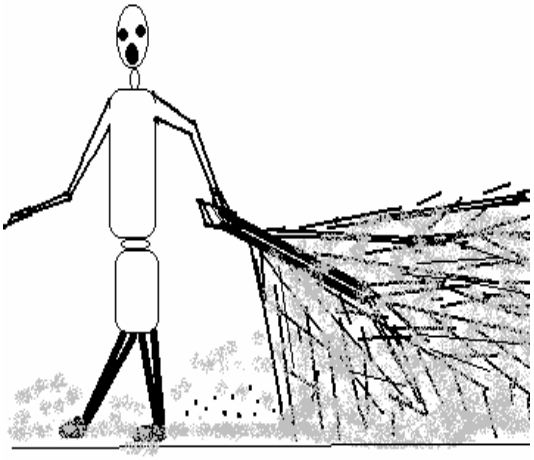

Figure 8.7. Seed covering by dragging a leafless tree branch.

Methods

Tuft division: Tuft splits may be dug out by hand and taken to the establishment area and planted in furrows.

Stem cuttings: Dependent upon favorable moisture conditions. A well-grown stand of mature stems bearing three nodes are cut and planted in furrows or surface broadcast and covered with soil. Two nodes are buried and one is left above ground. The spacing for most grass species is 0.7 × 0.3 m within and between rows. For runner grasses, 2 × 2 m spacing is recommended if weed control is adequate and early season grazing avoided (Figure 8.8).

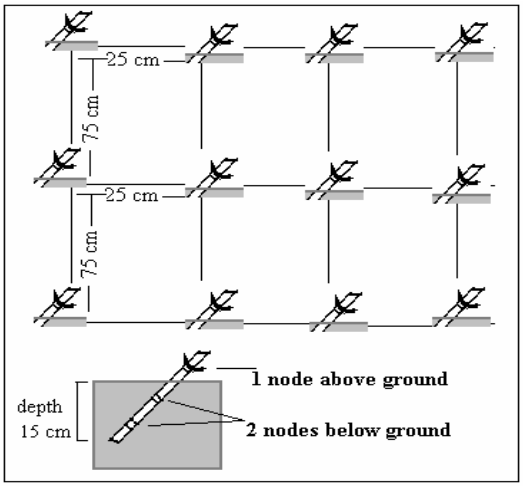

Figure 8.8. Vegetative (stem cutting) propagation.

Propagation by seedlings

Browse trees and shrubs have a better chance of survival if planted as seedlings. It is advisable to raise seedlings two months ahead of the rainy season using plastic bags in a seedling nursery.

The procedures are as follows:

- Prepare a mixture of fine sand, forest soil and farmyard manure.
- Mix well and moisten by sprinkling with water and fill small plastic bags/pots.
- Arrange the bags/pots under a nursery shed and plant viable seeds (two seeds per hole if seed is not limiting).
- Supply adequate water daily. Monitor germination and remove any weeds.
- Thin seedlings to one strong plant per pot.
- At the start of the rainy season, dig planting holes in the target field a week or so before planting to allow adequate water infiltration.
- Preferably on a cloudy day, plant the seedlings in the prepared holes. Fill the hole first with the topsoil followed by the subsoil and press firmly.

8.2.3. Management after sowing

Weed management

The newly established pasture has to be kept free of coarse weeds, especially broadleaf weeds, which are usually a threat to sward consolidation. Remove weeds by hand or by spraying herbicides before weeds flower. This reduces competition when grasses are weak while minimizing further perpetuation of weeds by seed.

Fertility management

Fertilizers should be applied according to the fertility status of the soil. To determine what nutrients are needed:

- Observe characteristic symptoms, e.g., leaf yellowing is likely a nitrogen deficiency.
- Undertake soil and plant tissue analysis.
- Know the characteristics of the plant, e.g., tall and rank-growing grasses such as elephant grass and *Panicum* species are heavy feeders and require more frequent fertilizer applications than thinner and shorter stature grasses.

Generally, legumes have a high requirement for phosphorus (P), sulphur (S) and Molybdenum (Mo); grasses have a high requirement for nitrogen (N), P, and Potassium (K). Levels of nutrients used will depend on soil type, species used, level of production required, and production system (cut-and-carry systems require greater maintenance inputs than grazing systems). Typical levels of nutrients required for annual maintenance (Cook *et al*, 2005) are 50–300 kg/ha N; 10–20 kg/ha P; 25–50 kg/ha K; 30 kg/ha S; and 100–200 kg/ha Mo. Nitrogen is often applied at each grazing or cutting. Phosphorus should also be applied especially if the legume component loses vigor due to grass dominance. Manipulating the ratio of application of nitrogen and phosphorus is a useful management technique to maintain a desirable balance between the grass and legume components.

Grazing/defoliation management

- The newly established pasture can be utilized within 2–8 months after sowing. This is only possible if proper grazing or cutting is ensured.
- Rotational or periodic grazing is usually recommended. However, some species may not respond to rotational grazing and this situation has to be treated cautiously. As a precaution, stocking rate should be highly reduced or grazing totally stopped when no more than 50% of the weight of herbage has been consumed.
- If sown pastures are well utilized and maintained with fertilizers, they will continue to provide high herbage yield for up to about five years and start to decline thereafter.

Transferable Message

- Select progressive farmers to demonstrate your choice of interventions. Usually, cultivated pastures should go with maintaining improved breeds. It is, therefore, advisable to promote cultivated pasture production among farmers that keep improved breeds.
- Organize a training session and show farmers the different methods of pasture establishment.
- Organize demonstration visits by other farmers and encourage discussions on the practice.

8.3. Agronomic Characteristics of More Important Forage Species

8.3.1. Annual fodder crops

Oats (*Avena sativa* L.)

Figure 8.9. Oats (*Avena sativa*).

- ***Botanical description:*** Erect annual grass up to 1.5 m tall (Figure 8.9).
- ***Adaptation*:** Commonly grown annual crop in cool areas for fodder or grain.
  - ♦ Altitude range: 1700–3000 m.a.s.l.
  - ♦ Climatic requirement: 500–800 mm mean annual rainfall, cold- and frost-tolerant.
  - ♦ Soil requirement: Fairly tolerant to water logging.
- ***Cultivation:*** Requires a well-prepared seedbed.
  - ♦ Propagation: By seed; sowing rate 70–80 kg/ha in pure stand. In mixtures: with vetch: 60 kg/ha + vetch 15–20 kg/ha; with pea: 60 kg/ha + pea 20 kg/ha.
  - ♦ Fertilizer requirement: Gives better yield when fertilized with nitrogen and phosphorus fertilizers.
  - ♦ Companion species: *Trifolium alexandrinum, Vicia dasycarpa, Vicia villosa, Lathyrus sativus.*
- ***Utilization:*** Fodder crop as green feed or conserved as hay.
- ***Productivity:*** Yields of up to 10–52 t/ha of fresh herbage have been reported.
- ***Reproduction:*** Seed yield up to 10 quintals/ha or more (1 quintal = 100 kg).

Figure 8.10. Vetch (*Vicia dasycarpa*).

- ***Special merits:*** It is the best annual fodder grass for the highland areas, often conserved as hay for dry-season feeding.

Vetch (*Vicia dasycarpa* L.)

- ***Botanical description:*** Climbing, sprawling annual legume (Figure 8.10).
- ***Adaptation:*** Medium- to high-altitude highlands.
  - ♦ Altitude range: 1500–3000 m.a.s.l.
  - ♦ Climatic requirement: Wide rainfall range, can survive as low as 400 mm.
  - ♦ Soil requirement: Versatile.
- ***Cultivation:*** Can be established on a rough seedbed.
  - ♦ Propagation: By seed at the rate of: 20 kg/ha (pure stand); 12 kg/ha (undersown); 5–12 kg/ha (pioneer component of pasture mix); 12–20 kg/ha (sown with oats).

- ♦ Fertilizer requirement: Apply 20–40 kg P/ha at planting.
- ♦ Companion species: Oats (*Avena sativa*).

- ***Utilization:*** As conserved fodder (hay) crop in mixture with oats; good for under-sowing maize and sorghum; excellent as pioneer crop.
- ***Productivity:*** Up to 6 t/ha DM as pure stand.
- ***Reproduction:*** Cross-pollinated. Seed yield 400–1000 kg/ha.
- ***Special merits:*** Excellent as pioneer crop and as fodder crop for haymaking.

8.3.2. Temperate perennial forage crops

Cocks foot (Orchard grass) (*Dactylis glomerata* L.)

Figure 8.11. Cocks foot (*Dactylis glomerata*).

- ***Botanical description:*** Tufted perennial (Figure 8.11).
- ***Adaptation:*** Highland adaptive, cold- and frost-tolerant.
  - ♦ Altitude range: Highlands 2000–3000 m.a.s.l.
  - ♦ Climatic requirement: Mean annual rainfall 400–1500 mm, cold- and frost-tolerant.
  - ♦ Soil requirement: Versatile in its soil requirement provided drainage is adequate.
- ***Cultivation:*** Requires a well-prepared seedbed.
  - ♦ Propagation: By seed, sown at the rate of 2 kg/ha.
  - ♦ Fertilizer requirement: Responds well to N and P application.
  - ♦ Companion species: *Trifolium alexandrinum, Vicia dasycarpa, Vicia villosa, Lathyrus sativus.*
- ***Utilization:*** Grazing or cutting should be moderate, sensitive to both under-use and over-use. Mainly utilized for mixed pastures.
- ***Productivity:*** Up to 5–9 t/ha DM.
- ***Reproduction:*** Seed production up to 200 kg/ha.
- ***Special merits:*** Cold- and frost-tolerant; good for grazing pastures for dairy industries.

Figure 8.12. White clover *(Trifolium repens L.).*

White clover (*Trifolium repens* L.)

- ***Botanical description:*** Trailing perennial legume up to 30 cm high (Figure 8.12).

- ***Adaptation:*** Cool tropical highlands.
  - ♦ Altitude range: 1800–3000 m.a.s.l.
  - ♦ Climatic requirement: Mean annual rainfall 800–1500 mm.
  - ♦ Soil requirement: Versatile.
- ***Cultivation***: Well-prepared seedbed
  - ♦ Propagation: By seed at 3–6 kg/ha.
  - ♦ Fertilizer requirement: Responds well to P and S application.
  - ♦ Companion species: *Bracharia humidicola, Digitaria decumbens, Pennisetum clandestinum, Setaria anceps.*
- ***Utilization:*** Most suited for grazing.
- ***Productivity:*** About 1.5–2.5 t/ha DM.
- ***Reproduction:*** Cross-pollinated.
- ***Special merits:*** Good as grazing pasture for high-altitude highlands.

Figure 8. 13. Buffel grass *(Cenchrus ciliaris L.*).

8.3.3. Tropical perennial grasses

Buffel grass (*Cenchrus ciliaris* L.)

- ***Botanical description:*** Tufted or spreading perennial grass 12–120 cm tall; has a large strong root system (Figure 8.13).
- ***Adaptation:*** Adapted to semi-arid conditions.
  - ♦ Altitude range: Sea level to 2000 m.a.s.l.
  - ♦ Climatic requirement: Mean annual rainfall 375–750 mm (does not do well in high rainfall areas, but its rainfall requirement ranges widely: 300–1000 mm); temperature 20–30^{o}C; less cold-tolerant than green panic.
  - ♦ Soil requirement: Prefers light-textured soils of high P status, but still performs well on self-mulching soils; has only moderate salt tolerance.
- ***Cultivation:*** Light cultivation.
  - ♦ Propagation: By seed at the rate of 6-8 kg/ha for drilling in rows and 12 kg/ha for broadcasting. Sowing depth is 1–2 cm; rolling or cattle trampling after sowing improves establishment.
  - ♦ Fertilizer requirement: Responds to N application up to 160 kg/ha. Buffel grass has a reputation as a phosphorus-loving grass.
  - ♦ Companion species: *Stylosanthes humilis, Neonotonia wightii, Macroptilium atropurpureum, Medicago sativa.*
- ***Utilization:*** Good for grazing and haying.
- ***Productivity:*** Buffel grass is not a heavy producer and herbage yields usually range between 2 and

Figure 8.14. Colored Guinea grass *(Panicum coloratum* L.).

8 t/ha DM.

- ***Reproduction:*** Apomictic; seed yield 10–60 kg/ha.
- ***Special merits:*** Excellent in drought and firing tolerance; recovers rapidly after drought-breaking rains.

Colored Guinea grass *(Panicum coloratum* L.*)*

- ***Botanical description:*** Tufted perennial with variable habit, up to 150 cm high (Figure 8.14).
- ***Adaptation:*** Adapted to drier (400 mm) lowland alluvial flood plains of southern Africa (Makarikari, Botswana)
  - ♦ Altitude range: 500–2000 m.a.s.l.
  - ♦ Climatic requirement: Rainfall 600–1200 mm; optimum temperature 17–21°C; susceptible to frost.
  - ♦ Soil requirement: Adapted to red and black clay soils. It makes its best expression on black clay soils.
- ***Cultivation:*** Requires a well-prepared seedbed. Propagation is by seed at the rate of 5–7 kg/ha for broadcasting and 2–3 kg/ha for row planting; sowing depth 2 cm. Planting by rooted cuttings can also be done.
  - ♦ Fertilizer requirement: Responds well to N application; reported to fix N (23 Kg/ha in 100 days).
  - ♦ Companion species: *Desmodium uncinatum, Neonotonia wightii, Macroptilium atropurpureum.*
- ***Utilization:*** Good for grazing and haying.
- ***Productivity:*** Yields are usually around 12 t/ha DM but ranges of 5.8–18 t/ha DM have been reported.
- ***Reproduction:*** Cross-pollinated sexual, with some apomixis; seed yields 45–400 kg/ha.
- ***Special attributes:*** Drought-resistant; tolerates seasonal waterlogging.

Elephant grass (Napier grass, English or *Zihone sar*, Amharic) (*Pennisetum purpureum*)

- ***Botanical description:*** Robust perennial with a vigorous root system, sometimes stoloniferous with a creeping rhizome, culms 180–360 cm high (Figure 8.15).
- ***Adaptation:*** Best-adapted to high-rainfall areas.
  - ♦ Altitude range: Sea level to 2000 m.a.s.l.
  - ♦ Climatic requirement: Rainfall 1480–1620 mm/y; optimum temperature 25–40°C; resists drought if successfully established. Susceptible to frost.
  - ♦ Soil requirement: Prefers deep, friable fertile soils.
- ***Cultivation:*** Full land preparation.
  - ♦ Propagation: Usually by stem cuttings buried in 15 cm furrows, 2 nodes in soil and one exposed. One ha of grass provides planting material for 15–20 ha.
  - ♦ Fertilizer requirement: Responds well to fertilizers applied after every cut.
  - ♦ Companion species: *C. pubescens, N. wightii, P. phaseoloides.*
- ***Utilization:*** Commonly used in a cut-and-carry system; also made into silage. For grazing, it should be heavily stocked to maintain it in a lush vegetative form; best grazed when the new growth consists of 5 new leaves. Slash coarse leafless stems. Makes good hay if cut when young; usually made into silage of high quality without additives.
- ***Productivity:*** Highest DM yield recorded is 84.8 t/ha when it was fertilized with 987 kg N/ha/yr

and cut every 90 days under rain-fed conditions (2000 mm/yr) (Puerto Rico). In Hawaii, it produced 336 t green forage/ha/yr. In Colombia, a 2.5 ha plot of elephant grass forage maintained 35 milking cows producing an average of 15 liters of milk/day supplemented with 1 kg concentrate per 4 kg milk.

- ***Reproduction:*** Cross-pollinated; erratic seeder.
- ***Special attributes:*** High DM yield; deep roots can forage widely for moisture and N.

Figure 8.15. Elephant grass, (Napier grass), (English) *Zihone sar* (Amharic) (*Pennisetum purpureum*).

Figure 8.16. Rhodes grass (*Chloris gayana*).

Rhodes grass *(Chloris gayana* Kunth)

- ***Botanical description:*** Stoloniferous perennial grass with the erect leafy stems up to 1.5 m bearing at the top 10–12 radiating brownish-green seed spikes (Figure 8.16).
- ***Adaptation:*** Wide range of adaptation; moderate frost tolerance.
  - ♦ Altitude range*:* 600–2000 m.a.s.l.
  - ♦ Climatic requirement: Rainfall 650–1200 mm.
  - ♦ Soil requirement: Versatile.
- ***Cultivation:*** Well-prepared seedbed. Propagation is by seed at the rate of 0.5–7 kg/ha depending upon amount of rainfall. Seeding depth should not exceed 0.6–1.3 cm.
  - ♦ Fertilizer requirement: Responds well to increasing levels of N application if in balance with P.
  - ♦ Companion species: *Stylosanthes guyanensis, Neonotonia wightii, Macroptilium lathyroides, M. atropurpureum, Medicago sativa, Centrocema pubescens.*
- ***Utilization:*** Good for grazing and haymaking. If underutilized, it becomes stemmy especially if soil fertility declines.
- ***Productivity:*** Under farm conditions, 5–8 t/ha DM; with high N application and variable cutting frequency yields up to 25 t/ha DM have been reported.
- ***Reproduction:*** Cross-pollinated; isolation distance of 200 m is recommended in seed production. Seed yields 65–650 kg/ha, often two crops per year.

- ***Special merits:*** It is the best perennial grass adapted to most medium- to high-altitude highlands of Ethiopia with moderate amount of rainfall. Good seeder so it can be established from home-grown seed. Its vigorous root system confers appreciable drought tolerance, although not as much as buffel grass, green panic or blue panic. It has special value in its salt tolerance. It is also tolerant to fire; withstands heavy grazing; is suitable for erosion control, being one of the best species for sowing on earthwork.

Figure 8.17 Para grass (*Brachiaria mutica*).

Para grass (*Brachiaria mutica* (Forsk.) Stapf)

- ***Botanical description:*** A short-culmed stoloniferous perennial grass up to 2 m high (Figure 8.17).
- ***Adaptation:*** Semi-aquatic high-rainfall/moisture area adaptive.
  - ♦ Altitude range: Sea level to 1000 m.a.s.l.
  - ♦ Climatic requirement: Minimum of 900 mm mean annual rainfall; 15–21°C mean annual temperature; frost sensitive.
  - ♦ Soil requirement: Alluvial and waterlogged soils.
- ***Cultivation:*** Light cultivation for vegetative and fine seedbed for seed propagation.
  - ♦ Propagation: Usually by cuttings of 25 cm or 3 node-sized stem spaced 1 m. apart. Also by seed at the rate of 2.5–4.5 kg/ha, no deeper than 1cm, roll after sowing.
  - ♦ Fertilizer requirement: Responds well to N and P application.
  - ♦ Companion species: *Desmodium heterophyllum, Pueraria phasioloides, Centrocema pubescens, Calopogonium mucunoides.*

Figure 8.18. Guinea grass (*Panicum maximum*).

- ***Utilization:*** Suitable for deffered grazing, start grazing after full establishment, avoid grazing/cutting close to ground level, makes good hay or silage with a DM loss of only 10%.
- ***Productivity:*** Two- to four-cuttings per season each, 2.5–7.5 t/ha DM, with irrigation, 84.3 t/ha fresh (24 t/ha DM).
- ***Reproduction:*** Usually by vegetative means.

Guinea grass (*Panicum maximum* Jacq.)

- ***Botanical description:*** Tufted perennial with a shortly creeping rhizome; variable habit 60–200 cm high (Figure 8.18).
- ***Adaptation:***
  - ♦ Altitude range: Sea level to 2500 m.a.s.l.
  - ♦ Climatic requirement: 780–1797 mm mean annual rainfall (usually in excess of 1000 mm); optimum temperature 19–23°C; does not tolerate heavy frosts.
  - ♦ Soil requirement: Versatile; more productive on fertile soils; tolerates acidity; does not tolerate drought or waterlogging.
- ***Cultivation:*** Full seedbed preparation is required.
  - ♦ Propagation: By seed at 3–6 kg/ha; by sods spaced 0.6 × 1.25 m; cuttings 15 × 45 cm spacing.
  - ♦ Fertilizer requirement: Responds well to N and P application.
  - ♦ Companion species: *Centrocema pubescens, Stylosanthes guyanenesis, Macroptilium atropurpurium, Neonotonia wightii.*
- ***Utilization:*** Stands defoliation if grazed or cut below 30 cm, graze only after the first seeding period. Makes good hay and silage. With optimum fertilization, stocking rate of 4.2 beasts/ha with annual live weight gains of 377 kg/ha for pure Guinea grass and 601 kg/ha in mixture with *C. pubescens* reported.
- ***Productivity:*** Up to 60 t/ha DM when 300 kg N/ha was applied (cv. Makueni) (Queensland); up to 26.8 kg/ha DM with 440 kg N/ha, cut at 40 days intervals (Puerto Rico).
- ***Reproduction:*** Facultative apomict, with 1–5% sexual reproduction. Seed yield 45–156 kg/ha; harvest seed after 12–24 days from panicle emergence.
- ***Special attributes:*** Wide adaptation, quick growth, easy to establish from seed, good response to fertilizers.

Figure 8.19. Green leaf desmodium (*Desmodium intortum*).

Figure 8.20. Common stylo (*Stylosanthes guianensis)*.

8.3.4. Tropical perennial forage legumes

Green leaf (*Desmodium intortum*)

- ***Botanical characteristic:*** Vigorous perennial herb with ascending or scandent, branched reddish-brown stems (Figure 8.19).
- ***Adaptation:*** Best adapted to high rainfall areas exceeding 900 mm, with altitude range 800–2500 m.a.s.l.
- ***Herbage yield potential:*** Varies widely from 3–20 t/ha DM in pure stands.
- ***Cultivation:***
  - ♦ Propagation: by seed at the rate of 1–2 kg/ha in rows 45 cm wide. Green leaf is highly specific in its Rhizobium requirement.
  - ♦ Fertilizer: Reported to respond well to P and K application.

- ♦ Companion species: Combines well with *Panicum maximum, Melinis minutiflora,Paspalum plicatulum, Digitaria decumbens Bracharia mutica, Pennisetum clandestinum.*
- ***Reproduction:*** Self- and cross-pollinated. Sensitive to photoperiod; it is a short-day plant. Seed yields 100–120 kg/ha.

Common stylo (*Stylosanthes guianensis* (Aublet) Swartz)

- ***Botanical characteristics:*** Erect or sub-erect perennial herb 30–120 cm high (Figure 8.20).
- ***Adaptation:*** Grows best under warm climate; wide range of rainfall 600–2500 mm; survives long dry periods; tolerates low pH or low P status due to endotrophic mycorhiza found in the roots.
- ***Herbage yield potential:*** Varies widely from 2.5–10–15 t/ha DM (as pure). Good for over-sowing natural pasture.

- ***Cultivation:***
  - ♦ Propagation: By seed sown at the rate of 2–3 kg/ha. Seed treatment essential by using one of the following methods:
    - Mechanical scarification of seed using drum scarifiers.
    - Boiling for 10 seconds.
    - Freezing to 17^{o}C for 7 days.
  - ♦ Inoculation is necessary for some cultivars.
  - ♦ Fertilizer: P is needed on poor soils, normal rates are in the order of 50–100–150 kg super-phosphate/ha.
  - ♦ Companion grasses: *Digitaria decumbens. D. smutsii, Chloris gayana, Cenchrus ciliaris, Melinis minutiflora, Setaria anceps Andropogon gayanus, Heteropogon contortus, Hyparrhenia rufa, Panicum maximum, Pennisetum polystachion.*
- ***Reproduction:*** Self-pollination, but cross-pollination can occur. Seed yield ranges 75–200 kg/ha.

Figure 8.21. Axillaris *(Macrotyloma axillare)*;.

Axillaris (*Macrotyloma axillare* (E. Meyer) Verde.)

- ***Botanical description:*** Climbing perennial legume (Figure 8.21).
- ***Adaptation:***
  - ♦ Climatic requirement: Best adapted to areas where rainfall exceeds 1000 mm; tolerant of drought but susceptible to frosting and water logging.
  - ♦ Soil requirement: Prefers light soil; tolerates soil acidity.
- ***Cultivation:*** Light cultivation.
  - ♦ Propagation: By seed at the rate of 3–5 kg/ha.
  - ♦ Fertilizer requirement: Responds well to N and

Figure 8.22. Lucerne (Alfalfa), (*Medicago sativa*).

P application.

- ♦ Companion species: *Panicum maximum, P. coloratum, Chloris gayana, Sorghum sudanense.*

- ***Utilization:*** Mixed pastures utilized for grazing and hay making.
- ***Productivity:*** Variable.
- ***Reproduction:*** Self fertilized; seed yield 200 kg/ha.

Lucerne (alfalfa) (*Medicago sativa* L.)

- ***Botanical description:*** Erect perennial herb with deep-growing taproot (Figure 8.22).
- ***Adaptation:***
  - ♦ Altitude range: Wide range of adaptation from 500–3000 m.a.s.l. altitude and above.
  - ♦ Climatic requirement: Best adapted to warm, temperate climate. Because of its deep-rooted habit, it can be grown in areas receiving as little as 550 mm of annual rainfall.
  - ♦ Soil requirement: It is quite intolerant of water logging and requires fertile, well-drained soils. It prefers neutral or alkaline (lime-rich) soils. It is susceptible to acid soils unless top-dressed with lime.
- ***Cultivation:*** Well-prepared fine, firm seedbed is required for best result. Propagation is by seed sown at a rate varying with soil moisture: generally 6 kg/ha for rain-fed; 2 kg/ha for areas receiving 600–750 mm of annual rainfall. The rate suggested when sowing in mixtures with grasses is 0.5–2 kg/ha. [Other reports suggest 8–10 kg for pure stand, 5–6 kg/ha for mixtures.] For irrigated pastures, the recommended rate is 14–15 kg/ha so as to obtain fine stems for best hay quality and to control weeds. Sowing depth of 0.5–1.0 cm for heavy soils. Seed inoculation may be necessary if native pastures do not contain medics.
  - ♦ Fertilizer requirement: Lucerne has high demand for nutrients. Phosphorus may be required for establishment.
  - ♦ Companion species: Combines with *Panicum maximum, Chloris gayana, Cenchrus ciliaris, Sorghum almum.*
- ***Utilization:*** Utilized as grazed mixed pasture, as hay or as green fodder. Cut or graze at 30–40 days interval or at 10% flowering.
- ***Productivity:*** Variable according to moisture supply. Yields of 7–9 t/ha/yr are expected and 11 t /ha/yr is quite often achieved.
- ***Reproduction:*** Cross-fertilized; bees necessary for pollination. Seed yields 100–300 kg/ha.
- ***Special merits:*** Lucerne is the most successful conserved fodder in the tropics and has special application in the dairy business. It is ideal for irrigated pasture. Under irrigated conditions at Debre Zeit, harvests every 3–4 weeks (12 times a year) have been possible.

Figure 8.23. Leucaena (*Leucaena leucocephala*).

8.3.5. Fodder trees and shrubs

Leucaena (*Leucaena leucocephala*)

- ***Botanical description:*** A long-lived shrub or tree up to 20 m high (Figure 8.23).
- ***Adaptation:*** Performs best under warm

climate at low altitudes less than 2000 m, sensitive to frost, drought-tolerant, can grow at 400 mm annual mean rainfall.

- ♦ Altitude range: less than 2000 m.a.s.l.
- ♦ Soil requirement: Well-drained soils; not tolerant to acid soils; favors a range of soils neutral to alkaline (pH 6.0).

- ***Cultivation:*** Light cultivation for direct sowing; dug holes for transplanting.
  - ♦ Propagation: Propagation by seed sown at 4–7 kg/ha, but different rate or spacing can be used depending on utilization; sowing depth: 2–3 cm. Spacing when sown 2–2.5 m between rows to up to 4.0 m between rows/alleys. Usually planted by seedlings.
  - ♦ Treatments: Seed treatment necessary. Hot-water treatment 60–80^{o}C; H_2SO_4 for 10 minutes.
  - ♦ Inoculation with appropriate rhizobium strain is helpful.
  - ♦ Fertilizer requirement: On acid soils, liming may be necessary.
  - ♦ Companion species: May be planted to pasture grasses in inter-row spaces.
- ***Utilization:*** Cut at 80–100 cm height every 6–8 weeks; use as supplementary ration 25–30%; beyond this level, animals develop enlarged thyroid gland or goiters because of mimosine (an alkaloid) preventing animals from using iodine efficiently.
- ***Productivity:*** Considered the best fodder tree in the world. Multipurpose (for fodder, fuel, pulp, immature shoots and seeds for human consumption, shade and hedge). Yields of 50 t/ha (cut at ground level) and 40 t/ha (at 75cm) have been reported. Despite inconsistent figures 10–20 t/ha DM can be expected.
- ***Reproduction:*** Self-pollination prevails, although cross-pollination is possible; prolific seeder.
- ***Special merits:*** Vigorous plant of high yield and high-quality protein; leaves and thin twigs well-accepted by livestock.

Figure 8.24. Sesbania (*Sesbania sesban).*

Sesbania (*Sesbania sesban* Scopoli)

- ***Botanical characteristics:*** Relatively short-lived (6–7 years) shrub or small tree up to 6 m high (Figure 8.24).
- ***Adaptation:*** A wide range of adaptation, 200–2400 m.a.s.l. Grows best under moisture-stress free conditions, versatile in its requirement.
- ***Herbage yield potential:*** The best fodder tree second only to Leucaena.
- ***Cultivation:***
  - ♦ Propagation: By seed; seed must be scarified by immersing the seed in concentrated sulphuric acid for 30 minutes; also mechanically by using drum scarifiers. Plant seedlings at the onset of first rains. Spacing: variable according to uses:
    - Continuous hedges: 50 seeds/m or 2–3 seeds/hole at 0.5 spacing.
    - Alley cropping: up to 4 m or more between alleys.
- ***Utilization:*** Cut at 0.5–1.0 m height at 6–8 week intervals; use as supplement (20–30%) with crop residues. There is no toxicity if higher levels are fed.

- ***Reproduction:*** Cross-pollinated; prolific seeder.

Pigeon pea (*Cajanus cajan*)

Figure 8.25. Pigeon pea (*Cajanus cajan*).

Botanical description: Erect shrub or short-lived perennial herb (2–3 years) up to 1–4 m high (Figure 8.25).

- ***Adaptation:*** Adapted to arid and semi-arid environments. Favors warm climate, drought-resistant but susceptible to frost; can grow at 500–800 m annual rainfall; tolerates acid soils.
- ***Cultivation:***
  - ♦ Propagation: Established from seed sown at the rate of 4–6 kg/ ha or 1–20 kg/ha broadcast. Spacing: about 1 m apart between rows.
  - ♦ Treatments: Seed scarification and inoculation are not necessary.
  - ♦ Fertilizer requirement: Responds favorably to P fertilizer but negatively to N.
- ***Utilization:*** Dual-purpose crop for food and forage. For forage: cut when the first pods begin to ripen at 50–25 cm height.
- ***Productivity:*** Up to 12 t/ha DM
- ***Reproduction:*** Essentially self-pollinated and self-fertilized, but cross-fertilization by bees can occur.
- ***Special merits:*** Dual purpose crop; tolerant to soil acidity. Can be used as a semi-permanent, perennial component in alley cropping systems. Grown as hedgerow for windbreaks, and as ground cover or shade cover for establishing plantation crops, e.g., coffee. Good nitrogen fixation makes it a useful green manure.

Figure 8.26. Tree lucerne (tagasaste) (*Chamaecytisus prolifer*).

Tree Lucerne (Tagasaste) (*Chamaecytisus prolifer*)

- ***Botanical characters:*** Shrub or small tree (Figure 8.26).
- ***Adaptation:*** Wide range of adaptation from low to 3200 m.a.s.l. altitude, the only browse legume adapted to higher altitude highlands of Ethiopia. Tolerates infertile and acid soils and droughts once established. Needs good drainage.
- ***Cultivation:***
  - ♦ Propagation is by seed sown directly or by transplanting. Spacing 30–50 cm between plants.
  - ♦ Seed treatment necessary. Dip in boiling water for 5–10 minutes.
  - ♦ Inoculate if possible.
- ***Utilization:*** Establishment is slow. Commence cutting in the second year. Cut at 1 m height every 6–8 weeks. Use as a supplement to crop residues.

- ***Reproduction:*** Seed yield up to 0.5 kg/tree.
- ***Special merits:*** Useful as a multipurpose fodder tree for cut-and-carry fodder, ornamental, windbreak and for bee forage, fuel wood and biogas. Tagasaste can be planted as a hedge and also has potential for alley-cropping systems. Grows well on light, well-drained sandy soils on slopes and hillsides. It has a wide range of adaptability to soil pH (4.0–8.5). Tagasaste grows well up to altitudes approaching 3,000 m in the tropics and is one of the few fodder trees that can withstand frost as low as -9ºC in the tropical highlands (Cook *et al*, 2005).

Figure 8.27. Fodder beet grown under supplementary irrigation and farmyard manure application at Debre Zeit Research Center.

8.3.6. Root fodder crops

Fodder beet (*Beta vulgaris*)

- ***Botanical characteristics:*** Biennial tuberous herb (Figure 8.27).
- ***Adaptation:*** Highland crop (1800–3000 m.a.s.l.). Needs long growing season, 5–7 months of 750 mm rain or over.
- **Soil*:*** fertile sandy soil, avoid water logging.
- ***Yield potential:*** Under well-fertilized and irrigated conditions at Debre Zeit Research Center, each tuber had a fresh weight of 37.5 kg in about 5–7 months growth period.
- ***Cultivation:***
  - ♦ Propagation:
    - Direct seeding 5 kg/ha; sowing depth, 2 cm; plant in rows 40 cm apart and thin to 20–25 cm between plants when two real leaves have been developed.
    - Transplanting from nurseries planted 1–2 months ahead of planting time gives it a competitive advantage over weeds.
  - ♦ Seed production is stimulated by cold: Altitude of 2500–2750 m.a.s.l. is suitable.
  - ♦ Fertilizer: Fodder beet is a heavy feeder and thus it should be planted near an animal corral for easy application of manure.
- ***Utilization:*** Used in intensive management systems in dairy or fattening enterprises. Beets must be chopped before feeding.
- ***Reproduction:*** Seed production is stimulated by frost. In Ethiopia, areas with altitudes of 2500–2700 m are suited for fodder beet seed production. Seed yield is about 400–500 kg/ha.

8.4. Forage Seed Production

The major impediments to the progress of improved forage development include:

- Poor availability of planting material both in amount and diversity.
- Imported seed is expensive and at times difficult to obtain on time. For example, a kilo of alfalfa seed costs more than Birr 100.00 (1 US$ = 9.2 Birr), a price that a subsistence farmer cannot afford.
- Certain forage legumes cannot be successfully grown without specific inoculum, which is not readily available and difficult to handle.

8.4.1. Suggested institutional arrangement to promote forage seed production

Establishment of a non-profit forage seed project

The demand and supply of forage seed has never been predictable. Sometimes, there is a demand for thousands of quintals, while at other times, thousands of quintals of seed are stored for long periods for lack of market. Therefore, until improved forage utilization is well-adopted and the demand becomes predictable, regional forage seed enterprises similar to the Ethiopian Seed Enterprise (but neither profit-making nor obligatory expense-retrieving) must be established. The enterprises can gradually pull out as demand increases and private investors get interested.

Promotion of seed producer cooperatives

In selected areas where demand for improved forage seed is high and the environment is convenient for seed production, farmers may be organized into cooperatives where they pool their land to produce seeds of elite forage crops to sell to users elsewhere. Assistance should be sought from regional governments for technical backstopping and providing facilities: foundation seed, farm inputs, irrigation and access to markets.

Site selection

Forage seed production sites must be accessible and as much as possible located in lands suitable for cultivation, irrigation, and fertilizing. Other ecological requirements for a suitable site include:

- A climate and soil suitable to most elite forage species or at least the target species.
- The area must be free of noxious weeds, pest and diseases.
- Adequate space to make isolation possible for multiplying cross-pollinated species.
- Adequate growing season with ample rainfall.
- Access to irrigation to make multiple harvests possible and guarantee against fluctuating rain distribution.
- Free from frost: ensure the site is not located in a frost-pocket in the landscape.
- Sunny weather during flowering to initiate reproductive development, flower opening, pollination and facilitate seed harvesting.

Seedbed preparation

A clean and firm seedbed is necessary to ensure a strong and dense plant population that will compete successfully with weeds and produce high quantity and quality seed.

Seed quality and treatment

Follow suggested procedures in the section under forage establishment.

Sowing operation

Small-seeded forages are usually broadcast on a fine and firm seedbed and then trampled by sheep and goats to ensure better soil–seed contact. If collection of shattered seed is expected for very small-seeded species, the seedbed has to be rolled lightly and leveled. Larger seeds are drilled in rows or buried by driving sheep and goats back and forth. Forage seed crops are usually drilled in rows wide enough (60–122 cm apart) to make weeding and harvesting operations easy, and seeding rates are

often low (2–7 kg/ha).

Fertilization

For grass-seed crops, nitrogen is the most limiting soil nutrient. Generous amounts of nitrogen, often in combination with phosphorus, substantially increase seed yield of grasses (100–150 kg/ha diammonium phosphate). Nitrogen application varies with soil fertility, moisture level and the type of species sown. Legume seed crops are independent of soil N levels as long as they effectively fix atmospheric nitrogen.

Weed, pest and disease control

- Weeds affect seed yields and quality. Efficient weed control reduces contamination with weed seeds during harvesting.
- Thorough and repeated cultivation, hand weeding, use of herbicides, crop rotations, etc., offer a reasonable degree of weed eradication.
- Pests like mole rats, porcupines, wild herbivores and insect pests can be a threat to pasture seed crops.
- Insect larvae of the Sesbania beetle (*Mesoplatis orchoptera*), for example, can devastate plots of stands overnight.
- Control measures against such serious insect pests could be expensive at an advanced level of infestation and thus prompt spot-spraying at the earliest detection with recommended chemicals is necessary.
- Diseases, especially fungal, are more serious in grasses than in legume seed crops.
- Disease-control measures in forage crops are based on the use of resistant crop varieties and employing pre-emptive cultural practices such as:
  - ♦ crop rotations
  - ♦ burning of infected plants
  - ♦ solar treatment of soil
  - ♦ use of clean and treated seed

Harvesting

- Efficient timing and harvesting techniques result in high quality and quantity of seed production.
- Species in the genera *Panicum* and *Brachiaria* are the most difficult in this regard where there is premature shattering or seeds are harvested by birds while still green.
- Techniques of determining optimum harvest time vary with the species. One has to closely watch the change in color, ease of removal from the rachis (or pod in legumes), and seed hardness.
- Grass species such as *Brachiaria* require sweating — a procedure whereby the upper portion of the crop, along with the inflorescence, is mowed at the right stage of seed development and heaped immediately after harvest and left under a shed to 'sweat' to assist the final maturation of the caryopsis. Thereafter, the material is gently beaten to separate the seed from the sheaves and cleaned.

Harvesting implements

At the smallholder level, the available simple and practical techniques are:

- Hand-picking of the inflorescence or pod.

- Shaking the sheaves and collecting the seeds falling on a sheet of canvas placed underneath the crop.

Cleaning and drying

The drying process must be done under a shed to protect the seed from direct sunlight. Grass seeds are more sensitive to drying processes than legume seeds and should be dried slowly under a shed to maintain high viability. Legume pods and grass inflorescence heaps should be turned regularly once a day to ensure uniformity of drying.

After drying, the material could be threshed by trampling with feet, lightly pounding with local wooden mortar (*mukecha*) or beating with sticks. Final cleaning can be done traditionally using a grass plate (*sefeid*) and sieve (*wonfeet*).

Storage

Cleaned and properly dried seed must be stored in a cool, dry place. Seeds may be stored in cloth bags which provide good aeration. For both grass and legume seeds storage in plastic bags should be avoided. Seed storehouses should have high roofs for efficient ventilation and to keep the temperature as low as possible. Vent holes around the wall above the ceiling will provide movement of hot air out of the space in between the ceiling and iron roof. The seed storeroom should be clean and free from insects and rodents. Generally, seed must be kept at a room temperature not exceeding 15^{o}C with a relative humidity below 45% for short-term (2–3 years) storage.

8.4.2. Suggested sources of foundation seed

Foundation seed for initiating forage seed multiplication may be found at/through one of the following:

- National and international research institutes
  - ♦ Ethiopian Institute of Agricultural Research
    - Holetta Research Centre
    - Debre Zeit Research Centre
    - Kuklumsa Research Centre
    - Bako Research Centre
  - ♦ International Livestock Research Institute
  - ♦ Farmer-to-farmer seed exchange
    - The most reliable and sustainable source for the smallholder farmer.
    - Organize and create awareness among farmers to raise and exchange forage seeds the same way they exchange food crop seeds.
  - ♦ Cost-retrieving projects at the *woreda* level.

Seed producers' cooperatives organized at the *woreda* level may operate seed production nurseries for elite forage species and varieties and sell the seed at a reasonable price just to cover the cost of production The *woreda* Ministry of Agriculture offices, besides organizing and monitoring the cooperatives, may offer technical training and guidance as to where foundation seed and other farm supplies can be obtained.

Transferable Message

1. Select progressive farmers to demonstrate your choice of interventions.
2. Organize a training session and show them the different methods of forage seed production.
3. Organize demonstration visits by other farmers and encourage discussions on the practice.
4. Organize forage-seed producers' cooperatives and seed supply chains, including exchange schemes for sustainable forage seed production.

8.5. Range Management

8.5.1. General characteristics of rangelands

Rangelands are areas where both wild and domestic animals graze on uncultivated vegetation. Rangelands do not support normal crop production due to one or more of the following environmental limitations.

- Unfavorable climate: particularly erratic rainfall. Most rangelands receive below 500 mm total annual rainfall, or sometimes as low as 200 to 350 mm.
- Poor soil:
  - Ruggedness, stone outcrop
  - Very thin soil horizon
  - Poor fertility
  - Excessive mineral accumulation, e.g., carbonates, sulfates, fluorides
- Topographic/landscape limitations:
  - Gully
  - Sloping
  - Waterlogged.

Such lands are typically referred to as marginal lands. The best use of such wastelands in agriculture is usually as rangelands for multiple benefits of:

- livestock production,
- game animal sanctuary, recreation, tourism,
- watershed, and
- conservation of biodiversity.

8.5.2. Objectives of range management

Range management is the science and art of maintaining maximum range forage production without affecting other resources or uses of the land. The central objective of range management is sustainable production of domestic and wild animals in a manner that protects the land.
The specific objectives of range management are listed below.

- Protect, improve and promote the continued welfare of the range soils, vegetation and animals.

- Optimum production of animal products (meat, milk, hides, wool/hair), wildlife and water (from watershed).
- Provide recreational sites.
- Conserve biodiversity of plant and animal genetic resources.

8.5.3. Distribution and features of the Ethiopian rangelands

Ethiopian rangelands are located around the periphery of the country and mostly found below 1500 m.a.s.l. They cover 61–65% of the total area of the country, are generally arid and semi-arid and are home to 12–15% of the human and 26% of the livestock population. There are three recognized rangelands that have been subjected to rangeland development programs.

- The Southern Rangeland (Borana Rangelands)
- The Southeast Rangeland (Jijiga and Bale Rangeland)
- The Northeast Rangeland (Lower Awash / Afar Rangeland)

There are humid and sub-humid rangelands in Benishangul-Gumuz (Metekel), and Gambella, along the frontier with the Sudan that have relatively abundant forage resources for a major part of the year. The major constraint in these rangelands is disease and parasite prevalence, especially Trypanosomiasis.

8.5.4. Common features of the Ethiopian rangelands

- Most rangelands are located in drier parts of the country, i.e., the Rift Valley and adjoining lowlands.
- They are arid or semi-arid lands, generally receiving below 600 mm annual rainfall.
- They share the same vegetation zone: the Somali-Massai Acacia/Commiphora woodland and bush land, which is an extensive vegetation zone covering East and Southeast Africa.
- They consist of arid soils (Aridosols), which are generally poor in fertility and usually contain excessive salts (saline-sodic soils).
- Topographically, they are usually low-lying plains below 1000 m altitude, with hot weather conditions.
- Pastoral and agro-pastoral modes of animal production predominate.

8.5.5. Constraints related to effective use of rangeland resources

- Keeping excessive numbers of animals for prestige and security against losses due to epidemic diseases.
- Lack of alternative feed resources such as crop residues, predisposing rangelands to overgrazing.
- Diseases and parasites.
- Lack of permanent water supply.

8.5.6. Livestock development prospects

There are several strategies for developing rangelands to increase livestock production. A few are listed below.

- Limit livestock numbers to match the available feed resources.
- Develop efficient grazing systems to maintain plant composition in favor of useful plants for grazing.

- Eliminate undesirable plants to give a competitive advantage to herbaceous grass and legume species and browse trees and shrubs.
- Reseed/over-sow range units that have favorable amount and distribution of rainfall with desirable forage species.
- Ensure fair distribution of watering facilities to ensure more equitable grazing pressure over the grazing resource.
- Develop efficient extension and veterinary services.
- Establish feedlots to increase offtake.
- Develop water-harvesting techniques, e.g., introduce earthen-pond construction and other techniques.
- Develop infrastructure: roads, veterinary clinics, marketing facilities, farmer training centres, etc.

8.5.7. Monitoring and proper utilization of rangelands

Primary indicators and the theory of proper use

The first indicator is too heavy grazing, beyond the growth capability of plants. When the best plants are overgrazed, the manager should take this as a sign for need of precaution and take appropriate measures. Improvements can be made by not grazing primary choice plants in excess of the permissive 50% of production for the season.

The ***theory of proper use*** states ***'never graze more than 50% by weight of those better plants by the end of the grazing season'***.

The following need to be known to implement this theory:

- The primary choice plants.
- What makes up 50% of current production, usually done by field sampling.

Monitoring of range forage using key site and key species

Key site is a grazing area which livestock instinctively prefer to graze first, and from where they consume the most forage throughout the grazing period. Key range site serves as a standard measure of the current use and management requirement of the entire range.

Key species are plant species that are more attractive to livestock than any other species in a range. They are high quality forage of a climax decreaser category (components of the climax vegetation that decrease in abundance with increasing grazing intensity). Key species serve as a unit of measure as to how to use the entire range.

Judging range sites using key site and key species

Key range site and key species can be used as a unit of measure in the utilization and management of a range. The principle is that if the most favored range site, along with the best forage species in the range, has not deteriorated neither will any other site in the range.

Selecting a key range site

A key range site is a site which is grazed the hardest and deteriorates rapidly if not properly managed.

It contains one or possibly two forage species that are a first-choice for grazing. A key site should be at least 25% of the total area of the range unit and must be far from high livestock concentration points, e.g., watering place, homestead, travel-ways. It must be accessible and grazed by choice through most of the grazing season or year, plus able to provide quality forage over most of the grazing period.

Once recognized, the key range site, with the 1 or 2 key species, provides a unit of measure for ''the true grazing value'' of a range unit.

Selecting a key species

As much as possible, the key species must be:

- a climax-decreaser type of high forage quality;
- able to respond to better management;
- relatively abundant, accounting for at least 20% of the forage;
- accessible to alleviate pressure grazing; and
- must be vigorous enough to insure normal development.

Judging the range site

Once the key site and the key species are determined, they then serve as a standard unit of measure for the entire range, and the subsequent measures to be taken. The manager (or group of livestock producers using the range) concentrates his observations on the key site and the degree of use that is made of the key species. Based on the response to use of the key site, the necessary adjustment in the management system is undertaken.

8.5.8. Over-sowing natural pastures

Over-sowing or partial reseeding is a technique of improving range forage, whereby adapted and productive pasture species are sown into the existing vegetation. The objective is to improve the yield, quality and palatability of the native pasture.

General considerations

Reseeding can be an expensive and risky undertaking in the sense that rangelands are vast areas of land, meaning that the operation will require high expenditure in terms of labor and planting material. In addition, it requires a change in grazing management, which is usually difficult to achieve. Therefore, the following should be considered before over-sowing is undertaken.

- Ensure that there are no cheaper techniques and reseeding is absolutely essential.
- Investigate all other options, viz.:
  - ♦ better livestock distribution
  - ♦ better system of grazing
  - ♦ reduced stocking
- Ensure that the grazing land can be controlled; otherwise reseeding should not be started until proper grazing management can be assured.
- Ensure that the grazing land meets the minimum growth requirement. Lack of success has been recorded in East Africa in reseeding areas receiving <375 mm of annual rainfall, but a high success rate in areas receiving a minimum of 625 mm.

- If reseeding is necessary, select the most suitable sites (better soil fertility and soil moisture) for reseeding first; inappropriate site conditions may increase the risk of failure. Deep fertile soils on level-to-gently slopping land are preferred. Shallow or rocky soils rarely justify expensive seeding.

Selection of species

Native species found on sites similar to those being reseeded are preferred to exotic ones in a reseeding program. A grass species for reseeding must be:

- Sufficiently drought-tolerant to survive and perpetuate itself and provide good quality herbage of fair or good grazing value.
- Easy to establish.
- Able to produce an adequate amount of viable seed which can be easily harvested.

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Sowing procedures

Seedbed: Make some form of simple seedbed preparation. The more complete the cultivation, the better the stand. Consider one or more of the following techniques:

- burning
- heavy grazing
- light cultivation

Timing: The most desirable time to seed non-irrigated areas is immediately before the season of the most reliable rainfall, and when temperature is favorable.

Plant diversity: A mixture of grasses, forbs, and shrubs will better meet the multiple needs of the farmer user (feed, fuel wood, erosion control, etc.). A pure stand has a risk of failure due to insect and disease infestation.

Seed rate and plant density

- Plant at double the usual seed rate.
- Aim at achieving one established plant of each species in each 0.9 m^2. As a general rule, at least one shrub and 10 desirable herbaceous plants per 9 m^2 should be present following revegetation.
- Ensure a good cover of soil or chaff after sowing.

Grazing control after reseeding

Reseeding of rangelands is useless unless stock numbers can be controlled. It is especially important to protect young seedlings from grazing for one or more years to allow grasses to become fully established and to reseed, thickening the stand.

Subsequent grazing should also be controlled, where the recommended procedure is to remove livestock from reseeded areas when no more than 50% of the weight of the herbage has been consumed. (The 50% use level can be determined by clipping an intact and grazed plant of the 'key-species' category, taking the weight difference and expressing as percent of intact plant weight).

Recommended species for reseeding tropical ranges

Species closely related to the native ones will have high chance of survival. A mixture of grasses,

herbaceous legumes and trees is preferred to a single species (Table 8.5.). For details of species characteristics and their specific applications, please refer to Appendix Table 8.1.

Table 8.5. Recommended species for reseeding degraded grazing lands.

Grasses	Herbaceous legumes	Trees
Bothriochloa insculpta	*Clitoria ternatea*	*Acacia decurrens*
Bothriochloa pertusa	*Desmodium intortum*	*Acacia siberiana*
Cenchrus ciliaris *	*Desmodium uncinatum*	*Calliandra calothyrsus*
Cenchrus setigerus	*Lotononis bainesii*	*Leucaena leucocephala*
*Chloris gayana**	*Macrotyloma axillare*	*Gliricidia sepium*
*Chloris roxburghiana**	*Neonotonia wightii*	*Sesbania sesban*
Echnochloa haploclada	*Stylosanthes guyanensis*	*Atriplex numularia*
Eragrostis curvula	*Stylosanthes scabra*	*Atriplex halimus*
*Eragrostis superba**	*Stylosanthes humilis*	
*Leptochloa obtusiflora**	*Stylosanthes hamata*	
Panicum coloratum	*Stylosanthes fruticosa**	

* Indigenous species

8.5.9. Grazing management and efficient use of rangeland resources

Grazing management is the manipulation of grazing animals to accomplish desired results in terms of animal, plant, land, or economic responses.

Aims

- To provide a supply of nutritious herbage over the growing season at a low cost.
- To avoid wasting herbage and inefficient utilization by the animal.
- To maintain the productive capacity of the sward.

Distributional control of animals

Distributional control aims to reduce animal movements and thus avoid destruction of the range by excessive grazing and trampling. The following methods can be employed to achieve uniform distribution of animals.

- Fair distribution of watering areas.
- Development of boreholes (wells) at several sites in the range.
- Use of fences to help control animal movements.
- Provision of salts (mineral licks) at different sites.
- Employing controlled grazing system (described under grazing systems) appropriate for the more intensively managed rangelands (ranches).

Basic principles of controlled grazing for natural pastures

- Provide rest or recovery period between grazing cycles.
  - ♦ During recovery, plants build up nutrient reserves that ensure continued vigor.
  - ♦ There is a need to take care of palatable species by controlling scrub and brush growth to avoid competition.
- Avoid heavy defoliation of key species during their active growing period.

- ♦ Plants use up to ¾ of root food reserve (when rate of carbohydrate production is greater than the rate of demand) to produce new vegetative growth until the plant nears flowering.
- ♦ Heavy defoliation during active growth will result in the valuable perennials to be replaced first by increasers, then by invaders and finally by bare ground.

As a precaution, stocking rate should be highly reduced or grazing totally stopped when no more than 50% of the weight of herbage has been consumed.

Grazing systems

The objectives of proper grazing systems are to:

- maintain a favorable balance between herbage species;
- maintain high production of good quality forage for the longest possible period;
- achieve efficient utilization of the forage produced; and
- achieve high rates of animal production.

Continuous grazing is an extensive system of grazing in which animals remain on the same pasture area for prolonged periods. Continuous grazing is a normal practice on rangelands and tropical savannahs where, in most cases, the low carrying capacity of the grazing resource may not allow employment of other intensive systems of grazing.

In continuous grazing systems, pasture areas are generally undergrazed during the rainy season and overgrazed during the dry season, with a consequent deterioration of the sward. A low stocking rate should be maintained to maintain the grazing system. Major disadvantages of the system include a build up of tick and nematode infestation and a lack of grazing distribution.

Rotational grazing is an intensive system of grassland management practiced on improved permanent or lay pastures. The grazing area is subdivided into a number of paddocks, usually at least six, and the animals are moved systematically from one to another of these in rotation. Each paddock is grazed for a period of 3–7 days, the length of the grazing period depending on stocking rate (often high, up to 25 cow equivalents/ha) and herbage growth rate.

The aim of this system is to use the pasture when it is young and highly nutritious and then to allow an adequate recovery period (See Figure 8.28).

1 →	2 →	3 →	4 →	5 →	6
3–7 days					18–42 days rest↓
↑←	←	←	←		← ←

Figure 8.28. An alfalfa pasture divided into 6 paddocks.

Strip grazing is a more intensive method of rotational grazing based on the use of electric fence, which is moved forward once or twice a day.

Advantage

- Selective grazing is minimized, resulting in more uniform consumption.

Applicability

- Highly productive and nutritious pasture.
- High-producing animals.

Deferred grazing is the setting aside of certain pasture paddocks for use at a later stage, e.g., standing hay.

Advantages

- Enhanced plant vigor.
  - ♦ Improved self-regeneration from fallen seed.

Soiling or zero grazing is the feeding of cut crops to housed stock.

Advantages

- Efficient herbage utilization.
  - ♦ No loss due to trampling.
  - ♦ Uniform herbage intake.
  - ♦ Control of bloat by wilting lush pasture.

Disadvantages

- High cost for labor or machinery.
- Bedding required for housed stock.
- Manure disposal is laborious.

Strategies during drought

There are a number of drought-mitigation strategies that pastoralists need to consider in anticipation of catastrophic droughts, which, nowadays are reported to recur every 2–3 years.

- Adjust stocking rate to the carrying capacity of dry years. Reduce stocking rate early.
- After drought, increase stocking rate gradually over a 1–3 year period.
- Plan for water availability; graze areas with limited water reserves first.
- Periodically rest pastures or delay grazing. Lengthen pasture rest periods during slow or no-growth times. Plants can withstand severe grazing if followed by proper rest periods. These rest periods allow plants time to replenish tissues above and below the ground.
- Cull more heavily before the market becomes flooded with animals.

Transferable Message

- Understand the traditional grazing management practices of the community.
- Build upon the traditional practices and convince the community to strengthen the practices of efficient utilization of communal grazing resources.
- Use community leaders to implement grazing land improvement practices.

8.6. Systems of Forage Utilization and Conservation

Systems of forage utilization fall into two major categories:

- Immediate use
  - ♦ grazing
  - ♦ green chop
- Conserved forage
  - ♦ standing hay
  - ♦ hay
  - ♦ silage

The objective is to maximize the utilizable yield of the forage crop. In deciding the usage system, one has to consider the following:

- Type and persistence of the forage: Species with persistent and strong root systems are preferred for grazing while fast-regenerating and erect-growing ones are suitable for haying.
- Type of the farm enterprise: e.g., green chop/cut-and-carry systems are suitable for dairying and fattening.
- Potential maximum forage yield versus expected loss in the type of usage: If low herbage yield is expected for some reason, wastage due to conservation must be avoided, e.g., silage has the disadvantage of wastage compared with hay.

8.6.1. Grazing

Grazing is the most common and the cheapest utilization method for both natural and sown pastures. In the case of sown pastures, prior to establishment, species have to be selected for palatability, accessibility, nutritive value and their ability to tiller profusely, resist defoliation and trampling, and respond to fertilization,.

Advantages

- Effective recycling of nutrients.
- Possible manipulation of transfer of nutrients from day grazed paddocks to night corrals via manure.
- Requires less labor and is less time-consuming.

- Animals can select their diet in both quality and quantity.

Limitations

- Loss of material due to trampling, fecal contamination.
- Selective grazing.
- Early maturity, leading to stemmy stands.
- Difficulty in clay soils, i.e., excessive plant damage and crusting.
- In some forage species, reduced content of soluble carbohydrates and subsequent production of toxicity of prussic acid (HCN), nitrite, and magnesium tetany is observed on cloudy days.
- Requires controlled grazing — fencing or shepherding.

Grazing capacity of native pastures

Grazing studies on native pastures at Holetta Research Center indicate that well-managed natural pastures could be stocked at 2 Tropical Livestock Units (TLU)/ha from July to end of December and 10 sheep/ha for year-round grazing with hay supplementation during the dry season. Cutting or grazing at 2-week intervals reduced total dry matter to about 50% of that obtained from a 4-week grazing interval, indicating that a rest period of at least 4 weeks was important.

8.6.2. Green chop/cut-and-carry system

Green chop is cutting green forage in the field and transporting it to the livestock (also called cut-and-carry system). It is a common practice in areas where grazing land is limited, e.g., traditional feeding of tethered beef cattle in Hararghe (Eastern Ethiopia); thinned maize plants; garden weeds; chat (*Catha edulis*) leftover ('*geraba*'), etc.

A cut-and-carry system involving improved forages is more economical for commercial dairy farms and feedlot cattle finishers, and holds advantages for small ruminant feeding as well. When the green chop feeding operation aims to collect animal excreta in a confined space and return it to the land to build soil fertility, it is called *soilage*.

Advantages of cut-and-carry system

- High recovery of plant material as it is not lost by trampling and contamination.
- Little selectivity because the system allows for rationing of animal intake.
- Feeding can be arranged at a convenient site.
- The excreta can be utilized as farm yard manure and applied where it is most required or composted.

Limitations of cut-and-carry system

- The continued removal of plant material could lead to deficiencies of soil nutrients, particularly potash.
- Requires high labor for cutting, chopping and transporting.

8.6.3. Standing hay (deferred feed)

Deferred feed is the cheapest and easiest way of conserving forage, as it does not require machinery or physical handling. It is a common traditional practice in rural areas of Ethiopian highlands where certain village communities by common consent defer the bottomland communal grazing lands for use during the dry season. It is also practiced by large ranch holders and pastoralists in the drier areas. On bottomlands, aquatic and semi-aquatic grasses such as *Paspalum scrobiculatum, Urochloa colona, Echnochloa pyramidalis, Pennisetum reparium, Pennisetum glabrum, Pennisetum salifex* and others can maintain a reasonably high level of nutrient content at maturity.

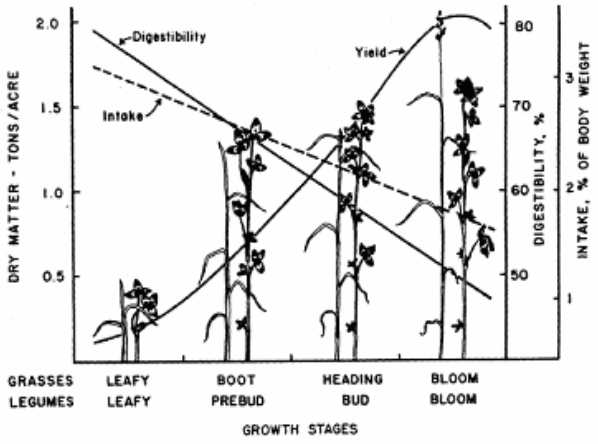

Figure 8.29. The relationship between the growth stage of the plant and yield, digestibility and intake

Limitations

- High risk of fire hazard.
- Possible occurrence of light rainfall where the culms and leaves become moldy, called "blackening", making the standing hay useless as forage.

8.6.4. Stored fodder

Storing fodder is an important operation in livestock farming to bridge the gap in feed supply during dry seasons, recurrent drought hazards, and during the cropping season when grazing land becomes scarce. The aim of conserving fodder is to harvest the crop at its maximum nutrient content and minimize losses while at the same time maintaining its acceptability to the animal. The time of harvest may be earlier if higher protein content is required or later if maximum dry matter is desired. Therefore, time of cutting is a compromise between quality and quantity of the harvested forage. Fodder is usually conserved as hay and sometimes as silage especially for dairy business.

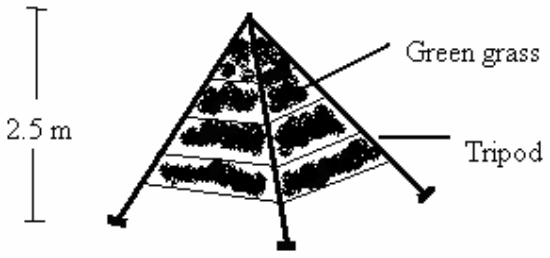

Figure 8.30. Hay making tripod.

Hay

Hay is feed produced by drying green forage to a moisture content of 15% or less. It is the most commonly stored fodder on the farm and used to level-out the feed supply throughout the year. Hay is generally the most convenient processed form of storage and an appropriate forage conservation method for small-scale farming. Well-processed hay is the cheapest form of feed during the non-grazing season.

Hay should be made at the optimum date to maximize yield and still fulfill the nutrient needs of the livestock. It is best cut early in the flowering stage. When cut earlier, the nutritive value is higher but yield is lower and the moisture content is too high for easy curing. If cut after flowering, the increased yield does not compensate for decreased palatability and nutritive value. The first cut of hay from a crop is usually of better quality than subsequent cuttings. The relationship between the growth stage of the plant and yield, digestibility and intake is shown in Figure 8.29.

Problems in haymaking vary according to the crop, climate and prevailing weather at harvest:

- Sub-humid and humid conditions:
  - Slowness of drying (the aim is to dry the crop as quickly as conditions will allow to avoid loss by spoilage).
- Hot, dry conditions:
  - Too rapid drying.
  - Shattering of the finer parts of the plant.
  - Bleaching, with consequent loss of carotene and vitamins.

Curing of hay

The grass should be dried quickly and not unduly exposed to the sun. Rain can cause leaf losses and leaching of nutrients. The loss of nutrients in haymaking is about 25% for temperate pasture grasses and 22–25% for tropical pasture grasses. Tropical pasture grasses generally take 50–55 hours of drying in good weather and 70–75 hours in poor weather.

Hay-making steps for the smallholder

- Harvest the plant at the optimum stage of maturity to maximize nutrient yield per unit of land. Most forages should be cut just after reaching an early bloom stage of maturity.
- Start harvesting after the dew has evaporated from the green material in late morning.
- Cut and place the material into small heaps about 20–30 cm high and turn the heap frequently in the sun to encourage quick drying. Raking (turning) should be completed before it is completely dry to avoid excessive shattering of leaves and overexposure to the sun. It is better if raking is done when the dew is on, especially when high leaf-shattering is expected. If the weather is humid or rainy, place the cut material off the ground using a home-made tripod with three poles to facilitate drying (Figure 8.30).
- The optimum permissible moisture content for storing hay is around 18–22%.
- When the initial moisture has evaporated, the material can then be placed under the roof of any shed, and allowed to dry completely away from the sun. Where a hay shed is not available, collect the cured hay as soon as it is sufficiently dry and store as stacks, which should be fairly compressed and loaf-shaped or conical shaped to shed rainwater (Figure 8.31).

Figure 8.31. Hay in carefully built and thatched stacks.

- Alternatively, a “baling box” can be used to make a tightly packed bale, tied with string. This will reduce wastage from shattering and make storage easier. Figure 8.32 shows the steps of baling roughages using a baling-box at a small-farm level. This is a procedure even the smallest farmer can use.

- In places with a long and severe dry season, tree legumes may lose their leaves during the driest period. Instead of being wasted, the leaves can be collected, dried, and used as a protein supplement. Herbaceous legumes such as desmodium can also be dried and stored. Legumes should be cut and carried to the place of storage when green to avoid losses from the shattering of leaves. Tree legume branches should be cut and the leaves allowed to dry on the branch. They can then be easily stripped off the branch and stored in a sack for later feeding.

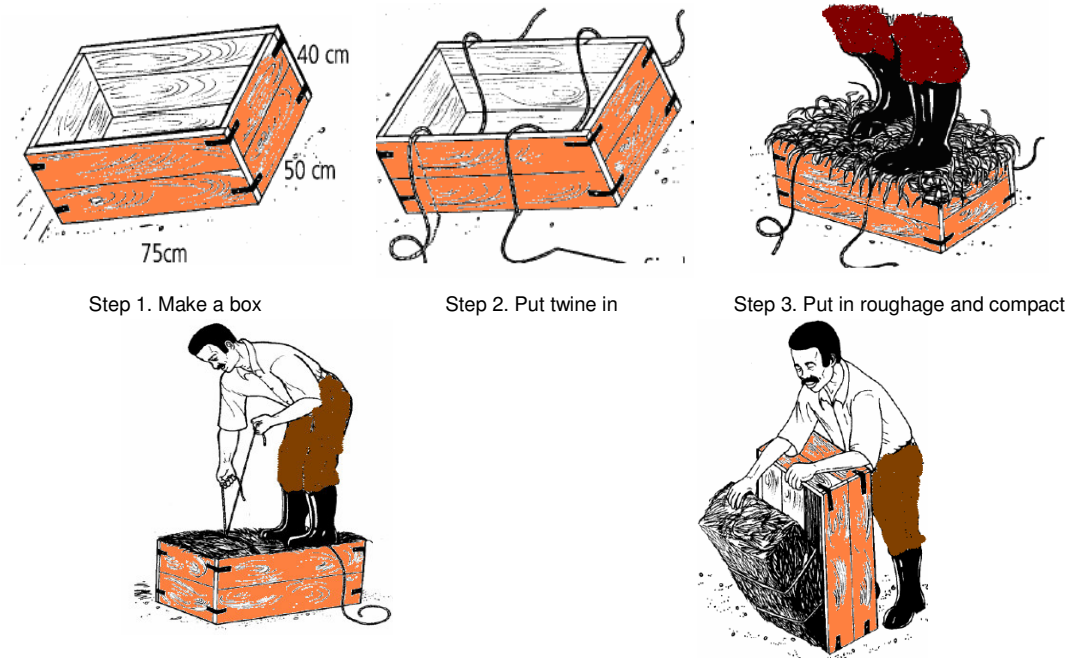

Figure 8.32. Steps in baling roughages using a hay-box (Adapted from Massawe et al.).

Harvesting implements

Machinery

Specialized dairy or beef industries use mechanical harvesters, which are tractor-mounted and driven by a power-take-off shaft. There are two types of such harvesters: the reciprocating blade mower (line mower), and the rotary slasher blade mower. The latter seems durable and efficient, especially for harvesting natural pasture from rough surface.

Hand tools

Machinery, even small-scale, is generally beyond the economic capacity of the subsistence farmer. The most widely (almost universally) used hand tool for harvesting grain and pasture is the sickle. While the sickle is more commonly used, the scythe is a more efficient hand tool for harvesting forage, cereal crops, and slashing weeds (Figure 8.33).

The scythe can mow at about five times the speed of the sickle. However, it requires:

- a sward that is reasonably free from obstacles
- to be kept very sharp by regular whetting throughout the day,

- some skill to use the scythe, and
- both hands for usage.

Forage crops are mown with wide cuts, advancing in a straight line and cutting away from the standing crop. A scythe cuts about 2½ times the length of the blade, so a 75 cm blade will mow a swath 175 cm wide if the crop is not too heavy, with the width reduced in a denser crop. On good, level, stone-free ground, about 500 m^2 can be mown per hour.

The scythe is not widely known or used in Ethiopia except in some areas near Addis Ababa, including Sululta and Holetta. In these areas, the scythe (locally known as *falch*) is widely used to harvest natural pasture for making hay. Hay is a source of cash income (commodity) in these areas and it is common to see a number of donkeys transporting haystacks to Addis Ababa, where they are sold to small-scale animal farms.

a. Parts of a scythe b. How to use a scythe c. Field mowed using a scythe

Figure 8.33. Mowing forage using a scythe.

Common losses of haymaking

- Leaf shattering
  - ♦ Leaves contain 2 to 3 times as much protein as stems.
  - ♦ Leaves are also richer in carotene, B-vitamins, minerals, and energy.
- Heat damage
  - ♦ Hay stored with excess moisture (25–35%) may tend to mold, and contain bacterial growth and heat.
  - ♦ Hay stored dry reaches a maximum of about 29°C.
  - ♦ Above about 49 °C, nutrient destruction or binding occurs. Proteins are most vulnerable to heat damage.
  - ♦ When temperature of stored hay reaches 71–73°C, there is a danger of spontaneous combustion.
- Fermentation/plant cell respiration
  - ♦ Converts sugars and starch to CO_2 and H_2O representing a loss of nutrients.
  - ♦ Reduces energy value.
  - ♦ Destroys carotene.
  - ♦ Under good condition, accounts for 5–7% of loss in total dry matter.
  - ♦ Rapid drying is the key to low fermentation losses.
- Bleaching
  - ♦ Color loss due to destruction of chlorophyll by sunlight.
  - ♦ Reduces carotene (related to greenness) or Vitamin A.

- Leaching
  - ♦ Washing of nutrients out of the hay by rainfall.

Factors influencing hay quality

- **Maturity:** Affects both yield and composition of hay.
  - ♦ Young plants are more digestible because they have less structural fiber and lignin, which are difficult to digest.
  - ♦ Young plants are higher in protein, minerals and carotene than older plants.
  - ♦ Young plants are more palatable, tender and less fibrous.
- **Leafiness:** Applies mainly to legume hay.
  - ♦ The percentage of leaves is the best index of actual feed value of alfalfa, clover and other legume hays.
  - ♦ Leaves are higher than stems in protein, fat, ash, nitrogen-free extract, calcium and phosphorus.
  - ♦ Leaves have a higher digestibility than stems.
- **Color:** Is an indication of maturity, the care exercised in curing, and the amount of weather to which the hay has been exposed.
  - ♦ A high percentage of natural green color (pea-green color) in hay indicates early cutting, good curing, high palatability, freedom from must or mold and high carotene content.
- **Foreign matter:** Indicates hay of low feeding value.
  - ♦ Injurious foreign matter, such as wire, stones, etc.
  - ♦ Poisonous plants, hard, bearded grasses etc.
- **Condition:** Refers to soundness of hay. Unsound hay is an indicator of poor quality and low nutrient content.
  - ♦ Contains excess moisture (under-cured).
  - ♦ Heated or hot hay, perhaps a burnt-brown appearance.
  - ♦ Has a musty or sour, rotten odor, generally due to heating.
  - ♦ Moldy.
  - ♦ Lacks the aroma of well-cured hay.
- **Texture**: Refers to the size of the stems. Texture is influenced by the thickness of the stand, maturity, percent leaves and the rainfall, soil fertility and other environmental conditions affecting the rankness of growth.
- **Variety**: Refers to kind or variety. Legume hay is more valuable than grass hay of the same maturity condition and foreign-matter content.

Standards of hay

Hays from sown pasture

Standards or grades of hay are generally based upon the percent of leafiness (in legumes), percent green color, percent foreign material, maturity or ripeness when cut, size and pliability of the stems, and general condition.

Hays from natural pasture

Three broad standards (grades) of hay are recognized based upon legume composition and quality of processing (curing) the hay.

Excellent hay

Excellent hay is cured forage, which includes a mixture containing a large amount of legumes and some grasses which are cut at an early, immature stage shortly after the legumes begin to bloom (1/8–1/4 of the plants in bloom) or shortly after the grasses form a head. For hay to be excellent quality, it must not be exposed to weather damage of any type, including sunlight for more than one or two days.

Good hay

Good hay would be cured forage which contains smaller amounts of legumes and more grasses than an excellent forage and is cut at a slightly later stage of maturity (about ½ of the plants in bloom). For hay to be rated as good quality, it must have little or no weather damage.

Fair-to-poor hay

Fair-to-poor hay is that which is mature at harvest (most of the plants in bloom); contains little or no legumes, and is exposed to some but not excessive, weather damage.

Silage

Silage is moist forage that is the product of acid fermentation of green forage crops that have been compressed and stored under anaerobic conditions in a container called a silo. A point of precaution in silage making is that it is not economically justified nor is there a special advantage to be gained in terms of animal nutrition by ensiling forages as long as the weather allows making good quality hay. However, there are certain advantages of silage which still do not rule out other cheap methods of forage conservation:

Advantages

- Where the production of high quality hay is not possible due to weather conditions.
- Silage saves feed that would be inedible in the dry state or would be damaged by rains.
- It is quite palatable and has a high content of carotene.
- It clears the ground early and completely for another crop.
- Storing a crop as silage instead of hay eliminates the hazard of fire.

Limitations

- It requires additional outlay for structures, equipment and power.
- It concentrates the labor of harvesting into a few days since the silo has to be filled quickly (in 1–3 days).
- Most silage has a low content of minerals and protein and is not suitable for use as the sole ration.
- If it is fed in place of legume hay in the ration, more expense must be incurred for high-protein feed.

Kinds of silos

Generally, there are four types of silos: stacks, trench silos, bunker silos and tower silos. The common ones applicable to the smallholder are stacks and trench silos.

Stacks

- Heaps of herbage (above ground) that are covered by plastic to exclude air.
- Used for ensiling grass and cannery refuse (by-product from food/vegetable processing and canning industries).
- Require adequate moisture in the crop.
- Need thorough packing to exclude oxygen.

Trench silos (clamp silo)

- Have three walls, which are sloped and built strongly to sustain the lateral pressure from the silage.
- For safety and prevention of waste, the walls should always be higher than the surface of the silage at the time of filling the silo.
- The silage should be packed tightly against airtight walls; otherwise wastage will occur.

Crops suitable for silage

Any green forage crop can be made into silage that will keep in good condition without an excessive loss of feed nutrients. Few feeds are improved either in palatability or in nutritive value by undergoing fermentation in the silo. On the other hand, none appear to be affected detrimentally to any marked extent. Very coarse or weedy crops and spiny plants become completely edible when made into silage.

Maize (Corn)

Corn is the common silage crop wherever it can be grown successfully. Silage made from corn is very palatable and will keep in good condition for 12 years or more. Yields range between 4 and 20 tons of silage from 9–45 tons of maize that may be harvested per hectare.

Sorghum

Various varieties of sorghum, including the forage sorghum (*S. sudanense*) are suitable for silage. They are dependable and yield more than maize in light rainfall areas. However, sorghum has a higher content of water and less grain and thus has less feeding value than maize.

Legumes

All legumes, including alfalfa, clovers, vetches, cowpeas, etc., can be made into silage successfully. If a crop is too mature to make leafy hay that will be eaten without waste, the legume crop can usually be made into silage that conserves more of the leaves and will be consumed with practically no waste. However, there is no special value in making legume silage if the crop can be hayed successfully.

The low, fermentable sugar content and the high protein and calcium content of legumes favor the development of undesirable types of bacteria during the fermentation process. Thus, special precautions must be taken in making legume silage or it will have low palatability and feeding value. When making legume silage fine chopping, tight packing, adequate covering and suitable drainage is essential.

- It is important to harvest the legumes at the correct moisture content, between 60 and 70%. In legumes, this is attained when cut at a growth stage from pre-bloom to 1/10 bloom stage.
- Fill the silo in shallow layers, each layer being allowed to heat to about 60°C before the next layer is added.
- Add molasses (18 kg of molasses per ton (1000 kg)) to provide fermentable sugar to favor development of desirable types of bacteria and facilitate the fermentation process. Molasses also improves palatability and odor of silages, especially those with high moisture content.

Grasses

Very good silage can be made from the grasses or mixtures of grasses and clovers that are ordinarily used for pasturage or hay.

- The crop grass should be low enough in moisture either naturally or by wilting so there will be little or no leakage of juices from the silo.
- The silo should have an open drain to let any free juice flow away from the silo in case the material is too wet. It is advisable to use about 18 kg of molasses per ton of grass if the moisture content is high.
- No molasses is necessary if the moisture content of immature grasses is below 70% (low enough to avoid leakage from the silo).

Harvesting the crop and filling the silo

- The fodder may be cut by hand and chopped by homemade, manually-operated rotary choppers that are more efficient than chopping by sickles.
- Hay and pasture crops may be cut using sickles or scythe and transported by animal-drawn carts to be dumped directly into the silo.
- In packing trench silage, livestock can be driven back and forth over the chopped material.
- Grasses and legumes need more uniform packing; such silages shrink away from the sides so special attention should be given to packing the top.
- It is advisable to fill the upper part of the silo higher than the sides.
- After filling, the silo should be covered with straw or unchopped maize and then covered with a polythene sheet.
- Trench silos must be filled high above the ground and then covered with straw and dirt. This will help to prevent spoilage by rain.

The fermentation process in the silo

When a green crop is put together in a heap, it continues to respire and in the process oxygen is consumed, CO_2 produced, and heat is developed. Several aerobic bacteria continue to increase in number until the oxygen is used up in 1–4 hours. The desirable temperature of silage after respiration stops is 27–38°C. If the temperature is lower, lactic acid-forming bacteria cannot compete with butyric acid-forming bacteria. On the other hand, temperature above 38–49°C result in sweet, tobacco-smelling, dark brown silage being formed; this is palatable but nutrients are lost (especially protein). The amount of fermentation products, lactic and acetic acids depends highly on the amount of sugar in the material from which these acids are derived by fermentation. A sugar content of about 6% is necessary for successful silage.

The normal fermentation process lasts about 21 days. Silage (maize) has been known to keep well for 12 years or more.

Transferable Message

- Select progressive farmers to demonstrate the choice of fodder conservation methods.
- Organize a training session and show farmers the advantages and the different methods of fodder conservation.
- Organize demonstration visits by other farmers and encourage discussions on the practice.

Glossary of Technical Terms

Browse: The part of leaf and current twig growth of shrubs, woody vines, and trees available for animal consumption.

Concentrate: All feed low in fiber and high in total digestible nutrients (TDN) that supply primary nutrients (protein, carbohydrate, and fat).

Carrying capacity: The optimum combination of products that can be derived from the land without degradation of the range.

Feed: Any non-injurious, edible material, including forage, having nutritive value for animals when ingested.

Forage: The part of the vegetation that is available and acceptable for animal consumption, whether considered for grazing or mechanical harvesting; includes herbaceous plants in mostly whole plant form, and browse.

Fodder: Any bulky green or dry plant material, which is used for stock feed.

Forage crop: Forage plants harvested before being fed to animals, e.g., hay, silage, green chop.

Grassland: Any land on which grasses predominate.

Green chop: Harvested forage fed to animals while still fresh.

Pasture: Grazing lands under relatively intensive management, usually supporting introduced forage species and receiving periodic cultural treatments, such as tillage, fertilization, mowing, and irrigation.

Pasture crop: Crops grown primarily for grazing.

Proper use: Grazing a range to a degree that will permit the best forage plants to make full use of the environment for maximum development during the current production season.

Permanent pasture (Conventional pasture): Medium-term grazing area on which the forage stand is principally perennial grasses and legumes and/or self-seeding annuals, and on which grazing tenure is indefinite but expected to exceed ten years.

Proper stocking rate: Limiting the number of animals which can be grazed in a given area of a pasture or range to match available feed resources.

Rangeland (Range): Uncultivated grasslands, shrub lands or forested lands with an herbaceous and/or shrubby under-story producing forage for grazing or browsing; may be native or seeded.

Range management: The science of maintaining maximum-range forage production without jeopardy to other resources or uses of the land. Grazing land management as applied to native and seeded rangelands.

Ranch: An economic unit of range or pastureland having defined boundaries together with its internal construction and improvement.

Roughage: Plant materials and other feedstuffs high in fiber and low in total digestible nutrients, usually bulky and coarse.

Supplemental pasture: A pasture of different kinds of forage grazed simultaneously and in conjunction with a base pasture; while the base pasture provides the primary source of grazing capacity, the supplemental pasture of enhanced nutritive quality serves to correct nutrient deficiencies in the total animal diet.

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Appendix Table 8.1. Characteristics of common forage crops.

Species	Rainfall (mm/yr)	Seed rate (kg/ha)	Tolerance to				Propagation	Nutritive value	Agro-ecology
			Drought	Waterlogging	Acidity	Frost			
HERBACEOUS LEGUMES									
Centrocema pubescens	900	3–5	fair	fair	good	poor	seed	very good	kola & w. dega
Desmanthus virgatus	500	1–2	good	fair	good	poor	seed	good	kola & w. dega
Desmodium intortum	700	1–2	fair	good	very good	fair	seed	very good	kola & w. dega
Desmodium uncinatum	700	1–3	good	fair	very good	fair	seed	very good	kola & w. dega
Neonotonia wightii	600	2–5	good	poor	very good	fair	seed	very good	kola & w. dega
Lablab purpureus	400	10–30	good	poor	good	fair	seed	very good	kola & w. dega
Lotononis bainesii	800	0.5–1	fair	very good	very good	good	seed	good	kola & w. dega
Lotus corniculatus	900	10–15	poor	fair	fair	very good	seed	very good	w. dega & dega
Macroptilium atropurpureum	500	1–3	good	fair	good	fair	seed	very good	kola & w. dega
Macroptyloma axillare	500	3–5	good	fair	very good	poor	seed	very good	kola & w. dega
Medicago scutellata	800	10–20	fair	very good	poor	good	seed	very good	kola, w. dega & dega
Medicago sativa	600	2–15	very good	poor	poor	very good	seed	very good	kola, w. dega & dega
Pueraria phaseoloides	1000	3 – 4	fair	good	very good	poor	seed	good	kola & w. dega
Stylosathes guyanensis	600	3–6	fair	fair	very good	poor	seed	good	kola & w. dega
Stylosanthes hamata	500	3–6	very good	poor	very good	poor	seed	good	kola & w. dega
Stylosanthes scabra	500	3–6	very good	poor	very good	poor	seed	fair	kola & w. dega
Trifolium repens	600	1–4	fair	fair	fair	very good	seed	very good	kola, w. dega & dega
Vicia dasycarpa	400	20	fair	poor	fair	good	seed	very good	kola, w. dega & dega
Vicia villosa	400	20	fair	poor	fair	very good	seed	very good	kola, w. dega & dega
Vigna unguiculata	300	20	good	poor	good	fair	seed	good	kola & w. dega
TREE LEGUMES									
Cajanus cajan	300	20–25	very good	poor	very good	poor	seed	very good	kola & w. dega
Calliandra calothyrus	1000	20–50 seed/m	fair	good	good	poor	seed/seedling	good	kola & w. dega

Species	Rainfall (mm/yr)	Seed rate (kg/ha)	Tolerance to				Propagation	Nutritive value	Agro-ecology
			Drought	Waterlogging	Acidity	Frost			
Gliricidia sepium	900	cutting	fair	fair	good	poor	cutting/seed	good	kola & w. dega
Leucaena leucocephala	400	20–50 seeds/m	very good	poor	poor	fair	seed/seedling	good	kola & w. dega
Leucaena pallida	400	20–50 seeds/m	very good	poor	poor	fair	seed/seedling	good	kola & w. dega
Sesbania sesban	500	20–50 seeds/m	good	good	fair	poor	seed	good	kola & w. dega
Chamaecytisus prolifer	500	20–50 seeds/m	good	poor	good	very good	seed/seedling	good	kola, w. dega & dega
GRASSES									
Andropogon gayanus	900	4–6	good	fair	very good	poor	seed	good	kola & w. dega
Brachiaria decumbens	1000	3–6	fair	good	good	poor	seed/split	fair	kola & w. dega
Brachiaria mutica	1000	2–6	fair	very good	poor	poor	seed/split	fair	kola & w. dega
Cenchrus ciliaris	250	1–4	fair	very good	fair	poor	seed	good	kola & w. dega
Chloris gayana	600	1–6	very god	poor	good	fair	seed	good	kola & w. dega
Dactylis glomerata	500	3–6	good	fair	fair	very god	seed	good	kola, w. dega & dega
Festuca arundinaccea	600	4–6	good	fair	fair	very good	seed	good	kola, w. dega & dega
Lolium perene	500	5–20	fair	poor	fair	very good	seed	good	kola, w. dega & dega
Melinis minutiflora	1000	1–4	fair	Poor	good	poor	seed/split	fair	kola & w. dega
Pennisetum purpureum	600	splits	good	Poor	good	fair	seed/split	good	kola & w. dega
Panicum coloratum	400	1–6	very good	very good	good	good	seed	good	kola & w. dega
Panicum maximum, var. Gatton	750	2–6	fair	Fair	good	fair	seed	good	kola & w. dega
Panicum maximum, var. Green	550	1–6	good	Poor	very good	good	seed	good	kola & w. dega
Panicum maximum, var. Guinea	900	2–6	fair	Fair	very good	fair	seed	good	kola & w. dega
Panicum maximum, var. Hamil	900	1–4	good	good	very good	fair	seed	fair	kola & w. dega
Paspalum plicatulum	900	6–10	fair	good	fair	fair	seed	fair	kola & w. dega

Species	Rainfall (mm/yr)	Seed rate (kg/ha)	Tolerance to				Propagation	Nutritive value	Agro-ecology
			Drought	Waterlogging	Acidity	Frost			
Phalaris aquatica	400	2–4	very good	very good	fair	very good	seed/split	good	kola & w. dega
Setaria sphaceleta	800	2–5	fair	good	good	good	seed/split	good	kola & w. dega
FODDER CROPS									
Avena sativa	600	70–80	fair	good	fair	good	seed	good	kola, w. dega & dega
Beta vulgaris	750	5	very good	poor	fair	very good	seed	good	kola, w. dega & dega

Designation: Traditional Ethiopian agro-ecological zones clustered into three major zones: *kola, weinadega* and *dega*. 1. *Kola* (including: *Bereha* (dry-hot), *Erteb Kola* (sub-moist warm) 2. *Weina-dega* (dry-warm, sub-moist warm) and Erteb Weina-dega (moist-cool) and 3. *Dega* (including Dega (cold); *Erteb dega* (moist cold) and *Wurch* (very cold or alpine). See the following description for the traditional agro-ecological sub zones.

Appendix Table 8.2. Description of traditional agro-ecological zones.

		Traditional Ethiopian Agro-ecological Zones			
Major zones Code No.	Major zone	Zone	Altitude (m)	Mean Rainfall (mm)	Temperature (°C)
1	Kola	*Bereha* (dry-hot)	500–1500	<900	>22
		Erteb Kola (sub-moist warm)	500–1500	900–1000	18–24
2	Weina-dega	*Weina-dega* (dry-warm)	1500–2500	<900	18–20
		Weina-dega (sub-moist cool)	1500–2500	900–1000	18–20
		Erteb Weina-dega (moist- cool)	1500–2500	>1000	18–20
3	Dega	*Dega* (cold)	2500–3500	900–1000	14–18
		Erteb dega (moist cold)	2500–3500	>1000	10–14
		Wurch (very cold or alpine)	>3500	>1000	<10
Source: Ministry of Agriculture (MoA) 2000. Agroecological Zonations of Ethiopia. Addis Ababa, Ethiopia.					