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37

RESEARCH PROGRAM ON Livestock

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Fodder production manual for extension staff and farmers in South Kivu and Tanganyika provinces of the Democratic Republic of the Congo

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RESEARCH PROGRAM ON Livestock

Fodder production manual for extension staff and farmers in South Kivu and Tanganyika provinces of the Democratic Republic of the Congo

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Introduction

Livestock contributes to the livelihoods of many people who are engaged throughout its value chain and also to the nutritional well-being of many rural communities of the DR Congo. The low meat and milk production of large and small ruminant livestock in the region is mainly due to low genetic potential, disease challenge, harsh weather conditions, low quality and/or quantity of feeds and the insufficient technical knowledge of methods of harnessing production and sustainable utilization of the available resources.

Grasses and legumes are the most important feed resources in ruminant animal nutrition. In fact, tropical forage grasses and legumes, as key components of sustainable livestock systems, have a major role to play in improving food security, alleviating poverty, restoring degraded lands and mitigating climate change in smallholder farming systems of Central Africa. Climate-smart tropical forage crops can improve livestock productivity and break the cycle of poverty and resource degradation. Sustainable intensification of forage-based systems will contribute to better human nutrition, increased farm incomes, increased soil carbon accumulation and reduction of greenhouse gas emissions.

In the DR Congo, livestock are mainly fed on forages of low nutritional value which are produced under rain-fed conditions and are therefore scarce during the dry season. This normally results in reduced animal productivity, especially during the dry season. There is need to increase the use of improved forage varieties and to improve knowledge of their management, conservation and utilization in home-mixed rations to ensure year-round supply of high-quality forage-based feeds. This training manual has, therefore, been developed to provide step-by-step, science-based instructions on forage production, conservation and feeding management practices to smallholder farmers, lead farmers, agro-entrepreneurs and extension workers in the South Kivu and Tanganyika provinces of DR Congo.

1 Major nutrients required by livestock

1.1 Introduction

Nutrients are substances obtained from food which are used in an animal's body to perform normal body functions such as breathing, pumping blood, fighting diseases, growing, gaining weight, reproducing and to produce the different animal products (such as wool, meat and milk). In addition to water, the two major nutrients are energy (which comes from carbohydrates in the form of sugars, starches, cellulose and hemicellulose found in plants and their seeds) and protein, found in animal products and also in plants and their seeds. The other nutrients are vitamins and minerals which are found naturally in most plants and if not, can be supplemented quite cheaply. Animals must eat different types of feed to supply the various nutrients they need. The feedstuff must therefore be easily digestible and the products (nutrients) quickly absorbed if the feed is to be useful. A diet that supplies both the right variety and amount of the different type of nutrients the body needs is referred to as a balanced diet. All livestock need balanced diets, just as humans.

Basically, nutrients are required by livestock for three purposes:

i. for the construction of body tissues (maintenance, growth and reproduction),

ii. for synthesis of products such as milk and eggs and

iii. as sources of energy for performing work. Work performance includes both metabolic (heat increment and maintenance) as well as physical work, e.g. walking and feeding.

Animal feed needs to meet the nutritional requirements of the animal. For ruminants it must contain certain basic nutrients to sustain a healthy population and combination of microorganisms (i.e. bacteria and protozoa) to maintain rumen function (i.e. keep the stomach healthy). In the case of all livestock, feed should not be mouldy or mixed with dirt and soil nor contain poisonous ingredients (for example, pesticides or herbicides residues on crops). The composition of feeds in a ration depends on the type of animals being fed and their stage of production. Cattle and goats, being ruminants, are better equipped to digest crude fibre than pigs or chickens. Young animals need more protein than adults, while animals producing milk need a higher protein content in the ration than non-lactating ones.

Generally, animals must have a ration containing:

- Energy (from carbohydrates and fats) to maintain the body and produce (milk, meat, work). The carbohydrates and fats not needed for production are converted to fat and stored in the body.
- Protein is needed for body building (growth) and maintenance as well as milk production. Without protein there would be no body weight gain nor milk production. Excess protein is converted into urea and fat.
- Minerals help in body building as well as in biological regulation of growth and reproduction. Minerals are also a major source of nutrients in milk.

- Vitamins help regulate the biological processes in the body and become a source of nutrients in milk.
- Water is essential for body building, heat regulation and biological processes and is a large component of milk as well as eggs.

Energy

Energy fuels all body functions, enabling the animal to undertake various activities such as moving, eating, breathing, reproducing and milk synthesis. Simply put, an animal requires energy to maintain itself. Milk production requires a lot of energy. If energy sources in the ration are inadequate, the animal will lose body condition and for milking cows, milk yield will drop, pregnant cows become ill after calving and the calf will usually be small in size. If there is excess energy in the ration, the animals become too fat. Cows that are too fat usually have difficult calving, often have problems with retained placenta, displaced abomasum and may suffer from milk fever and ketosis.

Sources of energy are roughages and concentrate supplements. Roughages are bulky, fibrous feeds, such as hay and straw, that have a low energy content per unit volume. They can have a high moisture content (e.g. fresh grass). Generally, feedstuffs with more than 18% crude fibre content and low digestibility are considered roughages. Ruminant livestock (e.g. cattle, goats, sheep) need a certain amount of crude fibre to maintain a healthy digestive system. On the other hand, high-yielding animals may not have enough capacity to consume the amount of roughage required to meet the energy requirement due to limitation of stomach size. For this reason, supplementing roughage diets with feeds high in readily available energy is often recommended. Local conditions can cause differences in chemical composition of the same feedstuff.

Energy can be obtained from several types of feedstuffs that contain either carbohydrates (in the form of sugars, starches, cellulose and hemicellulose found in plants and their seeds) or lipids (fats and oils). Carbohydrates are the major source of energy in the diet of animals. Examples of energy sources are:

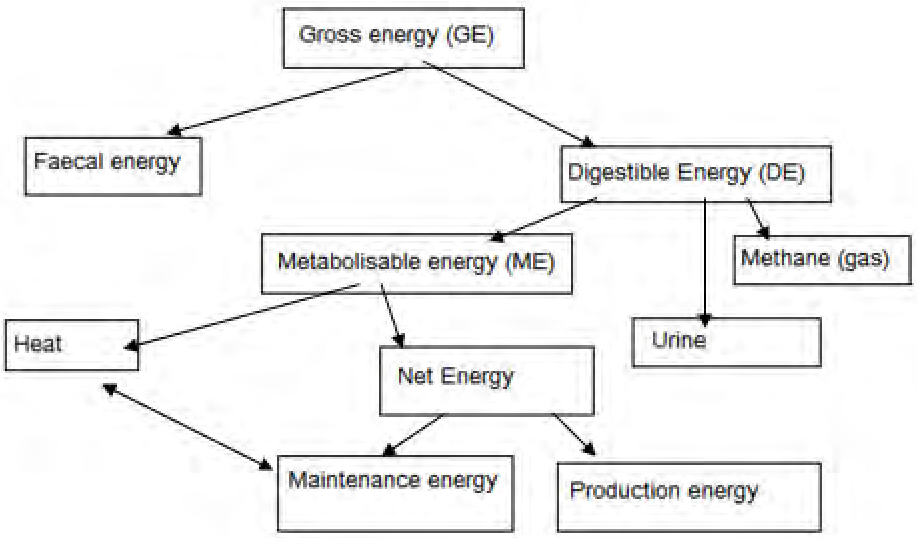
- Sugars: sugars are soluble in water, making them readily available to the animal. Examples of sources are molasses, sugar beet and sugarcane.
- Starch: starch is the main form of carbohydrates stored in plants. It is the main component of cereal grains and some roots (e.g. maize, potato tubers).
- Fibre: forming the structural part of plants, fibre is present in large quantities in roughages (plant materials used for feeding livestock). The fibre is broken down by microorganisms in the rumen (microbial enzymes) into products that the animal can use. It is also important in maintaining high levels of milk fat. Sources include grasses, fodder crops and crop residues. Carbohydrates constitute 50%–80% of the dry matter (DM) in forages and grains.
- Lipids (fats): contain about 2.25 times more energy than carbohydrates per unit weight. Generally, plants are good sources of oils while animal products contain fats. Most plant seeds contain a small amount of lipids. The exception is oilseed plants, which may contain as much as 20% lipids (cotton, sunflower and soybean seeds) and are better sources of lipids than animal fats.

All the energy contained in a feed is referred to as the gross energy (GE). This is the energy that is available when the feed is completely burned. For instance, fresh sugarcane forage has a GE content of 18.2 MJ per kg of DM. This GE is a value of the feeds itself and is not influenced by animals. However, only parts of the nutrients in feeds (digestible nutrients) are available for the animal. Figure 1 shows feed energy within the animal.

Cattle can digest sugarcane forage for 68% of the energy. The rest is lost in the faeces. Therefore, digestible energy (DE) for sugarcane in cattle is 11.3 microjoules (MJ)/kilogram (kg) DM. Pigs can digest only 37% of all energy in sugarcane forage, so the DE for pigs is only 6.7 MJ/kg DM, much lower than that for cattle.

When calculating rations, the value of feeds and requirements of the animals must have the same system. If energy of feeds is given in metabolizable energy (ME), the requirements of animals should be stated in ME to be able to calculate rations. The feed system used is mainly determined by the available information from feedstuffs and animals and the wish to be more or less precise. It is a compromise between the costs of research and analysis and the benefits of using a very sophisticated feed system.

Figure 1: Fate of feed energy within the animal



It is important for plants fed to animals to be high in energy or protein or preferably both. Natural grass (veld) can supply these nutrients in substantial amounts only for about three months of the growing season. After that veld is not adequate for high meat production, milk yields and fertility. Usually by the end of the dry season (in August), there is often not enough grazing for the animals, especially in a dry year. Commercial concentrates have energy derived from maize and maize by-products and protein from oil seeds which have been pressed for oil, but all these are very expensive compared to energy and protein from forage crops produced on the farm. Feeding commercial stock feed should only be done when farm-grown forages are not able to meet the animals' requirements. If commercial stock feeds are fed in place of farm-grown forages, it is a sure way of losing a lot of money—unless, of course, the value of the animal or animal products justifies the additional cost.

In summary, farmers need to produce forages for their animals in order to:

- Provide higher quality feed than the natural pasture can supply
- Increase overall carrying capacity of grazing systems
- Fill gaps in the feeds supply over the long dry season
- Provide a specialist crop for both feeding in the rains and for conserving
- Provide nutrients for the animals which are much cheaper than those found in commercial stock feeds
- Avoid conflicts between crop and livestock farmers when animals graze

Protein

Protein is the second most important nutrient in terms of the quantity required. Proteins are made up of building blocks referred to as amino acids. Proteins provide the building material for all body cells and tissues (e.g. blood, skin, organs and muscles). It is, therefore, a major component of products such as milk and meat. Deficiency of protein results in low yields of animal products.

Good sources of protein for livestock include:

- Oilseeds and oilseed cakes: residues after the oil is removed from oilseeds, e.g. cottonseed meal or cake, whole cottonseed, whole soybeans (cracked) or meal and sunflower meal or cake
- Products of animal origin, such as fishmeal, blood meal, meat and bone meal, feather meal and by-products from milk processing (e.g. skim milk and whey)
- Herbaceous legumes such as lucerne, desmodium and fodder trees (e.g. Calliandra and Sesbania)
- Non-protein nitrogen (N): ruminants can obtain protein from sources that do not contain true proteins, such as urea and poultry waste (contains uric acid). These sources are referred to as non-protein N sources. Microorganisms in the rumen use the N in urea to synthesize protein for their own growth.

Severe protein deficiency may cause excessive weight loss in mature animals, reduced growth rate in young animals and also underweight of newborns.

Protein and rumen microbes

In ruminant livestock, most of the protein in feed is broken down by microorganisms in the rumen (rumen-degradable protein) and re-synthesized into bacterial protein. The bacterial protein then become the source of protein to the animal. By-pass proteins are proteins resistant to microbial breakdown referred to also as rumen undegradable protein, and pass intact to the small intestines where they are digested and absorbed directly into the body.

Protein and meat and milk production

The requirement of protein for muscle and organ growth is reflected in the large daily requirement for protein for growing animals. Young, growing cattle need relatively high levels of crude protein (CP) in their diets to support muscle growth. Crop feeds or forages for suckling calves should contain at least 15% CP. Heifers as well require a high concentration of protein in the diet. They must have access to good-quality forage or be fed supplemental protein to achieve adequate growth prior to their first breeding season. Protein requirements in sheep and goats also vary with stage of production.

Gestation has little effect on the animal's protein requirement until late gestation. About two-thirds of the fetal growth occurs during the last one-third of pregnancy, and the protein intake of the animal should be increased to ensure the animal will be in good condition at the time of giving birth. Increasing animal size adds to the daily protein requirement but not nearly to the extent that lactation does. As mature size increases, more protein is required to maintain the heavier muscle mass and to permit faster gains that must be made by young females of larger breeds.

Lactation is the most nutritionally stressful activity. The modern commercial beef cow produces around 10 kg of milk each day during peak lactation. Milk contains a high concentration of protein. Therefore, lactating cows, particularly during early lactation, require nearly twice the daily protein of dry cows. Milk contains approximately 3.2–3.5% protein. Thus, a cow producing 10 kg of milk per day secretes 320–350 grams of protein daily. Cows have little ability to store protein in the body and so it must be supplied in the diet daily to maintain the milk yield. Protein should be 15–18% of the total ration of a dairy cow depending on milk yield.

Minerals

Minerals are chemical elements required in small amounts but are important components of the ration. They are essential for animals to remain healthy and for the body to function properly, for the development and maintenance of strong bones and for successful reproduction and production of animal products such as milk and eggs. Minerals form an important component of animal feed ingredients. When an element classified as essential is lacking in the diet, animals will show deficiency symptoms, which are eradicated or prevented by inclusion of this particular element in the diet. Some elements are required in relatively large amounts compared to others. For these reasons the minerals have been classified as macro-minerals (required in larger amounts) and micro-minerals (trace-minerals) (required in minute amounts).

Of the 20 elements that function in animal nutrition, carbon, hydrogen, oxygen and N are regarded as the non-mineral elements. The other 16 are referred to as the mineral elements which function in animal nutrition. Of these seven are macro-minerals (required in fairly large amounts) and nine are micro-minerals (required in very small or trace amounts). Different livestock types have different mineral requirements, which will be described under each livestock type.

Some minerals can be stored in the animal's body (copper in the liver, calcium in the bones) and signs of deficiencies are exhibited after a long period of inadequate feeding. Minerals that are not stored in the body show signs of deficiency more rapidly.

- The macro-minerals are calcium (Ca), phosphorus (P), potassium (K), sodium (Na), sulphur (S), chlorine (Cl) and magnesium (Mg).
- The micro or trace minerals are iron (Fe), iodine (I), copper (Cu), cobalt (Co), fluorine (F), manganese (Mn), zinc (Zn), molybdenum (Mo) and selenium (Se).

Sources of minerals

Although roughages and concentrates contain minerals, the types and amounts vary widely and hence may not meet nutritional requirements. During ration formulation, macro-minerals Ca, P and Mg are taken into account. Roughages supply adequate amounts of K and common salt can adequately provide Na. Some ingredients (supplements) are added to supply a specific mineral (e.g. limestone, salt, magnesium oxide).

Vitamins

Vitamins in ruminant feeding

Vitamins regulate biochemical reactions by which energy and protein sources in the diets are used for maintenance, growth and reproduction. Vitamin status of ruminant livestock is affected by rumen fermentation as well as diet composition. For most productive animals, young, lush green pastures (grasses or legumes) are a good source of both water-soluble and fat-soluble vitamins. As a result, livestock fed on these pastures will normally obtain sufficient vitamins (especially vitamins A and E) for their metabolic processes from this source. Large deficiencies are often encountered in intensified production systems where farmers are seeking high livestock weight gains, milk production and reproductive performance. In such situations, there is high metabolic demand for vitamins and farmers cannot rely on forage feeds alone. Livestock subjected to stress (e.g. through confinement, crowding and competition for water and food) also have a higher need for vitamins. To avoid losses in production due to any of these conditions or to achieve high productivity, it is often advisable to supplement ruminants with fat-soluble vitamins (vitamins A, D and E).

Livestock living outdoors will normally synthesize their own vitamin D. Vitamin D is produced when animals are exposed to direct sunlight, for which reason it is always advisable to give livestock time to spend in the sun.

Rumen microbes will synthesize most of the B-vitamins and vitamin K required by an animal, but in high producing animals it will be necessary to supplement vitamin K, thiamine, niacin, vitamin B12, cholin and biotin. Similarly, most animals can synthesize vitamin C at tissue level or find it from green foliage. Beta-carotene and/or vitamin A can be stored in the liver and body tissues during periods of high intake and used during periods of low intake. Therefore, supplementation will be necessary only in exceptional cases.

For high-producing ruminants it will be beneficial to include small amounts of feed that are of animal origin to supply vitamin B12, as this vitamin is only found in animal products. Vitamin A deficiencies in ruminants may cause reduced feed intake, slow weight gains, night blindness, swollen hocks, knees and brisket, total blindness, diarrhoea, muscular incoordination, staggering gait, reduced sexual activity, low fertility in bulls, poor conception rates and abortion. For these reasons it is advisable to supplement ruminant feed with vitamin A (or carrots if available) during periods where little green fodder is available.

Vitamins in pig nutrition

As in ruminant livestock, intensified production for improved weight gains, feed efficiency and reproductive performance in pigs will inevitably increase their metabolic demand for vitamins. Pigs that have access to pasture can depend to a large extent on pasture to provide a significant amount of vitamin nutrition. Young lush pastures will contain ample supplies of vitamins A and E. Piglets that are weaned early will require a lot of vitamin supplementation (especially vitamin C, pyridoxine and carnitine) for maximum performance, especially for pigs that are bred for increased body growth or body protein accretion.

Adequate supplementations for vitamin A, D and E are required for optimum immune response. Vitamin D increases bone strength and vitamin E produces better meat quality. As in ruminants, pigs can produce sufficient vitamin D by themselves if they are given a chance to spend time in direct sunlight. Under normal circumstances, pigs on pasture can synthesize sufficient vitamin K from endogenous gut bacteria. However, with wide use of antibiotics, the endogenous bacteria are regularly eliminated, and this creates a need for vitamin K supplementation. Therefore, as a general recommendation, all four fat-soluble vitamins (A, D, E and K) should be added as supplements to all pig rations. In addition, four B-vitamins (B12, niacin, pantothenic acid and riboflavin) must be added to all pig rations.

The recommended sources of vitamins for smallholder pig producers are as follows:

- Vitamin A: add 2–3% good quality Stylosanthes meal or similar (such as dried crushed comfrey or amaranth leaves) to the normal pig rations. Another alternative can again be carrots if cheap enough and available.
- Vitamin D: try to expose the pigs to sunlight. If this is not possible, vitamin D supplementation is recommended.
- Riboflavin: this is found in green plants, fishmeal or milk products. If none of these are used in the pig feed, supplementation with riboflavin is recommended.
- Vitamin B12: this vitamin is only found in animal products such as fishmeal, blood meal or for open range pigs and poultry, insects, grubs etc. If your pigs are mostly fed on soya meal for their protein, a small addition of fishmeal will be beneficial.
- Vitamin E: effective vitamin E utilization is dependent on adequate Se, and Se is sometimes deficient in feed from some areas. If Se content of feed is a problem, the production of vitamin E will also be a problem. Seek advice on vitamin E from your livestock nutritionist.

Fibre

For animals to lead a healthy life, they must consume enough dietary fibre to keep the stomach/rumen healthy and functioning. However, there are limits; too high content of fibre (lignin, dry cellulose) may fill the stomach without supplying enough nutrients. The more fibrous the feed is, the lower the energy and protein content and the more energy it takes to digest it.

Various livestock species have different adaptabilities to high-fibre diets. In pigs and poultry diets, a minimum level of dietary fibre has to be included to maintain normal physiological function in the digestive tract. A major concern when including fibre in diets for mono-gastric animals is that high dietary fibre content is associated with decreased nutrient utilization and low net-energy values. However, the negative impact of dietary fibre on nutrient utilization and net-energy value will be determined by the fibre properties and may differ considerably between sources. Moreover, dietary fibre may have other positive effects such as stimulating rumen function, increase satiety, affect behaviour and overall improve animal well-being. Fibre is one of the more important nutrients in a ruminant livestock diet because of its role in maintaining rumen function and health.

In dairy cattle, providing adequate fibre while attempting to meet energy needs can be a challenge particularly in rations for fresh and early lactation cows. Determining the correct fibre level for the animals is not an easy task as there is no single ideal level for all feeding situations. The objective of all feeders, however, should be to provide sufficient fibre to maintain rumen function, rumen pH and cow health. Cattle farmers must provide a minimum of 19% acid detergent fibre and 40% forage in the ration DM and keep a close watch on particle length.

Water

Water is a necessary compound of plants and animals. Growing plants contain 70–80% water and animals contain 70–90% water. Water has several important functions in the animal body such as regulation of body temperature, carrier of nutrients and regulation of tissue structure. Water is needed to make saliva for swallowing feed and for chewing the cud, for feed to be digested, to cool the body when it is too hot and to remove waste materials from the body in the urine and faeces. In addition, a milking cow (also suckling sows, camels and donkeys) needs water for milk production. Lack of water will kill an animal faster than lack of any other nutrient. Lack of sufficient amounts of water or provision of poor-quality water will seriously reduce animal performance. Table 1 summarizes the normal range of water consumption for adult animals.

Table 1: The normal range of water consumption for adult animals

Livestock type	Water consumption in litres/day
Camels	Every 5–8 days as much as they can drink (up to 100 litres or one third of body weight)
Beef cattle	35–60 litres per head
Dairy cattle	30–80 litres per head
Horses	24–36 litres per head
Donkeys/mules	Twice a day, as much as they can dink (10–25 litres)
Pigs	15–25 litres per head
Sheep and goats	5–20 litres per head
Chicken	40–50 litres per 100 birds = 0.5 litre per bird
Turkeys	40–75 litres per 100 birds = 0.75 litre per bird
Rabbit	50–150 millilitres (= 0.1 litre) water per kg body weight (small cup)

Water should be available at all times (except for camels, they can do with water every 5–8 days) and be clean and fresh. Remember that young animals also need water. Even when they are milk fed, it does not always fulfil their need for liquids, and especially not if the animal is active and if the weather is warm or hot and dry, or even windy.

Livestock fulfil their need for water from three major sources:

- Free drinking water or snow
- Water contained in feed
- Metabolic water produced by metabolic activities

The first two are sources of major concern in the management of livestock. Because of the large variation in water intakes, an estimate of water intake should be made based on production factors, which affect water intake. Water consumption requirements depend on factors such as:

- Type, age and size of animal
- Rate and composition of weight gain
- Pregnancy
- Lactation
- Type of diet
- Level of DM intake
- Level of activity
- Quality of water
- Temperature of the water offered and surrounding air temperature.

The nutrient requirements of different types of livestock are presented in Appendix I.

2 Forage production and management

2.1 Forage and fodder

Fodder refers particularly to feed of a vegetative nature given to the animals (including plants cut and carried to them), rather than that which they forage for themselves. It includes hay, straw, silage, compressed and pelleted feeds, oils and mixed rations, and sprouted grains and legumes.

Forage is plant material (mainly plant leaves and stems) eaten by grazing livestock. Historically, the term forage has meant only plants eaten by the animals directly as pasture, crop residue or immature cereal crops, but it is also used more loosely to include similar plants cut for fodder and carried to the animals, especially as hay or silage.

Feed selection and palatability refers to animals distinct preferences for particular types of feed. Animals' feed preferences are influenced by feed availability, plant structure, animal's nutrient deficiencies (e.g. salt) and appetite, and of course, different species of animals prefer different types of feed. The term palatability is a subjective concept and refers to the assumed reason behind an animal's choice of one source of feed over another (e.g. the choice between different parts of a plant or the choice between different plants). Selection, on the other hand, is an objective term, referring to the actual choice that is made. The ability of an animal to select feed of an adequate quantity and nutritive value affects its productivity.

Grazing time is the amount of time a ruminant spends consuming feed. While generally applied to actual grazing on pasture, the definition can be widened to include time spent browsing, consuming stover etc. Grazing time is largely determined by the availability and nutritive value of feed, weather conditions and by the management system used. There is often an inverse relationship between grazing time per day and the quantity and quality of feed available.

What are fodder crops?

Fodder crops are plants which, when grown as a crop, have been found to produce high yields of plant material which are also high in nutrients suitable for livestock requirements for maintenance and production. Natural pasture is a forage but is not grown as a crop, so is termed forage, not fodder crop. Fodder crops produce much higher yields than natural forages and because they produce high yields, they can be fed to cattle as both green forage during the rains and conserved for the long dry season. A wide variety of crop species fodder production are available (Table 2). However, there is need to select species/varieties that are suitable to the specific area and that meet the farmers objectives.

Some of the factors that will affect one's selection of forage species are:

- Soil and climatic adaptation
- Intended use
- Types of livestock system planned
- Amount of forage required
- Whether pure stands or grass-legume mixtures are desired

Potential fodder crops

Table 2: Potential fodder crops for different agroecological zones

Region	Grasses/fodder crops	Legumes
Semi-arid Altitude 1,000–1,800 metres above sea level (masl) Rainfall < 650 millimetres (mm)	*Andropogon gayanus* *Cenchrus ciliaris* *Chloris roxburghiana* *Eragrostis superba* *Panicum maximum*	*Siratro* *Stylosanthes scabra*
Warm, wet, medium altitude Altitude 1,200–1,850 masl Rainfall 1,000–2,500 mm	*Panicum maximum* (Guinea grass) *Setaria sphacelata* (setaria grass) *Ipomea batatas* (sweet potato) *Pennisetum purpureum* (Napier grass) *Sorghum almum* (Columbus grass) *Sorghum sudanense* (Sudan grass) *Trifolium laxum* (Guatemala grass) *Chloris gayana* (Rhodes grass) *Panicum coloratum* (Coloured guinea) *Panicum maximum* (Giant panicum)	*Calliandra calothyrsus* *Desmodium spp* *Dolichos lablab* *Leucaena spp* *Neonotonia wightii* *Sesbania sesban* *Stylosanthes guianensis*
Cool, wet, medium altitude Altitude 1,850–2,400 masl Rainfall 1,000–2,500 mm	Avena sativa (oats) Rhodes grass Coloured guinea Columbus grass Congo signal Giant panicum Guatemala grass *Pennisetum clandestinum* (Kikuyu grass) Napier grass Setaria grass *Cynodon dactylon* (star grass) *Sorghum Sudanese* (Sudan grass) Sweet potato	*Desmodium spp* *Dolichos lablab* *Lupinus albus* *Lupinus angustifolius* *Medicago sativa* (lucerne) *Mucuna* spp *Neonotonia wightii* *Stylosanthes guianensis* (stylo) *Vicia* spp (vetch)
Cold, wet, high altitude Altitude 2,400–3,000 masl Rainfall 1,000–2,500 mm	*Festuca arundinacea* (tall fescue) *Trifolium* spp (clover) Kikuyu grass *Lolium perenne* (perennial ryegrass) Oats	*Medicago sativa* (lucerne) *Vicia* spp (vetch)

2.2 Some forage crops grown in the Central Africa region

Grasses

Pennisetum purpureum (Napier grass)

Figure 2: A pure stand of Napier grass (Photo credit: ILRI/Ben Lukuyu)

Pennisetum purpureum, also known as Napier grass or elephant grass, is a species of perennial tropical grass native to the African grasslands. It is tall and forms robust bamboo-like clumps. This species has high biomass production, at about 40 tonnes (t) fresh matter per hectare (ha)/year and can be harvested 4–6 times per year.

Napier can be propagated through seeds, however as seed production is inconsistent, collection is difficult. Alternatively, it can be planted through stem cuttings. The cuttings can be planted by laying them along furrows 75 centimetres (cm) apart, both along and between rows. Some varieties have low water and nutrient requirements, and therefore can make use of otherwise uncultivated lands. Napier grasses may improve soil fertility by protecting arid land from soil erosion. It is also utilized for firebreaks, windbreaks, in paper pulp production and most recently to produce bio-oil, biogas and charcoal.

Napier grass varieties

The commonly grown Napier grass varieties or cultivars include:

- Clone 13: resistant to white mould disease. It is a high yielder, but its thin stems make it difficult to establish. It is also susceptible to Napier grass head smut disease.
- French Cameroon: A high yielder, established easily from canes. Susceptible to Napier grass head smut disease.
- Kakamega 1 and 2: varieties developed in Kenya. Both are tolerant to Napier grass head smut disease and are high yielders. Kakamega 1 has a higher growth rate than Kakamega 2 or Bana.
- Ouma 1 and 2: new varieties developed in Kenya that are resistant to Napier stunting disease.
- Interspecific hybrids between Napier grass and pearl millet (*P. americanum*)
- Bana grass: leafy and with few silica hairs, which cause irritation during handling. However, it is susceptible to Napier grass head smut disease (*Ustilago kameruniensis*).
- Pakistan hybrid: does well in dry areas.

Where to grow Napier grass on the farm

Pure stand

Napier grass and Napier crosses can be established as a pure stand where:

- Land is available (Figure 2)
- The plot will be used for bulking (to provide planting material to other farmers)
- The farmer plans to intercrop with legumes in future (Figure 4)

Along contours and boundaries

Napier grass can be grown along contours or boundaries where:

- Land is sloping and a farmer wants to use it for soil conservation (Figure 4)
- Land is limited so the farmer cannot set aside for growing Napier alone (Figure 3)

Figure 3: A pure stand of Napier grass

Figure 4: Napier grass intercropped with Desmodium intortum

(Photo credit: ILRI/Godfrey J. Manyawu)

How to establish Napier grass

Common method

- Prepare land during the dry season in order to kill weeds effectively.
- Plan to plant at the start of the heavy rains season, when the soil is moist. Allow two heavy downpours before planting.
- Dig holes 15–20 cm wide and 15–20 cm deep at a spacing of 0.5 m x 0.5 m in high rainfall areas and 0.5 m x 1 m in low rainfall areas.
- Apply 1–2 tablespoons of diammonium phosphate (DAP) fertilizer or 1 kg of farmyard manure (FYM) per hole.
- Place a 2–3 node cane at a slanting position in the soil, ensuring that two nodes are covered by the soil (Figures 5 and 6).

Figure 5: Napier grass canes ready for planting

Figure 6: Common method of planting Napier grass

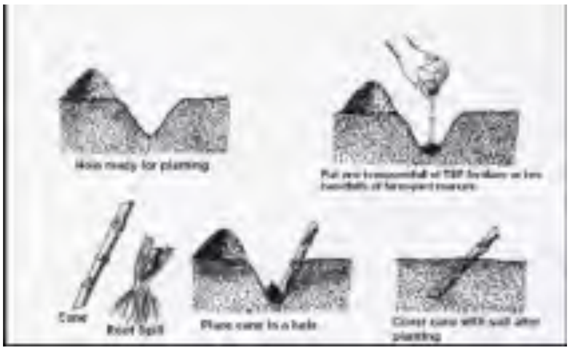
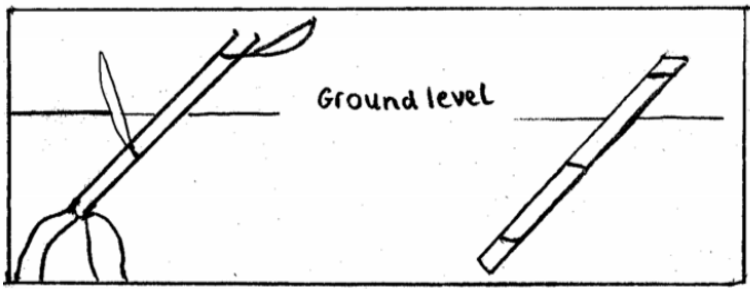


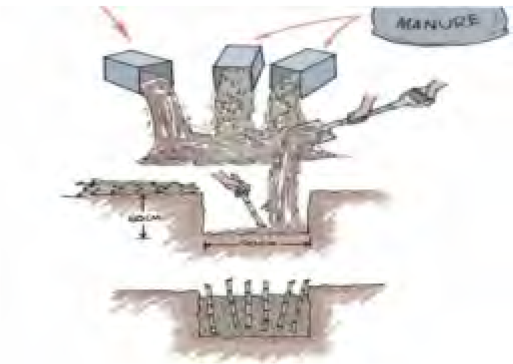
Figure 7: Planting the rooted tiller or stem cutting of Napier grass



"Tumbukiza" method

- Dig round pits 60 cm wide and 60 cm deep, with 60 cm between the rows or rectangular pits 60 cm deep, 60–90 cm wide and 90 cm long. Separate topsoil (approximately top 15 cm) from subsoil.
- Mix 1 debe (20 litre tin) of topsoil with 1–2 debes of FYM and put into the pit.
- Plant 5–10 cane cuttings or root splits in round pits.
- In rectangular pits, plant 5–10 cuttings or root splits for every 90 cm pit.
- Leave about 15 cm unfilled space at the top of each (Figure 8).

Figure 8: Tumbukiza method of planting Napier grass (Source: Lukuyu et al. 2012)



Benefits of the tumbukiza method:

- Less land is required
- Regrowth is faster in the dry season
- Green forage is available even during the dry season

How to manage Napier grass

- Weed after each harvest to maintain high productivity.
- Harvest when 1 m high or every 6–8 weeks to obtain optimal quality and quantity.
- Maintain a stubble height of 5–10 cm from the ground level at each harvest to avoid weakening the root system, which leads to low production in subsequent harvests.
- Apply FYM at the rate of 5–10 t ha-1 or slurry after every 4–6 harvests. Inorganic N fertilizers can also be used at the rate of 60–90 kg N ha-1 (5–8 bags of calcium ammonium nitrate (CAN) fertilizer).
- To increase yields during the dry season, one of the split applications of the recommended rate of N fertilizer should be done 1–2 months before the end of the rainy season.

Intercropping

Napier grass can be intercropped with forage legumes in both methods of planting. Legumes that can be intercropped with Napier grass include *Desmodium intortum* (greenleaf desmodium), *Desmodium uncinatum* (silverleaf desmodium), *Stylosanthes guianensis* (stylo) and *Macrotyloma axillare*. When intercropping under the conventional method, make furrows along the Napier grass lines or in between rows and drill desmodium seed at a seed rate of 3 kg/ha, mixed with 40–60 kg P_20_5 ha^{-1}. In the tumbukiza method, drill desmodium seed in between the tumbukiza holes.

Diseases and pests

Napier grass is attacked by various fungal diseases in localized areas:

- In Central Kenya, Bana grass, French Cameroon and Clone 13 are attacked by head smut caused by *Ustilago camerumensis*. Kakamega 1 Napier variety has been found to be tolerant to this disease.
- In western Kenya, Napier grass has been found to be attacked by *Helminthosporium* spp. New varieties of Napier grass such as Ouma have been found to be tolerant to this disease.
- Snow mould fungal disease is common to all Napier grass varieties except Clone 13. However, this disease is not a threat to herbage production.
- Pests are not a problem to Napier grass.

Harvesting

- Napier grass is ready for harvesting 3–4 months after planting and harvesting can continue at an interval of 6–8 weeks for 3–5 years.
- Leave a stem length of 10 cm from the ground at harvesting.
- Napier grass is fed green to livestock. Chop the harvested Napier grass (and desmodium if in mixture) to reduce wastage while feeding to animals. Do not graze animals directly on Napier grass. A dairy cow can consume 70 kg or 7 headloads of fresh Napier grass per day.
- Excess green feed can be preserved in the form of silage.

Potential yields

Yields depend on agroecological zone and management but on average Napier grass can give 12–25 t/ha of DM yield. One acre of Napier grass planted by the conventional method can give enough feed for 1–2 dairy cows for one year. One acre of Napier grass planted by the tumbukiza method can give enough feed for 2–3 dairy cows for one year.

Tripsacum andersonii (Guatemala grass)

It is a robust perennial grass, forming large mats up to 5 m across with tangled stolons and rhizomes, shallow-rooted. Flowering culms up to 3 m tall, up to 5 cm diameter at the base. Leaf blades up to 120 cm long and remarkably (up to 10 cm) wide, shortly tomentose on the upper surface; under surface and upper leaf sheaths are glabrous. Terminal and axillary inflorescences can have 5–8 slender racemes.

Figure 9: *Tripsacum andersonii* (Guatemala grass)

The nutritive value depends on the frequency of cutting because the heavy stems become very fibrous with maturity, generally low in protein relative to digestible carbohydrate if not managed and fertilized. With adequate N fertilizer, CP of leaf remains high (12%) even at late maturity. It is said to be poorer quality than *Pennisetum purpureum*, but this would depend on relative stages of growth. *Tripsacum andersonii* is a perennial fodder, suitable for cut-and-carry feeding systems and is especially useful as green feed during dry conditions. It is also used for low to moderate quality silage, as a stout hedgerow (living fence) or for contour strips with or without companion legume on hill land, especially that growing cassava (*Manihot esculenta*). It is planted as a break to reduce insect pests, and to combat bacterial wilt of potatoes, and also for soil erosion control, mulching and as a soil conditioner in drained swamps.

Advantages of Guatemala grass

- Not infected by Napier stunt or Napier head smut diseases
- Grows well in a wide range of climatic zones
- It is easily rotated with other crops
- Produces high quantity of quality forage

Where to grow Guatemala grass on the farm

Just like *Pennisetum purpureum*, *Tripsacum andersonii* may be established as pure stand (Figure 10) where:

- Land is available
- The plot will be used for bulking (to provide planting material to other farmers) or
- The farmer plans to intercrop with legumes in future

It can also be grown along contours and boundaries where:

- Land is sloping and farmer wants to use it for soil conservation
- Land is limited so the farmer cannot set aside for growing Napier alone.

Figure 10: A pure stand of *Tripsacum andersonii*

How to establish Guatemala grass

- Cut root splits to 20–30 cm
- Plant one root split per hole (Figure 11)
- Apply either one soda-bottle caps per hole (one bag triple superphosphate/double superphosphate (TSP/DAP) per acre) of TSP or DAP fertilizer at the rate of 1–2 handfuls of FYM/compost manure at the rate of per hole per acre at planting
- Cover with soil firmly

Figure 11: A root split of *Tripsacum andersonii*

How to manage Guatemala grass

- Weed promptly whenever weeds appear
- Harvest by cutting—First harvest at 3–4 months after planting. Maintain a stubble height of 10 cm to encourage quick regrowth. Chop to 2–3 cm pieces and feed fresh to livestock. Subsequently harvest at 6–8 weeks (1.5–2 month) intervals.
- After every second harvest, apply 2–3 bottle caps of CAN per stool or two bags per acre, or apply 2 handfuls of FYM/compost per stool (4 t FYM/compost per acre).
- Well-managed Guatemala grass produces 5–7 t of DM per acre in a year. This is enough to feed one dairy cow per year. When plenty, make silage for dry season feeding.

Brachiaria ruziziensis (Congo grass)

Brachiaria ruziziensis or Congo grass (Figure 12) is a forage crop that is grown throughout the humid tropics. With fast growth at the beginning of the wet season due to strong seedling vigour, ease of establishment, good seed production, yield and the ability to suppress weeds it has the ability to develop into the most important forage crop planted in the tropics.

Figure 12: *Brachiaria ruziziensis* (Congo grass)

(Source: https://alchetron.com/Brachiaria-ruziziensis#-)

It is a tufted, creeping perennial crop with short rhizomes forming a dense leafy cover. Culms arise from many noded creeping shoots and short rhizomes, growing to a height of 1.5 m when flowering. Leaves are soft but hairy, up to 25 cm long and 15 mm wide. Inflorescence consists of 3–9 relatively long racemes (4–10 cm), bearing spikelets in 1 or 2 rows on one side of a broad, flattened and winged rachis.

It can be established from seed which is inexpensive, although it needs to be stored for six months after harvest to break dormancy. Alternatively, the grass can be established vegetatively from stem cuttings with root nodes. It requires light soils with moderately high fertility though it does not tolerate strongly acidic conditions and performs best in a well-drained soil. It requires a reasonably high rainfall, though it can endure dry spells, with 1,000 mm or more being preferable. It requires a well-prepared seed bed, but light disc harrowing gives good results. Although it responds well to light, with light intensity increasing yields, it can also be planted for grazing under light shade conditions. Optimum growth occurs at 33/28°C day/night with a minimum temperature of 19°C.

Improved varieties of Brachiaria grass

Mulato

Brachiaria cv. Mulato and Mulato II are a result of breeding by the International Center for Tropical Agriculture (CIAT) in Columbia. They are hybrids which have resulted from crosses involving three species: *Brachiaria brizantha, B. decumbens* and *B. ruziziensis*. The last one is used as a bridge. The result is a hybrid that is apomictic (nonsexual reproduction), meaning that the seeds produced are true-to-type (their genes do not change). In reality, they are like clones of the mother plant. This is an ideal situation that is not common with many crops and forages. The pasture will not lose vigour and persistence.

Growing Mulato

Mulato grows in well-drained soils of medium to high fertility with pH 5–8. Like Napier grass, it responds well to well-matured manure. It is drought tolerant and has potential to grow well in relatively drier areas of western Kenya with mean annual rainfall of not less than 700 mm and mean daily temperatures higher than 30^{o}C. Trials show that the grass does well under irrigation in arid and semi-arid areas, and under rain-fed conditions in the transitional zones.

Mulato Brachiaria is best propagated by seeds, though it can also be planted from vegetative material. Seed is the most appropriate mode of establishment for farmers who want to plant large plots of the grass. Where the seed is not readily available locally, farmers are advised to use vegetative propagation by cuttings. When using seed, a farmer needs 10–12 kg/ha. Seed is sown at the onset of rains in well-tilled seedbeds. An important feature of the Mulato Brachiaria is that its stems are capable of rooting when they come into contact with moist soil especially caused by trampling of animals. Mulato II performs very well not only in grazed systems, but also in cut and carry system.

How to grow Brachiaria grass from a nursery

Brachiaria grass can be grown in different climates but it does better in areas with medium to high rainfall. Brachiaria grass is very nutritious and produces a high amount of forage ranging between 250–300 bales per acre per cutting. This brochure gives you guidelines to plant and manage one acre of Brachiaria crop from seeds to achieve high quality and yields.

Nursery establishment:

- Select an area measuring at least 2 x 6 m.
- The areas should preferably be near the homestead for monitoring and supervision.
- It should be closer to a water source for ease of watering.
- Clear the selected area of all weeds and grasses.
- Measure the nursery area of 1 m x 5 m. Double dig the nursery to a fine seedbed (dig it twice to at least a depth of 0.5 m while removing stones, roots and any underlying material).
- Raise the seedbed by 0.5 m. This will prevent water logging in the seedbed and also facilitate good root development.

Sowing the seeds:

- Use a string to make straight furrows at a spacing of 5 cm between the rows.
- Make furrows along the row to a depth not exceeding 2 cm. This should give you 18–20 furrows.
- Drill 0.5 kg of seeds evenly in the furrows and cover lightly with soil. Ensure all seeds are covered by the soil. Water the seedbed immediately after drilling.

Caring for the nursery:

- When drilling is complete mulch the seedbed with dry grass, straw, dry banana leaves or any such kind of material. Mulching helps to preserve moisture in the seedbed.
- Young germinating seedlings are usually delicate and can easily die if exposed to direct sunshine. Put up a simple shed over the nursery to protect germinating seedlings.
- During the days when there is no rain, water the seedbed twice daily (morning and evening) using a watering can with a nozzle. Be careful not to excessively water the seedbed. This will cause water logging that could stress seedlings.
- Farmers should closely monitor the seedbed to ensure the nursery is not destroyed by scavenging birds, pests and diseases. Protect your seedbed from being damaged if need be.
- Seeds will start to germinate after 5–7 days.
- As soon as you observe that germination has started, remove the grass mulch to allow seedlings to grow.
- The seedlings will remain in the nursery 4–6 weeks. During early stages of establishment, weed infestation is likely. Monitor closely and remove any emerging weeds manually.

- From the third week gradually remove the shade that is covering the seedlings to allow in more light. This will make the seedling stronger and ready for transplanting.

Transplanting seedlings:

- Seedling will be ready for transplanting in 4–6 weeks.
- Identify and plough or dig one acre of land in advance before the onset of rains.
- It is recommended that transplanting should be done during the wet season.
- Dig holes at a spacing of 25 cm (plant-to-plant) and 50 cm line-to-line.
- Farmers are advised to plant Brachiaria seedlings with well-dried FYM. Transport the manure closer to the field in advance. Apply one handful of manure per hole.
- The seedlings should be transplanted during the cool hours of the day preferably in the evening.
- Water the nursery in the morning hours to soften the ground to allow easy uprooting of the seedlings.
- Remove each seedling with soil attached to the roots. Seedlings can be carefully arranged on trays or gunny bags and transported for planting.
- Plant one rooted tiller per hole. Planting more than one tiller per hole creates competition between plants and reduces the area of land that could have been planted.
- It is advisable to save some seedlings in the nursery to replace seedlings that die after transplanting.

Managing the Brachiaria crop

Weed control:

- Inspect the field one week after transplanting and replace the seedlings that have died.
- Brachiaria grass is able to out-compete weeds on its own once it is well established. However, farmers will need to control weeds manually in the early stages of growth.

Pest and diseases:

- During the growing period inspect the crop for any pests and diseases. Red spider mites and shoot borers are common pests that attack Brachiaria grass.
- Once Brachiaria grass is attached, red spider mites will be found everywhere on the plants and it is important to take care of the infestation before plants become permanently damaged. A plant that is infested by red spider mites will start to look unhealthy and will have a dusty appearance to the undersides of their leaves. Pesticides can be used to eliminate red spider mites but preventing an infestation is best. Work to keep plants healthy and the areas around the crop free of weeds to keep red spider mites away. Also, make sure plants have enough water. The water will help keep the red spider mites away as they prefer very dry environments.
- Brachiaria grass can also be attack by army worms. When army worms attack, they feed on grass shoots. Insecticides can be applied successfully in the very early stages of an attack. Adult worms become resistant to chemical applications. Treatments are applied in the evening before the army worms emerge to begin feeding.

Harvesting:

- The stage of harvesting will differ according to the climate. However generally, Brachiaria grass will be ready for the first harvesting 3–5 months after establishment. At this stage the Brachiaria grass will be about 1 m in height. Subsequent harvests can be made every 8–12 weeks, depending on climate.
- The grass must be cut at a height of 5 cm above the ground using a machete or a sickle. A motorized brush cutter can also be used.

- Brachiaria can be fed as a green forage. Chop the green forage manually using a machete or a chuff cutter or use a motorized chuff cutter or chopper. It can be conserved as hay and silage.

Utilization of Brachiaria grass

Mulato Brachiaria can be grazed or cut and fed to animals in stalls and feedlots. Where animals graze, the duration depends on the number of animals. Sufficient time must be given to a pasture to grow back after intensive grazing. Rotational grazing will give grass time to regrow. Where farmers cut and carry to feed the animals, the grass is ready for the next cut in about 45–50 days during the rainy season. At this stage, the grass has higher nutrient content, especially protein, than Napier.

Mulato Brachiaria has high biomass production capacity. Therefore, it is a good alternative for making silage and hay for use during the dry season. Its production and nutrient content depend on soil fertility and its management, as well as the stage of harvesting. Research indicates that the grass holds huge potential for the dairy and beef industry, especially in the drier areas where Napier grass does not do very well and in areas affected by the Napier stunt disease. Mulato Brachiaria also has shown potential to be incorporated in the smallholder maize growing farms under the 'push pull' system that helps farmers to deal with pests, while providing a source of fodder for the livestock.

Legumes

Annual trailing legumes

Mucuna pruriens (velvet bean, Mucuna)

Figure 13: Mucuna pruriens vegetative crop, flowers and seeds (Chakoma et al. 2016)



Mucuna is an annual climbing shrub with long vines that can reach over 15 metres (50 ft) in length (Figure 13). When the plant is young, it is almost completely covered with fuzzy hairs, but when older, it is almost completely free of hairs. In young *M. pruriens* plants, both sides of the leaves have hairs. The stems of the leaflets are two to three millimetres long (approximately one tenth of an inch). Additional adjacent leaves are present and are about 5 mm (0.2 in) long.

M. pruriens bears white, lavender, or purple flowers. Its seed pods are about 10 cm (4 inches) long and are covered in loose, orange hairs that cause a severe itch if they come in contact with skin. The itch is caused by a protein known as mucunain. The seeds are shiny black or brown drift seeds.

M. pruriens, a legume belonging to *Fabaceae*, is consumed and promoted by smallholder farmers in Africa, South America and South Asia. It grows fast and its long growing season in frost-free environments protects the soil through the wet season and improves soil fertility. It is a cover crop and green manure because it can establish very quickly without requiring complete soil preparation, regular weeding and disease control. It is a valuable fodder and feed legume, suitable in intercropping systems and can be grown with maize, pearl millet, sorghum or sugarcane for support.

In many parts of the world *M. pruriens* is used as an important forage, fallow and green manure crop. Since the plant is a legume, it fixes N (40–70 kg N/ha) and fertilizes soil. In some areas, the beans are eaten and can also be fermented to form a food similar to tempeh. Vines and foliage can be used as pasture, hay or silage for ruminants while pods and seeds can be ground into a rich protein meal and fed to all classes of livestock though in limited amounts in monogastrics.

Cultivars

There are different varieties of mucuna and composition of nutrients may vary slightly, especially in protein content. The mottled type was found to have 27.7% CP, while black and white had 25.8% CP. Some local varieties in Zambia also showed a difference in CP. The speckled variety had 24.95%, green 23.7% and black 22.5%. The CP has also been found to be 28.1% in white and 24% in speckled and black types.

Advantages of Mucuna:

- Fast growing
- Seeds easy to produce (few pests, easy to harvest, good yields)
- Achieves very high seed yields (7–11 t dry grain/ha)
- Seeds very rich in protein (23–28% CP) and high in digestibility (>95%) and adapted for use by ruminant livestock. Non-ruminants are easily affected by its high L-Dopa contents (content in seeds 3–7%).
- Ease of establishment—large seed, does not need complete land preparation and covers the soil quickly
- Improves soil fertility
- Resistance to pests and diseases
- Supresses weeds hence less labour required for weeding. Velvet bean is one of the most suitable crops for reclaiming land infested with weeds, notably *Cynodon dactylon*.
- High mineral contents, i.e. K, Mg, Ca and Fe, and lysine contents in grain
- Can be used to make high quality hay and concentrate feed (seeds).

Limitations of Mucuna:

- Presence of toxic and anti-nutritive compounds in seed (especially L-dopa). Use as food and feed for monogastrics is problematic, without processing.
- Low palatability of foliage
- Limited drought tolerance
- Low tolerance to very acidic, low fertility soils.

Cultivation

Land preparation

Due to its large seeds, the crop does not require a high degree of land preparation. Minimal soil disturbance is encouraged using manual or mechanized equipment.

Fertilizer and lime requirements

Application of 500–700 kg/ha lime (preferably dolomitic lime on sandy soils) is recommended to encourage nodulation and efficient use of fertilizers. Velvet bean will thrive on soils where available soil P is low. Application of 200–250 kg/

ha SSP (18.5% P2O5) is sufficient for optimum herbage and seed production. Alternatively, one can apply 250–300 kg of compound fertilizer (preferably 7 N: 14 P: 7 K).

Legumes do not normally require N (e.g. ammonium nitrate (AN)) fertilizer, since they can fix soil N in their root nodules. However, in soils with very low N level, a single application of no more than 114 AN kg/ha (40 N kg/ha) will be necessary to boost plant growth, 3–4 weeks after germination.

Planting

a) As single crop

Seed is sown at a rate of 35–40 kg/ha in single crops at the beginning of the wet season, using inter-row spacing of 0.9 m and within row spacing of 30–40 cm. A lower seed rate (wider spacing) is advisable in semi-arid conditions, to reduce competition for moisture. Mucuna seeds are large and should be planted at a depth of 3–7 cm.

b) Intercropping with maize/sorghum

Velvet bean is a very vigorous climber. Therefore, it should be planted in between the cereals 3–4 weeks after emergence (depending on predicted annual rainfall), ideally after the firsthand weeding if farmers are not using herbicides. If planted too early and densely, it can choke the cereal, thereby reducing cereal yield.

Planting velvet bean within the same row as maize and in between the maize plants facilitates weeding and spraying. However, delaying the planting of the legume for more than four weeks after sowing cereals may result in shading by the cereal crop and severe reduction in legume yield. It is advisable to sow one seed per hole, at a spacing of 50 cm within row.

Weed, pest and disease control

It is advisable to keep the crop weed free by weeding as soon as they start appearing. This will also reduce pest infestation. Velvet bean is well known for resistance to most pests and diseases. However, there have been reports of complete devastation by leaf-eating caterpillars. Farmers should consult the local extension officer for advice on controlling disease outbreaks or pest damage, including advice on compatibility of crop chemicals when farmers desire to use mixtures.

Harvesting time and yield estimates

Mucuna is normally harvested for hay making once only in the growing season—usually at 50% early flower formation. Its flowers are normally buried in the leaf canopy. Due to its profuse seeding ability and the high feeding value of its grain, farmers prefer to harvest it when the pods are mature and dry. Then, they can harvest the foliage residue together with the pods. However, this foliage and the mature pods are hairy and itchy, making it uncomfortable to harvest and process. Mucuna has achieved average herbage yields of 7–11 t DM/ha and average seed yields of 0.5–2 t in medium to high potential areas of Zambia. At the early flowering stage, its forage contains 10.4% CP, making it a good source of protein for large/small ruminant livestock, when fed fresh or as hay. Forage collected after pod maturation averaged 6.8% CP. Mucuna seed contained 25–27% CP and the pod-6 shells 7–8% CP. The seed is high in L. dopa (up to 7%), an anti-nutritional factor that causes intestinal disruptions especially in non-ruminants when fed in high doses.

Fodder conservation

As already indicated, Mucuna should be harvested for hay making at booting stage. This kind of foliage normally dries to 75–80% DM content (safe for storage) in 3–5 days. Intercropped forage is best conserved as silage. No sugar additives will be required if the mixed crop is harvested when the cereal component is in milk-dough stage. Such silage will be high in CP content compared to silage from maize or sorghum only.

Seed production

Pods can be hand harvested and spread on a clean surface, under shade, to dry before shelling. Hand shelling is done by pounding the dried pods with long sticks. Thereafter, clean seed is obtained by winnowing from a basket. Farmers can use shelling machines. Mucuna can yield up to 2 t of clean seed per ha. It is not usually necessary to treat Mucuna seed against grain weevils or rodents.

Lablab purpureus (Dolichos lablab)

Figure 14: Lablab purpureus: vegetative plant, flowers and seeds



Source: https://plants.ces.ncsu.edu/plants/all/dolichos-lablab-lablab-purpureus/

A short-lived perennial or annual legume, *Lablab purpureus* (dolichos bean, Lablab) (Figure 14) is cultivated as human food, green manure, cover crop and animal fodder. A summer growing annual or short-lived perennial fodder legume sown for grazing and conservation in tropical environments with a summer rainfall, it is a vigorously trailing, twining herbaceous plant, resistant to disease and insect attack. Stems are trailing to upright, reach to 3 m in length and are robust. Leaves are large and trifoliate, with the leaflets having a broad ovate-rhomboid shape measuring 7–15 cm long. The dorsal side of the leaf is smooth with the underside being hairy.

The growth period can vary from approximately 75–300 days, depending on variety and agro-climatic conditions. Under appropriate conditions, it will produce maximum vegetative growth of 130 days post germination, with additional growth possible subject to temperature. Once established, Lablab is highly drought resistant, often staying green during the dry season. The average yields of Lablab grown under a range of conditions is around 3,200 kg/ha of DM yield.

Due to its potential for use as a vegetative cover, soil improvement qualities, ability to fix N through biological nitrogen fixation (BNF) and control weeds, Lablab is an important species. Lablab can be used in a pasture environment or can be fed as a supplement to animals on poor quality diets during the dry season. A summary of available literature reports indicates that *Lablab purpureus* contains an average of 17% protein, 46% neutral detergent fibre, 41% acid detergent dibre. Average DM yield is about 6 t/ha, with DM digestibility of 53%. The seed yield ranges from 1.1–3.4 t/ha with 23–28% CP. These nutritional characteristics coupled with the other environmental benefits make Lablab a suitable fodder crop for the tropics.

Cultivars

Common cultivars used in Central Africa are:

Rongai: this is a late-flowering variety with white flowers, seeding poorly in frosty areas. Rongai seeds are light brown in colour. The Rongai cultivar was derived from material from the Rongai district of Kenya. Rongai is a late maturing white flowering cultivar that will continue to grow until cut or damaged by frosts. In the absence of frost, flowering may continue for several months. It has higher forage yields and hence appropriate for use as off-season fodder bank. It should be noted that the Rongai cultivar is most prevalent in the tropical forage legume.

Highworth: the Highworth cultivar originated from Coimbatore, South India and is morphologically similar to Rongai. Contrasting with the green foliage, white flowers and light brown seeds of Rongai, foliage of Highworth has a purple band near the leaf axil, purple flowers and black seeds. Highworth is an early flowering line with high seed-yielding ability. It is suitable for pulse production and forage uses. It was originally intended for grain production in areas where early frosts prevented the seeding of Rongai. Highworth pods are above the leaf canopy, which makes seed harvesting easier.

Lablab has several advantages:

- It is highly palatable compared to Mucuna.
- It provides better late season grazing because it is not only drought resistant, it is able to grow in a diverse range of environmental conditions world-wide.
- It is more compatible than cowpea with forage sorghum or maize when intercropped.
- It gives higher yield of materials for conservation than do forages such as cowpea when drought sets in.
- It has better resistance to diseases such as phytophthora rust and stem rot, which wipe out many cowpea crops.
- It has better resistance than other forages, such as cowpea, to attack by insects like the bean fly.
- It can be grazed in a pasture setting or as a companion crop to maize, cut as hay or mixed with silage.

A major limitation to widespread adoption is that Lablab is much more prone to insect attack compared to velvet bean. Therefore, requires more attention (or TLC—tender loving care) to establish.

Cultivation

Land preparation

Seedbed preparation:

- Lablab has a large seed thus does not require a fine seedbed as does lucerne.
- Highest yields are obtained on land that has not been previously cultivated (fallow land).
- It grows well in acidic soils.

Planting:

- Space at 45 cm between rows and 30 cm from plant to plant, placing 2 seeds per hole.
- Use 60 kg/ha seed.
- Use 1–2 bags TSP per ha or 5–10 t/ha of well-decomposed FYM.
- To achieve high forage yields, inoculation with appropriate strain of Rhizobium bacteria is necessary on lands where Lablab has not been grown before.

Management:

- Harvest for fodder at an interval of 6 weeks (1.5 months) leaving a stubble height of 15 cm from ground level.
- Weed as required.
- To get optimal yields in quantity and quality, harvest at early flowering stage.

Use:

- Lablab can be conserved as hay or ensiled.
- It can be fed green to dairy cattle as a legume supplement.

Cannavalia braziliensis (Brazilian Jackbean)

Cannavalia braziliensis is a weak perennial, herbaceous legume that can form a complete ground cover (Figure 15). Leaves are almost hairless and attach to the stalk as three small leaflets. It bears purple flowers, 2–2.5 cm long. Pods are largely smooth/hairless, 12–20 cm long and approximately 1 cm wide, of brown to dark-brown colour, dehiscent with an average of 12 seeds. Seeds are light brown to brown, approximately 11 mm long and 8 mm wide, with a black hilum, 6 mm long. One thousand seed weight is 590–730 g.

Figure 15: *Cannavalia braziliensis* vegetative part, pods and seeds

Grows well on a wide range of soils, from very acidic (pH 4.3) to alkaline (pH 8.0) and is adapted to low-fertility conditions. Root growth and biomass production are affected by soil compaction, though less than in the case of *C. ensiformis*. There are indications of salinity tolerance, however the information available is not conclusive.

There is a high level of hardness in the seeds, hence scarification of seeds before sowing is necessary to break the seed hardness and to subsequently obtain even establishment. With 75 minutes sulphuric acid or 30 minutes hot water (80°C) treatment, germination rates of 80% and 50% respectively, can be achieved.

C. brasiliensis is sown in rows 40–50 cm apart and with 20 cm distance between plants in the row, equivalent to 50 kg/ha seed. For seed production, seeds are sown in rows 1 m apart and 20 cm between-plant distance, equivalent to 20–30 kg/ha of seed. Seed is sown at a depth of 2–5 cm.It is mainly used as green manure, fallow and erosion control. In view of its ample and deep root system, the species can contribute to amelioration of soil structure, to stabilization of erosion prone sites and to nutrient cycling.

Because of the medium decomposition and N mineralization rates of the biomass, nutrient release synchronizes well with the nutrient demand of annual crops such as maize and rice, when the green manure biomass is incorporated before sowing of the succeeding crop. As a result, N recovery is higher than for most other green manure plants and can reach N recovery rates of mineral N fertilizer.

C. brasiliensis forage and seed is also used to improve the value of stubble grazing during the dry season. In addition, its seed has high lysine content and could be used as a component in concentrates for poultry and swine. However, its use in livestock feeds may be limited by the presence of antinutritive and toxic compounds. To inactivate the antinutritional compounds, seeds need to be broken, soaked in water for 48 hours and subsequently cooked for one hour. In poor regions of northeast Brazil, seed is used as food in times of low food availability.

Annual legume niches

Some legumes are preferentially grown within the homestead, while others are grown far from the homestead, close to streams or on farm edges. Intercropping legumes with main crops or integrating a few rows of legumes between two plots of main crops is commonly practiced. Forage legumes are also intercropped with other crops such as maize and cassava or grown as pure stand in small plots around homesteads and later mixed for feeding with natural forages. Generally, annual legumes are attractive because that they can be grown as ley crops or in combination with cereals, without much disruption to food production.

Choice of forages and integration into farming systems depends on topography, land availability and tenure. In high altitude, erosion-prone sites with high population pressure, grasses may be preferred over legumes and mainly grown on field contours and anti-erosive hedges. When land tenure does not allow for perennial forage grass, cultivation of forage legumes may be preferred.

Perennial legumes

Desmodium uncinatum (Silverleaf desmodium)

Figure 16: *Desmodium uncinatum* (silverleaf Desmodium)

Desmodium (Figure 16) can be grown as a sole crop or as an intercrop with grasses.

Establishment

Two methods of establishing Silverleaf are common—from seeds and from cuttings.

Establishment from seeds:

- Silverleaf requires a fine, firm and weed-free seedbed.
- Seedbed preparation should be done well before the onset of rains.
- Use 3–5 kg/ha (2 kg/acre) silverleaf seeds.
- During planting, mix seed with 2 bags of TSP or 4 bags of single superphosphate (SSP) fertilizer. Farmers can also use 5–10 t/ha of well-decomposed FYM.
- Drill the seed into shallow furrows 2.5 cm deep spaced at 30 cm or 50 cm; cover with little soil.
- For intercropping with Napier grass, make furrows between or along the Napier rows and drill silverleaf seed and fertilizer mixture in the furrows.

Establishment from cuttings:

- Use mature parts of silverleaf vines.
- Use freshly cut vines.
- Bury 2 nodes leaving 1–2 nodes above the ground.
- Space at 30 cm or 50 cm from row-to-row and 15–30 cm from vine-to-vine.
- Use the same rates of fertilizer as for seed but place it in holes.
- To maximize germination, ascertain that the amount of rain before planting has been adequate.

Management:

- Keep the stand free of weeds, especially during the early stages before the crop covers the ground, by using hoe or herbicide 2,4-D amine 72% at the rate of 2.5 litres per ha.
- Top dress with 2–4 bags of TSP or SSP fertilizer every year to maintain high yields of silverleaf herbage and seed.
- For herbage production, make first cut 3–4 months from planting. Subsequent cuttings should be at intervals of 6–8 weeks.
- Spray against harmful pests, especially when producing Desmodium seed.
- Harvest seed when the pods have turned brown by hand stripping the ripe pods and store in a dry place after threshing to avoid rotting.

Use:

- Cut and feed in green form.
- Cut and conserve as hay, whole or chopped.

Yields:

Yields of 9–10 t/ha DM per year of 18–20% CP have been reported under good management. An acre can produce 30–60 kg of seed.

Other benefits:

When intercropped with maize it will:

- Provide N to the crop
- Inhibit the growth of weeds, e.g. Striga
- Reduce damage by the maize stemborer
- Control soil erosion.

Stylosanthes guianensis (sqntylo)

Figure 17: A mature crop of *Stylosanthes guianensis* in the field

Stylosanthes guianensis (stylo) (Figure 17) performs well in wetter and warmer areas and in sandy soils. Its ability to grow well in soils of low fertility is particularly valuable both to provide good-quality grazing on these soils and to improve the fertility of the soil. It is useful for weed control and grows well in pasture mixtures containing Rhodes grass. It grows rather slowly in early establishment stages but persists better in grass-legume mixtures than does silverleaf desmodium.

Seedbed preparation:

Prepare a firm, fine seedbed.

Planting:

- Drill at a spacing of 30–40 cm rows or broadcast the seed, especially when over sowing.
- Sow 3–4 kg/ha of seed.
- Apply 1–2 bags TSP per ha.

Management:

- Weed as required.
- When grown in a grass-legume mixture, graze to reduce the shading effect of grass during the early establishment stage.
- Harvest or graze at 6 weeks at intervals of 1.5 months, leaving a stubble height of 5 cm.

Use:

- Graze or cut and carry.
- Cut and conserve as hay.

Yields:

The whole stylo plant has a CP content ranging from 12.1–18% and DM yields ranging from 4.1–6.7 t/ha per year.

Centrosema pubescens (Centro)

Figure 18: *Centrosema pubescens*

Centro (Figure 18) is a popular climbing legume with wide leaves, which gives abundant foliage without woody stems. It produces large quantities of easy-to-harvest seeds.

Climate and soils

Centro gives a lot of herbage under warm and moist conditions but survives even where rainfall is only 750 mm per year. It withstands dry conditions for up to five months. Centro grows in a wide range of soils, from sandy loams to clays.

Establishment

It establishes well in a well-prepared seedbed. Centro is best grown from seed at a rate of 5 kg seed per ha. The seeds of centro are large and so they should be covered with soil when sown. Centro is slow to germinate but grows vigorously once it has established.

Intercropping with grasses

Centro combines well with Napier grass, Guatemala grass and setaria.

Fertilizer application

Centro grows well in fertile soils without fertilizers. Where soils have low fertility, apply a phosphate fertilizer such as SSP, at 125 kg per ha.

Weeding

During establishment, keep centro weed free. Once established, it competes with weeds fairly well. Where there are many broad-leafed weeds, slashing the whole garden helps greatly, particularly if the weeds have not yet dropped their seeds.

Diseases and pests

There are no diseases and pests of economic importance.

Cutting

Centro persists well with frequent cutting similar to that of any fodder grass with which it is growing as a mixture. An interval of 3–4 weeks is ideal depending on soil fertility and rainfall.

Feeding

The feeding management of centro is similar to that of the fodder grass with which it is growing. It makes good hay in combination with Rhodes grass and setaria.

Macroptilium atropurpureum (Siratro)

Figure 19: *Macroptilium atropurpureum* foliage, pods, flowers and seeds

Siratro (Figure 19) is a deep-rooted legume with trailing and climbing stems; it produces a lot of palatable fodder. It has dark-green leaves.

Climate and soils

It is drought resistant because of its deep roots, and productive under a wide range of soils. It requires 600–800 mm of rainfall per year. The performance of siratro is poor at heights above 1,600 m.

Establishment

Siratro establishes best in a well-prepared seedbed. It is sown from seed at a rate of 5 kg per ha. Seed treatment using hot water softens the seed coat and quickens germination. Inoculation is not necessary for siratro because it nodulates freely with the cowpea rhizobia in the soil. It is very slow to establish when planted from cuttings.

Intercropping with grasses

It combines well with a wide range of grasses including Napier, Setaria and Guinea grass.

Fertilizer application

On fertile soils, no fertilizer will be necessary for a number of years, but establishment and vigour will be better with an annual application of phosphate fertilizers, such as SSP, at the rate of 100 to 125 g per ha.

Weeding

Siratro competes well with weeds. Under good conditions where there is enough moisture, warm temperatures and fertile soils, establishment takes 3–4 months.

Diseases and pests

Under very wet conditions, siratro can be attacked by fungal infection. Root rot is also common with siratro as a result of root nematode attack. However, these diseases and pests are of little economic impact.

Cutting

Cutting siratro at 15 cm from the ground every four weeks maintains the crop in a vigorous state.

Feeding

Siratro is highly palatable. When grown in mixture with grasses or when fed as a mixture with cut-and-carry forage, it improves the quality of the feed being offered to the animal. CP content of siratro foliage varies from about 12% in older material to 25% in younger material.

Where to grow perennial legumes

In the highly populated areas where there is scarcity of arable land particularly in high altitude areas, niches used by farmers for growing perennial legumes include farm boundaries, under trees, in banana plantations and as live fences and around field edges. In areas prone to erosion, perennial legumes may be planted in hedgerows for erosion control.

Table 3: Dry matter yield (t/ha) of forage species tested in different climatic zones of Sud-Kivu, eastern part of DR Congo (Muhimuzi et al. 2014)

Forage species	Muhongoza (1,548 m)	Nyacibimba (1,955 m)	Kamanyola (940 m)	Tubimbi (1,100 m)
Cannavalia braziliensis	2.1	3.2	6.9	1.5
Desmodium uncinatum	5.4	2.6	6.0	0.3
Stylosathes guianensis	1.6	4.1	6.8	2.1
Pennisetum purpureum cv. French Cameroon	3.4	5.6	10.1	3.6
Pennisetum purpureum local	6.2	7.5	-	1.9
Tripsacum andersonii	2.4	1.3	2.6	2.4

2.3 Forage mixtures

Forages can be planted in monocultures or mixtures. Mixtures can be simple or complex, with two or many species composing a mix. A mixture of species in a pasture can adapt to a wider range of conditions. Some species tolerate wet conditions, some dry, some acidic and some alkaline or sodic soils. Mixtures provide some insurance to unexpected conditions or a variety of conditions which may occur in a single pasture. Planting a forage mixture often provides advantages to seeding a single species.

Some advantages of forage mixtures include:

- Better adaptation across fields that have diverse topography, soil types or salinity levels
- Forage production is more consistent across the season, because each species' production peaks at different dates
- More efficient use of soil moisture and nutrients
- Animal gains may be greater due to a more balanced diet

- Mixed stands may have greater longevity, with more adapted species replacing less-suited species over time
- Less susceptibility to insect and disease infestations

Mixtures can improve the feed quality. Legumes have a higher protein content than grasses. Growing animals have a high protein requirement that can be met to a large degree by adequate legumes in the forage mix. Furthermore, the palatability and digestibility may also be improved. The advantages of mixing a grass and a legume centre around utilizing the best qualities of each.

The mix may:

- Extend the growing season of a pasture
- Improve the quality of forage
- Reduce N fertilizer requirements because of the legume's N fixation capacities
- Prove more adaptable for a wider range of conditions
- Improve flexibility to survive environmental conditions
- Reduce susceptibility to insect and disease attacks
- Improve the palatability
- Utilize grass to quicken the curing of hay
- Increase the organic matter content of the soil over time because of grass root systems
- Reduce weed encroachment
- Reduce erosion
- Produce higher yields

If hay or silage making is the goal, the thought of using mixtures should consider those species that can be harvested at the same time.

Although planting a legume with a grass does not mean all N fertilizer needs will be met, grasses can eventually benefit from being planted in soil where legumes fixed atmospheric N. A rule for mixtures is ‘remember simplicity’. A large number of species in a mixture, sometimes called a ‘shotgun’ mixture, should be avoided. Often a single grass and a single legume will best provide the benefits intended.

Forage monocultures have the following advantages compared to forage mixtures:

- Easier to seed
- More uniform palatability, thereby reducing selective grazing
- Uniform growth and regrowth characteristics
- More stable plant composition
- More predictable peak production date
- In some cases, the only species fully adapted to the site or intended use

Generally, monoculture forage crops are easier to manage successfully than forage mixtures. The most important point to remember when selecting a forage mixture is to select only species that are adapted to the site and complement the production characteristics of the other species in the mix.

Some fundamental principles or rules to be followed when establishing forage mixtures include:

- Include at least one grass.
- Keep the mixture simple by using only two or three species.
- Species must be adapted to the area.
- Species must be appropriate for their intended use.
- Species must be compatible with each other.
- Species must not differ widely in palatability.
- Species must be similar in maturity pattern and vigour.

It is advisable to use only one grass in a mixture. This is due to the wide variation in grass vigour, palatability and maturity patterns. Using a number of grass species may result in spotty grazing and wasted forage. Examples of grass-legume mixtures and their effect on live weight gain of cattle are presented in Table 4.

Table 4: Grass-legume mixtures and effect on live weight gain of cattle

Grass	Country/ region	Climate/ ecosystem	Legume species	Live weight gain		Reference
				Grass alone	With legume	
Native (*Heteropogon contortus*)	Australia, Central Queensland	Dry subtropics	*Stylosanthes humilis*	83 kg/animal/yr	121 kg/animal/ yr	Shaw and Mannetje (1970)
Native	Australia, Northern Territory	Dry tropics	*Centrosema pascuorum* 1	-183 g/animal/d	489 g/animal/d	McCown et al. (1986)
Urochloa mosambicensis	Australia, Northern Queensland	Dry tropics	*Leucaena leucocephala* cv. Cunningham *L. diversifolia*	381 g/animal/d	723 g/animal/ d2 532 g/animal/ d2	Jones et al. (1998)
Brachiaria humidicola	Venezuela, Táchira	Humid tropics	*Desmodium ovalifolium* 4	336 g/animal/d	385 g/animal/d	Chacón et al. (2005)
Brachiaria decumbens	Colombia, Llanos	Subhumid (savannah)	*Pueraria phaseoloides*	124 kg/animal/yr	174 kg/animal/ yr	Lascano and Estrada (1989)
Andropogon gayanus	Colombia, Llanos	Subhumid (savannah)	*Stylosanthes capitata*	120 kg/animal/yr 240 kg/ha/yr	180 kg/animal/ yr 280 kg/ ha/yr	CIAT (1990)
Brachiaria dictyoneura	Colombia, Llanos	Subhumid (savannah)	*Centrosema acutifolium* cv. Vichada *Stylosanthes capitata*	191 g/animal/d	456 g/animal/d 446 g/animal/d	Thomas and Lascano (1995)
Brachiaria decumbens	Brazil, Mato Grosso do Sul	Subhumid (savannah)	*Calopogonium mucunoides*	327 kg/ha/yr	385 kg/ha/yr	CNPGC (1988)
Pennisetum purpureum cv. Kurumi	Brazil, Santa Catarina	Humid subtropical	*Arachis pintoi*	716 g/animal/d	790 g/animal/d	Crestani et al. (2013)
Brachiaria brizantha	Costa Rica, Guápiles	Humid tropics	*Arachis pintoi*	139 kg/animal/ yr8 597 kg/ha/ yr8	166 kg/animal/ yr 8 736 kg/ ha/yr	Hernández et al. (1995)
Brachiaria brizantha	Mexico, Veracruz	Wet-dry tropics	*Cratylia argentea*	580 g/animal/d	839 g/animal/d	González-Arcia et al. (2012)

N.B. d = day, g = grams, yr = year.

3 General guidelines on fodder production and management

3.1 Fodder establishment

When to plant

Annual forages should be planted when effective rains are received, when a farmer is sure that the real season has commenced, to avoid false season breaks that lead to droughts during the crop establishment period. This will be the same period when farmers normally start to plant maize and beans. Plant early to increase the chances of adequate moisture during the critical germination and early growth period. Replanting must be done within the second or third week of establishment, if gaps are observed at some planting stations.

Depending on size of land to be established and practicalities of carrying out weeding operations, perennial fodders can be planted at the start or middle of a wet season. In large-sized plots, mid-season planting helps to minimize need for weeding operations and to enable young perennial fodder crops to establish with minimum competition from annual weeds. Replanting must be done when gaps are observed at planting station, within the field.

Seed quality

Seed quality has a large impact on establishment success and subsequent forage yields. Certified seed will have good germination and seedling vigour, low amounts of weed seeds present and will be of a recognized variety. Certified seed or planting material assures seed quality and characteristics of the variety, such as relative yield, disease resistance and winter hardiness. This allows for selection of characteristics best suited for existing growing conditions. Using cheap seed may result in very significant yield losses and increased risk over the life of a stand. Always choose certified seeds and verify seed tags for germination and contamination with other seeds. It is desirable to use seed with a minimum 80% germination. The seeds should also have enough food reserves for the seedling to reach the soil surface and grow rapidly. When vegetative planting material is used, it should be well-fertilized and mature when harvested for planting. It should be pure (according to variety/cultivar) and free of weedy plants.

How to plant

- Use quality seed. Clean seed with high germination will result in rapid establishment and reduced weed problems in the establishing crop.
- Plant forage seeds when the chances of success are best based upon rainfall patterns and temperatures.
- Place seed at the correct depth. Most forage species should not be seeded deeper than 12 mm (1/2 inch). Some small-seeded species, such as birdsfoot trefoil and timothy, should be seeded at 0.6 cm (one-quarter inch) deep or less.

- Sow into a firm seedbed. Good seed to soil contact is required for rapid germination of forage seeds. Soil should be firm enough that a footprint will leave virtually no depression in the soil. Clean, unworked stubble makes a good seed bed.
- Measure seed accurately. Most forage seeds are small and/or chaffy and are seeded at low rates. Seeding implements must be able to consistently apply seed. Mixing chaffy seed with cracked grain, cover crop seed or fertilizer (not with inoculated legumes) can improve flow of seed from the planter to ensure they are spread evenly.
- Control weeds. Clean up fields prior to planting, paying particular attention to perennial weeds. Control weeds in the year of establishment, using cultural or chemical means.
- Use appropriate seeding rates. Ideal seeding rates vary with average available precipitation. Seeding rates will be lower in drier areas.
- Carefully consider the use of cover crops. Cover crops can protect forage seedlings from wind damage and provide an economic return in the year of establishment. However, cover crops compete with forage seedlings for moisture, light and nutrients. Cover crops reduce establishment success and usually reduce the subsequent yield of the forage. The negative impacts of cover crops on forage seedlings become more apparent under dry conditions and may result in the forage failing to establish. Cover crops are not recommended in the brown soil zone.
- Remember that forages are slow to establish and may require over a year to do so.

Propagation of the various forage species depends on the nature of the seed or cuttings used. Generally, forage legumes and some grass species are planted from seed, while others such as Pennisetums and Tripsacum are planted from rooted tillers or stem cuttings. Forages are usually planted in rows for convenience, but seed can be broadcast if the soil is prepared to receive it. Vegetative propagation is usually done by hand, although tractor operated planters can be used. Vegetative material may be in the form of rhizomes, stolons, stem pieces or cuttings (splits). Such materials are genetically identical to the parent plant. The spacing used between rows and within rows is determined by the forages species and planting arrangements used.

In developed countries, several methods and types of machines have been developed over the years for planting forage crops—from manually broadcasting the seeds to very sophisticated vacuum precision planters. One's choice will be based upon type of crop to be sown and availability of equipment. Some crops, like the small grains, require good soil-to-seed contact and need to be drilled or incorporated, while other crops, such as clover and ryegrass, can be broadcasted and rolled.

Table 5: Planting guide for common pasture grasses

Pasture crop	Establishment method	Spacing	Seed rate	Fertilizer rate	Estimated yield of hay in bales per cutting
Rhodes grass (*Chloris gayana*)	Seed	Drill in rows 30–40 cm apart	1–2 kg/ha	150 kg DAP/ha	350–400/ha
Andropogon/gamba/whisky grass (*Andropogon gayanus*)	Seed	Drill in rows 30–40 cm apart	1 kg/acre of clean seed	100 kg DAP fertilizer per acre at planting	200–250/acre depending on soil fertility and rainfall
Cenchrus (African foxtail grass) (*Cenchrus ciliaris*)	Seed	Drill in rows 30–40 cm apart	0.5–1 kg/acre	Fertilizer not necessary but sow in fertile soil	Approximately 100/acre
Star grass (*Cynodon plectostachyus*)	Splits	1 m x 1 m	-	1.5 bags NPK (20-20-20) fertilizer/acre	Approximately 100/acre

Pasture crop	Establishment method	Spacing	Seed rate	Fertilizer rate	Estimated yield of hay in bales per cutting
Kikuyu grass (*Pennisetum clandestinum*)	Cuttings/ stolons	1 m x 1 m	-	Plant in highly fertile soils but top dress with N fertilizer after grazing/cutting	Best for grazing

If the seedbed is very loose, it may need to be firmed by rolling before broadcasting the seeds. After broadcasting the seeds, the soil should be harrowed very lightly to cover the seeds with approximately 0.6–1.27 cm (1/4–1/2 inches) of soil. Thereafter, a roller can be used to pack and firm the soil around the seed. Where seeds are broadcast on a loose seedbed, only cultivating may be needed to obtain sufficient seed-to-soil contact. For small seeds, such as Rhodes grass or white clover, disking (harrowing) can cover the seeds too deeply, so only rolling should be sufficient.

Since planting material can be very expensive and not readily available, producers can establish their own nursery and use it to expand their plots. This practice reduces the cost for planting material and time spent between harvesting and planting, increasing the chances of better establishment. However, it is essential to have a weed-free area before establishing a nursery and to maintain it well-fertilized and clean for producing high quality seed.

Weed control in forage crops

A weed management plan will help ensure success in forage establishment. It is important to control weeds during establishment because newly emerged forage seedlings are extremely susceptible to weed competition. Newly emerged pasture seedlings can easily be out competed for moisture and nutrients by weeds, leading to establishment failure. Therefore, planning and implementing a weed control strategy prior to and during establishment is very important.

Controlling weed invasions by clipping (or cutting back) can be effective, but it should not be done too early because this will remove only the tops of the weeds and leave active buds that will produce fresh branches and provide more competition. On the other hand, clipping too frequently can reduce seedling development and as a result, yield reduction may occur the following year.

On perennial pastures, the use of herbicides should be targeted more on perennial weeds, as annual weeds often tend to be a big challenge in the first year of establishment, before pasture seedlings are able to defend their own space. Pre-emergence and post-emergence herbicides may replace the need for a companion crop to manage weeds during forage establishment. It is a challenge to find suitable herbicides for controlling weeds in grass-legume mixtures during establishment. For optimum growth of new forage seedlings, minimizing weed and insect competition, maintaining optimum soil fertility and employing optimum harvest management play an important role over the life of the forage stand.

Inoculation of legumes with Rhizobium bacteria

Pasture legumes form a symbiotic (mutually beneficial) association with specific soil bacteria (rhizobia) to meet their N requirements. To aid this natural process, legume seed is usually inoculated with an appropriate strain of Rhizobium bacteria prior to planting to encourage BNF. After germination, the Rhizobium bacteria forms nodules on the plant roots. These nodules house millions of rhizobia that convert N from the air into a form the plant can use in a process known as N fixation. This enables the crop to utilize gaseous soil N and ammonia to synthesize nitrates, which can be used by the plant to make amino acids. Well-nodulated forage legumes can grow without the need for N fertilizer.

The association between the host plant and its rhizobia is very specific and pasture legumes must be inoculated with the correct rhizobia strain (or group) for maximum N fixation. In many soils, sufficient numbers of rhizobia bacteria are already present to adequately infect legume roots, particularly if the same legume species has been grown in the field within the past few years. Inoculation is recommended when the legume being planted has not been grown in the field for the past three years. Inoculation ensures that sufficient bacteria will be in the soil for proper N nutrition of the legume plant. The cost of inoculant is low and the potential yield benefits are substantial.

Inoculants are live bacteria. Therefore, they should be kept cool and moist until planting to get successful legume root nodulation and N fixation. The shelf life of these products varies from several weeks in the case of some pre-coated seeds to three years for the freeze-dried powder. Some legume seed is sold already coated with inoculants. In most cases though, the inoculant will need to be purchased separate from the seed and mixed with the seed just prior to planting. Commercial inoculants are specific to legume types. Be sure to obtain the right one for the crop being seeded.

Inoculants come in four different carriers:

- Peat-slurry or sugarcane bagasse: the inoculum is carried in peat slurry or sugarcane bagasse to ensure preservation and facilitate easy application. Peat is applied as a slurry to the seed coat so that rhizobia are in direct contact with the seed. In the case of bagasse, the Rhizobium is separated from bagasse by washing with 5% sucrose solution. Thereafter, the solution is smeared on seed and allowed to dry with the sugar acting as a sticking agent. When seeding mixtures of different pasture legume seeds, each cultivar should be inoculated separately and then mixed together.
- Freeze dried powders: inoculants containing freeze-dried rhizobia are available as soluble powders in 30 g glass vials. They become active when the powder is reconstituted with liquid. The product also comes with a pack of protecting agent, which assists Rhizobium survival during planting. Treated seeds need to be drilled into moist soil within five hours of application. Avoid contact with pesticides and fungicides. These products have a shelf life of up to three years when stored at4°C–10°C and not opened.
- Granular: granular inoculants are stand-alone products that can simplify the delivery of rhizobia to the seed. The technology is an alternative to the labour-intensive slurry mix-lime process and can provide greater flexibility in sowing operations (such as sowing ahead of rain). Note that dry sowing can increase the risk of establishment failure from false breaks of season. The physical separation of the rhizobia from the seed also allows insecticides and fungicides to be applied to the seed, which would otherwise be damaging for the rhizobia. Granules are manufactured from either peat or clay and must be drilled with the seed to ensure rhizobia are placed in close proximity to the seed.
- A pre-coated seed form, with inoculum as part of the pellet—Some seed companies sell pasture seeds that contain rhizobia as part of a complex seed pellet, which may also include insecticides, fungicides and micro-fertilizers. Lucerne is an example of pre-inoculated seed, because the rhizobia for the species survive well in this form. If purchasing pre-coated seed for some species such as clovers, ensure the seed has been freshly coated, as rhizobia for these species will die to low levels after three weeks. The main advantage to this approach is convenience. The main disadvantage will usually be cost, since pre-treated seed will cost more than untreated seed. Nevertheless, purchasing pre-inoculated seed is like buying insurance to virtually guarantee successful nodulation of the crop.

Kinds of inoculants needed for commonly grown forage legumes

- Alfalfa group (*Rhizobium meliloti*): Alfalfa, black medic, burr clover (medic), button clover (medic), sweet clovers (yellow and white)
- Cowpea group (*Bradyrhizobium japonicim*): Alyceclover, cowpea, kudzu, peanut, Lespedeza and Lima bean
- Pea and vetch Group (*Rhizobium leguminosarum*): Bigflower vetch, common vetch, hairy vetch, winter pea, Caleypea, garden peas, lentils
- Trefoil (*Rhizobium loti*): Birdsfoot trefoil
- Clover group (*Rhizobium trifolii*)
- Clover I: Berseem clover, crimson clover, Lappa clover, Persian clover and rose clover

- Clover II: Rose clover and subterranean clover
- Clover III: Alsike clover, ball clover, hop clover, Ladino clover, red clover and white clover.
- Clover IV: Arrowleaf clover
- Lupine group (*Rhizobium lupini*): Blue lupine, white lupine
- Bean (*Rhizobium japonicum*): Soybean

A list of stockists in each DR Congo province where farmers can purchase inoculant is presented in Appendix II.

Selecting quality inoculants

- Inoculant should contain only rhizobia capable of producing effective nodules. Effective inoculants may consist of one or several elite strains.
- Inoculant should provide large numbers of viable rhizobia allowing for application of at least 10,000 bacteria per seed.
- Carrier medium must protect the rhizobia in the package and on the seed. It should be easy to apply and adhere well to the seed.
- Inoculant must be free of other bacteria which might be detrimental to rhizobia or to the young legume seedling. Some inoculants contain other beneficial root bacteria.
- Inoculant must be packaged to protect the rhizobia until it is used. The package should allow exchange of gases and retention of moisture.
- The package should provide clear instructions and list the legumes that it effectively nodulates and carry an expiry date beyond which the product cannot be considered dependable.

Inoculant labelling and storage requirements

The information required on the legume inoculant package should include:

- Name of the crops for which the inoculant is intended
- Scientific name of the Rhizobium species
- Number of live rhizobia per gram
- Expiration date beyond which the product cannot be used
- Lot number for quality control feedback
- Instructions for use
- Net weight of inoculant
- Trade name, manufacturer and address
- Necessary storage conditions

Legume inoculants are perishable and quickly lose their effectiveness when exposed to a temperature of 40°C or more. Inoculants retain their effectiveness for six months or longer when stored at a temperature around 20°C. This period can be extended if refrigerated near 4°C but freezing inoculants damages the product.

Guide to successful inoculation

- Use the correct inoculant for each legume. Check the label for the legume species you are planting.
- Protect inoculant from sun and heat to keep it alive. The ideal storage temperature is 4–26°C.
- Store inoculant in tightly closed bags.
- Use a sticker when inoculating seeds.
- Use the recommended amount of inoculant. Use no less than 5 g per kg of seeds.
- Inoculate seeds just before planting.
- Apply soil inoculant when the soil is moist or just before irrigation.
- Cover the furrows after planting inoculated seeds.
- Use more inoculant under adverse conditions.

Some common mistakes in inoculant handling and use:

- Exposing inoculants to temperatures above 30°C
- Using inoculants after their expiration date or after they have been exposed to high temperatures
- Letting inoculants dry out
- Mixing fertilizer with inoculated seeds.
- Broadcasting inoculants onto dry soil
- Applying additional inoculant to the surface when the soil is dry

Application of fertilizers on forage crops

Once the crop is established, the soil fertility program will focus on maintenance of good plant nutrient levels in the soil for the life of the forage stand. The most important part of the maintenance program is regular soil testing to determine the need for lime, P, or K to replace the large amount of nutrients removed in the forage. On grasses, N (as AN (34.5% N), DAP (18% N and 46% P_20_5) or Urea (46% N) fertilizers or high-quality manure) will also be an important part of the maintenance fertility program. Compost or dung manure can be used effectively on grasses, but it may not be suitable for legumes, if it is high in N content. When N supplied by fertilizer is higher than 40 kg/ha, there is a chance that BNF is hindered by too much N.

There may be a few situations where micronutrients may be required. Plant analysis, when properly used, is an excellent tool for improving the fertility management of perennial forage crops.

The best management practice for achieving optimum soil fertility is to test the soil several months prior to planting the grass crop. Farmers should keep in mind the following guidelines when testing their fields:

- Maintain an optimum pH level of 6.0–6.5. If the soil pH becomes less than 6.0, other nutrients such as P, Ca and Mg become less available to the plant. It is best to optimize the soil pH several months before planting. If the soil is excessively acidic, an application of limestone is recommended. Under most climate conditions, the lime will begin to show its effect by increasing the pH of the soil within three months. However, it is usually best to apply the limestone six months before planting.
- Maintain adequate N to obtain high yields. Yearly applications of N are needed after establishment of the grass crop. Some common sources of N fertilizers are urea, 28% urea-AN solution, AN and manures. If legumes were properly inoculated at seeding and are well nodulated, they will have all of the N they need for optimum

production. There is no need to apply supplementary N to them. Besides being uneconomical, adding N to a legume stand will not increase yield, and can greatly increase the competition from grass and weeds which can shorten the life of the stand. Even though manure is a good source of N, it is generally considered uneconomic to apply manure to forage legumes.

- Establish optimum P concentrations prior to planting by incorporating sufficient amounts into the topsoil. P is essential for plant growth, especially for protein synthesis and enzymatic activity. It is much more difficult to substantially increase P levels once the grass crop is established because P is slow moving, and it easily binds with ferrous ions in the soil to form insoluble complexes that render P_20_5 unavailable. Some common sources of P are single (18.5% P_20_5), double (36% P_20_5) or triple 46% P_20_5 super phosphate, diammonium phosphate, mono-ammonium phosphate and ammonium polyphosphate.
- High-yielding grass forages have a high demand for K especially if they are harvested for cut-and-carry feeding systems. It is very important to build the soil K levels up to the critical level before planting, which can be done by broadcasting K-containing fertilizer on the soil and working it into the soil. Some common K-containing fertilizers are muriate of potash (60% potash), sulphur-potassium-magnesium (Sulph-Po-Mg), blended fertilizers and manures. If manures are used, it is best to wait 10–14 days after manure application before planting. The manure should be worked uniformly into the soil to a depth of at least 10–15 cm (4–6 inches).
- Maintain sufficient levels of Mg. If Mg levels are low in relation to K levels, the plant will tend to take up more K. This condition can contribute to grass tetany 'shock' in livestock that feed on the forage. If the addition of Mg is recommended, the most common Mg fertilizer sources are dolomitic limestone, magnesium oxide and Sulph-Po-Mg.
- Keep an eye on sulphur deficiencies. Sulphur is an important constituent of proteins in plants. Rarely does a sulphur deficiency occur, but when it does, it most likely occurs in sandy soils with very low organic matter content. The sulphur status is considered low when sulphur concentration in the leaf tissue is less than or equal to 0.20%. If additional sulphur is needed, the most common sources to use are flowers of sulphur (yellow powder), Sulph-Po-Mg, gypsum, ammonium sulphate and manures.

Take precautions when adding micronutrients to the soil. The plant requires these nutrients in very small amounts and an over-application can be toxic to the plant.

Establishing optimum soil fertility before planting will pay benefits in greater yields and better quality of grass forage over many years. Trying to make large changes in the soil's fertility after the crop has been established is expensive and not as effective as doing it before planting. Soil testing is the best way to assess soil nutrient levels. Crop inspecting and tissue testing allow for fine-tuning fertilizer application and problem diagnosis. Some soil testing labs will do an economics report on fertilizer application, for a nominal fee, which analyses the benefit versus the cost of applying fertilizer.

Using annual crops for forage

Annual forage or field crops, such as cereals (hereafter referred to as annuals) make excellent fodder crops and can be utilized not only through the growing season, but also throughout the year to extend the grazing season by providing supplemental or emergency pasture for grazing livestock. However, growing annuals for pasture is generally more expensive than utilizing perennials for pasture. Annuals can provide producers with the ability to graze crops when they would traditionally be feeding stored feeds. This reduces the harvesting, handling, feeding and manure disposal costs. Annuals give the producer more flexibility within their livestock operation. Any annual crop can be utilized for annual pastures provided it is palatable and nutritious to livestock. These crops can be any of the species that produce sufficient growth throughout the growing season to provide forage.

Some crop species that may be considered for this purpose include the following:

- Sudan grass: A rapid growing warm-season grass which can produce a good quality forage if managed properly.

- Pearl millet: can be grown for supplemental forage. It tends to have smaller stems and is leafier; it does not produce prussic acid.
- Wheat: can produce more tonnage than barley and is of higher quality than rye. After grazing, it can be harvested for grain, silage or hay.
- Rye: quick growth makes it the most productive of the small grains for pasture. Rye is of poorer quality than the other small grains and can become unpalatable if allowed to mature past the boot stage.
- Triticale: can be used for pasture, silage, or hay. It is managed similarly to wheat and has a higher forage yield, but lower quality as compared to wheat.
- Oats: commonly used as a companion crop for seeding legumes or as a catch crop; it may be used as hay, silage or pasture.
- Brassica crops (turnips, kale, and rape): can be described as high-yielding, high-quality, and fast-growing biennial crops. The crop is utilized during the seeding year only.
- In several areas, crops such as sorghum, rice, peas, corn and many other crops are commonly grown and used as green feed, silage, pasture or swath grazing in a livestock production system. Some producers have used annuals such as sorghum-Sudan grass and millet.

Annual crops are productive and flexible, allowing them to be used effectively to deal with feed shortages. However, adequate levels of nutrients in the soil, particularly N in the case of cereals, are required in order to obtain maximum profitability from annual forages. If crops are stressed prior to or during use, nitrate levels in the crop should be monitored. Nitrates can poison livestock if present in high concentrations (0.5% or greater).

Pasture

Annuals can be used for pasture and fit well into complementary grazing systems. The choice of crop depends on when the additional pasture is required. High stocking rates are required on annual forages to reduce trampling losses and prevent cereals from heading and losing quality. Rotational grazing is useful to achieve the required grazing intensity and allow for plant recovery following grazing. Expected grazing productivity of annual pasture ranges from 25–150 grazing days per acre depending on the soil zone.

Greenfeed

Annuals can be used for greenfeed production. Timing of cutting has a large impact on subsequent feed quality. Considering the required feed quality prior to harvest will allow the operator to cut the crop at the appropriate time to maximize the value of the greenfeed crop. Generally, fibre content increases and protein and energy decrease as annual cereal forages go from boot to hard dough stage. The decline of protein and energy levels is slower in barley than in oats, triticale and rye. Annual forages produce the highest yields and protein when harvested in the dough stage. The relative performance of annual species varies with soil zone.

Improved grazing management

More pasture for more months

Economical production of high-yielding, high-quality forage is a necessity for a successful livestock operation. Grazing management is one of the cornerstones of successful forage production. Since feeding costs are the single greatest expenditure in a cattle operation, management of the grazing resource has large impacts on the financial success of the operation.

Forage plants require certain conditions to survive and produce to their potential. Managing a forage stand for livestock production is a balancing act between providing growing conditions that allow the forage species to maintain its vigour and providing a satisfactory level of forage for the grazing animal. The manager controls grazing by regulating the season, intensity and frequency of grazing on a pasture. Species of forage and past use history will influence how the pasture will react to management.

The season of use should take into account the particular species being grazed. Each forage species has growth characteristics that make it conducive to grazing during certain times of the year. If necessary, forage species can be grazed outside their optimal grazing period. However, the subsequent rest period must be longer to avoid decline in the health of the forage stand. The rest period must occur when growing conditions allow for growth and recovery of the pasture.

Grazing intensity refers to the amount of vegetation removed in a grazing period. Most improved pasture species can have up to 70% of the above ground vegetation removed, while native range should have lower levels of use, in the range of 50%. After imposing higher level of grazing (or other forms of utilization) the subsequent rest period needs to be longer to enable the crop to restore root crown resources that are used to support regrowth. In the case of native rangelands, heavy early season grazing or excessively high levels of use will necessitate rest periods of up to one year to allow for adequate recovery. Factors such as the species of forage, growing conditions, rainfall, intensity and timing of grazing will all influence the rest period required on a pasture. Tall veld in Natal for instance was found to show increased productivity when the period of grazing was reduced from 20 to 2 days, and the period of rest increased from 20 to 60 days. The combinations which gave the highest production were the 10 days in and 60 days out rotation which required only 7 grazing camps. In general, highest yields came from the lowest days of grazing and highest days rest (Tainton et al. 1977).

Stocking rates

The stocking rate is the number of animals grazing in a given area of land for a season or year. Setting a stocking rate involves balancing forage removal with forage production and should accurately reflect the production capacity of the pasture. Stocking rates are affected by the species of forage, age of the stand, soil zone and texture, fertility levels and growing conditions. For instance, the mean annual grazing capacity of kikuyu grass pasture was found to be 6.7 cows/ha, kikuyu grass-annual ryegrass mixture, 8 cows per ha and kikuyu grass-clover mixture 5.3 cows per ha.

Animal distribution

Animal distribution is the degree of use by livestock of all areas of a pasture. It is desirable to have even distribution across all areas of the pasture. Uniform animal distribution reduces selective grazing—this occurs when livestock over graze the most palatable plants and under graze the rest. Uniform animal distribution also reduces waste of forage. Areas located far away from water sources or areas difficult to access by livestock will not be used, while areas more accessible are overused and will decline. Animal distribution can be improved by increasing the number of livestock in a pasture and reducing the amount of time they are in it. This can be achieved by reducing size of land grazed while maintaining herd size (i.e. increasing stocking density). Both of these techniques more effectively increase stocking density.

Other methods to improve animal distribution include locating salt licks in under-utilized areas of the pasture and burning or fertilizing under-utilized areas to increase their palatability and attractiveness to livestock. Developing new water sources or limiting access to existing ones is an effective way to change use patterns of livestock.

Balancing forage supply and demand

Feed costs are a major expense in any livestock operation. The longer livestock can remain on pasture and harvest their own forage, the lower the cost of feeding. This indicates that most producers should attempt to develop a supply of adequate quality as economically possible and as late as possible in the season.

Grazing systems

A grazing system can be described as a conscious effort to influence the time, space, duration and intensity of grazing events on an area of land to suit management goals. Successful grazing systems integrate a number of tools and resources to achieve well-defined goals. A common goal in many grazing systems is to have high livestock performance at acceptable costs and risks, while improving or at least maintaining pasture productivity.

Planning is the first step

The aim of a good pasture management program is to:

- Use the pasture in the most efficient manner, so that the highest yield per unit area is achieved.
- Have vigorous growth and persistence of pasture.
- Maintain desirable grass or legume species and control those which are unwanted or are harmful.

There are many types of grazing systems with varying levels of complexity. However, before any one grazing system is selected, planning must occur to determine which grazing system is most suitable to the production unit. Every unit is different, and a generalized grazing system should be custom tailored to the features and resources present on each farm or ranch.

Important terms

Grazing period: This is the season and number of days during which a pasture is grazed.

Deferment: A delay of grazing (or a period of non-grazing) in a pasture until the key forage species set seed and seeds mature.

Rest: A period of non-grazing for a full year.

Objectives of grazing management

- Meeting the feed demand of livestock/animals for targeted production
- Effective and efficient utilization of forage resources
- Maintenance/restoration of plant vigour for sustainable production

There are several grazing options that can be practised on these pastures by farmers:

Rotational Resting (this is in areas where farmers have access to large areas of rangeland or pasture):

- Also called deferred grazing
- Can be (i) year-long (ii) seasonal resting (split-season resting)
- At least one camp more than no. of cattle groups
- Rest each camp in turn for full restoration of veld
- Review by Gammon (1978) indicated that a 4 paddock 3 herd system with 4-month rest/year had better cattle performance vs. continuous grazing in South Africa and USA at moderate stocking.

Rotational grazing

This is where pastures are divided into portions and cattle allowed to graze in one portion at a time and moved to another portion to allow for the pasture to regrow. This grazing method controls internal and external parasites by cutting their life cycle and it also ensures better utilization of pastures. However, rotational grazing is relatively costly as the paddocks must be well fenced off.

- At least one camp more than number of herds
- Graze each camp in turn
- Rest sufficiently long to allow/ensure adequate forage regrowth, to maintain unrestricted consumption of forage DM

Four variations exist:

- High performance grazing/controlled selective grazing
- High utilization grazing/nonselective grazing
- Short duration grazing
- Savory grazing method

Within limits, the shorter the period of stay and the longer the period of absence, the better to obtain forage of high quality (Booysen 1969)[1]

(i) High performance grazing (lenient)

- Also called high production grazing or controlled grazing
- Graze up to level where the acceptable species are still able to regrow rapidly and produce high levels of forage

(ii) High utilization grazing (hard)

- Graze until almost all species have a high level of utilization

(iii) Short duration grazing

- Graze for short period to ensure that animals do not affect regrowth

(iv) Alan Savory's short duration grazing (Holistic Resources Management)

- Use very high stocking intensity to obtain "animal impact", impose non-selective grazing. Claims that subsequent grazing has high quality and high edible DM yields to support high stocking rates. Claims not yet proved by empirical data/hard data.
- Best suited to flat, humid areas
- Requires the most fence of all the systems
- Developed by Mr. Alan Savory in Zimbabwe, Africa

Forward or lead grazing

This is a form of rotational grazing whereby animals with the highest nutritional requirements for example lactating or growing stock are given priority to access to the best pasture and then moved to yet another new paddock. They are followed by cattle with less nutritional needs for example breeding bulls, which graze on the lower quality pasture left by the high nutritional group.

1 Booysen, P.D. 1969. An analysis of the fundamentals of grazing management systems. African Journal of Range and Forage Science 4 (1).

Continuous grazing

This is a common grazing method for many farmers, where animals are maintained on single pasture throughout the grazing season. Though relatively cheap, stocking densities in this system are low because pasture's quality tends to deteriorate. It increases external parasite load due to continued animal presence in a given area.

Creep grazing

Creep grazing involves establishment of two pastures, one of a higher quality (e.g. grass-legume mixture) and the other of a lower quality. Calves and lactating cows which require a great deal of nutrition are allowed into the higher quality pasture while the rest are fed on the lower quality pasture.

Strip grazing

This method is common in developed countries or large farms and is aimed at ensuring effective utilization of feeds. It is labour intensive and utilizes a movable fence (in most cases an electric fence) ahead and behind grazing animals thus the name strip grazing. The fence is moved only after a given strip has been thoroughly grazed.

Optimum grazing is determined by many factors, including:

- Type of pasture
- Type of animal
- The economic environment

The selection of a grazing method is sometimes based solely on personal choice or what is currently being promoted. However, the grazing method or grazing system selected must be adapted to the forage plant species being grazed, the grazing season, the physical features of the grazing land, the nutritional needs of the kind and class of livestock to be grazed and management objectives.

Potential animal health hazards

Bloat

Bloat is a potentially lethal expansion of the stomach in ruminant animals which can occur after they have eaten large quantities of legume forage. During digestion, legumes can create a stable foam in the rumen that blocks the normal escape of gas. Distention of the stomach creates breathing difficulties that can be lethal. Fear of bloat causes many producers to avoid the use of forage legumes, such as lucerne or clovers. However, most of the specific situations that cause bloat can be avoided.

Methods to reduce bloat risk:

- Do not turn livestock directly onto a lush, vigorously growing legume field. Ensure the animals are fed prior to turnout and avoid turning out in the morning, when dew increases plant moisture content.
- Seed pastures to a mixture of grasses and legumes to reduce legume intake.
- Where appropriate, feed bloat control products containing poloxalene or Rumensin.
- Consider use of non-bloating legumes (sainfoin, cicer milkvetch) or low-growing types (certain clovers).
- Certain breeds and strains of livestock seem to be prone to bloat. Bloated animals can be saved if prompt action is taken, in consultation with a veterinarian.

Prussic acid/nitrate poisoning

Two most frequently reported animal health problems associated with annual grasses are prussic acid poisoning and/or nitrate poisoning. Prussic-acid poisoning occurs in Sudan grass and sorghum-Sudan grass hybrids. In general, ruminants are more susceptible to prussic-acid poisoning than swine or horses. Toxic levels of prussic acid occur most commonly after a killing frost or drought.

Minimizing the prussic-acid poisoning hazard in forage

Nitrate poisoning usually occurs when high rates of N fertilizer are used in one application and then a drought or sudden weather change occurs. High nitrate levels are especially found in the lower stems. The nitrate in plants harvested for hay does not dissipate as it cures, so problems can occur when the hay is fed. There can also be problems in grazing the stubble after the leaves and upper parts of the plants are consumed and livestock begin eating the lower parts of the stalk. Nitrate poisoning can occur in pearl millet as well as in the sorghum-Sudan grass hybrids and Sudan grass. The concern is reduced when the forage is harvested as hay. General rules include:

- When turning lactating animals out on lush spring pasture, supplement with high Mg mineral blocks or mineral-salt mixtures to reduce the incidence of grass tetany.
- If seed is treated with a fungicide or other type of treatment, be sure to follow harvest restrictions on the label.
- Remove dairy animals from small-grain pasture at least two hours before milking to reduce the problem of off-flavored milk.
- Split N applications to avoid nitrate poisoning.

When emergency or supplemental forage crops are needed, the economics of production should be considered. Annual forage crops can aid in making the most of growing seasons and can enhance forage cropping systems for livestock producers.

Forage conservation

Forages can be conserved to feed livestock during periods of shortage caused by limited pasture growth or inadequate pasture conditions or fed as a supplement. Although several methods have been proven as efficient ways to store and preserve forages, it is important to keep this fact in mind: at best, conserved forages can rarely match the nutritive value of fresh forage because some losses of highly digestible nutrients (sugar, protein and fat) are unavoidable during conservation and storage. The goal in forage conservation is to focus on minimizing losses which start immediately after cutting.

When selecting a conservation method, a producer should consider the suitability of the forage for a given method, storage capability, weather conditions and the intended use of the conserved forage. The selected conservation technique should maximize nutrient conservation efficiency and minimize production costs. Conserved forages can take the form of hay, haylage and silage.

The main difference between silage and haylage is the initial DM concentration level at which the forage is harvested and packed to achieve optimum anaerobic and fermentation conditions. Three different moisture levels can be achieved: high-moisture silage (≤ 30% DM), medium-moisture silage (30–40% DM), and low-moisture (wilted) silage (40–60% DM). Low-moisture silage is referred to as haylage. When baled and wrapped, haylage is referred to as baleage. High-moisture silages are more prone to potential seepage losses (that is, effluent or leachate from the silo), undesirable secondary fermentation (resulting in butyric acid, which results in a rancid smell) and high DM losses (silo shrink). On the other hand, preservation as haylage depends more on achieving adequate packing (high density) to maintain anaerobic conditions. Achieving high density at packing is more difficult in drier forage. Nevertheless, high density is critical in haylage to maintain anaerobic conditions because microbes are less active, and fermentation is lower in haylage than in higher moisture silage.

Silage

What is silage?

Silage is the final product when green forage of sufficient moisture (> ~50%) is compacted, conserved and stored anaerobically (oxygen free) under conditions that encourage fermentation of sugars to organic acids. It is a conservation method that preserves feed for many years while retaining its nutritive quality. The forage is fermented in a silo (pit or polythene bag) for use during periods of feed scarcity. A source of readily fermentable carbohydrate like molasses is added to aid the fermentation process. Other authors recommended the use of maize bran in Napier grass-based silage to replace molasses which is not readily available. Adding a high-protein fodder like Gliricidia sepium or cassava leaves is recommended to improve the protein content of the silage. The quality of silage made from fresh or dry cassava chips as the source of carbohydrate was similar to silage where maize bran was used.

Three of the most critical factors for silage production are:

- Rapid removal of air
- Rapid production of lactic acid that results in a quick lowering of the pH (this is the result of adequate fermentation processes)
- Rapid feed out once the silo is opened and exposed to air to avoid heating and spoilage

Silage quality

Silage that has undergone unsatisfactory fermentation will be unpalatable and in some cases even poisonous. Such silage may be recognized by the following characteristics:

- Strong, pungent and unpleasant smell
- Strong ammonia smell
- Contains excess moisture when squeezed or continually oozes from the base
- Will be damp, mouldy or slimy and dark brown

Good quality silage will:

- Retain much of its green colour or be pale yellowish brown
- Have a good aroma
- Contain lactic acid greater or equal to 8%

The ensiling process

Principles of making silage:

- The material to be conserved must have a high nutritive value.
- The forage must not be contaminated with soil.
- The forage should be chopped into pieces no longer than 5 cm (2 inches) in length to facilitate good compaction to reduce air in the silage.
- Expel as much air as possible from the forage through compacting.
- The pit silo should have a slope to drain effluent and minimized spoilage.
- Seal the pit silo or close the polythene bag tightly to prevent re-entry of air and rainwater.
- Silage processing and sealing should be done in the shortest possible time to minimize contamination.

- When removing silage from the silo for feeding, the opening should be minimized and closed immediately to prevent spoilage.

Biology

Silage fermentation can be classified as either primary (desirable) or secondary (undesirable). Primary fermentation is carried out by lactic-acid-producing bacteria and is classified as homofermentative (the one product of fermentation is lactic acid) and heterofermentative (multiple products of fermentation are lactic and acetic acids and ethanol). Secondary fermentation is carried out mainly by enterobacteria (which produce lactic, acetic, succinic and formic acids, and ethanol), clostridia (produce butyric acid) and yeasts (produce ethanol). Lactic acid production is preferred over the other fermentation products due to faster and lower pH drop (stronger acid) and limited silo shrink. Shrink occurs from plant and microbial respiration, fermentation, runoff and loss of volatile organic compounds. If anaerobic and acidity conditions are not met, silage is more prone to shrinking during storage compared to hay. Good fermentation should result in DM losses of less than 10%.

Phases of silage fermentation

An overview of the four phases of the silage production process is as follows:

- Aerobic: this phase usually lasts for approximately one day. During this period, plant cells and microbes will metabolize sugars and starch in the presence of oxygen, generating heat in the process. Silage temperature is elevated to about 32°C, and water may be lost (as seepage) because of respiration and compaction. If anaerobic conditions are not achieved quickly, high temperatures (>54°C) and prolonged heating will occur due to the growth of unwanted aerobic bacteria, yeast and moulds that compete with beneficial bacteria for substrate. Therefore, it is critical to ensure good compaction, proper moisture and good sealing, all of which lead to a rapid transition to anaerobic conditions.
- Fermentation: once anaerobic conditions are achieved, lactic acid bacteria and other anaerobes start to ferment sugars into lactic acid, mainly, and other organic acids to a lesser extent (such as acetic and propionic) that will drop the silage pH from about 6.0 to a range of 3.8–5. Alcohols such as ethanol will be generated too, but with no contribution to the acidification process. Rapid decrease in pH prevents breakdown of plant proteins and helps inhibit growth of spoilage microbes. Consequently, lactic acid production is preferred to ensure a low silo shrink. The fermentation phase usually lasts from one week to more than a month, depending on crop and ensiling conditions.
- Stable: as long as anaerobic conditions are maintained, silage can be stable for months and up to years. However, under practical conditions, silage should be used within a year of its production. Slow entry of air through areas that were not properly sealed can slowly deteriorate material; thus silos should be constantly checked and maintained to avoid any potential break of seal integrity.
- Feed-out: once a silo or bale is opened, it should be used as quickly as possible to avoid aerobic deterioration of the material. When oxygen becomes available in the ensiled material, yeasts metabolize the organic acids which in turn cause the pH to increase and further restarts the aerobic activity (such as moulds) causing greater silage spoilage. The design of a typical silo face should allow for the daily removal of approximately 15 cm (6 inches) of face material (for reference, each 15 cm daily removal is equivalent to one week of exposure to air). Silo opening should occur only after the fermentation phase has been completed (that is, after 3–6 weeks). The suggested approach is to wait approximately 2–3 months before opening a silo.

Types of silos

A silo is an airtight place or receptacle for preserving green feed for future feeding on the farm. Silos can be either underground or above ground, the qualification being that the silo must allow compaction and be airtight. Some types are described below:

- Silage can be made in large plastic sacks or tubes. The plastic must have no holes to ensure no air enters. This is popularly referred to as tube silage.

- Silage can also be made in pits that are dug vertically into the ground and then filled and compacted with the silage material.
- An above-ground silo is made on slightly sloping ground. The material is compacted and covered with a polythene sheet and a layer of soil is added at the top. When finished, it should be dome shaped so that it does not allow water to settle at the top but rather collect at the sides and drain away down the slope.
- The trench silo is an adaptation of the pit silo, which has long been in use. It is much cheaper to construct than a pit silo. Construction is done on sloping land. A trench is dug and then filled with silage material. This method is ideal for large-scale farms where tractors are used. Drainage from rain is also controlled to avoid spoiling the silage.
- Tower silos are cylindrical and made above ground. They are 10 m or more in height and 3 m or more in diameter. Tower silos containing silage are usually unloaded from the top of the pile. An advantage of tower silos is that the silage tends to pack well due to its own weight, except for the top few m.

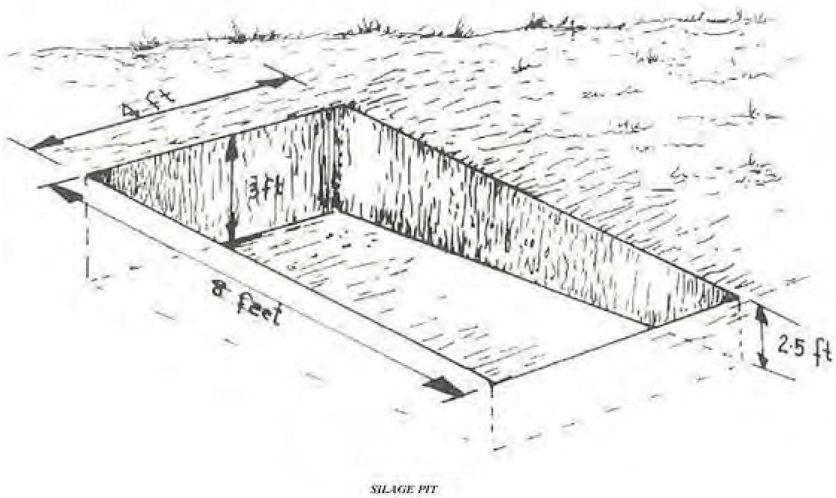
Preparing the material

- After harvesting, wilt the forages in the sun for a day to reduce moisture content.
- Chop the forages into pieces of about 5–7 cm (2–3 inches) length.

Preparing the silage pit

- The size of the pit (Figure 20) varies with the material and labour available for ensiling. The one t pit described here is convenient for training.
- Prepare a shallow pit 2.4 m (8 ft) long, 1.2 m (4 ft) wide, dig 75 cm (2.5 ft) deep in the shallow end and 90 cm (3 ft) deep at the deep end. This will hold about 1 t of silage.
- Place polythene sheet on the side and bottom to prevent contamination with soil.
- Dry forage may be used at the bottom of the pit silo instead of polythene sheet.

Figure 20: Illustration of a pit silo



Filling the silage pit

- Place the forage and cassava leaf in the pit to two-thirds full.
- Add a third of the fermentable substrate.
- Press the forage down with feet or drum full of water to force out air.
- Compact the silage until it becomes difficult to insert a finger through the stack.

- Repeat the process until the pit is filled up to form a dome shape.
- The shorter the pieces the easier it is to compact.
- Cover the pit with polythene sheet to prevent water and air entry.
- Then place a soil layer of 60 cm (2 ft) thickness over the polythene for further compaction.
- Complete the entire process quickly (within a day or two).
- Prevent entry of air or water to maintain quality.
- Wilted material should produce little or no effluent unless the stack is poorly sealed.
- The fermentation process is complete in three weeks when the silage can be used.
- Silage can be stored for years without loss of quality unless air is allowed in.

Using the pit silage

- Open the pit from deep end to remove enough material for one day and cover the open end.
- After removing the amount of silage to be fed, cover with polythene sheet and replace the weights immediately to minimize air entry into the silage.
- Feed after milking to avoid milk tainting if silage is used for cattle.

Management practices for making better silage

Crop factors

An ideal crop to be ensiled should have an adequate level of sugars (measured as water-soluble carbohydrates) to be fermented, low buffering capacity (that is, the resistance to changes in pH) and a stand with a DM concentration above 20%. The concentration of water-soluble carbohydrates is critical for fermentation and varies among crops. Legumes have higher buffer capacity (resistance to allowing a drop in pH) and, therefore require further wilting relative to other crops (35–45% DM) for adequate ensiling. In general, crop suitability for ensiling follows this order: maize> sorghum > ryegrass>, bermudagrass > legumes.

Harvest maturity

In the case of legumes, grasses and cereals, maturity stage defines optimal harvest time and wilting is required in most cases to achieve the target DM concentration for ensiling. Corn, however, is different. Although examining the kernel milk line is always recommended, the decision of when to harvest should be made based on the DM concentration of the standing crop because it is ensiled directly afterwards.

Moisture

Moisture concentration affects the rate and extent of fermentation. Forages should not be ensiled with more than 70% moisture (or less than 30% DM concentration) due to potential seepage losses and growth of undesirable bacteria which results in undesirable fermentation. Wilting is needed in most cases when ensiling grasses and legumes.

As moisture decreases, less acidity is needed to inhibit undesirable bacteria that are more sensitive to low moisture than the desirable lactic acid bacteria. Low moisture is one of the factors that explains why wilting is beneficial for legumes and grasses. When wilting forages, adjust the mower conditioner for a narrow swath and then allow the swath to dry without further manipulation until the crop is chopped. Research shows that this procedure minimizes field losses of the plant leaves which are of higher nutritive value than stems.

Particle size

The optimal particle chop length is a balance between the particle size needed to achieve good compaction in the silo and the effective fibre requirements of ruminant livestock, especially lactating animals. The recommended theoretical length of cut (TLC) is 1.9–1.2 cm (3/8–1/2 inch) for unprocessed corn and legume silages, and 1.9 cm for kernel-processed corn silage. Sorghum silage should have a similar TLC to corn silage and grasses, and cereal silages should have a similar TLC to legume silages. Kernel processing is highly recommended when making corn silage to improve starch digestibility. Kernel processing should not be done, however, if whole plant DM concentration is less than 30% due to risk of increased seepage losses.

Packing density

Attaining a high density in a silo is important because it determines the porosity at which air moves into the silo and subsequently the amount of spoilage that occurs during storage and feed out. Silage density is influenced by DM concentration, TLC and packing intensity. Different types of silos require different packing strategies and target densities for appropriate ensiling. In general, a shorter TLC and processing will result in higher silage densities due to a decreased stiffness of the material.

Sealing

Good sealing with plastic sheets and concrete barriers will prevent oxygen from entering the silo. Care must be taken to seal any holes with UV-resistant tapes, especially in low-moisture silages where porosity is greater.

Additives

Several types of additives are available that can be used for silage making. Additives can help in every phase of silage making. Nevertheless, good harvesting practices are the main drivers of silage quality. In general, additives can be classified as stimulants or inhibitors of fermentation, and nutrient sources. Specific effects of additives include the following:

- Provide fermentable carbohydrates
- Inhibit undesirable types of bacteria and promote desirable bacteria
- Furnish additional acids (such as propionic acid) directly to decrease pH
- Modify moisture
- Extend aerobic stability during feed-out (bunk life)

Bagged or tube silage

Silage can be made in large, black plastic sacks. The advantages include:

- Plastics silage bags are an economical alternative to traditional silage storage systems, such as pits and silos when related, harvest and storage losses are considered.
- It is an effective way for preserving feed with minimum nutrient loss. (The anaerobic environment that is created eliminates spoilage from the growth of yeasts, moulds and adverse bacteria while maintaining essential proteins and nutrients).
- Allows farmers to store silage anywhere they need it. A well graded and well drained ground surface is all that is necessary.
- The silage is completely sealed in the bag. This means that all the acid is retained in the silage, unlike that in pit silage when it seeps out through the bottom of the pit as effluent. This compensates for the longer pieces of forage and poorer compaction than that found with silage machinery, so that the quality of the silage is just as good.

- Ensiling in a bag avoids the hard work of having to excavate silage from the face of the pit silo daily. This reduces losses from aerobic spoilage usually associated with pit silos because a bag is fed out within a few hours or days. Spoilage losses can be very high (>50%) in pit silos when aerobic stability of the silage is poor.
- In most cases bagged silage is portable and easy to store so that any member of the family can carry it to the feed trough.

Disadvantages

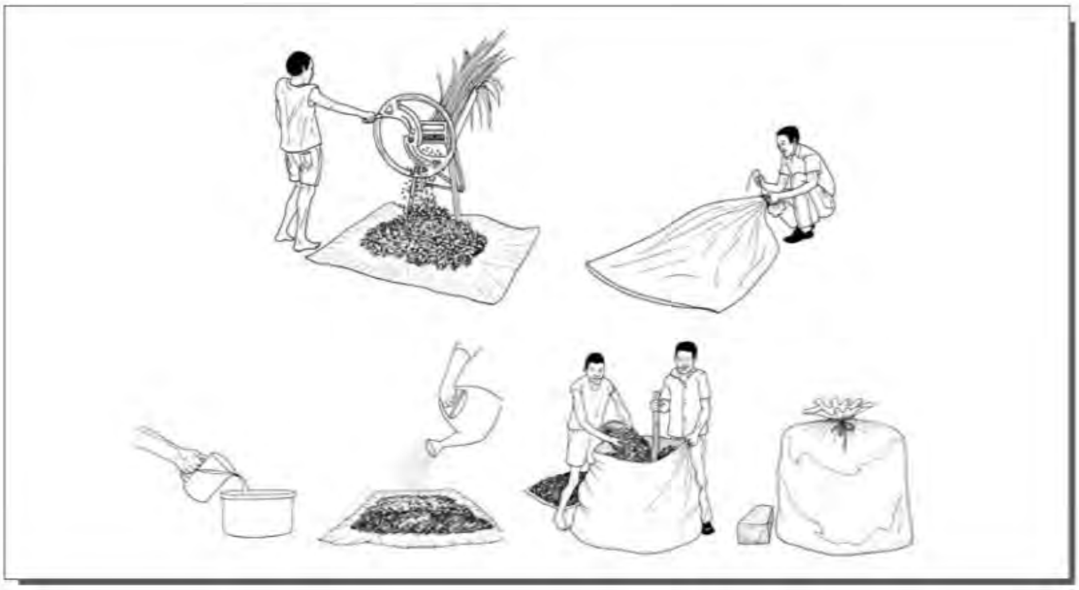
There are a few disadvantages to using silage bags. Among them are:

- The importance of pest control to prevent damage on the bags
- Contamination and disposal of the plastic once silage is removed from the bag
- The need to chop the green mass, as chopped material tends to make much better silage because more air can be squeezed out of it during the packing process, and the small pieces are ideal so as not to puncture the bag

The process:

- Chop the wilted material to be ensiled into pieces not more than 2.5 cm long.
- Sprinkle the chopped material with a molasses and water mixture; for every sack use 1 litre of molasses mixed with 2–3 times as much water. This is especially important for material like Napier grass that has low sugar content. Maize bran or cassava flour can be added to improve the carbohydrate (energy) content.
- Place the chopped material, sprinkled with the molasses and water mixture, into the plastic tubing (1,000 gauge) with a width of 1.5 m. Cut a 2.5 m length, tie off one end and fill with the material, compressing it well, then tie the other end to seal (Figure 21). Stack the filled sacks until needed. Fermentation is usually complete after 21 days.

Figure 21: Process of making silage in bags—chopping, sprinkling with water and molasses and compressing



(Source: Lukuyu et al. 2012)

Hay making

Hay is grass, legumes or other herbaceous plants that have been cut, dried and stored for use as animal feed, particularly for grazing animals such as cattle, horses, goats and sheep. Hay is also fed to smaller animals such as rabbits and guinea pigs. Pigs may be fed hay, but they do not digest it as efficiently as fully herbivorous animals.

Hay can be used as animal fodder when or where there is not enough pasture or rangeland on which to graze an animal, when grazing is unavailable due to weather (such as during the dry season) or when lush pasture by itself is too rich for the health of the animal. It is also fed during times when an animal is unable to access pasture, such as when animals are kept in a stable or barn.

Cutting for maximum quantity and quality

A major goal of hay production is to maximize tonnage of harvested forage. Forage quality is also a very important component of successful haying. Striving for high tonnages of hay while also trying to maximize protein and nutrient harvest is a good practice. Determining when to harvest in order to maximize both DM yield and nutrients can be done if the relationship between DM accumulation and protein content dynamics in the crop are understood.

Generally, DM accumulates during the growing season and peaks late in the season. Conversely, forage quality is very high early in the season and declines as the season progresses. The goal is to determine at which point in time these two lines intersect. This point will determine when the best compromise between yield of DM and nutrients will occur.

In the case of alfalfa, the point at which 10% of the flowers on the plant are blooming is the best time to cut for maximum quality and yield. In the case of most grasses it is best to cut after the boot stage, but before heading.

Steps for making hay

Visual assessment

Hay is cut when about 10% of the crop is flowering. Plants must have a high leaf-to-stem ratio—the more leaves the better because they are packed with nutrients.

Mowing

The first stage is to cut the grass. This must be done when the grass is fully grown (long before it has seeded). At this stage, the plant is full of energy, protein and sugars but is not over mature, so that it produces tough, stocky hay. Forage crops produce more yield as they mature but nutritive value and palatability decrease at first bloom or heading (anthesis stage), so good hay must be harvested to balance the best quantity with quality. It must also be cut when expecting 3–5 days of sunny weather to dry the hay. The height must be perfect because cutting too low will damage the crown and affect the plant's ability to regenerate. It is recommended to cut (swath) the hay so that drying and baling the hay can be done efficiently while maintaining the quality.

Swathing so that a long stubble remains will help air to circulate around the windrows that rest on the stubble and promote drying. Swathes may also condition the hay by crushing the cuticles or surface tissues of the plants. Desiccants are also available to break down or disrupt the cuticle surface.

Conditioning

Hay conditioning machine is used to "squish" the plant stems and leaves. This process helps extract nutrients and make it easier for cows to digest. It also increases the speed and consistency of drying.

Drying

Dry the hay to 15–20% moisture. Forage is up to 90% moisture so a great deal of drying must take place. Forage in windrows can be 25% moisture within a few days with favourable temperature and relative humidity. Windrows should be designed so that the hay dries as quickly, evenly and completely as possible. Conditioning swathes helps the leaves and stems to dry at similar rates. Turning the windrows over facilitates drying. Turning hay in a tumble weed fashion leads to leaf loss and is discouraged. Extremely hot, dry weather can cause the forage leaves to dry too much before the stems dry causing the leaves to become brittle. Brittleness results in breakage and loss of leaf matter which lowers the quality of the hay. Forage managers may turn off irrigation several days before swathing so that plants and the ground are dry as well as using favourable weather for drying.

Raking

It usually takes 3–4 days for the hay to dry properly. The rake is used to rake the hay back into windrows or to turn over the drying windrows. It is then ready to be picked up by the baler.

Baling

When the hay is completely dry and in windrows, it is ready to be baled. Square bales are used to feed in small batches. Round bales are used primarily for cattle. The hay is picked up in the front of the baler and rolled up into a large tube usually 1.8 by 1.5 m and weighing about 453 kg.

Hauling and stacking

Once the hay is baled, it is safe from the weather. Even if it rains, the outer layer of the bale will form a thatch of about 5 cm (2 inches), which protects the inner part of the bale. The bales are hauled out of the fields to the haystacks, which are located close to the areas where they will be used. The hay is stacked in stacks of about 170 bales each.

Small-scale hay making (box baling)

Bales can be made by hand using a simple wooden frame (Figure 22). The frame should measure 100 cm x 50 cm and be 40 cm deep and be open at the top and bottom. First, two lengths of sisal twine are laid across the frame and left to hang over the side. Hay is then placed in the frame, tightly compressed—for example by walking on the hay—and then when the box is full of well-compacted hay, the bale is very tightly tied with the twine before pushing it out of the frame (Figure 23).

Figure 22: Wooden box for bailing hay

(Source: LOL 2014)

Note: A cheaper alternative to using a box is to dig a pit with the same dimensions as the box and then lining the pit with plastic paper (Figure 24). The rest of the procedure is the same.

Figure 23: Process of making hay using the box method (Source: Lukuyu et al. 2012)

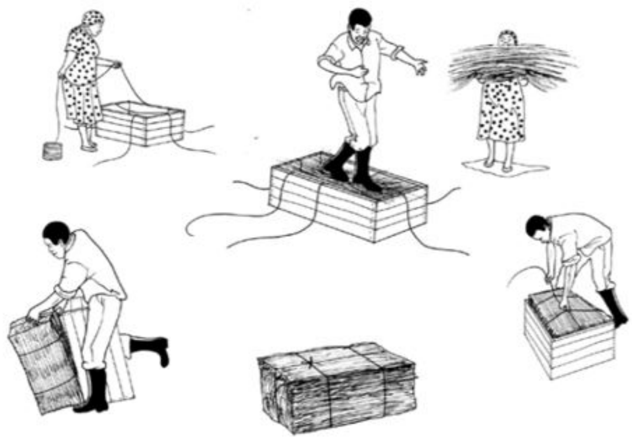
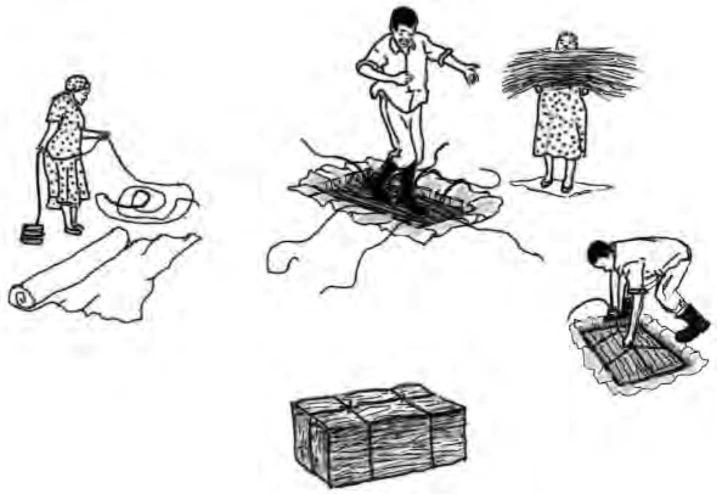


Figure 24: Process of making hay using earthen hole method



(Source: Adapted by Godfrey J. Manyawu from Lukuyu et al. 2012)

4 Feeding animals

4.1 Practical feeding strategies

Livestock keeping is a major source of income and for all livestock keepers livestock feeding and nutrition are major concerns. Inadequate nutrition is a major cause of low live weight gains, infertility and low milk yields and other health issues in livestock. Many livestock keepers face challenges in optimally feeding their animals.

Figure 25: Cow feeding on a small-scale dairy farm

Feed additives

A feed additive is defined as a feed ingredient of non-nutritive nature that stimulates growth or other type of performance, improves the efficiency of feed utilization or that may be beneficial in some manner to the health or metabolism of the animal. Examples of feed additives for dairy cattle are anti-helminthic (dewormers), anti-bloat agents, rumen buffers (NaHCO3, MgO), flavouring agents (molasses), rumen microbes for fibre digestion (Yea sac) and growth promoters or hormone-like substances. For feed manufacturers it is now common practice to add yea sac and rumen buffers to commercial dairy concentrate. Also, some farmers who offer total mixed rations to their cattle use these feed additives. On smallholder farms feed additives are not commonly added to dairy cattle rations.

4.2 Dietary protein/energy ratios for various ages and physiological states

Definition, interpretation and uses

Nutrient/energy ratios are used as indices of dietary quality in relation to several specific nutrients and to express nutrient goals which, in turn, are the basis for dietary guidelines. The reasoning behind this is that energy requirements are the main driving force for food intake and, consequently, for the intake of nutrients present in that food. Therefore, a diet is adequate if it satisfies the requirements for all nutrients when it is eaten in amounts that will satisfy energy requirements. Thus, the protein/energy ratio is often used to describe the 'protein quality' of a diet. That ratio is generally expressed as the percentage of protein energy in the diet, that is, the ratio of protein energy to total dietary energy, where 1 g protein provides 4 kcal or 16.7 kJ of ME. It is abbreviated P/E ratio or Pcal%.

A 'recommended P/E ratio' indicates the amount of protein that the diet should provide relative to total energy, and it does not denote a constant relationship between protein requirements and energy requirements. In fact, recommended P/E ratios vary with changes in protein or energy requirements. This is illustrated for example where two different P/E ratios can be calculated due to the fact that physical activity has a strong influence on energy requirements and little or none on protein requirements.

Calculation of recommended P/E ratios

The following must be taken into account to calculate a P/E ratio:

- Protein requirements. These vary with age, sex and physiological state (i.e. gestation and lactation). Since the goal of the P/E ratio is the evaluation or recommendation of a diet that will satisfy protein requirements of a population when mean energy requirements are satisfied, the safe level of protein intake (i.e. the amount of dietary protein that will satisfy the needs of the whole population) must be used in the calculations. An increment of 25% of the mean protein requirement should be used, as recommended by the United Nations Food and Agriculture Organization (FAO).
- Protein quality and digestibility. Protein recommendations are based on the intake of food proteins, with a reference value of 100% for digestibility and a pattern of indispensable amino acids where none is limiting. Diets that include mostly forages or mixtures of forages have lower protein digestibility, and their chemical composition may or may not have limiting amino acids. A correction must be applied to increase the protein component (numerator) in the P/E ratio of those diets and compensate for the lower digestibility. Usually, no correction is required for their amino acid composition, since it is assumed that the intake of adequate amounts of the diet will satisfy the needs for total N and all indispensable and conditionally indispensable amino acids.
- Energy requirements. In addition to age, sex and physiological state, energy requirements are strongly influenced by the physical activity associated with the breeding system used. This must be considered to define the total energy component (denominator) of the P/E ratio.

4.3 Feed quality

Animals are exposed to many feeds, with diets varying in different regions and farming systems. The productivity of livestock is highly dependent on the quality of feeds. This is because the feed quality determines the intake and availability of ingested nutrients for utilization by the animal. Consequently, farmers are not only faced with the problem of knowing the quality of the feeds but also the factors that influence the quality. This section provides information about quality indicators of livestock feeds and the background of some measurements of feed quality often encountered in livestock. The highlights include physical indicators and some scientific feed evaluation methods that can be employed to determine feed quality.

The physical nature of the feeds can pose serious limitations to efficient utilization of a feed or a ration comprised of several feed resources. However, the influence of physical attributes of feeds on quality is often ignored. Some of the physical aspects that can limit the quality and utilization of feeds in animal production are briefly discussed.

Stage of growth

The nutritive quality of forages varies as they grow towards maturity. Consideration of the stage at which both biomass yield and nutrient content are optimal is therefore important. After attainment of maturity, the forages generally depreciate in nutritive value. This is mostly due to increased fibrous material, particularly lignin. For many forages, the leaves die off systemically after attainment of maturity, and this reduces photosynthetic activities. As a result, there will be reduced accumulation of nutrients: the yield ceases to increase. These factors are important to consider when harvesting forage for conservation as hay. For instance, when making hay from grass (e.g. Rhodes grass) and legumes (e.g. lucerne) it is generally advisable to cut at the onset of flowering up to the time of 50% flowering. For a vegetatively propagated forage such as Napier grass, cutting height is the most important physical consideration for quality. Studies have shown that optimum harvesting height for Napier grass ranges between 50–60 cm (dry season) and 130–140 cm (rainy season). Another disadvantage of a mature stage and dying leaves is that the leaves fall off and are lost from the roughage. The leaves in general contain the most easily available feeding value.

Texture

The physical/textural changes which occur as forages grow can impact palatability, intake and animal digestive physiology. For instance, high intake of succulent young forages (e.g. lucerne, vetch, clover and Comelina spp) may cause bloat. At a young stage the DM content of some forages can be very low (e.g. sweet-potato vines and Napier grass), and this can limit adequate intake of DM to support the desired level of production. The palatability can be compromised as the forages age because of increase in toughness and crude fibre. This can further complicate issues if some species and classes of livestock e.g. young ones are unable to consume fibrous old and tough forages.

Ratio of stem and foliage

It is important to have knowledge of the nutritive attributes of the various morphological components of the individual forages. In fodder crops, the leaf is in most cases the most nutritive component, hence the need to consider the utilization of a forage when the biomass yield and leaf-stem ratio are optimal.

Processing

When animals are stall fed with chopped roughage, the particle size may play an important role in selection, intake and digestibility. For instance, the chop length of ensiled maize stovers have been shown to influence the selection where leafy parts are consumed more, and the overall intake is reduced with increase in chop length. Also, where different feed resources are to be mixed, the particle size must be considered to enable homogeneity in mixing.

Some ingredients necessary in the diets may not be in appropriate physical/textural form for livestock intake. Generally, animals do not prefer powdery or finely processed feeds. Also, feed resources like molasses (semi-liquid) need to be mixed appropriately with a carrier feed. Some feed additives or supplements are better provided in pellet or lick block forms.

Appearance and colour

Generally, feeds have their own typical appearance, which the farmers are or should be familiar with. The appearance can be an important attraction to both farmers and animals. Deviation from the typical appearance should be taken seriously as this may have implications on quality. The colour of specific feed resources can be good indicators for the quality of the feed. Thus, feed users need to know the typical colour of feeds so that when there is deviation from the norm, precaution can be observed.

For most fresh forages, a green colour indicates good quality. For instance, greenness may depict good growing conditions, hence abundance of nutrients. It may also indicate absence of diseases, pests and parasites. Appropriate colour can be used by farmers to judge the stage of harvesting. In concentrates and processed feeds, it is more difficult to judge the quality based on the colour. Whole grains on the contrary can be judged well on colour and shine.

Freshness

Freshness of the feeds can be indicated by colour, smell and/or presence of mould and temperature. Generally, the animal intake will be negatively affected as the feed deteriorates in freshness. Consumption of stale feed can harm the animal due to toxicity.

Presence of visible undesirable objects is also a good pointer to poor quality. The foreign bodies may include soil, pieces of glass, polythene, nails and metals and wood particles or rodent faeces. Visual inspection of feeds should not be neglected, because this can lead to harmful or at worse fatal consequences for the animals being fed. Be sure that there are no poisonous plants or parts included in the feed and no residues of pesticides or herbicides.

Acceptability

Most animals have a natural instinct for feed preference. It is therefore possible that a good feed may be rejected because animals are not familiar with it. On the other hand, rejection of certain feeds can be a good indicator of hidden factors which should be identified and eliminated to improve the intake. In this regard, it may be dangerous and unethical to provide such a feed in mixtures where the animal cannot select and are forced to consume it. It is therefore necessary to ascertain the factors causing rejection and the benefits of such a feed before its use.

4.4 Voluntary DM intake

Voluntary feed intake is the amount of feed eaten by an animal when the feed is given unrestricted access to it. The DM intake is affected by many factors, among them being:

- Availability of water
- Type and quality of roughage
- Feeding frequency
- Amount of concentrates given
- Digestibility of the feeds
- Condition of the animal
- Weather conditions

Roughages are very important in the diet of ruminants because they supply the crude fibre which is necessary for proper functioning of the rumen. Optimally 18–20% of the DM intake has to be crude fibre. If the crude fibre content is too low for lactating animals, milk fat content in the milk can fall. On the other hand, if the crude fibre content is too high, the animal will not be able to consume sufficient DM. Thus, it will not receive all its requirements of energy and proteins, and hence productivity will drop.

Factors considered when developing feeding standards

- Animal species and breed, e.g. swine, cattle (dairy, beef)
- Age of the animal
- Physical activity of the animal (e.g. the grazing animal does more physical activity hence it needs more energy giving feeds than one which is stall fed)
- Physiological activities, e.g. growth, reproduction and production.

Objectives to be met when formulating a ration

- The ration should be well balanced.
- It should be palatable in order to ensure high intake.
- It should be economical without compromising the first and the second objectives.

Balanced diet

A ration is balanced when all the nutrients an animal requires are present in the feed an animal consumes during a 24-hour period. When an animal consumes nutrients in excess or in insufficient amounts, the ration is imbalanced. Some imbalances have drastic consequences and if not corrected may lead to the death of the animal (e.g. milk fever due to Ca imbalance in dairy cows). However, most imbalances are difficult to identify as they result in some degree of loss of production, which causes animals not to realize their genetic potential.

General rules of balancing rations

- Rations must meet nutritional needs of an animal.
- An animal must have a certain amount of fibre DM in its ration.
- Rumen or stomach capacity limits the quantity of feed an animal can ingest.
- Two minerals, Ca and P are important when balancing rations. The ratio of Ca:P should be between 1:1 and 2:1 and it is more important than the total amount being fed.
- The total amount of protein in the ration (which meets the animal requirements with about 5–10% above the requirement) is measured by either total protein (TP) needs of the animal or digestible proteins (DP).
- Energy (with 5% allowance above the animal requirement) measure in the ration may be expressed as follows:

    a. DE

    b. Total digestible nutrient (TDN)

    c. ME

    d. Net energy (NE)

- Cost of the ration must be considered.

Steps in ration formulation

Ration formulation is the recipe, that is, the list and amounts of feed ingredients to be included in a ration. Before formulating a ration, the following information is needed:

- Age and body weight of cow
- Milk yield and fat percentage
- Stage of lactation and pregnancy and lactation number
- Feeds available and their nutritive values.

Obtain information on nutrients from feed requirement tables developed by various bodies (e.g. NRC 2001).

Feedstuffs (ingredients)

Prepare an inventory of all available feedstuffs. For home-made rations, use materials available at home as much as possible; commercial feeds may use a wider range. The nutrient composition of each feedstuff should be known. Ideally, an analysis of the ingredients should be done but if it is not possible, obtain estimates from textbooks. Book values, however, can at times be misleading, especially for by-products due to their great variability. Consider the palatability of the ingredient and any limitations such as toxicity. Always consider the cost of the ingredients. Least-cost formulations should be made to obtain the cheapest ration.

Type of ration

Ration type may be complete (total mixed ration), concentrate mix or a nutrient supplement of protein, vitamin or mineral.

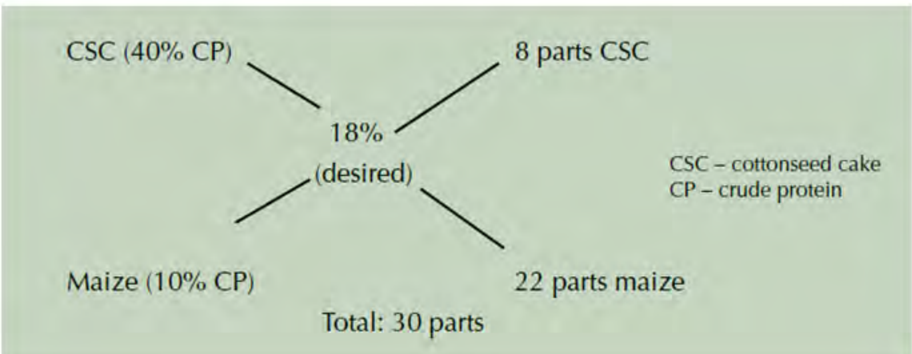
Expected feed consumption

Rations should be formulated to ensure that the animal consumes the desired amount of nutrients in a day. For example, if a heifer requires 500 g of crude protein per day and consumes 5 kg of feed, the crude protein content should be 10%. If it consumes 4 kg per day the crude protein content should be 12.5%.

Calculations

The simplest formulation is when two ingredients are being mixed to balance one nutrient. Using a Pearson's square method allows blending of two feedstuffs or two mixtures. It is of greatest value when only two ingredients are to be mixed. One of the more important numbers is the number that appears in the middle of the square. This number represents the nutritional requirement of an animal for a specific nutrient. It may be crude protein or TDN, amino acids, minerals or vitamins. An example of how to make a ration with 18% crude protein using cottonseed cake (40% crude protein) and maize (10% crude protein) is presented in Figure 26.

Figure 26: The Pearson's square used for simple ration formulation



Steps

- Subtract the lesser value from the larger diagonally. (Hence from the figure, 40 minus 18 = 22 and 18 minus 10 = 8.)

- One ingredient must have a higher nutrient content than desired and the other must have a lower value.
- No ration can be formulated with a higher nutrient content than the highest of the ingredients or vice versa. (You cannot make a ration of 18% crude protein if both ingredients are higher than 18% or lower than 18%.)
- Therefore if 8 parts of cottonseed cake are mixed with 22 parts of maize, the mixture will have 18% crude protein.

If expressed as percentage (100 kg feed) then:

8/30 x 100 = 26.7% cottonseed cake

22/30 x 100 = 73.3% maize

Therefore, to make 100 kg of the feed ration, use 73 kg maize and 27 kg cottonseed cake.

Developments in ration formulation

Today, almost all rations are formulated with the aid of a computer compared with only a few years ago when all rations were hand calculated. Use of computers has resulted in more complete evaluations of nutrient profiles in rations and allowed for economics to be included in ration formulation decisions. The four most common ways of expressing computer ration information are:

Analyze: A ration analysis is a summation of all the feeds and nutrients they contribute in the ration. An analysis does not balance the ration and therefore does not correct any nutrient deficiencies or excesses. The amount of each feed along with its nutrient composition, must be known to obtain an accurate ration analysis.

Balancer: A ration balancer program combines feeds to meet the nutrient specifications set for a ration. The amount of each feed to be included in the ration will be determined based on its nutrient contributions and how it fits with other feeds in meeting nutrient specifications. A balancer program does not consider feed costs or profit.

Least cost: A typical least cost formulation involves specifying the nutrient requirements or constraints for the ration and then finding the combination of feeds that meet or exceed these constraints at the lowest cost per pound of DM. Least cost formulations change as feed costs change. An opportunity or break-even cost for feeds not used in the ration will often be given. When the price of an unused feed goes below the opportunity price, it is considered a good buy and the ration should be reformulated to see how much of that feed can now be used in the ration.

Maximum profit: A true maximum profit ration program includes a least cost function, incorporates milk price information, and uses a maximum profit (income over feed cost) as one of the constraints or specifications to formulate on. The difference between maximum profit and least cost or balanced rations is that the computer selects feeds and a milk production level to obtain a maximum profit; whereas, in least cost or balanced rations the computer selects only feeds to meet the nutrient requirements specified for a given level of milk production.

Here is a list of feed formulation software one can be downloaded free of charge and use to formulate livestock feed:

- Best Mix feed formulation software: https://www.adifo.com/products/bestmix-feed-formulation
- Animal feed formulation software: http://animalfeedsoftware.com/index.php
- Least cost formulation software: http://www.ecomixonline.com/
- http://www.feedipedia.org/node/23164

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6 Appendices

Table 6: Daily nutrient requirements for meat-producing goats[1,2]

	Young goats[3]		Does (50 kg)				Bucks (36–54 kg)
Nutrient	Weanling (13.5 kg)	Yearling (27 kg)	Pregnant (Early)	Pregnant (Late)	Lactating (Avg milk)	Lactating (High milk)	
DM kg	0.9	1.35	2.0	2.0	2.0	2.25	2.25
TDN %	68	65	55	60	60	65	60
Protein %	14	12	10	11	11	14	11
Ca %	.6	.4	.4	.4	.4	.6	.4
P %	.3	.2	.2	.2	.2	.3	.2

[1] Nutrient requirements of goats in temperate and tropical countries. 1981. National Research Council.
[2] Pinkerton, F. 1989. Feeding programs for Angora goats. Bulletin 605. Langston University.
[3] Expected weight gain > .44 lb/day (1 lb = 0.45 kg)

Table 7: Crude protein needs of a cow at different stages of lactation

Milk production	Crude protein requirement (%)
Early lactation	16–18
Mid lactation	14–16
Late lactation	12–14
Dry	10–12

Source: Moran 2005.

Table 8: Nutrient requirement of a mature cow approx. 500 kg live weight, with peak milk production of 5 litres/day

			Daily nutrients as percentage of intake			
Period	Month since calving	Intake (kg DM/day)	TDN % DM	CP % DM	Ca % DM	P % DM
Early lactation	1	10.4	58	9.7	0.26	0.17
	2	10.8	59.1	10.3	0.26	0.18
	3	10.6	58.6	10	0.27	0.18
Mid lactation	4	10.3	57.4	9.4	0.25	0.17
	5	10.0	56.4	8.7	0.23	0.16
	6	9.7	55.3	8.2	0.21	0.15
Mid lactation	7	9.5	54.7	7.8	0.2	0.14
	8	8.9	48.7	6.8	0.16	0.13
	9	9.0	49.9	7	0.16	0.13
Late lactation	10	9.0	51.6	7.4	0.27	0.17
	11	9.1	54.2	7.9	0.26	0.16
	12	9.4	57.6	8.8	0.26	0.16

Source: Adapted from University of Arkansas (2018)

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