

TUSKEGEE UNIVERSITY
Cooperative Extension Program

Year-Round Pasture Production and Management

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“...grazing should be managed appropriately so that each species can survive the grazing pressure and no species is wasted because of underutilization.”

Introduction

Good pasture is the basis of a successful ruminant livestock production. Major production cost of any livestock is feeding cost, which varies from 60 to 80% of the total production cost. Feeding cost, and eventually production cost of a ruminant livestock enterprise, can be reduced by improving pasture productivity and quality as well as extending the production duration. In a warm region like south Alabama, many producers depend on perennial warm-season pasture to feed their ruminant livestock. Warm-season pastures produce in the warm portion of the year generally from April to October. This gives rise to lean-production for about five months from November to March, when a producer needs to invest a significant amount to procure hay, agricultural byproducts, and concentrate feeds. Similarly, in a cold region, producers have perennial cool-season pasture, which produce in the cool portion of the year

and remain dormant during summer. So, there will be not much green forage during summer, and producers need hay or other preserved feed to sustain livestock production. However, a skillful producer can extend production duration and increase the productivity and quality of pasture by combining suitable cool-season and warm-season forages. Introduction of legumes in the pasture increases the quality and productivity.

Higher productivity, quality, and extended production duration of forages means less requirements of supplementary feed and lower the cost of production. However, once there are multi-species forages, grazing should be managed appropriately so that each species can survive the grazing pressure and no species is wasted because of underutilization. Before selecting any forage species to be introduced, it will be better to do soil test and find out suitable species for your pasture soil. Also, necessary liming and fertilization should be done periodically based on soil test recommendation. This manual presents general guidelines on various aspects of year-round pasture production and management.



Forage Definitions and Physiology

Annuals and perennials

Annual forages grow and mature during favorable seasons and die at the end of the season within a year; examples are annual ryegrass, wheat, oats, cowpea, soybean, and crimson clover. Some annuals, if managed properly, can reseed, so may not need to be planted every year. However, if harvested before seeds are matured and dropped into the soil; annuals need to be cultivated each year. Perennial forages survive for several years – grow and mature in favorable seasons and become dormant during off-seasons; examples are bahiagrass, bermudagrass, dallisgrass, johnsongrass, switchgrass,

white clover, and sericea lespedeza. When managed properly, perennials, once established successfully, produce during favorable seasons for several years.

Grasses and legumes

Grasses are monocots – produce single seed leaf and have parallel leaf venation. Examples are corn, bahiagrass, bermudagrass, rye, wheat, oats, and ryegrass (Fig. 1a). Legumes are dicots – produce two seed leaves, have reticulate leaf venation, and bear seeds in pods. Few examples are clovers, peas, beans, sericea lespedeza, and kudzu (Fig. 1b). Grasses are good



source of energy while legumes are good protein source. Legumes roots are colonized by *Rhizobium* bacteria, form root nodules, and fix nitrogen (Figs. 2 and 3). Different legumes have specific *Rhizobium* bacteria, so while introducing legumes into a new field, legume seed must be inoculated properly to establish the stand successfully and get good production. Because of nitrogen fixing ability of legumes, when grasses and legumes are grown together, application of nitrogen fertilizer may not be necessary – so saves money.

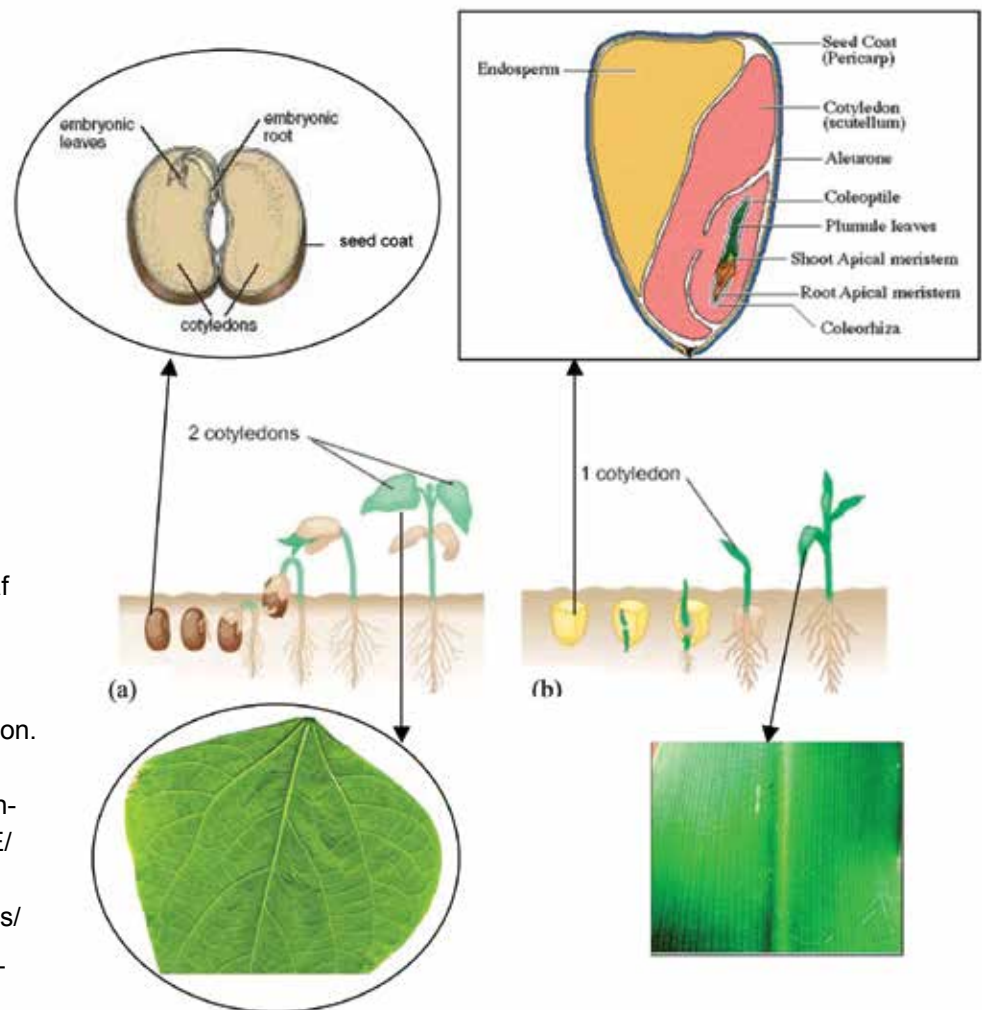


Figure 1. Examples of dicot and monocot seeds, seedlings, and leaf venation: (a) Bean and (b) Corn

Sources: http://www.biologycorner.com/resources/mono_di_germination.gif
http://3.bp.blogspot.com/_NfIGV0h-1wfl/Rw7Fqnr4drl/AAAAAAAAABE/fZt-GwtNSZY/s400/cornkernel.gif
http://glencoe.mcgraw-hill.com/sites/dl/free/0078664276/281029/ct_u2_ch11_q3.jpg

Amount of nitrogen fixed (pounds per acre per year) vary depending on the forage species and environmental condition; however, amount of nitrogen fixation ranges from 50 to 150 for a good stand of annual clovers and vetches; 75 to 200 for birdsfoot trefoil, white clover, and red clover; 150 to 200 for alfalfa. For good nitrogen fixation, minerals like calcium, molybdenum, iron, sulfur, phosphorus, and copper should not be deficient; good moisture should be available (25 to 75% of field capacity), but water logging condition has an adverse effect; pH should be favorable for the given legume crops, low pH is unfavorable.



Figure 2. Root nodules on effectively inoculated white clover.
Source: http://www.dpi.nsw.gov.au/__data/assets/image/0008/157490/fig2-innoculating.jpg

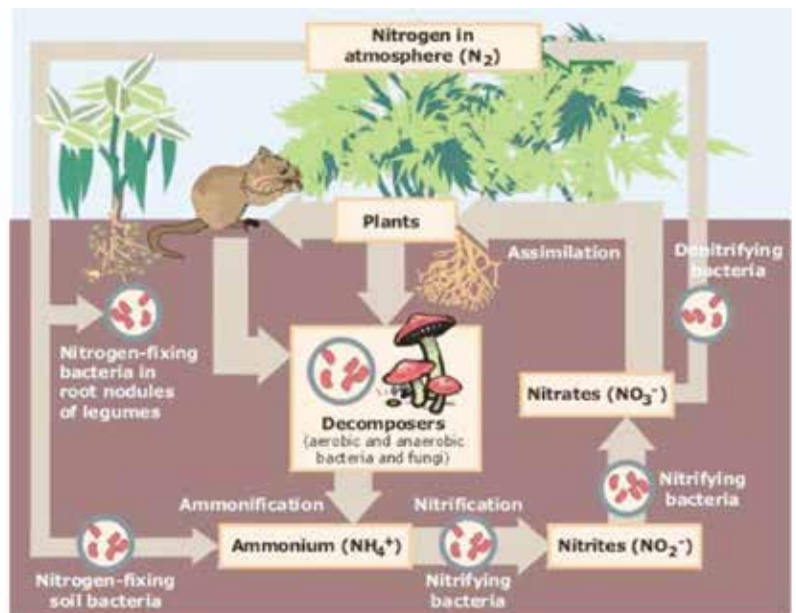


Figure 3. Nitrogen fixation and the fate of fixed nitrogen.
Source: http://upload.wikimedia.org/wikipedia/commons/thumb/d/de/Nitrogen_Cycle.jpg/400px-Nitrogen_Cycle.jpg

Prostrate, semi-erect, and upright grower

Some forage species are prostrate such as bahia-grass, common bermudagrass, and subterranean clover. Bahiagrass has rhizomes, and bermudagrass and subterranean clover have stolons. Rhizomes remain under soil surface while stolons crawl on the surface. Both of these structures have nodes and internodes, and each node serves as tillering/growth points; they also store food. When leaves and up-grown shoots are removed through grazing or manual harvest, new leaves and shoots emerge from the nodes. Because of this phenomenon, such species can tolerate close and continuous grazing. Few types of forage are semi-erect type such as tall fescue, orchardgrass, and arrowleaf clover; they have food storage and buds near the ground, and are fairly tolerant to close grazing except under stress conditions. Forages like switchgrass, coastal bermudagrass,

Optimum temperature for warm-season species is about 85 to 95oF, whereas 60 to 80oF is ideal for cool-season species.

sericea lespedeza, and alfalfa grow upright. These forages have food reserves in stem bases and/or roots for regrowth and persistence. Continuous close grazing is not suitable for such species because continuous defoliation deplete food reserves and does not support vigorous plant regrowth. Rotational stocking with a rest period or continuous stocking at a rate low enough to leave higher stubble is required for these species.

Warm-season and cool-season species

Warm-season forages are originated under tropical and sub-tropical climates, grow and mature in warm sea-

son portion of a year (late spring, summer, early fall), and die or become dormant in winter. Bahiagrass, bermudagrass, switchgrass, bluestem, and sericea lespedeza are few examples of warm-season forages. Cool-season forages are originated under temperate climates, grow in cooler portion of a year (spring, fall, some portion of winter), and die or become dormant during summer. Few examples of cool-season forages are oats, rye, ryegrass, tall fescue, and clovers. Optimum temperature for warm-season species is about 85 to 95F, whereas 60 to 80F is ideal for cool-season species. However, individual legumes vary in terms of temperature with 65-75F for clover, about 78F for alfalfa, and 80 to 85F for tropical legumes. Growth of warm-season grasses fall rapidly when temperature falls below 70F, with virtually no production at 50F.



Pasture Plant Physiology

Photosynthesis

Physiology is a live process for a living being to survive, produce, and propagate from generation to generation. Photosynthesis is a major physiological process of green plants. In this process, green plants manufacture food (organic compounds also called photosynthate) using atmospheric carbon in the form of carbon dioxide (CO_2) and water absorbed from soil in the presence of sunlight. Photosynthesis takes place in chloroplast of green plants, especially leaves. Warm-season forages, also called C_4 forages as they fix energy into 4-carbon chain during photosynthesis, are more efficient in

using sunlight and water to produce food as compared to cool-season forages. The efficiency of C_4 forages in converting solar energy to food energy is 5-6%. The captured energy is not lost for photorespiration, oxidation of carbohydrates during photosynthesis. Since C_4 forages are more efficient in solar energy and water use and minimum loss due to photorespiration, they are more productive than cool-season forages.

Cool-season forages are also called C_3 forages because they fix energy into 3-carbon chain during photosynthesis. Their photosynthetic efficiency in terms of sunlight conversion to food energy is around 3%. Loss of photosynthate (organic products from photosynthesis)



due to photorespiration in C3 plants is significant; it is suggested that 15% - 40% of the light energy captured in photosynthesis gets lost in photorespiration. Such losses increase at high temperatures. Thus, C3 plants are better adapted and more efficient in cool environments than in warm environments. Most C4 species are able to increase photosynthesis even up to the full sun light. Conversely, most C3 species reach light saturation before full sunlight. Usually, C3 species become light saturated at 25 to 50% of the full sunlight. C4 forages are more productive but have higher fiber content; C3 forages have less fiber and more nitrogen content, so have higher quality.

Food manufactured during photosynthesis is first used in and surrounding parts of photosynthetic site for tissue growth and development. Excess food is transported to other parts and used for tissue growth and development. Surplus food after fulfilling the requirements for tissue growth and development is stored in various plant parts. Stored food is used for regrowth after defolia-

(Fig. 4).

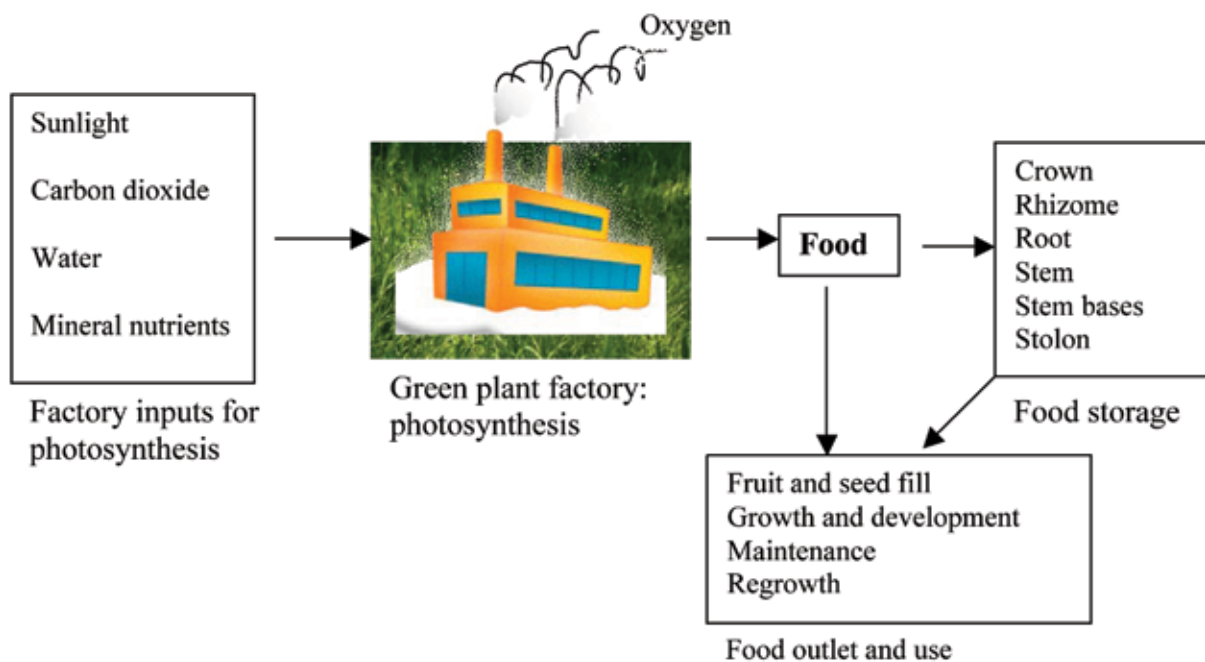


Figure 4. Schematic diagram of food manufacture through photosynthesis, and storage and utilization of manufactured food.

Forage growth and regrowth

Forage seeds under favorable environmental condition develop into seedlings. For the first few days, these seedlings fully depend on nutrients present in seeds. Then they slowly develop leaves and begin photosynthesis. Before being able to perform photosynthesis, seedlings need to have enough food available in the seed; a good quality seed have enough food for seedling establishment. Use of poor quality seed will result in weak seedlings and poor stand establishment. Young forage seedlings should be exposed to sunlight for photosynthesis because seedlings under inadequate sunlight may not develop well as compared to those exposed to adequate sunlight. Therefore, shading should be avoided

and exposed to enough sunlight when seeds are germinating. Similarly, in a mixed pasture with short and tall species, forage harvest or grazing should be managed properly to make sure that tall species are not shading short species to inhibit latter's photosynthetic activity (Fig. 5).

When seedlings are growing rapidly, nutrients available in the seeds as well as all the manufactured food from photosynthesis are utilized for tissue growth and development. For example, soybean leaves depend on imported food (from seed) before they achieve 50% of mature size; when leaves are developed to 50% of the mature size, they become self sufficient (Fig. 6). After this point, they start exporting the manufactured food to other parts and after full maturation and under good environmental condition, leaves may export 60-80% of the manufactured food to other plant parts.

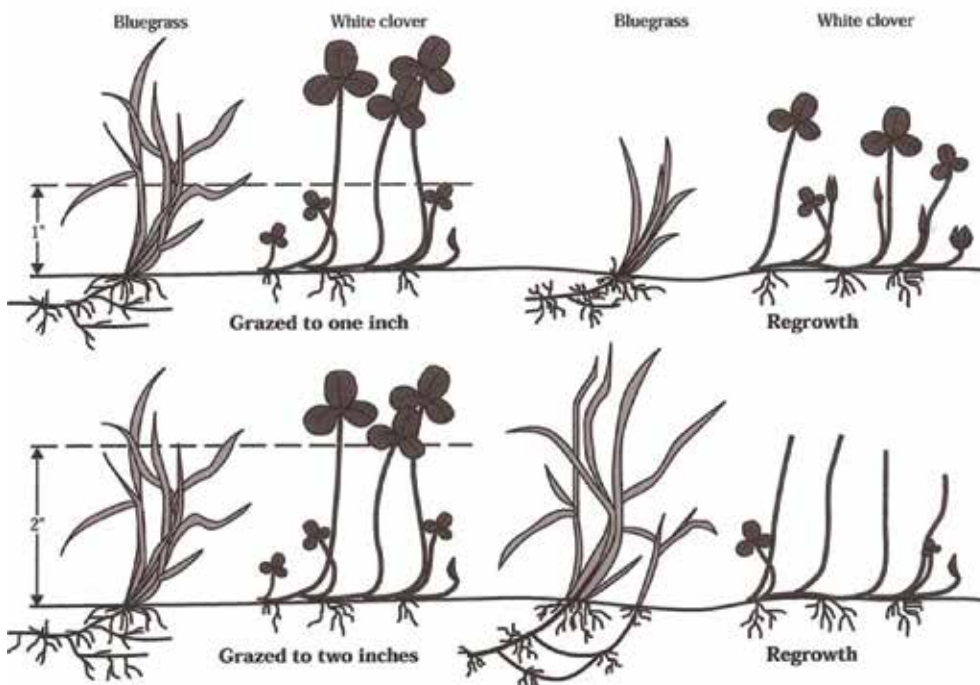


Figure 5. Lower grazing height is favorable whereas taller grazing height is detrimental for the regrowth of shorter species (white clover) in a multi-species pasture (Blaser, 1986).

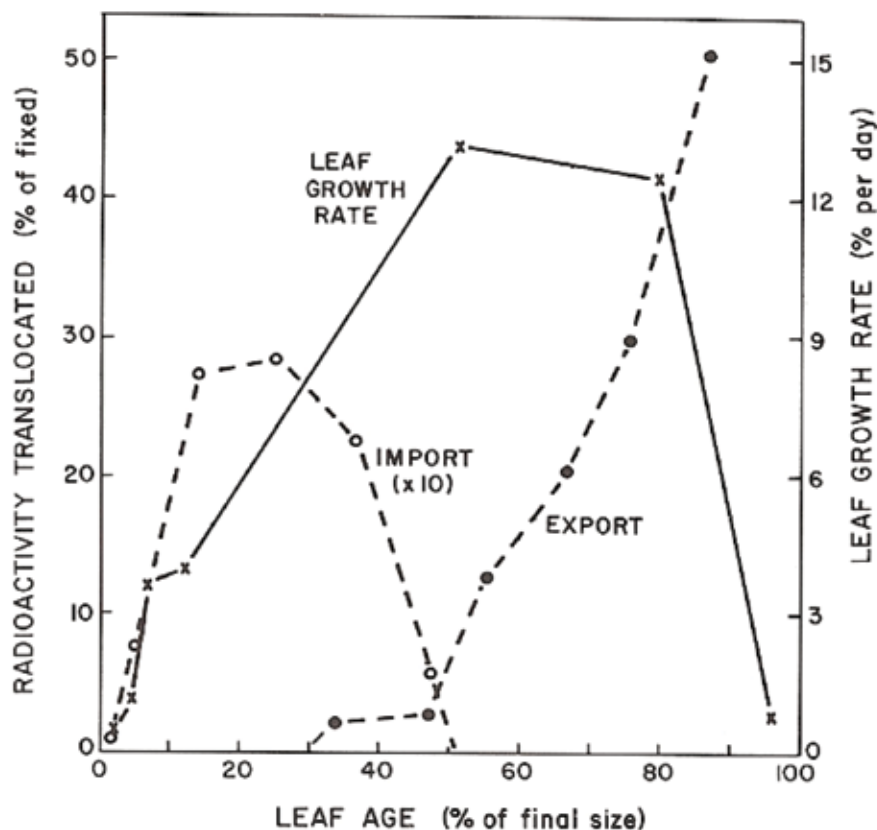


Figure 6. Manufactured food import and export of a soybean leaf (Thrower, 1962 – from Gardner et al., 1985).

When plants are growing fast, all manufactured food may be utilized and minimum or none of the food may be available for storage. When leaves are fully expanded and plant growth rate slows down, surplus food is stored in different parts like crown, stems, stem bases, roots, rhizomes, and stolon depending on the forage species (Fig. 7). This reserve is used when there is not enough leaf area present for photosynthesis like after defoliation and when plants go dormant. Recommendations on grazing or harvest-

ing heights for different forages presented later in this manual are based on leaving enough leaf area for vigorous regrowth.

Temporary storage of manufactured food and its utilization for seed fill in rice has been shown in Figure 8. From germination to tillering, there is no storage; food storage begins when vegetative growth slows down, reaches maximum at flowering, and then mobilized to seed during seed filling. Similar trend of food storage and remobilization can be expected in annual forage crops as well. Unlike in rice, forage crops are harvested or grazed just before flowering,

around flowering, or at the beginning of seed fill depending on the species, and the regrowth is expected to occur by utilizing the stored food if there is not much leaf area left for photosynthesis.

In case of perennials, stored food is crucial to survive during dormancy and regrow in the next growing season. However, if the defoliation (removal of leaves) becomes too frequent, there would not be enough food reserves for regrowth. As a result, regrowth goes on decreasing after each harvest and plants become weak. If there is not enough reserve for perennial plants by the time they go dormant, their vigorous regrowth can not be

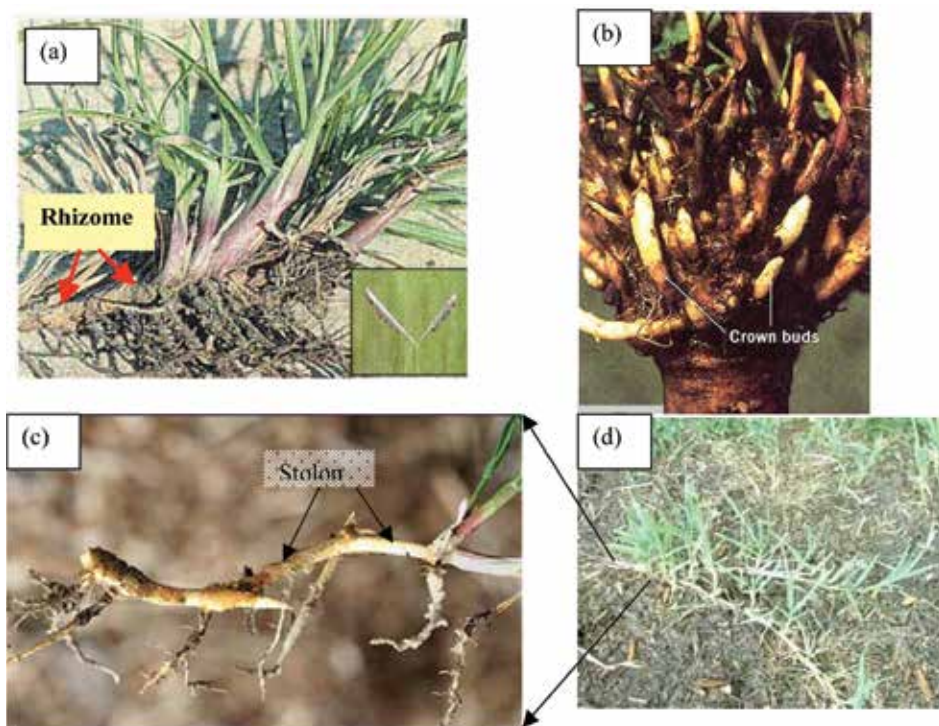


Figure 7. Food storage sites of few types of forage: (a) rhizome in bahia-grass, (b) crown in alfalfa –buds are emerging from the crown, (c) stolon in bermudagrass, (d) stolons of bermudagrass are creeping on the ground surface and shoots are growing from each node on the stolon.

Source:

(a) <http://www.egreenlawncare.com/Bahiagrass.gif>

(b) <http://forage.okstate.edu/images/medicjpg's/alfalfa/crown-buds.jpg>

(c) <http://extension.missouri.edu/explore/images/ipm1007bermudagrass02.jpg>

(d) http://utahweed.org/pics/bermudagrass_ad1.jpg

expected in the next season. If defoliation of forage plants are not managed properly to leave enough reserve and/or leaf area for photosynthesis, plants may extinct from the pasture and need to be reseeded and established again.

Stored food is more important for legumes than grasses. It is because graz-

ing off the upper one-half to two thirds of a legume pasture removes most of the leaf area, but not with grasses. Therefore, legumes must nearly always grow back from new crown shoots and from root food reserves, while vigorously-growing grasses usually have considerable leaf area to support regrowth. Legume regrowth would not be affected much whether 50 or 90% of the leaf area is removed, but grass regrowth is reduced with lower leaf area.

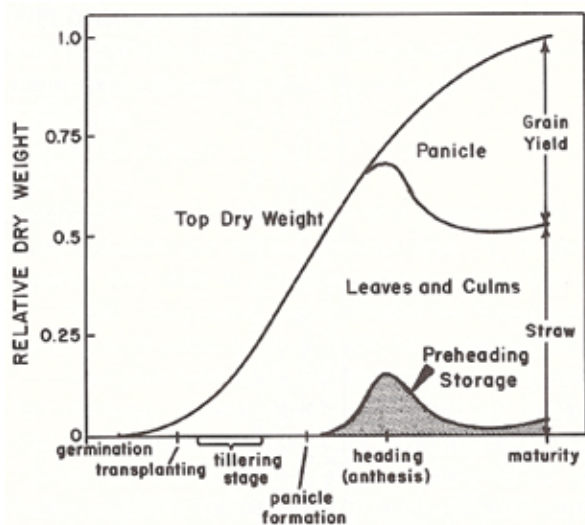


Figure 8. Temporary storage and mobilization of manufactured food and dry weight of various parts for different growth stages in rice (Adapted).

Source: Gardner et al., 1985; Maruta and Matsushima, 1975.

Key points

- 1. Forages can be classified into different categories based on how long they persist once established, number of cotyledons they have, growth pattern, and growth season.**
- 2. Green plants manufacture food in the presence of sunlight through a process called photosynthesis. Leaves are very important for photosynthesis.**
- 3. Enough leaf area or stored food should be present for survival and vigorous growth and regrowth of forages.**

When seedlings are growing rapidly, nutrients available in the seeds as well as all the manufactured food from photosynthesis are utilized for tissue growth and development.



Soil test, liming, and fertilization

It is very important to maintain optimum soil condition for successful establishment and good production of any forage species. At the beginning of forage cultivation, one needs to know soil texture, pH, and nutrient status; soil texture and pH are major indicators to select forages. It is because some species do well in sandy soil while some others are suited in heavier soil having better water holding capacity. Similarly, few types of forage may grow well in somewhat acidic soils while others may require pH close to neutral. In the subsequent testing, only pH and nutrient status will be enough for appropriate liming and fertilization for

the pasture species you have. Routine liming and/or fertilization without knowing the existing pH and nutrient status is not appropriate because such application may be either more or less than the required amount; under-application may not give you the full advantage of your investment of time and money, and over-application will be wastage of money and time, trigger environmental pollution, and also may not be beneficial to the pasture plants. Since soil test results are very important for selecting suitable forage species, liming, and fertilization, one has to be very serious and careful in collecting soil samples and dispatching them to the soil testing laboratory.

Soil sample collection and delivery procedure

Soil samples should be collected such that they represent whole pasture soil. Collect 0-4 inches deep (for perennial pastures) or 0-6 inches deep (or to the depth of tillage for annual pastures) core of 15-20 random samples from uniform pasture area no more than 20 acres and mix in a bucket to composite. From this, collect around 1 pint of sample into a sample delivery bag from your county office (if available) or in an airtight clean container. Label the sample well with name and address, pasture species grown, and sample collection and delivery date. If you have different soil types in different portions of your pasture, then prepare and send composite sample from each portion separately. Also, if different pasture species are grown in different portions of pastures, then composite samples from each portion need to be sent separately.

Perennial pastures should be soil tested at least once in 2-3 years. Fields used for hay production, overseeded in winter or tilled and planted to annual forage crops should be tested each year. Soil samples should be collected around the same time each year to know the progress.

Plant nutrition, liming, and fertilization

Plant roots absorb water and mineral nutrients from soils and used for manufacturing food through photosynthesis. Major mineral nutrients required for plants are nitrogen, phosphorus, and potassium. However, legumes do not need to be fertilized with nitrogen fertilizer as they are capable of fixing atmospheric nitrogen (79% of the Earth's atmosphere is composed of nitrogen gases); fixed nitrogen can also fulfill the nitrogen requirement of non-leguminous plants grown together with legumes or grown after legumes are harvested, died, or gone dormant. Therefore, grasses grown together with legumes comprising 30% or more of the forage stands do not need nitrogen fertilization.

Nitrogen is a component of chlorophyll, green pigments present in most plants that absorb solar energy for photosynthesis. Nitrogen deficient plants cannot grow well and have yellowish appearance. Nitrogen fertilizer cannot stay in soil for a long time; it may leach to the lower soil layer that is beyond the reach of plant roots, so may not be available to plants. Substantial leaching can occur when there is a heavy rainfall especially in sandy soil. Also, nitrogen can be lost through surface runoff. Other ways of nitrogen loss are through 1) microbial denitrification, by which ammonium or nitrate-nitrogen is converted to gaseous nitrogen (nitrous oxide, nitric oxide, or nitrogen gases) that escape from soil to atmosphere (Fig. 3), and 2) volatilization of ammonium or urea. To minimize the potential loss, it is suggested to apply nitrogen in divided doses when plants require it the

most like when they are actively growing.

Phosphorus is required in photosynthesis process. It is also essential for the formation of fruits and seeds, root growth, and growth and survival of seedlings. Unlike nitrogen, there is minor chance of phosphorus loss from soil; so, application of single annual dose will be appropriate. Potassium is necessary to maintain cold hardiness, fight with diseases, and enhance root growth and development of many species. In terms of loss from soil, it is intermediate between nitrogen and phosphorus. Two or more applications annually would be necessary to meet the crop demand.

In addition to three major minerals mentioned above, plants require many other minerals but in trace amount. Calcium, magnesium, and sulfur are called secondary nutrients. When adding lime for pH correction, calcium addition should be enough. Magnesium is important in photosynthesis and can be supplied through dolomitic lime application. Plants also may show response to sulfur application. Micro mineral nutrients include manganese, iron, boron, copper, molybdenum, chloride, zinc, and nickel. In most of the South and with most of the Southern forages, there is usually no response to addition of these minerals. However, for clover seed and alfalfa production, 1.5 and 3 lb/A of boron is required, respectively. Animals grazing forages grown in copper deficient soil may show copper deficiency (symptoms include anemia, poor growth, bone disorders, infertility, depigmentation of

hair and wool, and muscular incoordination). If available, animal manure can be used to fertilize the pasture. However, manure should be tested for the concentration of different mineral nutrients present, and lacking or minerals in short supply should be supplemented to fulfill the plant requirements.

Although there are enough mineral nutrients in soil, plants may not do well beyond certain pH range. A pH value indicates how acidic or alkaline a substance is. The pH scale ranges from 0 to 14; a pH of 7 is neutral, a pH below 7 is acidic, and above 7 is alkaline. Too acidic or too alkaline soil is not good for pasture productivity because many mineral nutrients in soil may not be available for plant roots. Most forage crops do best in pH range from 5.8 to 6.5, however, some forage may do well beyond this range. It is always wise to check for pH and add lime as necessary for optimum pH. Acidic soil should be corrected with lime application 3-6 months prior to planting while establishing crops for the first time. Soil alkalinity can be corrected by adding sphagnum peat (peat moss), elemental sulfur, aluminum sulfate, iron sulfate, acidifying nitrogen, and organic mulches. However, alkalinity is not a common problem in Alabama pasture soil.

One has to always remember that lime and fertilizer should be applied to maintain an adequate range of pH and nutrient status in soil. Lower rate of application may not be enough to meet plant demand, and higher rate of application will be toxic to the plant (Fig. 9). Therefore, lime and fertilizer application based on soil test recommendation is the best option for optimum production and resource use.

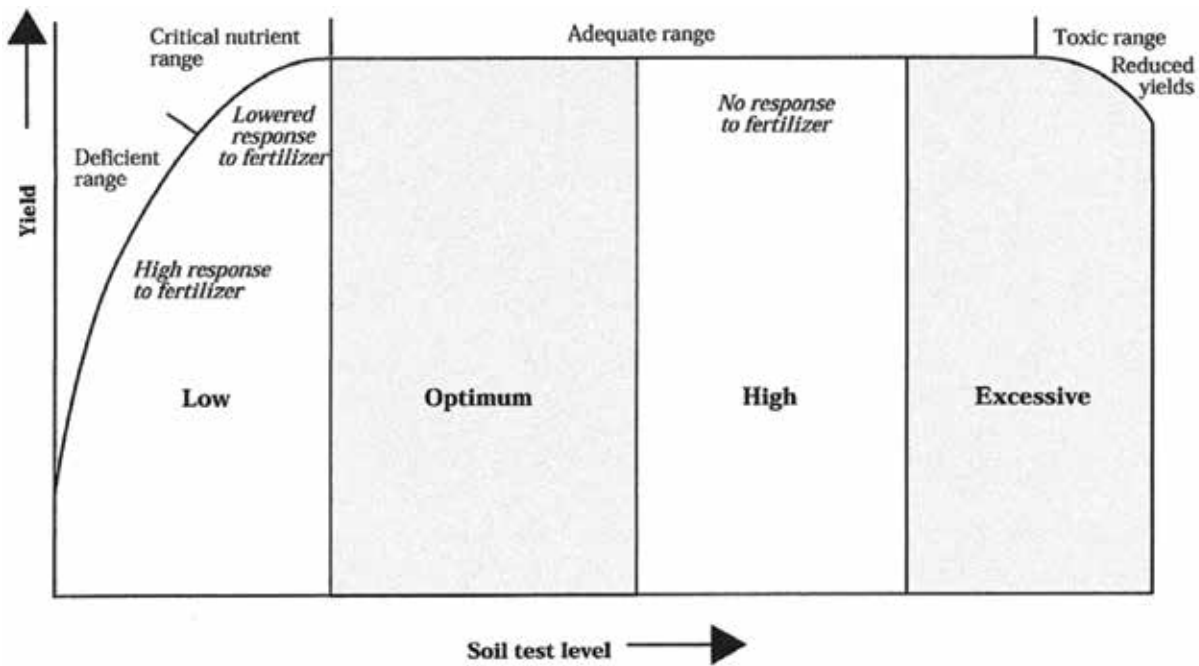


Figure 9. Yield response of forage to level of fertilizer use.
Source: Serotkin, 1994.



Forage selection and cultivation

Forage species should be selected based on pasture soil and environmental condition. Locally adapted forages will have less risk and will establish more successfully. Objective of forage production should be clear in the beginning. To produce forage throughout a year, one should combine warm-season and cool-season species. Introduction of legumes improves forage quality as well as fix atmospheric nitrogen. Also, existing warm-season perennial pasture can be improved by overseeding with cool-season grasses and legumes. No-till drill machine is very useful to plant forage seed in the existing grass sod without disturbing the

existing forage much. Cool-season forages will produce during spring and fall as well as around winter and warm-season forages will produce during warm portion of a year. Therefore, there will be almost a year-round production of forage when cool-season and warm-season forages are combined in a pasture (Fig. 10). Warm-season and cool-season forages commonly adapted in the southern USA are presented in Table 1, from which a producer can select species suitable to his/her pasture conditions.

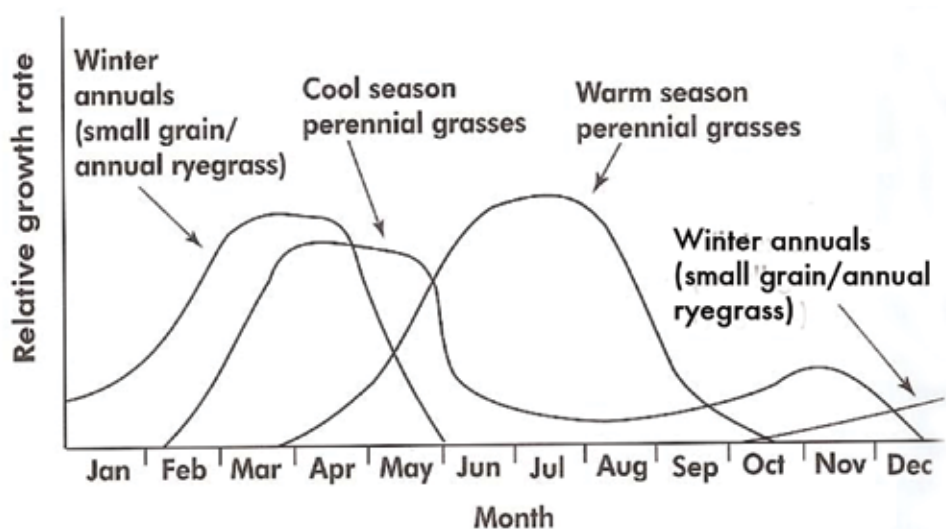
When one has very sturdy warm-season grass like bahiagrass in the pasture, it may be difficult to establish warm-season legumes into the existing pasture.



In such a case, legumes can be planted separately and allowed access to grazing animals for a limited time like around two hours daily to fulfill the protein requirements of grazing animals. Usually, warm-season grasses are poor in quality and may not fulfill the protein requirements of grazing animals, especially those requiring high plane of nutrition like growing or lactating animals. Grazing these animals on legume pasture for few hours daily will avoid the necessity of purchased supplementary feed. Legume forage can also be used to make hay and supplement the poor-quality pasture grazing. While planting legume seeds, inoculation is necessary.

Figure 10. Growth curves for cool-season perennial grasses, warm-season perennial grasses, and winter annuals.

Source: Ball et al., 2007.



Inoculation of legume seed

Seed inoculation is mixing seeds with appropriate *Rhizobium* bacteria so that bacteria can colonize the legume root, form nodule, and fix nitrogen. These bacteria and legumes maintain symbiotic relationship – plants provide required energy for bacteria and bacteria fix and supply nitrogen to host plants. In the new field, bacteria may not be present, so if

not inoculated legumes cannot perform well. To be successful, inoculums should be appropriate for the given legume, it should be fresh and handled properly within temperature range of 40-70F or kept refrigerated while storing for a short time. Improper handling and storage of inoculums may kill bacteria, inoculation can be a waste. Producers should check the label and follow the steps strictly for successful inoculation. When introducing legumes into a new field, there can be a dramatic difference in production between inoculated and not inoculated seeds; Figure 11 presents an example.

Table 1. General classification of forages frequently grown or found in the southern USA.

Grasses			
Perennials		Annuals	
Warm season	Cool season	Warm season	Cool season
Bahiagrass Bemudagrass Big bluestem Carpetgrass Caucasion bluestem Dallisgrass Eastern gamagrass Indiangrass Johnsongrass Switchgrass	Kentucky bluegrass Orchardgrass Perennial ryegrass Reed canarygrass Smooth bromegrass Tall fescue Timothy	Browntop millet Corn Crabgrass Forage sorghum Foxtail millet Gran sorghum Pearl millet Sorghum-sudan hybrids Sudangrass	Barley Oats Rescuegrass Rye Annual rhygrass Triticale Wheat
Legumes			
Perennials		Annuals	
Warm season	Cool season	Warm season	Cool season
Kudzu Perennial peanut Sericea lespedeza	Alfalfa Alsike clover Bridsfoot trefoil Red clover White clover	Alyceclover Cowpea Korean lespedeza Soybean Striate lespedeza Velvetbean	Arrowleaf clover Ball clover Berseem clover Bigflower vetch Black medic Burclover Button clover Caleypea Common vetch Crimson clover Hairy vetch Hop clover Lappa clover Persian clover Subeterranean clover Sweetclover Winter pea

Source: Ball et al., 2007.

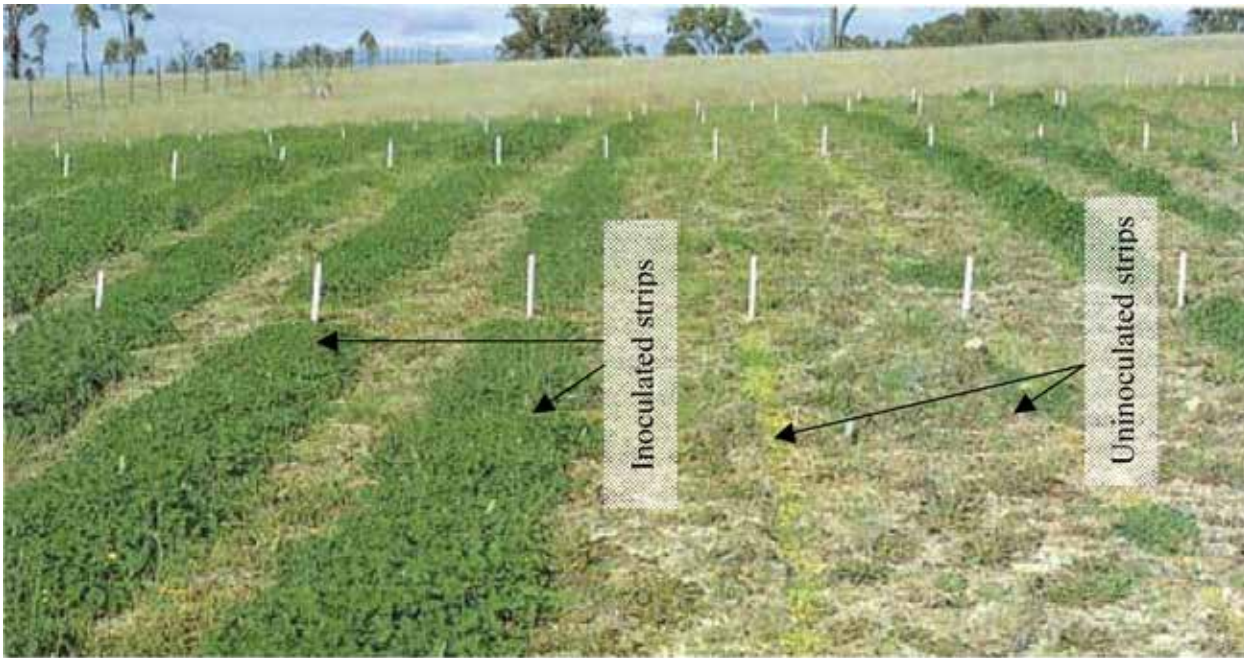


Figure 11. The dark green vigorous strips were sown with inoculated seed and the yellow to light green strips were with uninoculated seed.

Source: www.dpi.nsw.gov.au/.../fig1-innoculating.jpg

Weed control

Any unwanted plant is called weed. Weeds compete with forage plants for nutrients, moisture, sunlight, and space, and lower pasture productivity. Weeds can be removed using mechanical, chemical, or biological means. Manual removal of weeds can be feasible if the occurrence is sporadic in a small area. Chemical means would be effective to control weeds occurring in a wide area. Many weeds present in pasture grazed by cattle alone can be

minimized by introducing goats; goats eat many varieties of shrubs and herbs that are generally avoided by cattle. Whichever method is used, weeds should be controlled when they are young and still growing before producing seeds. Once seeds are dropped, more weeds will come up in the next season resulting in wastage of money and time spent for weed control. If weeds are not controlled, they gradually take over pasture since the grazer select against them. For example, we can see in Figure 12 that forages are eaten by grazing cattle, but weeds are untouched giving better environment and less competition for weed plants to grow and propagate.

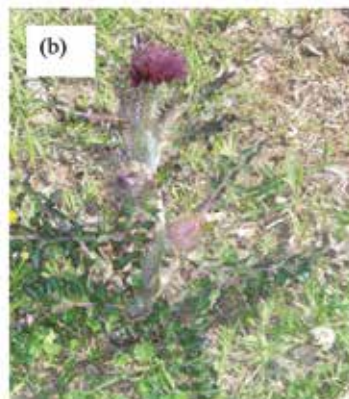
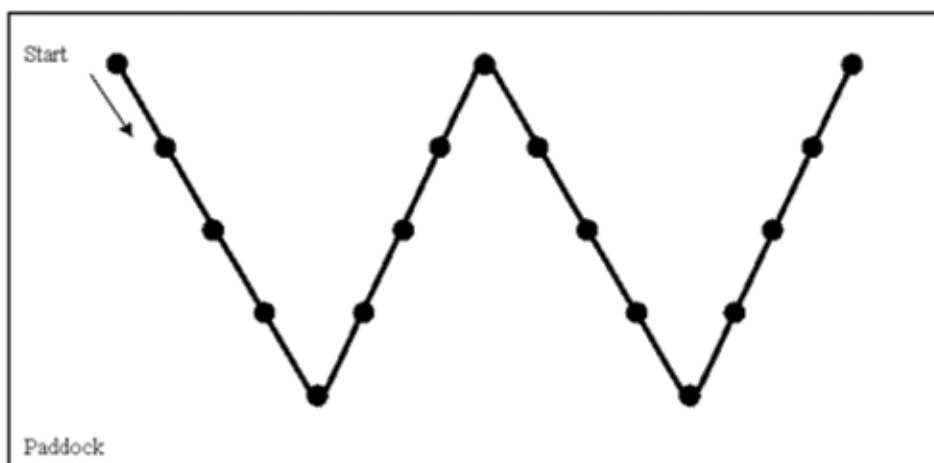


Figure 12. Forages are eaten but weeds are left in the pasture by grazing cattle and offered a suitable condition for weed propagation, (a) *Rumex* sp. and (b) Thistle in Alabama's Black Belt.

Yield estimation

It is very important to know the quantity and quality of forage available in your pasture for proper grazing management. By estimating yield, one can know the carrying capacity, which is useful to determine the stocking rate. Yield can be estimated using forage height, but it varies depending on forage species, season, overall height of the forage canopy, and thickness of the forage stand. In general, for cool-season grasses and legumes, spring pasture will be denser than summer or fall; grasses have more dry matter than legumes. The distribution of yield in the forage canopy will be different for grasses and legumes – grasses have the densest part near the ground, while upper canopy is the densest for legume stands. This is because grass leaves are more concentrated towards the base and legume leaves are mostly present in the middle to upper part of the canopy.



25 foot-steps interval



Rising Plate Meter or Pasture Ruler datum collection

Yield can be estimated directly by hand clipping the forage samples. Samples should be clipped to ground level from random spots fixed in advance or at certain fixed interval, let's say every 15-, 20-, 25-footstep, or more depending on the pasture area to estimate, diagonal to the pasture or in W-shaped as shown in Figure 13 to account for the maximum variation in the forage production. The samples should be weighed just after clipping and weighed again after drying to get the moisture content and dry matter availability. Indirect method of estimating forage yield is by knowing the forage height. Pasture ruler is used to measure forage height.

There is information already worked out on the quantity of forage available per acre for each inch of forage height for various forages in different locations. For example, the available forage per inch per acre for some selected forages has been presented in Table 2. However, forage yield varies depending on the forage species, growth stage, and environmental condition. Therefore, it would be worthwhile to calibrate the yield to be estimated using pasture ruler at the beginning. For calibration, yield has to be estimated with hand clipping method wherever we measure the forage height, and yield per acre should

be calculated. Forage height can be measured following a W pattern in a given pasture. If a pasture is small, at least 15 samples need to be measured. Average height is calculated from the data and yield per inch per acre is calculated by dividing the yield per acre by average height of forage for the given pasture.

Figure 13. An example of collecting forage samples in a W pattern.

Source: http://www.forages.psu.edu/topics/pastures/yield/how_to_calibrate.htm

Table 2. Approximate pounds of available forage per inch per acre.

Forage species	Forage dry matter (Pounds per inch per acre)	
	Average	Range
Alfalfa or alfalfa-grass mixture	225	75-400
Arrowleaf clover	200	100-300
Bermudagrass	260	150-500
Caucasian bluestem	180	75-350
Crimson clover	200	100-300
Kentucky bluegrass	160	100-175
Native warm-season bunchgrasses	100	50-250
Orchardgrass	180	75-300
Orchardgrass-clover	200	100-350
Red clover	220	100-300
Annual ryegrass	250	75-400
Oats, rye, wheat	150	75-250
Tall fescue	210	100-350
Tall fescue-white clover	190	80-325

Source: Ball et al., 2007.

Forage Quality

Fiber and protein contents determine the quality of forage. Forage with high protein and low fiber content is considered of high quality, and quality degrades with decreasing protein and increasing fiber content. Young leaves and shoots are of high quality while older leaves and stem are low in quality. Some forage species are higher in quality while others are low in quality. Generally, legumes are high quality and grasses are lower in quality. Therefore,

incorporation of legumes into the pasture increases forage quality. Maturity is another factor to influence forage quality; fiber increases and protein decreases as forage matures from leafy vegetative stage to stemmy reproductive stage. For example, quality change in forages at different stages of maturity has been shown in Table 3; both crude protein (CP) and total digestible nutrients (TDN) remained the highest at vegetative stage for all three forages, and decreased as they matured. Various maturity stages of grasses and legumes can be identified with their physical characteristics (Table 4).

Table 3. Change in quality with stage of maturity of forages.

Maturity	Tall fescue		Red clover		Alfalfa	
	%CP†	%TDN	%CP	%TDN	%CP	%TDN
Vegetative	20	73	20	74	24	70
Early reproductive	13	61	18	69	20	65
Full bloom	19	48	15	62	14	58

†CP - Crude protein. It is calculated by multiplying the nitrogen content of forage with 6.25.

^TDN - Total digestible nutrients present in the forage.

Source: Gerrish and Roberts, 1997.

Table 4. Maturity stages and physical characteristics of grasses and legumes.

Stage of Maturity	Physical characteristics
Grasses	
Vegetative	Leafy growth, few stems, no reproductive growth
Late vegetative	Stem is elongating
Boot	Stem elongated, top of stem swollen
Early bloom	Seed heads (flower heads) begin to emerge
Mid bloom	At least 25% of seed heads emerged, pollen beginning to shed
Full bloom	Most seed heads emerged; seed forming, seed soft and immature
Dough	Seed becoming harder and having a dough like consistency
Mature	Seed hard and ready for harvest
Legumes	
Vegetative	Leaf and stem growth; no buds, flowers, or seed pods
Bud	Buds begin to swell and become apparent at a few nodes
Late bud	Several nodes with buds; buds more swollen
early flower	A few buds open, flower color apparent
Late flower	Many flowers apparent
Early seed	Green seed pods apparent on a few flowers
Late seed	Many green seed pods apparent; some seed pods turning brown
Mature	Seed pods brown to black and dry; seed ready to harvest as moisture content permits

Source: Ball et al., 2007.

For assessing the quality, forage samples are routinely analyzed using detergent method developed by P. J. Van Soest. This method partitions the forage

components into different fractions as presented in Table 5. From the results of this analysis, we can estimate the digestible portion of the given forage and various other feeding qualities using different prediction equations.

Table 5. Forage fractions and their components using the detergent methods of Van Soest.

Fraction	Components
Cell Contents	Lipids
(Portions soluble in neutral detergent - neutral solutions of sodium lauryl sulphate and ethylenediaminetetraacetic acid)	Sugars, organic acids, and water soluble matter Pectin Starch Non-protein nitrogen Soluble protein
Cell-wall contents - neutral-detergent fiber (NDF) (Fiber not soluble in neutral detergent)	
1. Soluble in acid detergent - 0.5 M sulphuric acid	Hemicellulose Fiber-bound protein
2. Acid-detergent fiber (ADF)	Cellulose Lignin Lignified nitrogen Silica

Source: McDonald et al., 1988.

Prediction equations

From ADF, digestible dry matter content of the given forage can be predicted using the following formula.

$$\text{Digestible Dry Matter (DDM)} = 88.9 - (0.779 \times \% \text{ADF})$$

Similarly, potential dry matter intake of a livestock as a percent of its body weight is predicted using following equation once NDF value is known.

$$\text{Dry Matter Intake (DMI, \% of BW)} = \frac{120}{\% \text{NDF}}$$

$$\text{Relative feeding value (RFV)} = \frac{(\text{DDM} \times \text{DMI})}{1.29}$$

Higher RFV indicates higher forage quality. However, the equation for predicting RFV best suits for legume forage when fed to lactating dairy cows.

$$\text{Relative forage quality (RFQ)} = \frac{\text{DMI, \% body weight} \times \text{TDN, \% dry matter}}{1.23}$$

For RFQ, DMI and TDN for grasses and legumes are calculated differently unlike presented in previous equations.

For legumes,

$$\text{DMI}_{\text{legumes}} = \left[\frac{(0.012 \times 1350)}{\left(\frac{\text{NDF}}{100} \right)} + (\text{NDFD} - 45) \times 0.374 \right] \div 1350 \times 100$$

$$\text{TDN}_{\text{legumes}} = \text{NFC} \times 0.98 + \text{CP} \times 0.93 + \text{FA} \times 0.97 \times 2.25 + \text{NDFn} \times (\text{NDFD}/100) - 7$$

For grasses,

$$\text{DMI}_{\text{grass}} = -2.318 + 0.442 \times \text{CP} - 0.0100 \times \text{CP}^2 - 0.0638 \times \text{TDN} + 0.000922 \times \text{TDN}^2 + 0.180 \times \text{ADF} - 0.00196 \times \text{ADF}^2 - 0.00529 \times \text{CP} \times \text{ADF}$$

$$\text{TDN}_{\text{grass}} = \text{NFC} \times 0.98 + \text{CP} \times 0.87 + \text{FA} \times 0.97 \times 2.25 + \text{NDFn} \times (\text{NDFDp}/100) - 10$$

~~NDF~~ = 48 hour in vitro digestion (% of NDF)

NFC = Non-fiber carbohydrates = organic matter (OM) – CP – ether extract – NDFn, % of DM

FA = Fatty acids = EE – 1, %DM

NDFn = NDF free of CP

In addition to fiber content, CP (crude protein) estimation is essential to find out the overall quality of forage. CP is estimated from the total nitrogen concentration of forage sample and multiplying the nitrogen concentration by 6.25 because nitrogen constitutes around 16% of plant proteins.



Higher RFV indicates higher forage quality.



Grazing definitions and concepts

Continuous and rotational grazing systems

Under continuous stocking system, animals are allowed to graze the whole pasture continuously throughout a grazing season each year. If a pasture has different forage species in different portion of a pasture, animals may overgraze the portion where there is forages of their choice while undergrazing certain other portions. Manager does not have control on where animal should graze. In a rotational stocking system, whole pasture is divided into two or more subdivisions (paddocks) through appropriate fencing, and animals

are allowed to graze one paddock at a time and moved to another paddock in a sequence or rotation based on forage availability. If a pasture has forage species resistant to continuous close grazing like bermudagrass and bahiagrass, then continuous grazing system is appropriate. However, a pasture having mixed species some of which cannot tolerate continuous grazing require rotational grazing since animals will selectively graze more palatable species and avoid or minimize grazing on less palatable species. A schematic diagram of different stocking systems has been presented in Figure 14.

Set and variable stocking

In a set stocking, a fixed number of animals are stocked in a fixed area of pasture for a certain grazing



period. In variable stocking, number of animals per unit of pasture is varied based on the available forage; more animals are stocked when forage production is high and animal number should be reduced when forage production goes down.

Strip grazing

A strip of a pasture is fenced temporarily with a movable fence and animals are allowed to graze the strip for a short time, which may vary from few hours to a day depending on the strip size and pasture availability. When the strip is grazed

to a desirable level, the fence is moved to allow animals to another fresh strip.

Creep grazing

Smaller animals are allowed to go (creep) to a certain portion of pasture having higher forage quality through openings in fence that allows smaller animals but prevent larger animals from entering. Creep grazing is practiced to fulfill the nutritional requirements of young growing animals grazing with their dams and other mature animals.

Forward creep

Calves are allowed to creep through a creep gate to a fresh pasture first and then dams are allowed to graze the same paddock.

Limit grazing

Animals are allowed to graze high quality pasture such as legumes or winter annuals for a limited time, e.g., for few hours everyday. Growing high quality forage on a separate piece of pasture and allowing animals to this pasture for few hours everyday is useful to fulfill the nutrient requirement of livestock grazing low-quality pasture.

First and last grazer

When there are different classes of livestock in terms of nutrition requirements, those requiring high plane of nutrition is allowed to graze the fresh pasture first. Then other classes of livestock in sequence of nutritional requirement are allowed to graze. For example, the grazing sequence can be 1) milk cows, 2) heifers, and 3) dry cows or 1) cattle and 2) sheep.

Single and mixed-species grazing

Single species grazing involves grazing a pasture by only one species of animals. Mixed-species grazing involves two or more species of animals, for example, cattle and goats. Mixing cattle and goats for grazing can be beneficial than grazing either species alone because goats eat many plant species that would

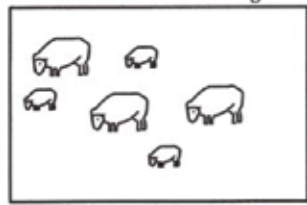
not be eaten by cattle, and cattle lower parasitic infestation in goats as the goat worm larvae ingested with forage by cattle are damaged when they are in the stomach.

Stocking rate and stocking density

Stocking rate is the number of animals stocked per unit pasture for a specified time period. Stocking density is the number of animals stocked per unit pasture at a point in time. For example, if 20 cows are stocked

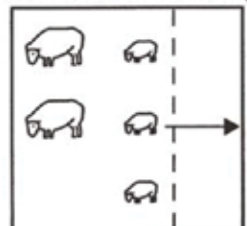
Allocation stocking methods

Continuous set stocking



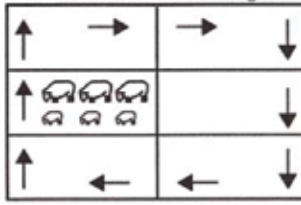
Animals access total area.

Continuous variable stocking



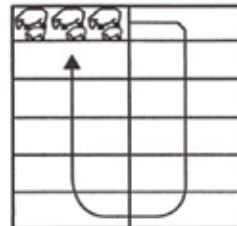
Area accessed by animals expands or contracts as forage supply dictates.

Set rotational stocking



Example: 6 day grazing period and 30 day recovery period.

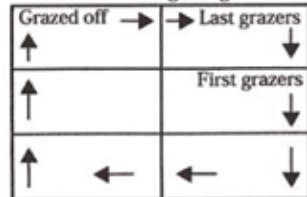
Variable rotational stocking



Example: Grazed 8%; Recovering 92%.

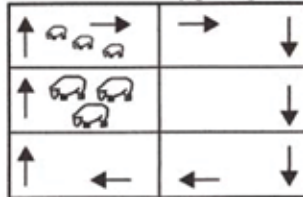
Nutritional optimization stocking methods

First-last grazing



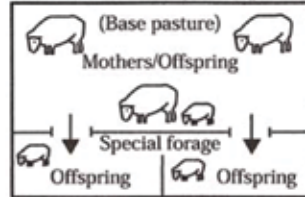
High performers graze first and low performers graze last.

Forward creep grazing



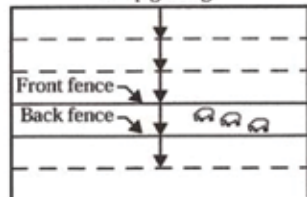
Offspring graze ahead of mothers, using special creep openings.

Continuous stocking-creep grazing



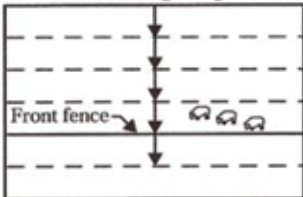
Mothers stay on base pastures, offspring creep graze special forage.

Strip grazing



Flexible areas offered each day (with back fence).

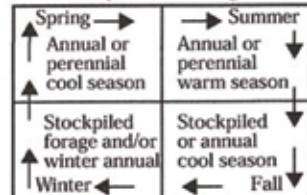
Frontal grazing



Flexible areas offered each day (without back fence).

Seasonal stocking methods

Sequence stocking



Deferred stocking

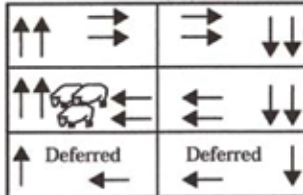


Figure 14. Diagrammatic representation of different grazing systems.

Source: Barnes et al., 1995; Hodgson, 1990; NRCS, 1997.

in 20-acre pasture for a grazing season, the stocking rate is one cow per acre. If the pasture is divided into four paddocks and each paddock is grazed by 20 cows for seven days rotationally, then stocking density is four cows per acre.

How grazing animals influence pasture?

Defoliation

Defoliation, removal of plant shoots or leaves, affect pastures differently depending on the forage species, selective grazing, defoliation frequency, amount of stored food and leaf area left, the physiological stage of plant, and weather conditions at the time of defoliation. Defoliation reduces leaf area and affects plant food storage, ultimately influencing shoot development, leaf area and root growth, light interception, soil temperature, and moisture. Grazing frequency and intensity should be kept at optimum level to avoid the untoward effects of overgrazing or under-grazing on the forage plants. Also, grazing should initiate at right physiological stage of forage plants.

Heavy and close grazing is harmful to certain grasses, such as orchardgrass, especially at the time when their growing points are being elevated prior to flowering. Continued overgrazing of tall-growing forage species generally weakens plants with reduced root systems, lowers forage yield, increases soil erosion and water run-off, and favors weed invasion. Continuous close grazing favors prostrate species like bahiagrass and common

bermudagrass over taller species such as switchgrass and coastal bermudagrass. Conversely, under-grazing or intermittent grazing facilitates the survival of tall species. Also, a significant amount of pasture biomass is wasted and forage quality goes down as forage plants mature in under-grazed situation. Moreover, clover stands decreases in grass-clover pastures when under-grazed because of the shade effect of the taller grass on the shorter clover. However, there is difference in shade tolerance among the clover types. For example, red clover is more tolerant to grass competition because of its upright growing nature. Similarly, crimson and subterranean clovers are more shade tolerant than arrowleaf clover. It is because arrowleaf buds do not develop near the stem base for initiation of new leaves under shade.

Appropriate frequency and height of grazing differs based on the growth pattern of plants, such as those growing tall upright, semi-erect, and prostrate.

Tall upright plants are easily defoliated by grazing and generally depend on food reserves in roots and/or stem bases for re-growth and persistence. Rotational stocking with a rest period or continuous stocking at a rate low enough to leave higher stubble is required for species such as alfalfa, sericea lespedeza, pearl millet, sorghum, johnsongrass, big bluestem, indiangrass, and switchgrass. Semi-erect species or those having food storage areas and buds near the ground, are fairly tolerant to close grazing except under stress conditions. Species in this group include tall fescue, orchardgrass, and arrowleaf clover. Prostrate species like bermudagrass, bahiagrass, Kentucky bluegrass, white clover, and subterranean clover are extremely tolerant to close grazing.

Trampling

Hoof pressure of grazing animals on the pasture injures plants and compresses the soil, reducing pasture production. Pasture plants responds differently to trampling damage. Ryegrass, tall fescue, Kentucky blue-

grass, bermudagrass, and white clover are more tolerant to trampling than small grains, orchardgrass, or red clover. Trampling damage is greater on wet than dry soils, on clay than sandy soils, on recently-tilled than settled soil, and with short forage than tall forage. Trampling of cattle on wet clay soils substantially reduce water infiltration, and increase surface runoff. Removing cattle from pasture during extremely wet periods can reduce trampling damage.

Excretion and nutrient cycling

Grazing animals recycle most of the nutrients removed from pasture back to it through excreta (dung and urine). The excreta of grazing cattle accumulate nutrients on certain areas of the pasture (around 20%), basically under shade and around the water source as well as feed supplemented area, if any. Pasture on such areas is not utilized. However, the excreta supply the organic matter, and other mineral nutrients to the soil enhancing the fertility of soil. Uniform distribution of excreta in the pasture is desirable; for this the watering and feeding facilities and shade has to be scattered accordingly.

Grazing behavior

Animals select and graze most palatable plants and plant parts first and less palatable later on. Generally, young, succulent shoots and leaves are more palatable than mature, woody stems and older leaves. When there are multiple species in a pasture, few species may be more palatable than others. So, most

palatable species will be grazed repeatedly as long as livestock can and cause its low availability or extinction in the uncontrolled grazing. Therefore, pasture having multiple species should be managed applying controlled or rotational grazing. Like selecting palatable plants, animals select comfortable spots to rest.

During hot weather, animals gather around where there are shade and/or water to keep them cool. Animals graze in the cooler part of a day and rest under shade and near water source when it is hot causing frequent trampling around the resting areas. Trampling is also high around salt and feed supplement spots. So, it is good to provide natural shade to animals away from water source and alter supplement spots time to time so that their distribution is divided into different areas and minimize soil trampling in some particular area. Where there is no natural shade (tree), it is beneficial to provide some artificial shade in the pasture so that animals are not stressed much in very hot day.

Key points

- 1. There are different kinds of grazing and stocking systems. A manager should choose an appropriate system or combinations of different systems depending on the pasture species, type of grazing animals present, and desired output.**
- 2. Grazing animals influence pasture by defoliation of forages, recycling nutrients into the pasture, and trampling.**
- 3. Animals selectively graze palatable forage portion and species. Stocking rate and grazing**

duration should be manipulated to avoid untoward effect of for-ages.

- 4. Grazing animals congregate around water source or shade during hot weather to keep them cool and trample these areas. To minimize too much trampling, watering and feeding facilities as well as shade should be located strategically.**



Grazing decision and management

Grazing decision has to be made to maximize forage utilization, animal performance, and profit. Deciding on a particular grazing system depends mainly on the forage species present in the pasture. Pasture containing species suitable to continuous close grazing such as bahiagrass, common bermudagrass, white clover, and subterranean clover can be grazed continuously. However, one should maintain stocking rate appropriate to forage availability. If a pasture contains mixed prostrate, semi-erect, and erect species, then rotational grazing is necessary for two reasons. First, semi-erect and erect species cannot tolerate continu-

ous close grazing and, second, animals will selectively graze the most palatable species and jeopardize their re-growth. Here, it will be reasonable to mention some of the conditions when rotational grazing would be more suitable than continuous grazing.

Situations when rotational grazing is superior to continuous grazing

- When pasture is not uniform in terms of quantity, quality, and composition, rotational grazing minimizes the pasture selection. The chance of selection is high in continuous grazing system, especially at a low stocking rate.
- When pasture needs to be irrigated, rotational grazing system gives an opportunity to avoid the possible



damage on soil and plants due to animals' action during and immediately after irrigation. Paddocks should be irrigated immediately after moving the animals out. In contrast, continuous grazing system does not provide the facility of animal movement for pasture irrigation, so the damage to soil and pasture is imminent.

- When there is not much feed or forage available, ration feeding can be practiced in a rotational grazing system and higher number of animals can be maintained for similar availability of pasture as compared to the continu-

ous grazing system.

- When running a dairy enterprise, more milk can be obtained from a rotational than continuous grazing system for two reasons. First, because of the establishment of social behavior in a rotational system due to splitting animals into smaller groups. Dairy animals in a small group feel happy and comfortable, and produce more milk (up to 20%) than when they are kept in a large group. Second, milking frequency can be increased as animals remain within a smaller grazing unit at a given time in rotational grazing system. In this case, a producer can fetch the dairy animals to the milking parlor more easily than when they are scattered over a wide area as in a continuous system, and increase the daily milking frequency. Research has shown that increasing milking frequency from 2 to 3 per day increases milk production by 20%.

- When pasture species are susceptible to continuous grazing, like alfalfa.

In other than above situations, rotational grazing may not excel the continuous grazing in an improved pasture with a proper herd management. Generally, for a lower stocking rate, continuous grazing is better than rotational grazing in terms of animal performance. It is because the quality of pasture is likely to be lower at a low stocking rate since much of the pasture is not harvested at proper physiological stage, so pasture matures and quality goes down. In such a situation, animals have access to a large area to pick up what they want in continuous grazing, but it is not so in a rotational grazing because they are confined to a small grazing units. At medium stocking rate, animals perform similarly in both grazing systems. At a high stocking rate, rotational grazing is better. In this case, the quality of the pasture is the governing factor and the quality is higher under rotational stocking. In case of low quality pasture like bermudagrass and bahiagrass, rotational grazing is slightly better

in terms of animal performance because forage quality is generally higher in rotational grazing as compared to continuous grazing. Nevertheless, one must not forget the high input costs associated with rotational grazing system as compared to continuous grazing system. There are several things to be considered to establish and manage rotational grazing system.

Establishment and management of rotational grazing system

Pasture subdivision

For a rotational grazing, whole pasture area needs to be divided into smaller units, paddocks, so that animals can be moved from one paddock to an-

other during a whole grazing season giving enough time for pasture re-growth in each paddock. Rotational grazing is based on the principle that pasture is benefited from shorter grazing period and longer resting period. So, number of paddock should be decided based on the resting period required for the pasture re-growth. Usually, 4-5 paddocks, but not more than 8 paddocks, will be enough. For four paddocks, there will be around one-week of grazing period and three-week of resting period for each paddock. Similarly, for eight paddocks, grazing period and resting period will be, respectively, of around 4-day and 28-day. In Figure 15, we can see that recovery period increases dramatically from zero to 15 days when pasture is divided into two paddocks. Then increment in recovery period goes on decreasing with more paddocks, and becomes negligible after eight paddocks. Therefore, there is no need to have more than eight paddocks.

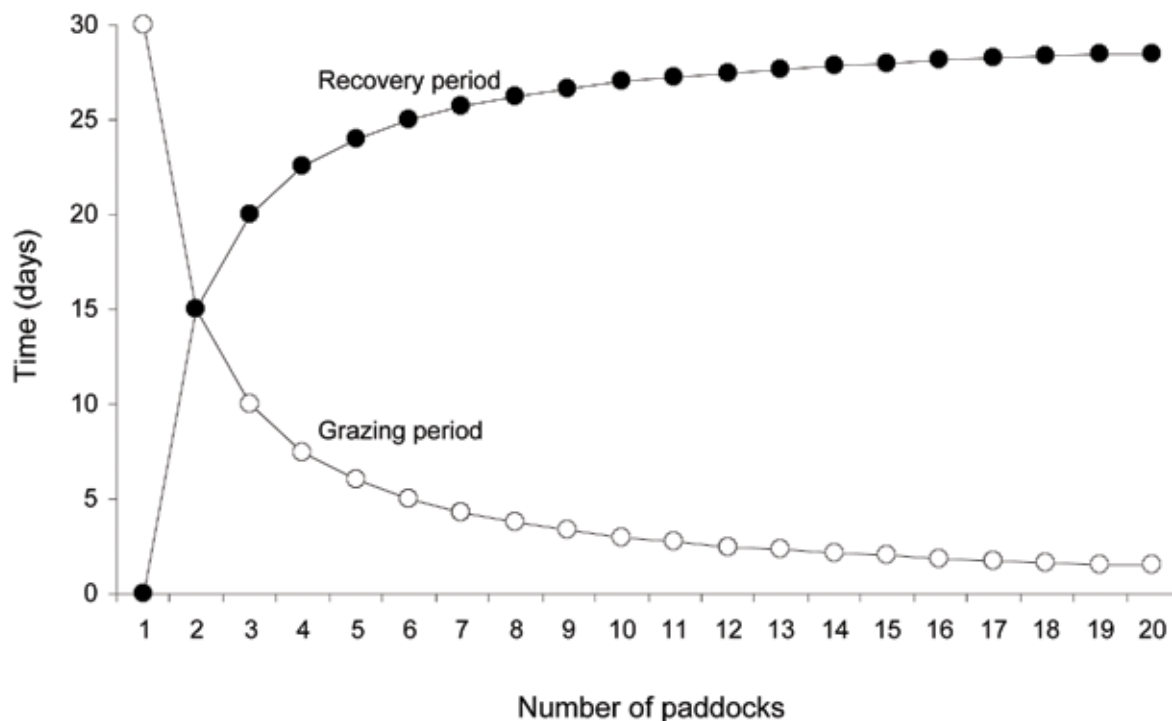


Figure 15. Grazing and recovery period for different number of paddock in rotational grazing with 30 days grazing.

Based on resting and grazing period suitable for forage species, number of paddock required can be calculated as follows.

No. of paddock required = (No. of days required for resting/no. of days grazed) + 1
 Suppose resting period required is 28 and grazing period is 4 for each paddock at a time, then number of paddocks required would be $28/4 + 1 = 7 + 1 = 8$ paddocks.

While dividing pasture into paddocks, following points should be taken under consideration:

- Each paddock should be uniform in terms of natural variation (quantity, quality, and composition of forage, shade, topography, access to water source) so that selection of forage species as well as space is minimized.

- Gates should be placed in such a way to facilitate easy movement of animals while transferring them from one paddock to another.

- Water tank should be placed towards the center of the pasture so that animals from any of the paddock do not have to travel a long way to drink. It is a good idea to keep animals within 600-800 feet of water source.

- Each paddock should be of similar size and production capacity and square shaped as much as possible.

Pasture management

Pasture can be planted at once or at different times to adjust with the animal movement in different paddocks. If planted once, animals should be allowed to graze the first paddock earlier than the optimum growth stage of pasture is reached, and move the animals faster to other paddocks so that the pasture would not be overgrown and lower the quality in any of the paddocks.

Table 6. Guidelines for beginning and ending heights and recovery period for selected forages under rotational grazing.

Forage crop	Target height (inches)		Usual recovery period (days)
	Begin grazing	End grazing	
Alfalfa (grazing type)	10-16	2-3	15-30
Bahiagrass	6-10	1-2	10-20
Bermudagrass	4-8	1-2	7-15
Big bluestem	15-20	10-12	30-45
Clover, white and sub	6-8	1-3	7-15
Clovers, all others	8-10	3-5	10-20
Dallisgrass	6-8	3-4	7-15
Eastern gamagrass	18-22	10-12	30-45
Fescue, tall	4-8	2-3	15-30
Indiangrass	12-16	6-10	30-40
Johnsongrass	16-20	8-12	30-40
Orchardgrass	8-12	3-6	15-30
Ryegrass, annual	6-12	3-4	7-15
Sericea lespedeza	8-15	4-6	20-30
Small grains	8-12	3-4	7-15
Switchgrass	18-22	8-12	30-45

Source: Ball et al., 2007.

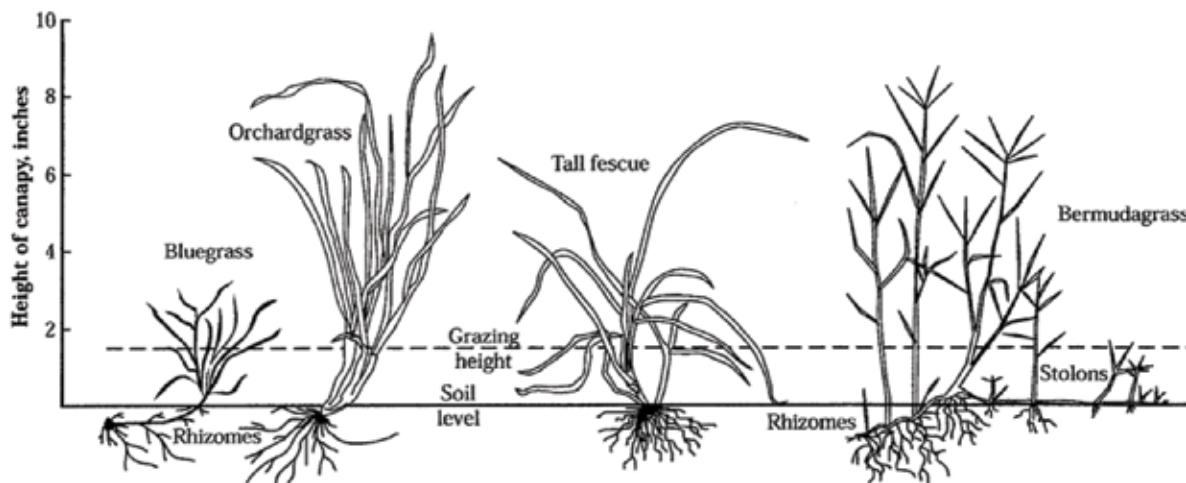


Figure 16. Nature of forage growth pattern influence grazing height.
Source: Blaser, 1986.

If animal grazing cannot catch up with the pasture growth in all paddocks, few paddocks should be mowed to make hay or burnt and rotate animals in the remaining paddocks to maximize the forage utilization. If pasture growth is faster, animals should be moved faster, and vice versa. One has to be flexible with animal movement frequency and sequence for the maximum utilization of pasture. If pasture in different paddocks is sown at different times, manage the movement of animals to harvest the pasture at optimum time, when the lowest leaves appear yellowing. Table 6 presents general guidelines on when to begin and end grazing various forage crops for proper pasture management. However, resting period may vary depending on the stubble height – longer resting period is required for shorter stubble height and vice versa.

In Figure 16, we can see why stubble height needs to be different for forages with different growth pattern. Bluegrass and bermudagrass can with-

stand close grazing because some leaves are left close to the ground and stored food present in rhizomes and stolons, however, grazing should be ended at higher stubble height for orchardgrass and tall fescue to leave enough leaf area for photosynthesis

Resting period has to match with growth cycle, which depends on forage species, environmental condition, and time of the year. Since growth cycle of most forage grown in Alabama vary between 21 to 35 days, rest interval of similar period should be adequate for designing a rotational grazing system. Rest period of 21 days or less may be enough for cool-season forages under good growing conditions, while warm-season forages during dry summer months may need 35 days or longer for proper recovery.

Change the stocking rate based on carrying capacity

Stocking rate should be adjusted based on the carrying capacity. Carrying capacity of a pasture indicates the number of animals the pasture can support to achieve a targeted performance for a specified period, which can be a grazing season or year after year, without detrimental effect on the pasture. Carrying capacity

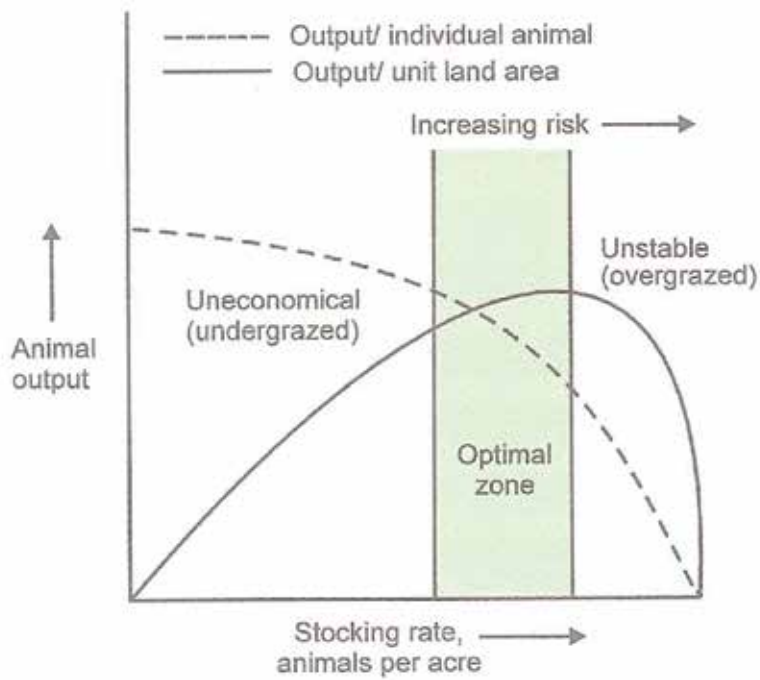


Figure 17. Relationship between stocking rate and animal output (per animal and per acre).
Source: Ball et al., 2007.

depends on the standing forage available for the grazing animals. When growing condition is most favorable, forage production remains high and be able to provide adequate dry matter to support more livestock. But under unfavorable conditions like limited moisture availability and other stressful conditions, production decreases and would not support the same

number of animals as under favorable production condition. Therefore, manager should adjust the stocking rate depending on the available forage. Understocking is the wastage of resources while overstocking is detrimental to pasture health and future production (Fig. 17).

Generally, ruminant animals require 2 to 5% dry matter of their body weight depending on the physiological stage, productivity, and animal species. For example,

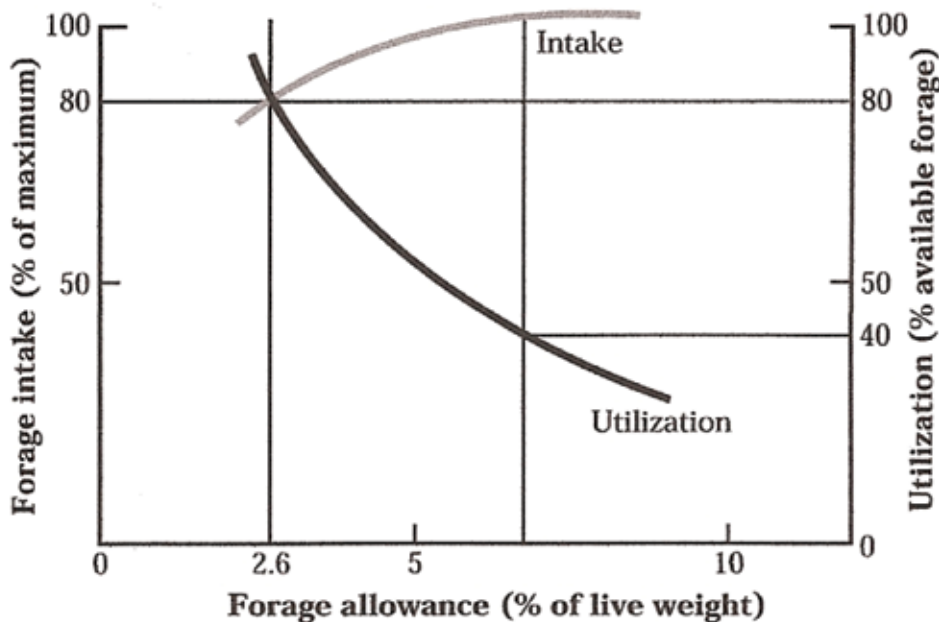


Figure 18. Forage utilization decreases with the increase in intake, allowing more forage than required is a wastage.
Source: Hodgson, 1990; NRCS, 1997.

a mature dry beef cow may need less dry matter (2.0-2.5% of body weight), whereas a lactating dairy goat may requires more dry matter (4.5-5.0% of body weight). From the pasture yield estimation and animals' dry matter requirement data, carrying capacity of a pasture can be estimated. Let's assume that a dry beef cow with 1000 lb body weight requires dry matter 2.5% of her body weight, then will need 25 lb ($1000 \times 0.025 = 25$) dry matter per day, which is equivalent to 83.33 lb green forage assuming that dry matter content of the available forage is 30 percent ($0.3 \times X = 25$, $X = 25/.3 = 83.33$ lb). One acre pasture with 1000 lb of available forage will support this cow for 12 days ($1000/83.33 = 12$). For grazing purpose, one should use the target stubble height while estimating the available forage mass. Supplying forages higher than animals' requirement is wasteful. Animals might eat more than their requirement if they have access, but utilization of the ingested forage decreases as the intake

increases (Fig. 18).

Overgrazing can seriously hinder root growth

Root is very important for plant production as it absorbs water and mineral nutrients necessary for photosynthesis. Maintaining root mass and volume is important for maximum forage production. Defoliation hinders root growth and with severe defoliation, root mass and volume decrease. It is because when there is not enough leaf volume for photosynthesis and only little or no stored food is available to meet the plant demand, whatever food available from photosynthesis or storage has priority to shoot development. As a result, roots die back and only limited amount is present in the shallow area. A deep and extended root system makes the plant able to access moisture and nutrients from deep and wide area. So, a producer needs to manage grazing (defoliation) so that root growth and development would not be hurt. Table 7 shows that 40% of the forage can be harvested without any detrimental effect on roots. When defoliation is increased by 10%, 2-4% root will stop growing; defoliation beyond 50% is very detrimental to root growth.

Table 7. Effect of defoliation on root growth.

Leaf volume removed (%)	Root growth stoppage (%)
≤ 40	0
50	2-4
60	50
70	78
≥ 80	100

Source: Dietz, 1989.

Key points

- 1. Choose grazing system based on forage species present in your pasture.**
- 2. Maintain 50% of the leaf area or do not graze lower than the recommended ending height so that remaining leaf area will be able to photosynthesize to support plant demand for regrowth.**
- 3. In rotational grazing, adjust grazing period to utilize the high-quality forage portions; move animals to next paddock before they begin to graze the new regrowth. Match rotation time to forage growth.**



Forage conservation for future use

Forage produced in excess during the high production season should be preserved as hay, silage, or stockpiled for use in the lean season. But emphasis should be given to extend the grazing season and minimize the duration of feeding preserved feedstuff because it is expensive than grazing.

Hay making

When forage production exceeds the requirements of grazing animals, excess forage can be harvested for hay. Or, some portion of the pasture can be used separately for hay production. For

hay making, green forage is harvested, dried, baled, and stored for future use. At harvest, green forage may contain 70-90% moisture and moisture content has to be reduced to 15-20% for baling. Rapid drying is necessary since there will be a greater loss as drying time increases. If baled and stored without drying properly, hay can be moldy. There can be several ways of hay loss, some of which have been listed below.

Losses in hay making and utilization

Respiration – in respiration process, oxygen is used to breakdown food material to release energy, and carbon dioxide and water are produced as byproducts. Forage biomass will be reduced if respiration continues after harvest; such loss can account for 2 to 16 percent depend-



ing on the drying conditions. Harvested forages continue to respire until the moisture contents drop below 40%, so faster drying is desirable.

Fermentation – breakdown of plant material starts and continues due the actions of plant enzymes, bacteria, and fungi soon after harvest. Higher moisture content is suitable for such breakdown. Exposure to bright sun and good aeration through the plant material stack reduces moisture content and fermentation.

Mechanical leaf loss – dried legume leaves tend to separate from the stem, so raking should start once forages are dried enough – before moisture content fall below 40 percent. Legume leaf losses may reach 5, 10, and 20 percent at moisture levels 50, 35, and 20 percent, respectively. Leaf loss increases dramatically if exposed to rain during curing or even after drying (Table 8).

Table 8. Different types of dry matter loss in alfalfa and red clover hay with no rain, or when exposed to rain during curing and on dry condition.

Type of loss	Alfalfa			Red clover		
	No rain	1.6" rain during curing	2.4" rain on dry hay	No rain	1.6" rain during curing	2.4" rain on dry hay
	----- % of initial dry matter -----					
Leaf loss	8.8	16.4	14.7	10.5	16.8	20.4
Leaching and respiration loss	1.3	27.7	39.1	0.5	32.5	34.7
Total loss	10.0	44.0	53.8	11.0	49.2	55.1

Source: Collins, 1983

Mechanical loss during collection and baling – there can be a huge loss during collection, transport, and baling; but a skillful operator can reduce such loss significantly.

Leaching and mold formation – hay nutrients can be leached if exposed to frequent, heavy rainfall such as when left on field after baling (Fig. 19). For example, loss due to leaching and respiration can reach up to 39 percent in alfalfa hay when exposed to 2.4” rain (Table 8). If rain infiltrates into bale, mold can develop and propagate deteriorating hay quality significantly. Mold can also develop if stored without drying properly and from moisture absorbed from soil when hay bales are left in field. Moldy hay may contain mycotoxins; livestock may not eat such hay readily and refuse a lot thereby resulting in a huge loss. Moldy hay can cause human disease known as “farmers’ lung”, so one needs to be careful while handling such hay.

Loss during feeding – A huge loss (up to 50%) can occur if animals are given unlimited access to hay because of trampling, soiling, defecation, and urination (on hay) (Fig. 21a). Also, animals eat up to 25-30% more than required when given unlimited access.

Minimize loss during storage and feeding

Hay bale should be tight not to allow water to penetrate it; legumes bales are usually loose and needs to be stored inside to prevent damage from rain. It is always preferable to store hay inside to minimize the loss. Long storage outside incurs 30% or more hay loss than when stored inside. If stored outside, do it in sunny and well-drained location. Minimize hay contact with soil by applying some dry and nonabsorbent bedding material like rock and concrete pad to reduce potential loss from moisture absorbed from soil. Also, hay bales can be covered with rain-proof material to minimize the damage from inclement weather condition (Fig. 20).

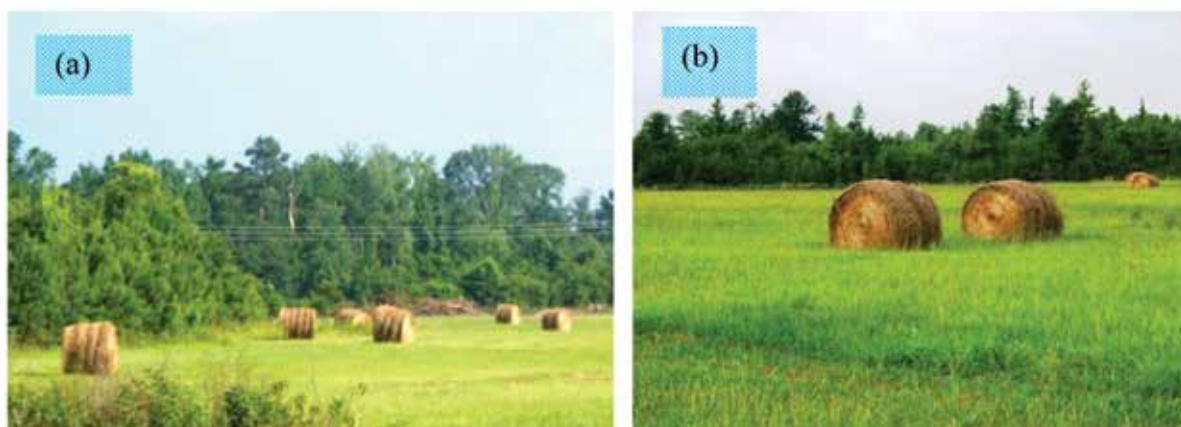


Figure 19. Hay left on the field after baling in Tuskegee, Alabama: (a) Picture taken around two weeks after baling – hay has bright golden color, and (b) Picture taken around two months after baling – outer layer of the bale is getting dull and darker color.

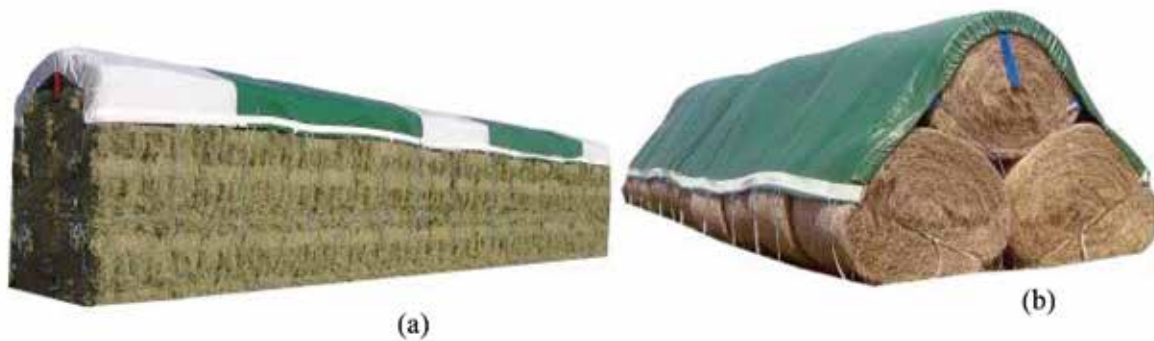


Figure 20. Square bales (a) and round bales (b) of hay stored with protective coverings to minimize weathering damage.

Source: <http://www.admani.com/AllianceAnimalHealth/Hay%20Tarp.htm>

Feeding loss can be minimized by 1) allowing animals for a limited time on a day - for one to two hours every day and 2) using hay rings (Fig. 21b), hay feeders, or hay racks (Fig. 22) so that animals can only eat but cannot trample, soil, or contaminate with excreta.

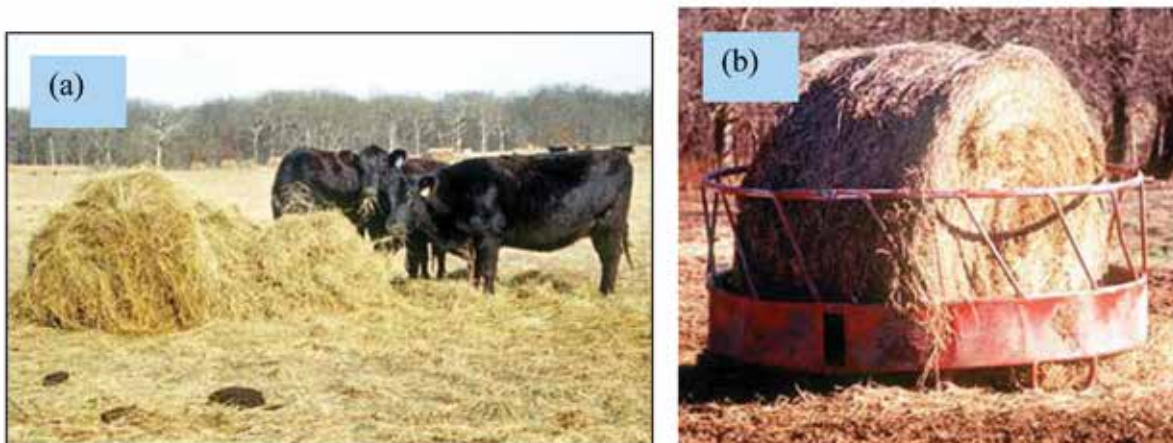


Figure 21. A huge feeding loss (a) can be minimized by enclosing a hay bale within a ring (b). <http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4570>



Figure 22. Few examples of hay feeders and racks: (a) movable hay feeder, (b) stationary hay feeder, (c) and (d) hay racks.

Sources:

(a) and (b) <http://www.thfeedsetc.com/hay.htm>;

(c) <http://www.walkinghgoats.com/equip.html>

(d) <http://www.davonsales.com/goatequipment.html>

In table 9, we can see that unlimited access of animals to a 7-day supply of large round or square bales of hay can result in 43% loss. Such loss can be prevented significantly by using hay racks.

Proper forages for hay – forages with lots of leaves and thinner stems are preferred because of ease of drying. Thick stem will take longer time to dry, leaves will dry earlier but stem will still have lots of moisture. While waiting for stems to

dry, quality of leaves and other thinner parts will degrade. So, stems could be cracked to hasten the drying process.

Harvesting time

Weather condition and forage maturity determine the harvesting time. Dry and sunny days will allow forage drying in a short time and avoid loss due to rain and preserve quality. The aim of selecting proper harvesting time is to maintain the highest quality in hay without compromising too much on quantity. Forage maturity suitable for hay cutting is shown in Table 10. If harvested earlier,

Table 9. Estimated losses (percentage of hay offered) from different hay-feeding methods.

Bale type	With rack		Without rack	
	1-day supply	7-day supply	1-day supply	7-day supply
-----Percent loss-----				
Small square bales	3.9	4.1	6.7*	
Large round or square bales	4.9	5.4	12.3*	43.0*
Formed haystacks	8.8	15.0	22.6	41.0
Small round bales (fed in place on pasture)			10.0	30.0

*Bales spread or unrolled across pasture

Source: Kallenbach, 2000.

there will be less dry matter and if waited longer, the quality will go down as forages mature.

While feeding hay, one need to have idea on how much hay is required to fulfill the requirements of his/her livestock. A dry beef cow will consume at least 15 lb of hay per day while a lactating cow may consume 25 to 30 lb or more per

day. Generally, ruminants will consume 2.5 to 3 percent of their body weight in dry matter per day, horses 1 to 2 percent. By using these numbers, one can calculate the approximate quantity of hay needed to overwinter a group of animals and still have enough left over for emergency needs. Table 11 presents some estimates of hay requirement for different livestock types.

Table 10. Recommended stages of maturity for harvesting hay crops.

Forage species	Time of Harvest
Alfalfa	Bud stage for first cutting, one-tenth bloom for second and later cuttings. For spring seedings, allow the first cutting to reach midbloom.
Orchardgrass, timothy, or tall fescue	Boot to early head stage for first cut, aftermath cuts at four to six week intervals
Red, arrowleaf, or crimson clover	Early bloom.
Sericea lespedeza	Height of 15 to 18 inches.
Oats, barley, or wheat	Boot to early head stage.
Soybean	When pods are about half-filled and before bottom leaves begin to fall.
Annual lespedeza	Early bloom and before bottom leaves begin to fall.
White (or ladino) clover	Cut at correct stage of companion grasses.
Hybrid bermudagrass	15 to 18 inch height for first cutting, then every four to five weeks or when 15 inches high.
Birdsfoot trefoil	Bud to early bloom or at correct stage for companion grass.
Sudangrass, sorghum-sudan hybrids, pearl millet	Height of 30-40 inches.

Source: Ball et al., 2007.

Silage making

Succulent forages and forages with big stem like corn and sorghum can be preserved making silage. Silage is prepared by fermenting green forage in silo – pit in ground, trench, tower, bunker, or plastic bag suitable for creating anaerobic condition (suitable to make air tight so that there would not be oxygen supply, by doing so acid forming bacteria can grow and function for fermentation). High energy crops like corn, grain sorghum, and small grains are extensively used for silage making. Forages having low energy like legumes may require energy addition for proper fermentation. Or, high energy crops can be mixed with legumes to obtain high quality silage.

Silage crops are harvested and wilted if necessary to obtain moisture content of around 65-70%. They are chopped to 3/8 to 1/2 inch and packed tightly so that minimum air is left in the silo. Silage crop is put into silo one layer,

compact this layer, and put and compact another layer until the silo is full. Fill the silo rapidly, don't let any time interval between fillings layers, and complete it continuously once it is started. Then quickly seal the silo so that no further air would enter the silo. If chopped fine and packed well, aerobic bacteria present there will use up remaining oxygen and release carbon dioxide (within 4-6 hours under a favorable condition), which will raise silo temperature. When the silo temperature becomes 80-100F, anaerobic bacteria develop and produce acetic acid. After the second or third day, lactic acid producing bacteria becomes active and produce lactic acid for 16-18 days until the pH drops to 3.6 - 4.2; when this pH is reached, all bacterial activity is stopped and fermentation is complete. Under favorable condition, silage should be ready in three weeks. Well-fermented silage should have pleasant smell and bright yellowish color. Foul smelling and brown or blackish color indicates low quality or spoiled silage. The quality of silage should remain intact as long as there is no oxygen or water entering the silo.

The quality of well-fermented and preserved silage depends on the stage of forage maturity at harvest. Also, care should be taken for the harvesting height,

Table 11. Estimated daily hay needs for different types of livestock.

Livestock type	Hay (lb per animal per day)
Dry, pregnant cows	15-20
Cows with calves	25-28
Replacement heifers	10-12
Bred yearling heifers	18-23
Herd bull	28-30
Stocker steers	10-14
Horse	24-30
Sheep	3-6
Goat	2-5

Source: Ball et al., 2007.

forage should be harvested high enough not to contaminate with soil. Soil hinders fermentation. Usual guideline of harvesting forages for silage making has been presented in Table 12. Silage should be fed as soon as possible after taken out from the silo to avoid possible degradation.

Table 12. Usual recommended stage of maturity for harvesting forage for silgae making.

Crop	Maturity stage
Corn	Kernels will be dented and black layer visible
Grain sorghum	Late milk to late dough
Forage sorghum	40 inches or late boot stage
Sorghum, sundangrass, johnsongrass, millet	40 inches or boot stage, whichever comes first
Small grains, ryegrass	Boot to early head
Soybeans	Late bloom, seed forming in pods and before lower leaves fall
Alfalfa	Bud to early bloom
Cool-season grasses	Boot to early head, first cutting; thereafter at four to six week intervals.
Hybrid bermudagrass	15 inches at first harvest, thereafter at four to five week intervals.

Source: Ball et al., 2007.

Stockpiling

For stockpiling, forage is allowed to grow and accumulate without interruption for around 70-80 days during the last growing season. The stockpiled forage can be strip grazed when there is no other forage available for grazing. This way grazing season can be extended and requirement of hay and supplementary feeding can be reduced. Tall fescue is

more suitable for stockpiling as compared to orchardgrass and warm-season grasses like bahiagrass and bermudagrass. Stockpiled tall fescue contains around 14 percent crude protein and over 60 percent digestible dry matter. Orchardgrass makes less growth in fall and deteriorates more in winter. Quality of stockpiled bahiagrass and bermudagrass is lower than tall fescue and their leaf deteriorates quicker. Stockpiled forage should be strip grazed or ration grazed to lower the wastage.

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