Concepts and Research-Based Guidelines for Forage-Livestock Systems in the Southeast Region

CONCEPTS AND RESEARCH-BASED GUIDELINES FOR FORAGE-LIVESTOCK SYSTEMS IN THE SOUTHEAST REGION.

Front cover photo credits: Liliane Silva, Alex Tigue and Valens Niyigena
Edited and designed by Liliane Silva
Printed by Wells Printing Services, Montgomery, AL

SUGGESTED CITATION: Silva, L.S.; Dillard, S.L.; Mullenix, M.K; Wallau, M.; Vasco, C.; Tucker, J.J; Keishmer, K.; Russell, D.; Kelley, K.; Runge, M.; Gamble, A.; Prasad, R.; Elmore, M.; Burns, M; Stanford, K.; Niyigena, V; Wickens, C.; Sawadgo, W.; Heaton, C. Concepts and research-based guidelines for forage-livestock systems in the Southeast region. Supported by the 2021 Southern Region SARE Professional Development Grant.

ACKNOWLEDGMENTS

Special thanks to Drs. Russ Muntifering (Professor Emeritus Auburn University), Renata Nave (University of Tennessee), Katie Mason (University of Tennessee), and David Jaramillo (USDA/Agricultural Research Service) for their contributions through revision of this guide.

PREFACE

This guide provides concepts and research-based information on animal, environment, forage, and soil topics for Extension educators and producers in the Southeast region. The authors do not assume any responsibility, make any guarantees, or offer any warranties regarding the results obtained from the use of any management strategies included in this guide.

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, through the Southern Sustainable Agriculture Research and Education program under award number SPDP21-04. USDA is an equal opportunity employer and service provider. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

AUTHORS

Liliane Silva
Clemson University

Leanne Dillard
Auburn University

Kim Mullenix
Auburn University

Marcelo Wallau
University of Florida

Carol Vasco
Auburn University

Jennifer Tucker
University of Georgia

Ken Kelley
Auburn University

Katelyn Keishmer
Auburn University

Matthew Burns
Clemson University

Max Runge
Auburn University

Michelle Elmore
Auburn University

Valens Niyigena
Alabama A&M University

Carissa Wickens
University of Florida

Wendiam Sawadgo
Auburn University

Audrey Gamble
Auburn University

Kent Stanford
Auburn University

Courtney Heaton
Auburn University

David Russell
Auburn University

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Overview of Seasonal Forage Production in the Southeast region

The seasonality of forage production is a major challenge for livestock production systems. In the southeast USA, perennial grasses are the primary species used in most forage systems. Due to their seasonality of production, there is need to plan to provide supplemental feed including hay, stockpiled forage, cool-season forages, or other non-forage supplements during cooler months. In order to extend the grazing season, adequate planning of your forage budget may be necessary to increase profitability, sustainability and feasibility of a forage system. This approach requires knowing your forage demand and your forage resources throughout the year.

The first step is to adequately choose forage species that are adapted to the soil and climatic conditions in the area. The choice of forage species must also be compatible with the goals for the enterprise, and attention should be given to management requirements, costs, and level of animal performance desired. It is highly desirable to select forage crops that complement each other, therefore increasing forage production over the calendar year. The figure below provides an overview of forage availability of various forage species or groups within a normal or average production year. The following chapters will provide information of commonly used perennial and annual grasses, legumes, and forbs.

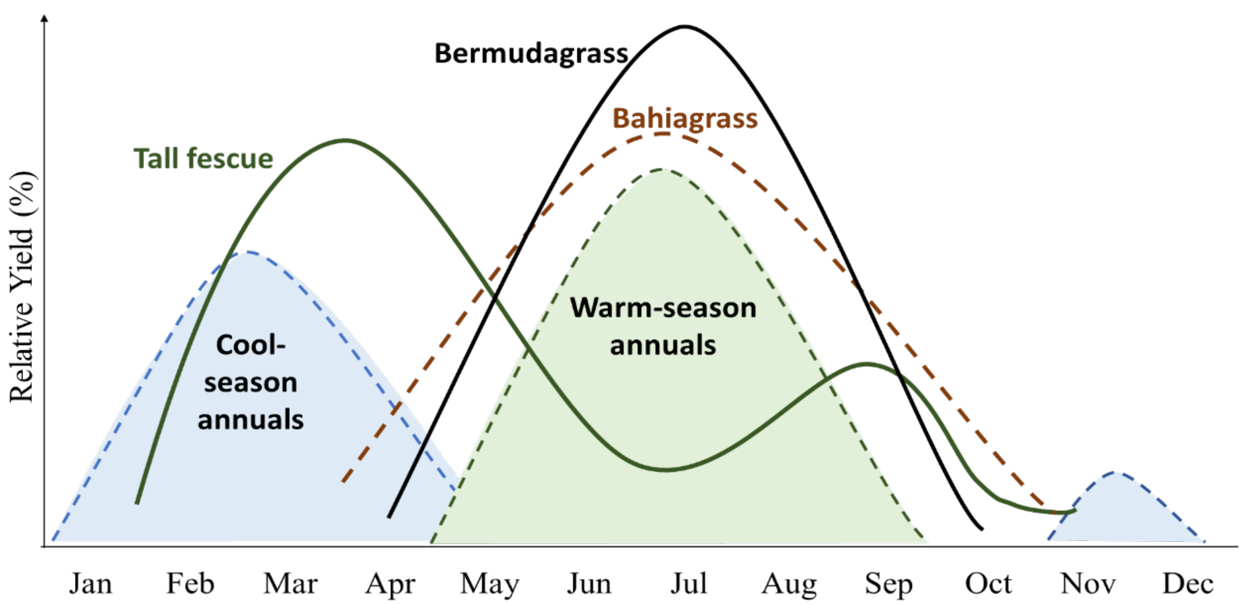


Figure 1. Seasonal forage production distribution representation for some of the most used forage species or categories in the Southeast region.

Warm-season grasses

They are well adapted to the environment conditions and are managed under grazing, or hay or baleage production. Below, we will provide an overview and planting recommendations for the most used species in the deep south region.

Perennial grasses

Bahiagrass

Bahiagrass is widely used in the southeastern US, mainly in the coastal plain region. It is established by seeds, and can tolerate drought, sporadic flooding, low soil fertility, and close grazing. Most forage production occurs from April through September and stands can be overseeded with cool-season annuals in the fall to extend the grazing season. There are specific differences among varieties on length of the growing season, cold tolerance, and growing characteristics. Diploid types (e.g., Pensacola, UF Riata, Tifquik, Tifton 9, Sand Mountain) have higher cold tolerance and can be adapted to the northern areas of the coastal plains. Tetraploid types (e.g., Argentine) are mostly confined to the Florida peninsula and coastal areas close to the Gulf. Bahiagrass is a dense, prostrate grass with shallow and horizontal stems (rhizomes) that form a thick mat (sod). The short, "J" shaped rhizomes are an important source of energy for the plants and protect growing points during grazing. The species is adapted to sandy loam soils and its optimal pH ranges from 5 to 6.5 and can grow 12 to 25 inches tall. Bahiagrass has low to medium nutritive value and generally goes dormant on in late fall/winter. In most of the Southeastern region, the best time to establish bahiagrass is during spring. The seed origin is particularly important to avoid introduction of weeds, especially brunswickgrass (*Paspalum nicorae*), and seeds should be of high quality and certified. The seeding rate recommended is 15 to 20 lb pure live seed (PLS)/acre. Seeds can be either broadcast or drilled to ¼ to ½" depth. Between 7 to 10 days after seedling emergence, the stand should be fertilized using 35 to 50 lb nitrogen (N)/acre. Potassium (K) and phosphorus (P) should be applied as recommended on soil report. Then, after 30 to 50 days, it is recommended to apply 50 to 75 lb N/acre.

Bermudagrass

Bermudagrass is adapted to moderately to well-drained soils, tolerant to grazing, with canopy height ranging from 6 to 25 inches and having both stolons and rhizomes. There are seeded and vegetatively propagated varieties, although most of the hybrids used in the eastern part of the SE region are the former. Hybrid varieties are generally more productive with greater nutritive value. The most common hybrids are Russell, Tifton 44, Cheyenne, and Tifton 85, although new varieties have recently been released (Newell and Mislevy). Tifton 85 bermudagrass (T85) has high productivity and nutritive value, supporting higher nutritional requirements for animal performance and functioning well under management for either hay or grazing; in this context, it is highly used in the Southeast region. Recently, the bermudagrass stem maggot [*Atherigona reversura* Villeneuve (Diptera: Muscidae)] has been identified as a challenging pest of T85. It was first noticed in 2010 by South Georgia hay producers and has a short life cycle (21 d). Planting bermudagrass hybrids is generally done using rhizomes, during the dormant season (winter) to a rate of 30-50 bushels of sprigs per acre. In southern areas, especially Florida, some of the varieties can also be planted using tops, to a rate of approximately 1000 lbs of fresh tops per acre.

Johnsongrass

Johnsongrass is a warm-season perennial rhizomatous grass. Similar to sorghum, it is a high-quality forage for cattle, but often considered a troublesome weed as it spreads easily into annual crops and hay fields, and it is actually prohibited for planting in some states in the SE region. Johnsongrass is very well adapted to the heavy clay soils in the Black Belt region of Alabama, Mississippi, and Texas, but it can be found in all soil types of the Southeast. Johnsongrass is moderately palatable, although not grazing tolerant and will not survive under continuous grazing management. When Johnsongrass is used as a forage crop, two significant toxicities that producers need to be aware of are prussic acid poisoning and nitrate toxicity. Prussic acid can buildup in the leaves of plants that have been stressed by long drought periods, a frost, or application of herbicides like 2,4-D. Johnsongrass can also contain toxic levels of nitrates. Accumulation of nitrates typically occurs following a period of drought or cool, cloudy weather that stunts growth. Unlike prussic acid, nitrates do not degrade over time, so it is important to test heavily fertilized Johnsongrass hay for nitrates.

Dallisgrass

Dallisgrass a warm-season bunchgrass used primarily as a volunteer pasture grass in the Southeast. It has an excellent tolerance to poor drainage and is best adapted to clay and loam soils in areas with good moisture. It has substantial carbohydrate reserves in its stem bases, and numerous buds, allowing it to have good tolerance to close grazing. Dallisgrass is often grown with red or white clover, which can be planted in the fall after a killing frost occurs. Optimal soil pH ranges from 5.6 to 8. Recommended seeding rate is 10 to 15 PLS/acre with seeding depth ¼ to ½" depth. Limitations to the use of dallisgrass include forage yield potential, which is often less than that of other warm-season perennial forage grasses. In addition, seed production is limited by low seed set and ergot infection. In late summer and early fall when seed onset occurs, ergot can cause toxicity in cattle called Dallisgrass Staggers, but seed heads can be clipped to eliminate the ergot problem if it develops.

Limpograss

Limpograss is a warm-season perennial grass adapted to wet and saturated soil conditions. It has a longer growing season than most of the perennial C4 grasses, being an excellent choice for fall or even winter grazing. Most of its use is in southern Florida, but new research developments and recent releases show promising results into northern Florida and southern Alabama. One of the main traits of limpograss is the high digestibility even into maturity, compared to bahiagrass, being a great choice for stockpiled forage. Nevertheless, crude protein concentrations are quite low, often requiring supplementation. Limpograss is planted during summer using vegetative material, at a rate of 1000 to 1500 lbs of mature tops per acre. Limpograss is also sensitive to certain herbicides containing auxins such as 2,4-D. It is recommended to provide P and K as required by soil report, and N to guarantee proper stand establishment and persistence.

Limpograss field newly established (top) and 2-mon old (bottom).

Native Warm-season Grasses

Native warm-season grasses are widely adapted to the Southeast, as these were the native plants to the region prior to European colonization. Typically, these grasses break dormancy in late March and early April and characterized by its rapid growth from mid-May through mid-summer, and then their growth slows in

late summer until they become dormant in October. Limitations to the use of native warm-season grasses in the Southeast are primarily related to the slow establishment period (multiple years before the stand can be used for grazing or hay) and management required for plant persistence. The following five species are commonly used: big bluestem, little bluestem, indiangrass, eastern gamagrass, and switchgrass. Their vigorous summer growth, drought tolerance and natural adaptability make them good candidates for forage production in the Southeast, however, usually they are of lower forage quality than some of other grasses used.

Annual grasses

Crabgrass

Crabgrass produces high quality forage and is widely adapted to the Southeast. While it is considered a weed in row crops and even in some forage production systems, it can be a valuable forage plant. There are several crabgrass species but the two most used are large or hairy crabgrass (*Digitaria sanguinalis*) and smooth crabgrass (*D. ischaemum*). Large crabgrass is the most common species that volunteers or is planted for forage. Crabgrass requires well-drained soils and pH ranging from 5.5 to 7.5. Seeding rate recommendation is 3 to 5 lbs PLS/acre and seeding depth should be ¼ to ½ inches. It requires proper soil fertility to sustain forage yield and quality and N rate should be at least of 120 lbs N/acre applied in split applications. Generally, crabgrass has around 15% crude protein and up to 60% TDN. Also, it is easy to manage it for reseeding, which can then be grown for subsequent growing season, and it can be used for grazing or hay production.

Pearl millet

Pearl millet has the potential to produce high-quality forage at large quantities during spring and summer months. It can be used for hay, as a silage crop, or for grazing. It grows well on a variety of soils, but yield is better on well-drained and fertile soils. It is adapted to sandy soils with low fertility and is reasonably tolerant to drought. The recommended seeding rate is 15 to 25 lb PLS/acre, and seeding depth is ½ inch to ¾ inches deep. Pearl millet can grow from 3 to 8 ft tall but requires adequate fertility to yield well. Weed control prior to planting is essential since weed competition may compromise stand establishment. It is important to scout for insects and diseases that may need to be controlled to avoid yield and quality decline. There is a need to be aware of the potential for nitrate toxicity which compromises animal health when consumed by livestock.

Sorghum

Sorghum is best adapted to warm regions and is a high-yield forage. There are different types of sorghum dedicated to grain or forage production. Sorghun is mostly used for silage, but it can also be grazed. Optimal soil pH is 6.5 and it requires proper soil fertility since expected yields are up to 20-ton per acre. Recommended seeding rate is 8 to 12 lb PLS/acre, or at a population between 70,000 to 120,000 plants per acre. Seeds can be planted at 1-2 inches deep. Prior to planting, weed control is crucial to avoid competition during establishment, although a series of pre- and post-emergence herbicides can be used. The planting window starts when soil temperature reaches 65°F at the 4-inch depth and can be planted well into the summer for a fall grazing. Crude protein ranges from 8 to 12% and TDN is usually up to 60%. It is important to scout for insects and diseases to develop an adequate management strategy for control since they can reduce both yield and quality. Forage sorghum hybrids vary in yield, quality, and maturity; therefore, it is important to choose a variety that properly meets the needs of your forage system. Caution should be used because of potential prussic acid poisoning or nitrate toxicity especially during the fall.

Sorghum sudangrass hybrids

Sorghum × sudangrass [(*Sorghum bicolor* L. Moench) × (*Sorghum × drummondii*)] is a cross between sorghum and sudangrass. It is a high yield forage, tolerant to heat, and drought and has a growth habit like pearl millet. Sorghum x sudan can be used for grazing, hay or silage. This forage hybrid is more severely affected by drought than pearl millet, and less tolerant of poor soil conditions and soil pH values less than 5.8 (Hancock, 2009). The seeding rate recommended is 12 to 15 lb PLS/acre and seeding depth should be one to two inches. There is a need to be aware of the potential for prussic acid poisoning or nitrate toxicity. Also, sugarcane aphid [SCA; *Melanaphis sacchari* (Zehntner)] is a significant pest in *Sorghum spp* compromising forage production and quality. There are multiple hybrids in the market which offer sugarcane aphid tolerance and ongoing efforts aim to determine insecticides and their respective rates to be used to control SCA.

Cool-season grasses

Perennial grasses

Tall fescue

Tall fescue is a perennial, cool-season forage and is one of the most important grasses in the USA, from Missouri to Virginia and into Central Mississippi, Alabama, and Georgia. It is a deep-rooted, long-lived bunch type grass. In the Deep South, it grows from February to June, and from September to November. It can be used for grazing or stockpiled in late autumn. The recommended seeding rate is 15 to 20 lb PLS per acre and seeding depth is ¼ to ½ inch. In general, tall fescue should be planted from September to October. Spring plantings are not advised due to summer weed pressure and increased likelihood of drought conditions after establishment. It is a desirable forage crop because of its range of adaptation and tolerance to continuous, close defoliation.

However, most tall fescue in the region is infected with the fungal endophyte *Epichloë coenophiala*. The Black Belt Research and Extension Center in Marion Junction, AL is the site of the first study linking to this fungus with a syndrome called fescue toxicity in beef cattle. This historic finding explained the poor performance that was often associated with fescue grazing. This endophyte produces an ergot alkaloid that causes the fescue toxicosis syndrome. Novel tall fescue varieties are available, and although they contain endophytic fungus, they do not produce the ergot alkaloids that are toxic to grazing animals.

Orchardgrass

Orchardgrass is a cool-season perennial bunchgrass suited for hay production or grazing management systems. Orchardgrass grows 2 to 4 ft tall and is less tolerant to drought and poor drainage than tall fescue. Usually, it is one of the first grasses to initiate growth during cool weather conditions and requires a pH ranging from 5.8 to 7 for good establishment and stand persistence. It is best adapted to the northern most regions of Alabama and Georgia, into Tennessee and North Carolina. In the Deep South, the planting window is from September and October. The recommended seeding rate ranges from 15 to 20 lb PLS/A, and seeding depth recommended is ¼ to ½ in. At planting it is recommended to apply 30 lb N per acre, and P and K fertilizer rates according to soil test results should be applied. Soil fertility is crucial for growth and development of grass seedlings, especially if they need to compete with voluntary weeds. Orchardgrass forage yield ranges from 4 to 8 ton/A but can be over 10 ton/A. Crude protein (CP) ranges from 10 to over 18%, depending on maturity stage at harvest. Total digestible nutrients (TDN) concentration ranges from 55 to 70%. Generally, orchardgrass is managed under hay production and has poor persistence under continuous grazing.

Annual grasses

Annual ryegrass

Annual ryegrass is a bunchgrass with shiny, smooth leaves. It tolerates wet, poorly drained soils better than small grains and is very responsive to N fertilization. Generally, in the southern region, most of its growth occurs from March through April. It makes it a good companion forage with other cool-season species, and these mixed swards can extend the grazing season in both late winter and spring. Recommended seeding rate is 15 to 30 lb PLS/acre and seeding depth is ½ inch to ¾ inch deep. The recommended planting window is late August (northern states) to December 1st (southern states). It is a high-quality forage that tolerates close grazing, and it can be also used for hay. It is a common practice to overseed ryegrass into perennial warm-season pastures. However, this can delay onset of growth of warm-season perennials in the spring.

Oat

Oat can be grown for forage, grain, hay, or silage. Oat is generally less cold-tolerant than other small grains and can be susceptible to winterkill. Compared with wheat, oat is more productive, and heads out slightly later in spring. The recommended seeding rate is 90 to 120 lb PLS/acre and seeding depth is one to two inches. Multiple varieties of oat are available, and performance changes depending on region. Consult local variety recommendation guides for more information. In southern regions where winters are mild, choosing a rust resistant variety is important. The recommended planting window is from late August to December 1st.

Cereal Rye

Most cereal rye grown is the US is used as a cover crop, pasture, or hay. Cereal rye is well-adapted to sandy or acidic soils characteristic of those found in the southeastern US. Optimum growth is exhibited in soils of pH 5.8 to 6.5. Cereal rye is more cold-tolerant than other small grains and is often a popular choice among producers for this reason. Recommended seeding rate is 90 to 120 lb PLS/acre and seeding depth is ½ inch to ¾ inch deep. Grazing may be initiated when the plant reaches approximately 6 inches in height and should be terminated at 3 to 4 inches in height.

Triticale

Triticale is a cross between wheat and rye and its use is increasing in popularity in the Southeast. Triticale retains the palatability of wheat with the growth vigor of rye. While not as cold-tolerant as rye, forage variety trials indicate that triticale often produce dry matter (DM) yields similar to rye, but with a heading date later than rye. Triticale is typically used to produce hay or silage, but is also a great forage for grazing especially when mixed with other small grains and ryegrass

Wheat

Wheat is an annual cool-season grass that can be used for grazing, hay or haylage/silage, or grain. While wheat grown in the US is mostly used for grain production, wheat can also be grown as a forage for animal production. Wheat is normally actively growing from fall through spring. It grows well under a soil pH range of 5.5 to 8.0. Recommended seeding rate is 90 to 120 lb PLS/acre and seeding depth should be one to two inches. Wheat is normally a choice in western and northern areas of the SE region and has limited productivity and more incidence of diseases in southern areas. Hessian fly can be an issue, and there are varieties more tolerant to the insect.

Non-leguminous Forbs

Brassicas

Forage Brassicas are cool-season annuals that can be utilized as forage during the fall and spring grazing seasons. Forage brassicas include varieties of rapeseed (rape), radish, turnip, swede, kale, and hybrids. Brassicas are quick maturing and can be grazed 60 to 120 days after planting, depending on species.

Brassicas are able to produce up to 4 tons of DM/acre, and varieties of turnip, radish, and swede produce a highly palatable and nutritious taproot that can be grazed during the last rotation of the season. Brassicas should be planted no more than ¼ inch deep with seeding rates of 4-5 lb PLS/acre for kale, rapeseed, and radish and 2-3 lb PLS/acre for swede and turnip.

Seeding rates should be cut by 50% if planting in a mixture. Brassicas are known to have very high quality and produces a large amount of biomass. When feeding livestock, brassicas should not be more than 50% of the diet to reduce Cu and I deficiency caused by plant secondary metabolites called glucosinolates.

Warm-season legumes

Legumes can capture nitrogen from the atmosphere and convert it into compounds that are readily available in the soil solution for plants. This process is called nitrogen biological fixation and occurs through a symbiotic association between the legume plant and microorganisms. For all legumes, it is crucial to guarantee that inoculant is still active on seeds before planting.

Perennial legumes

Rhizoma perennial peanut

Rhizoma perennial peanut is originally from South America and is well-adapted to the US Gulf Coast regions of South Carolina, Georgia, Florida, Alabama, Mississippi and Louisiana. It has high yield and nutritive value and can be used for hay production or under grazing management. New varieties and technologies have helped decrease establishment costs and cope with its slow rate of establishment. Proper soil preparation and soil pH/fertility testing should be conducted prior to planting. Lime and fertilizer should be applied as recommended by soil test report. Prior to planting a monoculture, proper weed control should occur. Rhizoma peanut is established by vegetative propagation using rhizomes. The planting rate is 80 bushels of rhizomes per acre. Ideally, rhizomes should be planted at 1-inch depth. Planting date should generally be late March through early July. A growing practice is to plant rhizoma peanut into warm-season perennial grasses, such as bermudagrass and bahiagrass. Strip-planting can be used, which involves using an herbicide to control the grass, followed by planting rhizoma peanut which will then spread horizontally into the field.

Figure 2. Rhizoma perennial peanut established into bahiagrass pasture.

Sericea lespedeza

Sericea lespedeza is a warm-season perennial legume native to eastern Asia and well adapted to the Southeast region. It is deep rooted and grows well on medium- to well-drained and clay to loamy soils. Sericea lespedeza may be used for hay production or managed under grazing conditions. Generally, it grows from April through November 1st, and its peak productivity occurs from June through August. Seeding rate is 20 to 30 lb PLS/acre and the planting window runs from March 15 to May 1st. Forage quality of sericea ranges from 12 to 16% of crude protein and 50 to 55% digestibility, but as height increases to 24 inches or more, sericea becomes fibrous and less digestible. A naturally occurring compound in sericea is tannin which is linked to reduced intake and digestibility of the forage. However, tannins increase the amount of protein bypassing the rumen of livestock contributing to more efficient use of the feed. Thus, in small ruminants, sericea helps to reduce internal parasite loads, including *Haemonchus contortus* (barber pole worm). It should be noted that in some regions of USA, especially in the West, sericea is considered a noxious weed and planting is prohibited. Consult your Extension agent before planting it for help.

Annual legumes

Cowpea

Cowpea is well adapted to grow under relatively dry conditions. Planting dates vary from mid-March for a spring planting to late August for a fall planting. Typically, it is suggested that growers wait until soil temperatures reach 60°F to plant. The recommended seeding rate is 30 to 40 lb PLS/acre and seeding depth should be from ¾ to 1¼ inches deep and recommended row spacing is 30 or 36 inches. Due to its adaptability, cowpea can be grown on relatively poor soils. Cowpea does not tolerate grazing well, therefore it is suggested to use it in mixtures with warm-season annual grasses that are intermittently grazed (e.g., pearl millet, sorghum × sudangrass).

Sunn hemp

Sunn hemp is a warm-season annual legume that can grow up to six feet tall. It tolerates drought and soils with relatively low fertility. The optimal soil pH ranges from 5 and 8.4. Sunn hemp grows best in sandy, well-drained soils and should be planted into a prepared seeded when soil temperature has reached 65°F. The recommended seeding rate is 25 to 30 lb of pure, live seed per acre. Seeding depth should be ¼ to one inch. Biomass accumulates in a substantial quantity between 30 to 60 days after planting, when plants reach six feet tall. Grazing should start around 45 days after planting, when plants are around one and one-half to three feet tall. The recommended stubble height remaining after grazing is 12 to 18 inches. Sunn hemp works well in mixtures with warm-season annual grasses such as pearl millet and sorghum × sudangrass, and can work relatively well with tall fescue.

Striate lespedeza and Korean lespedeza

Both, striate annual lespedeza (*Lespedeza striata*) and Korean lespedeza (*Lespedeza stipulacea*) have shallow taproot and pink flowers. Optimal soil pH ranges from 5.5 to 6. Recommended seeding rate ranges from 15 to 40 lb PLS/acre and they should be planted from March to May. Crude protein normally ranges from 12 to 15% with TDN ranging from 50 to 55%. They grow well with cool-season bunch grasses, such as tall fescue, but require adequate management. Striate lespedeza exhibits narrower leaflets, and its flowers and seeds are borne in leaf axils, whereas Korean lespedeza flowers and seeds are found at the ends of stems. The prostrate growth pattern of Striate lespedeza makes it better suited for grazing over hay production. Korean lespedeza is more drought tolerant and is susceptible to bacterial wilt and tar spot which can result in summer leaf loss and thinned stands. Korean lespedeza is less competitive than striate lespedeza with companion grasses.

Cool-season legumes

Legumes can capture nitrogen from the atmosphere and convert it into compounds that are readily available in the soil solution for plants. This process is called nitrogen biological fixation and occurs through a symbiotic association between the legume plant and microorganisms. For all legumes, it is crucial to guarantee that inoculant is still active on seeds before planting and apply required micronutrients, mostly boron and molybdenum.

Perennial legumes

Alfalfa

Alfalfa is a high-yielding, perennial legume that is well-suited for hay, silage, baleage, and grazing. Alfalfa requires well-drained, high fertility soils and has limited tolerance to pests, and disease pressure. Prior to planting alfalfa, soil pH and fertility testing must be conducted. It is recommended to collect soil samples to a 15-inch depth, by dividing the soil profile into two layers, surface (0 to 8-inches) and subsoil (8 to 15-inches). Soil pH should range from 6.5 to 7.0 in the topsoil surface and be around 5.5 on subsoil. Lime application should be completed at least six months prior planting to allow for soil incorporation. If the subsoil pH remains acidic, application of gypsum ($CaSO_4$) can be an alternative to help neutralize it. Adequate levels of boron (B) and molybdenum (Mo) are essential for nodule formation for biological nitrogen (N) fixation, and some varieties may include base levels of these in the seed coat for establishment. Most alfalfa seed is pre-inoculated and requires proper storage and handling to guarantee seed quality. If seeds purchased are not inoculated, or inoculum viability is unknown, inoculant (Type A, *Rhizobium meliloti*) should be purchased and applied according to label instructions. Alfalfa seeding rate is 20 to 25 lb/acre, and seeds should be planted to about ¼ inch deep. After establishment, a general recommendation is for every ton of alfalfa harvested to apply 12 lb of phosphorus (P_2O_5) and 50 lb of potash (K_2O) per acre.

Supplemental Mo and B are recommended yearly or every other year during the life of the stand. Below is the seeding date window for Fall planting (Table 8):

Table 8. Seeding date window for Fall and Spring alfalfa planting in the Deep South.

Location/Planting Date	Seeding Date Window	Comments
Tennessee and North Georgia/Alabama (Fall)	Mid Aug through Oct 1^{st}	Requires 6 to 8 weeks of growth prior to 1^{st} hard frost event
South Alabama/Georgia and Florida (Fall)	Oct through Nov 1^{st}	

Alfalfa-bermudagrass mixtures

In the Southeast region, seeding alfalfa with bermudagrass is a viable alternative since both species have similar soil drainage and fertility requirements. Mow or graze the warm-season grass to a short stubble height (~ 2 inches) before planting. Then, spray glyphosate at a rate of 9 ounces per acre of 5.5 lb. of active ingredient to induce grass dormancy and control weeds. Plant with a no-till drill no deeper than ½ inch. The general recommended seeding rate is 12 to 15 pounds per acre of pure live seed on a 14-inch row spacing for mixed alfalfa-grass stands. Once established, nitrogen fertilization is not needed if there is at least a 30% alfalfa present in the stand. It is recommended to soil test annually and apply P and K according to recommendations. Potassium fertilization is especially important and rates up to 300 lb/acre are recommended, in split applications throughout the season. Boron should be applied annually at a rate of 2 to 3 lbs/acre. This can be foliar applied or in a granular form blended with other fertilizers. Molybdenum should be applied every two years in the late winter or early spring at a rate of 3 ounces per acre (8 ounces of sodium molybdate in 25 gallons of water per acre). Defoliation events should occur when the stand is at 10% bloom or generally every 28 to 35 days. Recommended stubble height is 4 inches. Timing of the first harvest of the season is critical to help ensure suitable growth conditions for both species in the mixture. Proper moisture for baling is ≤ 20% for hay and 40 to 60% for baleage. Fields should be scouted often, from spring through late fall, to address any pest problems in a timely manner. For grazing-tolerant varieties, rotational stocking is recommended with a stubble height of 4 inches and rotation of animals every 28 to 35 days.

White clover

White clover is a cool-season perennial legume with creeping growth habit and high grazing tolerance. It is often planted in a mixture with other cool-season forages to extend the grazing season. The optimum pH is from 5.5 to 6.0 and proper soil fertility is necessary for establishment, persistence, and productivity. Before planting white clover, it is important to make sure there is no herbicide residual in the soil because that can lead to stand failure. The recommended seeding rate is 2 to 3 lbs/acre and the planting window ranges from late August to early Nov. Seeding depth should not exceed ¼ to ½ inches. A mature stand of white clover can fix from 40 to 100 lb N/acre. In a clover-containing system, improved forage yield and quality increases animal performance. Crude protein ranges from 15 to 25% with high digestibility. Rotational grazing is recommended with stubble height of two to four inches. Although white clover is more tolerant to 2,4-D applications than other clovers, this herbicide can damage a stand unless rates are low.

Annual legumes

Arrowleaf clover

Arrowleaf clover is characterized by non-hairy, arrow-shaped leaves with a V white water mark. Its flower becomes tinged with pink or purple colors as it matures. It requires pH ranging from 5.8 to 6.5. The planting window is late September through early November. Recommended seeding rate is 5 to 10 lb PLS/acre of inoculated seeds and seeding depth is ¼ to ½ inch. Depending on the percentage of the inert material in pre-inoculated seeds, consider increasing the seeding rate. If the information on the seed bag indicates the inoculation date has expired, the seed should be reinoculated before planting. It can be planted with other cool season forages. The peak of production occurs in early April through May and crude protein ranges from 16 to 20%. Recommended stubble height is 4 inches and, when harvesting for hay, it should be cut at bloom stage.

Ball clover

Ball clover has non-hairy leaflets, white flowers and late maturity. It is widely adapted and can tolerate poor drained soils. Seeding rate recommended is 2 to 3 lb PLS/acre and seeding depth should be from ¼ to ½ inch. Peak of production ranges from late March through May and can be managed for reseeding under grazing. Crude protein ranges from 16 to 20%.

Berseem clover

Berseem clover has oblong leaflets and yellowish-white flowers. The optimal soil pH is 7 or higher and it is adapted to loam soils. Recommended seeding rate ranges from 12 to 18 and 2 to 2.5 lb PLS/acre for broadcast and drilling, respectively. Seeding depth should be from ¼ to ½ inch. Recommended stubble height is 4 inches. Crude protein ranges from 18 to 24% and is a great choice to use in a mixture with other cool-season species due to its high protein content.

Crimson clover

Crimson clover has pubescent leaves and stems and crimson flowers. It requires well-drained soils and does not tolerate calcareous soils. The recommended seeding rate is 20 to 30 lb PLS/acre and seeding depth should be from ¼ to ½ inch. It is the earliest producing of the clovers. The peak of production occurs from March through April. It can be used for grazing or hay production with a stubble height of 4 inches. Crude protein typically ranges from 16 to 20% and digestibility can be up to 80%.

Red clover

Red clover is a biennial or short-lived perennial. It grows best on well-drained loamy soils with a pH of 6 or higher but can tolerate less well-drained and moderately acid soils. Red clover is used as a winter annual in the Deep South. It is productive for one year in central and southern Alabama and Georgia but may remain productive for longer in the other northern regions, for example Tennessee and Mississippi (Hoveland et al., 1981b). The recommended seeding rate is 4 to 9 lb PLS/acre and seeding depth should be from ¼ to ½ inch. Red clover is low-yielding in February through March compared with other legumes but has the potential to provide a substantial amount of good-quality forage in late spring and into the summer. It is quick growing, easily established, and provides a source of nitrogen and high-yielding forage rich in protein. It can be planted with small grains, as a companion crop and can be overseeded into warm season sods.

Hairy vetch

Hairy vetch is winter hardy and requires well-drained fertile soils with optimal pH ranging from 6 to 7. Recommended seeding rate is 15 to 20 lb PLS/acre and the seeding depth of ½ to 1 inch. Planting window is late Aug through October, and it can be planted in a mixture with other cool-season forages. It can be managed under grazing or single-cut hay production. The peak of production of hairy vetch should be in late March through late April/May.

Overview of Forage Physiology, Morphology, and Growth

In this section, we explore some of the basic concepts and considerations of plant physiological, morphological and growth characteristics relevant for pasture and grazing. Plant physiology can be a very complex and intimidating topic, but here we will try to relate some of those concepts to important processes in the field. This basic knowledge can help achieve a greater level of understanding of the effects of management on forage production and utilization. The processes are also universal, and apply to all different systems, management styles and forage plants.

Basic concepts of plant physiology

Photosynthesis is the primary mechanism for energy input in plants and thus for life on Earth. Through light absorption, plants can transform water and carbon dioxide into energy that is used for growth, maintenance, and reserve. This process occurs inside structures called chloroplasts and is mediated by a molecule called chlorophyll which captures light (especially on the blue spectrum) and transforms into plant energy (ATP and NADPH) while freeing oxygen from water. There are different chlorophyll molecules, all of which have one molecule of Mg and four molecules of N (hence a major component of a plant's "crude protein" content). There are two major distinct carbon fixation pathways that classify plants as either C3 or C4. This nomenclature differentiation is based on the first product generated through the photosynthesis process and represents some important changes in the leaf anatomy, optimal plant growing conditions, and utilization.

The C4 plants evolved to be more efficient in fixing carbon at higher temperatures, where expenditures from respiration are high. While stomata are open for capturing carbon, the plant also loses water. Furthermore, because of the higher dissolution of oxygen at high temperatures, the reaction sites of the photosynthesis (RuBisCo) capture oxygen rather than carbon dioxide, resulting in photorespiration (or oxidative photosynthetic carbon cycle), which increases the energy cost of photosynthesis. In C4 plants, an extra step is added to concentrate carbon dioxide around the RuBisCo, an enzyme in the chloroplast which mediates the fixation of carbon dioxide and oxygenation. This occurs in a specialized structure called Kranz anatomy where the mesophyll cells are clustered around the bundle-sheath cells, the location of chloroplasts, forming an extra ring. This adaptation increases the photosynthetic efficiency of C4 plants (Figure 3) through the suppression of photorespiration and allows photosynthesis to occur even when stomata are closed. In other words, C4 plants can operate better in high temperatures and under water stress, while taking less chlorophyll to perform photosynthesis, which in turn represents a lower concentration of N on plant tissue and greater concentration of cell wall.

Generally, legumes and cool-season grasses are C3 plants, while warm-season grasses are C4. Some of the main differences between C3 and C4 plants are:

- optimal range of temperature for growth is 90 to 95 and 65 to 75°F for C4 and C3 plants, respectively.
- C4 plants are more efficient photosynthetically than C3 plants, producing greater dry matter per unit of nitrogen and per unit of water.
- However, under shaded conditions, C3 plants tend to perform better.
- In general, C4 plants have lower digestibility and crude protein concentration than C3 plants, especially given the different morphological structures (bundle sheath) and greater cell concentration.

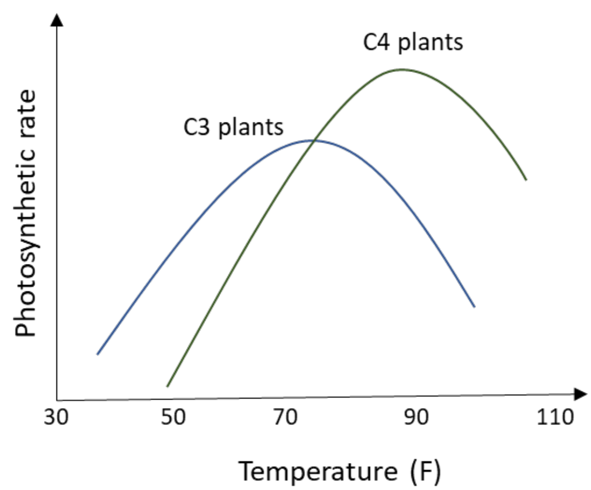


Figure 3. Representation of photosynthetic rate of C3 and C4 plants. Adapted from Ball et al. (2015).

Plants also respond to differences in light conditions, daylength and temperature. This is called *seasonality* and has an important effect on forage production and utilization. First, in the beginning of the season when growing conditions are not optimal (e.g. temperature too high or too low, daylength too short or too long), the growth rate of plants is slow. For summer species, as the days grow longer in the spring and temperatures come up, growth rate increases and reaches a maximum in the summer, when light and temperature conditions are optimal. For perennial crops, that first "green up" represents the break of dormancy, when plants reemerge from the dormant season. During this phase, the growth rate is very slow, and plants depend on stored carbohydrate reserves to grow. Grazing at this point can reduce or delay plant growth. Entering fall, daylength decreases, which signals the plants to enter into reproductive cycle or start accumulation of reserves. In perennial crops, although environmental conditions are still suitable for "growing", photosynthates are allocated to replenishing reserves, rather than vegetative growth. A heavy grazing or hay cutting close to the end of the season can stimulate plants to grow again which can affect reserve accumulation for the off season, reducing persistence. Similar but inverted process occur for winter forages. Some species are not sensitive to daylength and will flower when a certain number of degree days (a measure of "accumulated temperature") is reached, while other species can present both behaviors depending on variety or hybrid selected. Within species, breeding efforts for increasing production season have created varieties that are less sensitive to daylength and can produce earlier and later in the growing season. This can be a great advantage but may also reduce winter hardiness on some warm season plants.

Plant morphology and growth habits

The basic plant morphological components (structures) are leaves, roots, stems and flowers. In **forage grasses**, leaves are composed of sheath, blade, ligule and in some cases, auricles. The sheath embraces the stem around the nodes, where it is attached. Although green and able to photosynthesize, the main function of the sheath is structural. Leaves are the main site of photosynthesis. Stems are divided into two forms:

vegetative and reproductive. While vegetative, stems are short (unelongated) and wrapped in older leaf sheaths to protect the bud (or apex, which are growth points) from herbivory. Once stimuli are right (daylength and/or temperature), the growth point differentiates into reproductive tissue, and stems elongate to emit the inflorescence where the flowers are. Elongated stems are divided into distinctive nodes and internodes, at the point of which the inflorescence emerges, preceded by the “flag leaf”. This phase is called “boot stage”. At this point, that phytomer is dedicated to reproduction and will in most cases cease vegetative growth. Next, inflorescences emerge (heading), and plant starts the anthesis process, when fully formed flowers start shedding pollen. Most forage species have the capability of creating tillers, which are new grass shoots that create whole new “plants” which are interconnected. Those tillers emerge from meristems or axillary buds, when in abundance of resources (especially light and nitrogen) and are key component of the total herbage production of plants. Tiller development normally begins in the initial phases of plant growth, as plants “close canopy”.

The root structure in grasses is fibrous (no tap root) and, usually, each tiller develops adventitious roots from nodes, and begins developing in similar fashion as a new seedling. Sod-forming grasses are generally characterized by their ability to produce either rhizomes or stolons, which are important propagation and reserve structures. Rhizomes are underground stems, and stolons are found at the soil surface, with new shoots and roots arising from nodes. With these structures, plant growing points are close to the ground. Bermudagrass and bahiagrass are sod-forming forages. Bunchgrasses have minimal spread laterally aboveground, but form a tufted growth at the crown, and plant growing points are elevated above the crown base. Upward growth means that growing points of bunchgrasses are more susceptible to removal by defoliation. Tall fescue, orchardgrass, dallisgrass and several native warm-season perennial grasses are considered bunchgrasses.

On **forage legumes**, leaves are connected to the stem by a petiole, and many times are composed by multiple leaflets. Both leaf and stem shapes are quite variable. Stems can be woody, and differ in length, diameter, and shape. In legumes, the shoot apex or terminal bud is at the tip of the stem (generally more exposed to grazing, like lespedeza and bird's-foot trefoil), hence regrowth normally comes through auxiliary buds at the lower nodes or stem. Some species, like most clovers, have long petioles exposing the leaves at the top of the canopy and protecting the growing points. This provides more protection from grazing. Other plants, such as alfalfa, have crowns right at the soil level from which new shoots emerge. Legumes generally have deep and prominent taproots, although some also produce rhizomes from which new plants emerge. Flowers and inflorescences in legumes are also variable, and many have specialized pollinator structures, being a great resource for insects. **Forbs** used in forage systems vary greatly in terms of morphology. Some brassicas have upright leaves bunched in the shoot apex, with virtually no stem elongation. Those also can form root-like structures called tubers.

Morphological characteristics and location of growth points affect how forages can be utilized. Plants that have upright growth and exposed growing points tolerate grazing less than plants that are cespitose and have buds close to or into the soil. Physiological stage also affects the positioning of the growth point. For example, in small grains, once the growing point differentiates (changes) from vegetative to reproductive growth, stems elongate and elevate the bud (boot stage). Plants are then very susceptible to grazing, and when the reproductive bud is removed, growth is not restored. Some other plants like ryegrass and sorghum can emit new shoots from internodes close to the soil surface and restore growth.

From emergence to utilization – concepts into practice

Most forage species, with the exception of a few that are vegetatively propagated (bermudagrass, rhizoma peanut, limpograss), start from seed. Seeds contain the embryonic plant and energy storage for the initial emergence phase. Once planted under favorable conditions (i.e., right soil temperature, moisture, oxygen, and specific light conditions) for the species, the seed will germinate. The *germination* process consists of initial emission of the radicle and then mesocotyl, which emerges and forms the first shoot (epicotyl), all of that being called a seedling. In this first phase of development, the plants depend on the reserves stored in the seed in the endosperm and cotyledon to develop. Thus, the smaller the seed, the less resources those plants will have to germinate. This influences planting depth and the success of the establishment in less-than-optimal conditions. Once plants emerge, cotyledons (rudimentary leaves which also store energy) and the first new leaves begin photosynthesis and roots start to take up nutrients from the soil.

Pasture growth can be divided in three marked phases: lag phase, exponential growth and stationary phase. Early on, when seedlings are small (or right after a heavy grazing event), the limited shoot and root structure has limited capacity of resource (water and nutrients in the soil and light) capture. This results in a slow growth rate (the amount of biomass accumulated per day). As plants grow or recover from grazing, the leaf area increases and roots start exploring more of the soil, gaining greater access to resources, which results in faster growth. This is the exponential growth phase. As plants grow further and start shading each other, then senescence begins and net growth (or net accumulation) decreases. The leaf lifespan is controlled by degree days (an index which considers daylength and temperature). Once reaching the end of its lifespan, the leaf starts to senesce and transfer nutrients to newer leaves. Once plants mature, they enter the reproductive phase (or reserve accumulation for perennial plants), which is also controlled by daylength and temperature. This last phase, the stationary phase, is also when the nutritive value is the lowest, because of the excessive amount of senescent material, increased fiber accumulation and diluted concentration of protein.

Thinking about plant community (i.e., a pasture), during the transition between the lag and exponential phase is when tillering occurs. Tillering is determined by genetic variation between plants, and environmental factors such as competition (plant population) and nutrient availability. Lack of nutrients in these early phases can delay and limit tillering, and thus, total forage production. The speed at which plants reach the stationary phase is also determined by genetics, seasonality and nutrient availability.

Ideally, forage utilization (i.e., grazing management) should focus on the exponential growth phase, where there is the best compromise between quantity and quality. There is a strong relationship between the intensity of grazing and length of regrowth period. If concentrating on the exponential growth phase, pasture can be managed with lenient grazing intensity and short regrowth periods for best animal utilization and plant growth. Long regrowth periods will put plants into the stationary phase, which limits total production, reduces quality and animal intake, and thus performance. Heavy defoliation will also limit plant growth and force animals to harvest poor quality forage at the bottom of the canopy (senesced leaves and stems). Defoliation, therefore, needs to respect a minimum leaf area (normally stubble height is used as a proxy) in order to sustain fast regrowth and not push the plants back into the lag phase. During heavy defoliation events, where little leaf area is left, plants will rely on reserves for regrowth. Repeated heavy defoliations (overgrazing) will cause depletion of reserves and decline of pasture conditions. In this case, longer regrowth periods are needed to allow plants to properly restore reserves.

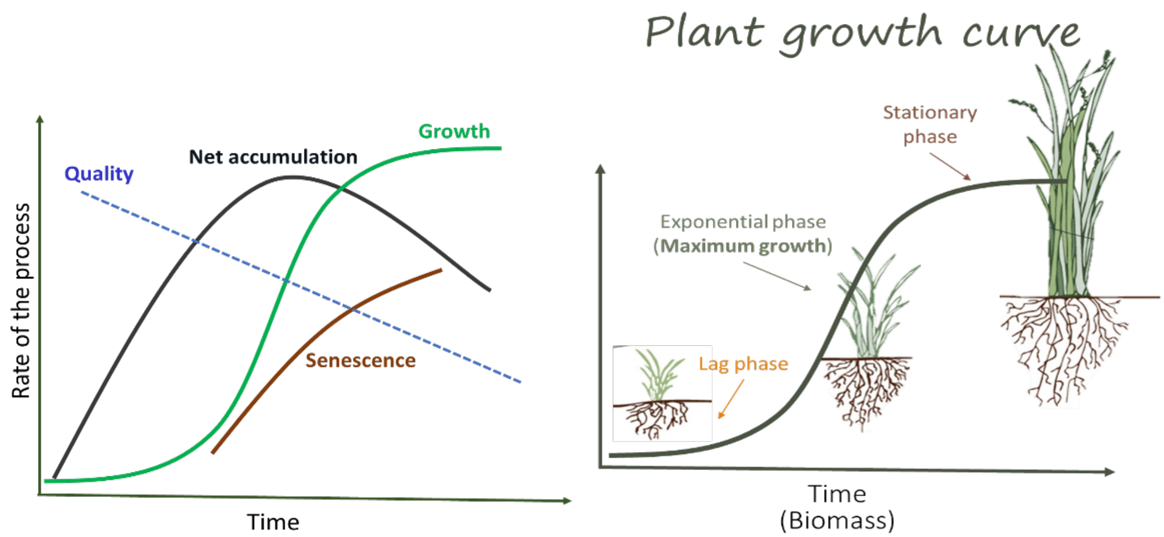


Figure 4. Representation of rate of process of physiological processes. Credits: Dr. Marcelo Wallau (University of Florida).

Recommended literature

1. Ball, D.M.; Hoveland, C.S.; Lacefield, G.D. 2015. Southern Forages. International Plant Nutrition Institute (IPNI).

2. Collins et al. 2018. Forages Volume I, an introduction to grassland agriculture. John Willey & Sons, Inc.

Soil Fertility and Nutrient Management in Forage Systems

Following soil test recommendations for nutrients and lime is important for achieving maximum forage production in pastures and hayfields. Soil fertility requirements vary according to type of forage and soil type. The goal of soil testing is to determine how much lime and fertilizer should be applied to maximize crop production while preventing environmental pollution. Decades of university research has been used to correlate soil-test nutrients with increases in forage yield. This research has been used to develop fertilizer recommendations for forages for public soil testing laboratories.

Essential nutrients for forage production

There are 17 essential elements needed for forage production. Of these 17 nutrients, 14 are supplied from the soil (Table 1). Primary macronutrients (N, P, K) typically must be supplied through fertilizer application. Secondary macronutrients (Ca, Mg, S) can also be limiting for forage production, but lime and N fertilizer applications often supply enough of these nutrients to maintain forage growth. Micronutrients rarely need to be supplied through fertilizer applications. Soil testing provides recommendations for the amount of fertilizer required to produce high-quality forages.

Table 1. Essential nutrients for forage crops.

Primary macronutrients	Secondary macronutrients	Micronutrients
Nitrogen (N)	Calcium (Ca)	Boron (B)
Phosphorus (P)	Magnesium (Mg)	Chlorine (Cl)
Potassium (K)	Sulfur (S)	Copper (Cu)
		Iron (Fe)
		Manganese (Mn)
		Molybdenum (Mo)
		Nickel (Ni)
		Zinc (Zn)

Collecting soil samples and interpreting reports

Most southeastern soils are naturally acidic (meaning that their pH is too low) and must be limed to create soil conditions that increase plant nutrient availability and decrease aluminum toxicity. Most forages grown in the Southeast perform best in soil with a pH between 5.8 and 6.5, however, there are a few exceptions. For example, alfalfa prefers a pH > 6.5. Maintenance of soil pH ensures that: 1) nutrients are in forms which are available to the plant, 2) aluminum toxicity does not occur, and 3) beneficial soil microorganisms, such as those that fix nitrogen for legumes, can function properly. Soil testing provides recommendations for the amount of lime required to increase soil pH to the level needed for optimal forage growth.

Soil acidity and nutrient content can vary widely throughout a field, especially in pastures, so it is important to take a representative sample of the field/area being tested. A soil sample should consist of 15 or more uniform “sub-samples”, taken to a depth of 3- to 4-inches for pastures and hayfields. Sub-samples can be collected with a soil probe or with a shovel. Sub-samples should be placed in a bucket and mixed well prior to placing into a soil sample box. In pastures, it is important to avoid sampling areas where cattle congregate, including feeding areas or shaded areas. These areas tend to be much higher in nutrient content due to manure deposition and are not representative of the entire field. Collect separate samples from areas of a field which are managed differently. For example, if one area is grazed, but an adjacent area has not, sample these soils separately. An individual soil sample should not represent more than 20 acres, so divide fields into smaller areas for sampling if > 20 acres. Soil samples should be collected every year for hayfields and every 1-2 years for pasture.

There are three important sections which provide lime and fertilizer recommendations within a soil test report:

1. **Lime recommendations** provide the amount of agricultural limestone needed to bring soil pH to the correct level for production. Recommendations are given in tons per acre of ground ag lime.
2. **Fertilizer recommendations for N, P_2O_5, K_2O** (Nitrogen, Phosphorus, Potassium) are given in pounds per acre. Various fertilizers contain different percentages of N, P_2O_5, and K_2O (Table 2), so the appropriate amount of fertilizer to apply must be calculated for specific fertilizer products. For example, if your soil test calls for 120 lbs of K_2O, and your fertilizer contains 60% K_2O, you will need to apply 200 lbs of fertilizer to meet forage potassium demands.
3. **Comments** give special instructions for fertilizing a specific crop. Always read the comments section of the soil test report, as it may give recommendations for regarding

timing and placement of fertilizers. It may also provide recommendations for micronutrients that are required for optimal growth of a specific forage.

Table 2. Common fertilizers and their nutrient content.

Crop	N	P_2O_5	K_2O	Ca	Mg	S	B	Cu	Fe	Mn	Zn
						lbs/acre					
Alfalfa Hay	415	94	401	151	36	26	0.43	0.11	1.67	0.45	0.3
Bahia or Bermudagrass Pasture	6	5	1	....	....	....	....	....	....	....	....
Bermudagrass Hay	400	92	345	48	32	32	0.13	0.02	1.2	0.64	0.48
Corn Silage	160	67	160	28	33	20	0.11	0.07	0.7	1.06	0.3
Fescue or Ryegrass Pasture	9	7	1	....	....	....	....	....	....	....	....
Clover	80	20	80	55	14	6	0.05	0.02	1	0.44	0.28
Sorghum-Sudan Hay	160	61	233	30	24	23	....	....	....	....	....

Table 3. Nutrient removal for forage crops.

Source	N (%)	P_2O_5 (%)	K_2O (%)	Other
Ammonium Nitrate	34	0	0	
Ammonium Sulfate	21	0	0	24% S
Anhydrous Ammonia	82	0	0	
DAP	18	46	0	
MAP	10	50	0	
Muriate of Potash	0	0	60	
Nitrogen Solution (28%)	28	0	0	5% S
Nitrogen Solution (30%)	30	0	0	2% S
Nitrogen Solution (32%)	32	0	0	
Sulfate of potash-mag (K-Mag)	0	0	22	21% S; 11% Mg
TSP	0	46	0	
Urea	46	0	0	

* This table can be used as a guide for understanding crop removal. Values reported in this table may differ from values from other sources. Nutrients not removed from the land are returned to the soil in organic residues. Crop removal should be adjusted in proportion to the actual yield.

For hayfields, fertilizer recommendations sometimes may be based on anticipated yields. For example, a recommendation for bermudagrass hay production is "after each cutting, apply 50 lbs N per ton of anticipated hay removed at the next cutting." This recommendation is based on nutrient removal in hay production systems. Nutrient removal can be an important consideration in overall soil fertility management for farmers. However, fertilizing based solely on nutrient removal could lead to nutrient deficiencies or result in overuse of some fertilizer nutrients.

Nutrient management considerations on forages

Nutrient management should be a focus of every livestock producer, especially in times of high input costs. Stored feed (hay) normally accounts for a significant percent of annual costs. Research studies have documented that 75-80% of the nutrients in a livestock operation are recycled through the deposition of manure and urine. Although the concentration of nitrogen, phosphorous and potassium is low in manure, the annual volume per animal is significant. Soil fertility needs can add up quickly when utilizing purchased inputs, but attention to nutrient management details can result in huge cost savings. Practical nutrient management first involves an understanding of how the nutrients in a livestock operation move around the farm. For example, hay that is grown and baled in one field is usually fed in a different location. The hay feeding method can either concentrate manure in a very small area around a hay ring or distribute it across a field if the hay is unrolled. Heavy use area protection is a commonly used practice for hay feeding areas. The hard surface used to feed on can be scraped clean at the end of the feeding season, with the manure spread back on the hayfield. In this example, there is a significant amount of cost and time devoted to the production of the hay, storing, feeding and subsequent scraping/spreading back on the hayfield. Every day that animals are grazing instead of eating hay should be money saved.

Proper grazing management through rotational stocking can evenly distribute manure and urine across the farm. Based on your management level and farm setup, there are multiple options for rotational grazing. The basic idea is to provide the amount of forage needed for a given number of animals for a limited amount of time on a certain amount of land. Once the grazing animals have consumed the desired amount of forage without overgrazing, they are rotated to the next allotted area. It is quite common for forage utilization to increase from 30% in a continuous grazing situation to 60% or greater through rotational grazing. This increase in forage use efficiency can lead to more grazing days and fewer feeding days. More days on pasture versus standing at the hay ring results in uniform manure distribution in the field where it provides the most benefit.

If less hay is needed, less acreage can be devoted to hay production and less fertilizer is required. Nutrient removal on bermuda/bahia pasture by grazing beef cattle only amounts to 6 pounds of nitrogen, 5 pounds of phosphorous and 1 pound of potash. In a bermuda hayfield, up to 400 pounds of nitrogen, 92 pounds of phosphorous and 345 pounds of potash are removed at a yield of 8 tons. It is easy to recognize the cost benefit of grazing versus haying an acre of land! There are other advantages to rotational grazing that should be considered for their value. It is common to see improvement in the forage stand, primarily due to the rest phase of grazing management. Stands that are thinned out can recover with rest and re-establish much need root systems. This can lead to faster recovery after grazing, higher yielding stands, and greater drought tolerance. The even distribution of manure and urine can provide more nutrition for some areas of a field that have not received much under continuous grazing, such as those furthest from water and minerals. The trampling action of the grazing animals can lead to more residue that contributes to soil organic matter content. It is common to see less runoff from fields with strong forage stands, so valuable nutrients are not lost to bodies of water.

Fencing and water availability are the two main factors that must be accounted for when designing a rotational grazing system. With properly placed cross fences (permanent or temporary), cattle can be used a tool to harvest forage and return valuable nutrients to the soil. Water is always the most limiting nutrient and can be used to keep animals grazing in a particular area if it is readily available. Consult with your local Extension office for assistance with these topics. Time spent evaluating new or modified management practices is well spent. For most decisions, there are many factors to consider and extra benefits beyond the primary objective. Evaluate where you can increase efficiency in the forage program on your farm and know that it might actually save some time as well.

Use of poultry litter in pastures and hayfields

Poultry litter is a great resource for livestock producers and the Southeast United States is fortunate to have this valuable by-product from the growing poultry industry. Poultry litter is an excellent source of slow release nutrients for forages. These nutrients include nitrogen, phosphorus, and potassium and micronutrients such as zinc, copper, boron, and manganese. Poultry litter applications also improve soil health by adding organic matter and improving water infiltration. However, improper use and mishandling of litter can potentially contribute to water quality problems, which can bring negative public perceptions of animal agriculture. Livestock producers can protect the environment by using best management practices (BMPs) to prevent nutrient loss. Many of these BMPs are common sense, but most are based on scientific research.

If you are new to the business or unaware of these BMPs, use the following practices as guidelines for successful and sustainable use of poultry litter in your livestock operation:

1. Many producers apply 2-3 tons/acre of poultry litter every year on their fields. Poultry litter can come from several sources such broiler houses, hen houses, or litter stored in stack houses. However, not all litter contains the same concentration of nutrients nor are the nutrients released in the same fashion. For example, the nitrogen content of broiler litter increases with the number of flocks raised in the poultry house. Normally, the longer the litter stays in the poultry house as bedding, the higher the nutrient content of the litter. Litter removed from the house and stockpiled for a longer period typically has a lower nitrogen value since a portion of nitrogen is lost through ammonia volatilization during storage. The nutrient content of litter also depends on whether the litter was stored in a covered shed or stockpiled in an open field, unprotected from rainfall. On average, litter has a 3-3-2 (N-P-K) fertilizer value but can be highly variable based on many additional factors. Laboratory analysis of fresh litter is the most reliable way to determine its nutrient content. It is recommended to collect representative samples and have these tested at a university soil testing lab or commercial lab for

three major nutrients (N, P_2O_5 and K_2O) before applying to forages. Litter testing not only helps to document the nutrient content but also is critical to determine the correct application rate.

2. Often, litter is not available at the right time for land application. In such situations, proper storage is essential for maintaining its value as a soil nutrient. The key to proper storage is to keep the litter dry, stack no more than 5 feet high to prevent fires, and cover the litter stack from rainfall. In situations where temporary storage of litter is necessary, store litter on a well-drained site, away from waterways and cover the litter with a well-secured tarpaulin or repurposed billboard vinyl to protect from surface runoff during rainfall events.

3. Choosing the right rate and correct application timing is critical when considering poultry litter as a nutrient source. Many producers apply poultry litter to meet the nitrogen needs of the forage. In doing so, excess phosphorus above the crop need is added to the soil. For example, an application of 3 tons per acre of a 3-3-2 litter in a bermudagrass field will result in application of 180 lbs. of N, 180 lbs. P_2O_5 and 120 lbs. of K_2O. The phosphorus removal rate for 8 tons of bermudagrass is 92 lbs/acre. This leaves a balance of 88 lbs P_2O_5 in soil every year. The phosphorus accumulates in the soil through repeated applications over years and can potentially cause water quality problems if the runoff water enters a creek or nearby water bodies. The application timing of litter is also critical to maximize the nutrient uptake by plants and prevent environmental losses via runoff or leaching. Litter application in the spring is a better option than fall for two reasons. First, many forages do not grow actively in the fall season; hence, the phosphorus uptake is negligible. Second, the Southeast U.S. receives a majority of its annual rainfall during the December-January time period. High amounts of rainfall in the fall causes the litter to release nutrients at a faster rate. In the absence of actively growing forages, most of the released nutrients are lost and are not available in spring when the plants need them the most.

4. Avoid application of poultry litter on slopes with a grade more than 15% or where runoff is likely. It is also important to observe setback distances with streams, wells, water supplies, roads, non-owner-occupied dwellings, and private property lines. For example, avoid litter application within 100 ft. of water source such as lakes, streams,

rivers and other surface waters. Care should be taken to avoid potential groundwater contamination near sinkholes and private drinking water wells, too.

5. Records that document the proper use of litter are a requirement in many states. Consult your local Extension or NRCS office to find out more about the regulations in your area. Compliance with those regulations will protect the litter user in the event of a complaint. Avoid spreading litter on windy days or hot and humid days when smell may be a concern and objectionable to your neighbors. When transporting litter on public roads, cover or tarp vehicles carrying the litter. These steps will help maintain a good relationship with the surrounding community.

Nutrient deficiencies

In addition to soil testing, visual observation is commonly used to aid in diagnosis of nutrient deficiencies in the field since plant symptoms, such as yellowing and stunted growth, are associated with specific nutrients. For trained observers, this approach may be helpful, but often more than one nutrient may be out of balance. In many cases, plant tissue sample analysis can be of great value. A plant tissue report provides a detailed description of main macro and micronutrients within plant tissue. For tissue analysis, it is recommended to take plant tissue samples randomly throughout a field to get a representative sample of the canopy strata of interest. Before collecting the tissue sample, check with the laboratory to determine how they suggest taking the sample and the amount required. For most forages, a plant tissue analysis is taken when soil test results have been inconclusive.

Figure 5. Nutrient deficiency in alfalfa plants.

Stand Establishment

Key steps for forage stand establishment

Site Assessment and Soil Fertility

Figure 6. Shoe imprint in a prepared seedbed. Photo Credit: Gerry Thompson (ACES).

- Ideally, an area to be planted should be visually assessed six months or more prior to planting. Any troublesome weeds should be controlled, and a planting strategy should be developed. An important step is to take soil samples to determine the baseline pH and soil fertility status. If soil pH is low, an application of lime will be necessary to bring the pH into the proper range for the forage crop to be planted. In areas to be tilled, lime can be incorporated as part of the final seedbed preparation. If no-till planting is to be used, lime should be applied several months before planting, if possible.

Land Preparation

- Disking, harrowing, and other measures are typically needed to achieve appropriate planting conditions prior to pasture establishment. Characteristics of a good seedbed include:
  - Most large clumps of soil or plant residues have been destroyed during the land preparation process.
  - The soil surface is level enough to support equipment for planting.
  - The seedbed is somewhat firm, or enough to leave a shallow imprint of your shoe in the soil surface when walking across the area (Fig. 6).

Seed Selection

Use recommended varieties adapted to the soil type and climatic conditions. Certified seed provides assurance of seed quality and guarantees exclusion of most weed seed. Refer to the seed tag for information on germination percentage, purity, and weed seed contribution as an indicator of seed quality. Non-certified seed, while cheaper, will often cost more in weed management and reseeding.

Seeding Rate and Time of Planting

- Plant according to seeding rate recommendations. Seeding rates and planting window for commonly planted forages are provided in Table 4.

Table 4. Seeding rates and dates for commonly planted forages in the Southeast.

Forage Crops	Seeding rate	Planting window range
Alfalfa	20 – 25 lb PLS*/acre	Aug 15th – Nov 1st
Bahiagrass	15 - 20 lb PLS/acre	Mar - July
Bermudagrass hybrid	15 - 30 bushels/acre	Late Feb to Aug 15th
Brassicas	5 – 10 lb PLS/acre	Feb – Mar; Sept- Oct
Cereal rye	90 – 120 lb PLS/acre	Aug 25th – Nov 1st
Clovers	20 – 30 lb PLS/acre	Aug 25th – Nov 1st
Oat	90 – 120 lb PLS/acre	Aug 25th – Nov 1st
Pearl Millet	15 - 25 lb PLS/acre	April 15th to July 15th
Rhizoma perennial peanut	80 – 100 bushels/acre	March – early July
Ryegrass	15 – 30 lb PLS/acre	Aug 25th – Nov 1st
Sericea lespedeza	15 – 30 lb PLS/acre	March – May; June - July
Sorghum	15 – 20 lb PLS/acre	Late Apr – July 1st
Tall fescue	15 – 20 lb PLS/acre	Sept - Nov
Wheat	90 – 120 lb PLS/acre	Aug 25th – Nov 1st

*Pure Live Seed (PLS). For more information, consult your local Extension agent.

Weed Control

Prior to establishment, the seedbed must be clean to limit weed competition. Fall vs. spring planting dates will determine the weed spectrum the forage crop will be exposed to. It is important to be aware of herbicides with long soil residual activity ahead of planting some species of forages, especially legumes.

Common forage establishment problems

Seed or Planting Site Issues

- Seed planted too deep or too shallow
- Poor seed germination
- Non-viable seed planted

Site/Environmental conditions

- Soil pH is too low or low soil fertility
- Herbicide residues
- Drought conditions
- Heavy, frequent rainfall following planting
- Seedbed is too wet or dry at planting/during the emergence period
- Freeze/thaw patterns
- Temperature fluctuations (extremely cold/hot, and swings in temperature)

Stand establishment in rotation with commodity crops

The use of forages in rotation with commodity crops is a common practice (Fig. 7). This practice allows forage production during cooler months of the year that can be either grazed or cut to produce conserved feed. Besides providing high quality forage for livestock, this practice improves soil health by increasing soil organic matter and water holding capacity, as well as increasing N through N fixation when using legumes. This practice increases soil organic matter input, reduces soil compaction, and lessens soil erosion. Also, for some commodity crops, it is crucial to grow other species to break soil parasite cycles. This practice requires appropriate timing to harvest previous crop, then adequate land preparation and sowing of the cool-season species or mixture. Forage can be utilized by grazing or by harvesting for hay or baleage.

Figure 7. Area of rotation of cotton and cool-season grasses at the Wiregrass Station at Headland, AL.

Overseeding perennial forage pastures to extend grazing season

A practice that has been widely used in the southern US is to overseed warm-season perennial forage stands with cool-season annual species to extend forage production. Due to climate conditions in this region, cool-season forages can grow throughout the cooler months providing areas for grazing or cutting to produce conserved feed. Overseeding pastures does not kill warm-season perennial pastures but, requires some practices prior to establishment to assure seed germination and establishment of the cool-season species. In preparation for sowing, the excessive vegetative growth must be removed either by grazing or mowing to optimize seed-soil contact. In some cases, a light herbicide dose is helpful to induce dormancy ("*put the grass to sleep*") to avoid green up in late Nov/Dec if temperatures warm up. A no-till drill should be used to optimize results, but some producers might choose to broadcast. For the latter, a roller/cultipacker can be used to optimize seed-soil contact. Generally, in bahiagrass and bermudagrass pastures, the planting date will be in late Sept/Oct to early Dec, depending on where the site is located and when the warm-season forage goes dormant.

Forage Management Practices

Forage management allows for strategic use of forage resources to meet livestock production needs. In production settings, forages are most often managed for **grazing** or **stored forage (hay, baleage or silage) production.**

Grazing Management Practices

Why Grazing? Grazing management plays a crucial role in determining forage production, forage quality, and animal performance in forage-based livestock production systems. When structuring management practices for a forage system, planning to meet requirements of different animal categories in terms of diet quality and duration of feeding will help achieve your goals. Other important considerations are management intensity, budget, and expected return on investment. Given the nature of agriculture production and interactions with factors beyond management control, there is not a ‘one size fits all’ method for all farms. Several grazing methods may be used to help achieve farm goals, and each farm is situation specific.

General Goals of Grazing Management Include:

- Improved grazing efficiency
- Reduced waste of forage in pasture and improved use of pasture space
- Conserve surplus forage for a time of later use (stockpiling/stored forage production)
- Increased animal performance
- Matching forage quality with production needs

To implement a successful grazing system, match the grazing method with the forage species, the animal, and the producer needs. Grazing methods include:

Continuous Stocking – Animals are stocked on a single pasture unit for the duration of the grazing season.

- **Pros:** Simple, widely used, allows animals to selectively graze and select for greatest quality first, low labor requirement.

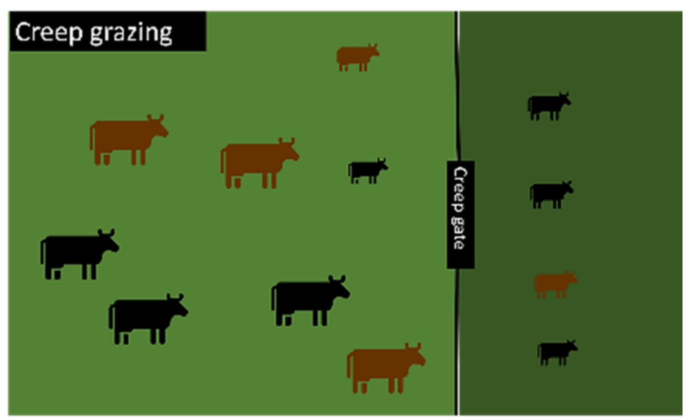
- **Cons:** May lead to overgrazing, overstocking and lower forage production, least efficient of grazing methods because animals can select what they want when they want from the pasture, and what they want to continually refuse.

Rotational Stocking - The pasture system is subdivided into paddocks that will alternate between grazing and rest for plant regrowth during the grazing season.

- **Pros:** The regrowth period can vary to avoid overgrazing or undergrazing and ensure replenishment of forage carbohydrate (i.e., energy) stores, desired forage accumulation, more uniform forage use compared with continuous stocking, and more even distribution of recycled nutrients from animals.
- **Cons:** Low to moderate management and labor required depending on rotation frequency and number of paddocks, requires multiple pastures.

*The concept of "rotational grazing" is the basis for most grazing methods implemented within a grazing system. The key to remember when utilizing rotational stocking is that **the rest period** (the time livestock are not grazing a specific paddock) **is just as important as the time spent grazing a given paddock.***

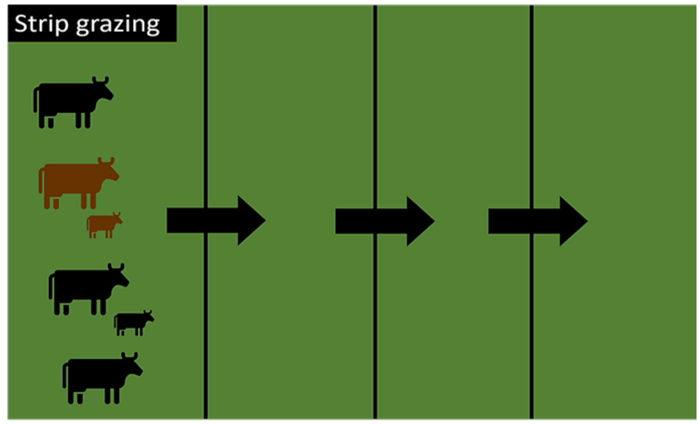
Creep Grazing – A grazing method that allows calves to have access to a greater nutritive-value forage adjacent to the area in which their dams are grazing.



Pros: Allows young animals with high nutrient requirements access to higher-quality forages first through a creep opening. Dams or larger animals with lesser nutrient needs are maintained on traditional base forages.

Cons: Infrastructure needed for creep grazing.

Strip grazing consists of using temporary fencing to have animals graze an area for a short period of time and subsequently provide access to other areas (strips) as needed. Animals can be 'back- fenced' out of the area previously grazed or 'frontal' graze across a pasture to allow for rest and regrowth.

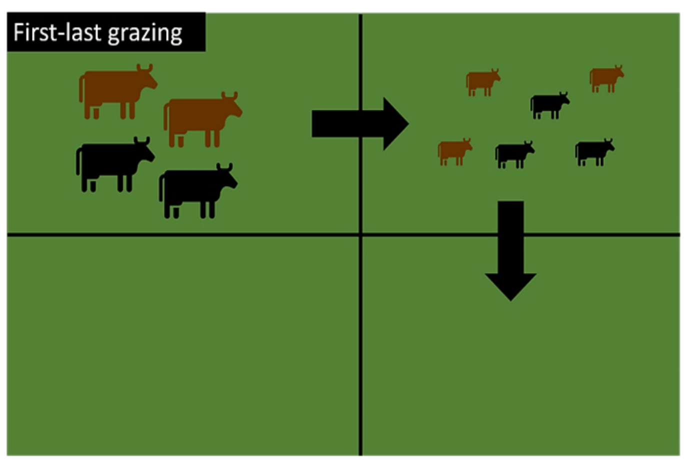


Frontal grazing, the act of allowing animals forward access without maintaining a back fence (i.e., grazing in a manner that is moving away from a permanent water source), is most commonly used when grazing stockpiled material that is dormant (i.e., not in active regrowth); restriction from the previously grazed area is thus not necessary.

Pros: This practice is commonly used when grazing stockpiled forages (e.g., tall fescue or bermudagrass), or when supplementing animal diets with higher quality forage such as winter annuals. This is the most efficient grazing method for forage utilization.

Cons: Medium to high labor requirement. Requires familiarization and proficiency with temporary electric fencing.

First-last grazing consists of allowing animals with higher nutritional requirements to graze a given pasture area first to remove the higher quality forage, and then continue forward in a rotation ahead of a second group. Animals with the lower nutrient needs complete the removal of available forage. This method can be applied for



different animal categories having different nutritional requirements (e.g., stocker calves and mature cows) or different animal species associated to optimize grazing (e.g., cows and goats).

Pros: Herd is sorted into nutrient requirement groups. Animals with highest nutritional needs have access to highest quality forage first. Rotation of animals allow for pasture rest and regrowth.

Cons: Medium labor requirement and infrastructure. Requires multiple paddocks, training of animals to follow system.

Limit Grazing – Animals are allowed limited time (e.g., a few hours per day or access on an alternate-day basis) in a typically higher-quality forage paddock, and then removed and returned to a lower- quality forage area (pasture and/or stored forage).

Pros: Efficient use of high-quality forage, helps meet animal nutritional needs and stretch base forage resources (such as hay or other grazed forage used in the diet)

Cons: High labor requirement, requires multiple pasture areas

Grazing Management Frequently Asked Questions

1. How Do I Know When to Start and Stop Grazing?

Under any management method, it is essential to understand how to estimate forage mass in order to properly adjust stocking rate. This information is provided in the "Appendices" section.

2. What Are the Appropriate Start and Stop Targets for Grazing?

Table 5 provides information on when to start and stop grazing various forages.

Table 5. Guidelines for rotational stocking. Adapted from Ball et al. (2015).

Forage species	Target height (inches) Begin Grazing	End Grazing	Regrowth interval (days)
Legumes			
Alfalfa (for hay)	10-16	3-4	28-35
Alfalfa (for grazing)	10-16	3-4	28-35
Clovers	8-10	3-5	20-35
Perennial peanut	8-10	4-5	28-42
Sericea lespedeza	8-15	4-6	20-30
White clover	8-10	3-5	20-35
Perennial grasses			
Bahiagrass	10-14	3-4	10-20
Bermudagrass	10-14	4-6	25-30
Dallisgrass	8-10	3-4	7-15
Tall Fescue	8-12	4-8	15-30
Annual grasses			
Annual ryegrass	6-12	3-4	20-30
Crabgrass	8-12	3-6	20-30
Pearl millet	20-24	8-12	20-30
Small grains	8-12	3-4	15-30
Sorghum/Sudan hybrids	20-24	8-12	15-20

3. **I want to graze as many days per year as possible. How do I do that?**

First, set a goal of how many grazing days per year you would like to achieve for your operation. A realistic goal in most of the Southeast US is 300 days of grazing per year, or the view of 60 to 90 days of hay feeding per year. Next, evaluate your forage base in your operation. The forage base consists of the main perennial forage species in the operation which provides the basis for grazing. This is usually a cool-season perennial such as tall fescue, a warm-season perennial like bahiagrass or bermudagrass, or a combination of both. Consider the time of year these forages are actively growing and when they are dormant. Can these forages be stockpiled to fill in production gaps during certain periods of the year? A common gap is in the late fall and early winter when warm-season forages have gone dormant, but cool-season forages are still establishing or have low productivity. Planting annual forage species which grow during traditional perennial forage production gaps may be an option for extending the grazing season during the year.

Stored Forage Production and Management

Keys to Producing High-quality Stored Forages

When to Cut?

- When plant is at the right stage of growth (Refer to table 6).
- When weather conditions are favorable
- Allow enough time to reach optimum moisture before baling
- Drying time varies by species and product

Table 6. Recommended stage of growth for harvesting various forage crops.

Forage species	Time of harvest
Legumes	
Alfalfa	Bud stage for first cutting after establishment; 10% bloom thereafter
Perennial peanut	Height of 10 to 12 inches or every 28 to 42 days
Sericea lespedeza	Height of 15 to 18 inches
Perennial Grasses	
Bahiagrass	Height of 10 to 12 inches or every 4 to 5 weeks
Bermudagrass	Height of 14 to 18 inches or every 4 to 5 weeks
Tall fescue	Boot stage†
Annual Grasses	
Annual ryegrass	Boot stage†
Crabgrass	10 to 12 inches in height or every 4 weeks
Pearl millet	24 to 30 inches in height
Small grains	Boot stage
Sorghum/sudangrass hybrids	30 to 40 inches in height

†Boot stage occurs when the seedhead is present in the flag leaf sheath but has not emerged.

What Time of Day?

- Morning: The forage is wetter which allows for greater leaf retention, but sugar concentration is lower; with a morning cut you get a full day of drying time which can be critical in dry hay production.

- Evening: The forage is dryer, but the energy levels may be greater due to increased carbohydrate concentration in the plant material. Carbohydrates are crucial in successful fermentation and drying time is decreased with baleage production; thus a later cut might be optimal.

Wide or Narrow Swath?

- As wide as possible to spread out material

When to Ted, Rake, and Bale?

- When the moisture content is just right!
- Tedding helps to increase hay-drying rates (decrease time to baling)
- Breaks up clumps and distributes the crop over the area to allow for increased sun and better air movement
- Initial tedding should occur with 2/4 hours of mowing
- Tedding should only occur when there is adequate moisture still in the plant to decrease leaf loss – avoid tedding legumes when >50% moisture)
- Tedding is not a required step in baleage production

What Should the Moisture Be at Raking?

- Hay:
  - 35-40% for legumes
  - 20-25% for mixtures
  - <20% grasses
- Baleage: 60% moisture

What Should the Moisture Be at Baling?

- Hay:
  - 18% moisture - Small squares
  - 15% moisture - Round bales
- Baleage: 40 – 60% moisture

Hay Storage – Why, How, Where

- **Weathering of hay bales** during storage can result in losses of dry matter and forage quality that reduces hay intake and compromises animal health and performance.

- **Store hay bales inside a barn** or **other covered** structure when possible.
- If hay is stored outside, **select a well-drained site away from trees**. Although the edge of a field can be a convenient place for storage, storing bales under a treeline reduces exposure to sunlight and promotes moisture holding in bales.
- **Store round bales in rows**, end-to-end in a north/south facing direction to maximize exposure to sunlight during the day. Leave 18 to 36 inches between rows of bales to permit sunlight and airflow.
- **Wait to store in a barn post-baling.** Don't move bales directly from field to barn on the day of harvest. All bales will go through some level of heating depending on actual moisture in the produce after baling. While removal from the field quickly is necessary for forage regrowth, it is good to allow for at least a short period of rest (a few days) between baling and barn storage to ensure proper internal temperature and decreased potential of combustion.
- **Contact of hay bales with soil results in much bottom spoilage**. If hay is stored outside, placing bales on rock, railroad crossties, or pallets can avoid contact with soil.
- **Reduce risk of fire**: bale at appropriate moisture range between 10 and 20% and monitor temperature of bales (Fig. 8). Internal hay temperature should be observed after baling to ensure internal temperatures are below 120°F degrees. The flashpoint or temperature to cause concern is between 140 and 150°F degrees. If bales are registering temperatures this high, remove them from the barn or structure.

Figure 8. Hay storage on proper barn construction (left) and hay fire inside barn (right).

Baleage and silage production and storage

In the Southeast USA, the use of baleage/haylage is increasing. Baleage is a fermented forage product that is stored in the absence of oxygen (anaerobic conditions). Naturally occurring bacteria on the plant surface utilize some of the readily available carbohydrates and produce organic acids that will help to lower the pH quickly and prevent spoilage and mold growth. When producing baleage, harvested forage is baled at 40 to 60% moisture. Thus, producing baleage reduces the time needed to bale harvested forage compared with hay (1 to 3 days vs 3 to 5 days drying time) helps maintain forage quality and reduces losses of dry matter. In terms of harvest recommendations for specific forages, the cutting time and stubble height are similar to those for hay production. After forage is harvested, the wilting time for lowering moisture concentration to an appropriate level prior to baling varies for different forage species, and depends on field and weather conditions. The wilting time can vary from 4 hours to a couple of days or more depending on field and weather conditions. For this reason, determination of the moisture of the harvested material is a quick test that can be done after cutting using a microwave (“Appendix B”).

Forage can be baled when the moisture level is appropriate, the, and bales can be sealed airtight with plastic using a bale wrapper. Bales should then be stored in a dry area. It is recommended to conduct forage analysis similar to that for dry hay before feeding. Use a hay probe with a corded drill for extra power to collect samples. After collecting the samples, tape the holes to prevent air and wildlife from getting inside the bales, which could cause damage and loss of forage quality. When a bale is later unwrapped, the feed should smell sweet/acidic, and free of excessive amounts of mold. Some wrappers seal individual bales separately, but there are also inline bale wrappers that prepare several bales for storage (Figure 9). Forage baled at higher moisture level than recommended will lead to issues with bale spoilage and loss of form during storage (Figure 10).

Figure 9. Inline (left) and individual (right) bale wrappers.

Figure 10. Moisture level at proper (left) and above (right) proper range impacts bale integrity during storage.

Silage is harvested forage that is ensiled at 65 to 70% moisture. Generally, the forage is chopped and compacted to eliminate oxygen. In the Southeast, silage is usually stored in an open-type concrete bunker or plastic silage bags (Fig. 11). Corn should be harvested for silage at the full dent stage or when the milk line is about 1/3 down the kernel. At

Figure 11. Corn silage stored in an open-style concrete bunker.

this stage, corn should be around 30 to 35% dry matter (or 65 to 70% moisture). At this stage, the corn ear has begun to fill in and achieve most of its nutritional value without significant leaf and stalk loss. Harvesting earlier than this may result in less desirable fermentation characteristics. The optimal particle size of corn silage should be ½ to ¾ inches in length, which will also pack more uniformly in a silo or bunker and can be quite palatable for cattle. Pack silage as uniformly as possible to prevent exposure to oxygen and decrease the opportunity for spoilage. With sorghum, forage-type varieties are usually used for silage because of their higher forage dry matter production potential.

Baleage Production Frequently Asked Questions and Tips

- **What is baleage?** Baleage is a fermented forage product that is stored in the absence of oxygen (anaerobic conditions). Naturally occurring bacteria on the plant surface consume some of the readily available carbohydrates and produce organic acids that will help decrease the pH quickly and prevent spoilage and mold growth.
- **Target Moisture.** When producing baleage, harvested forage is baled at 40 to 60% moisture. Thus, producing baleage reduces the time needed to bale harvested forage compared with hay (1 to 3 days vs 3 to 5 days drying time). The reduced timeline helps maintain forage quality and reduces losses of dry matter. ***Information on how to test your forages for moisture content can be found in the Appendix.***
- **Harvest Timing – Based on Forage Growth.** The ideal time of cutting (days) and recommended stubble height (inches) by forage species are the same as recommended for hay production.
- **Harvest Timing – Based on Time of Day.** Weather, drying conditions and total hours of drying time are important during baleage making. Remember that sugars accumulate in the plant throughout the day and are greatest in concentration just before sundown; so a late-afternoon or early-evening cut should be considered, as sugars are a key component in fermentation.
- **Wilt Time.** After forage is harvested, wilting time varies depending on the forage species, and on field and weather conditions. The wilting time can vary between four hours to a couple of days or more. Wilting is a key process in baleage

production, and ample time should be allowed for proper wilting. Raking and baling immediately behind the mower without allowing for wilt is not recommended.

- **Baling.** When the moisture level is appropriate (40-60%), the forage can be raked and baled, and bales can be sealed airtight with plastic using a bale wrapper. Ideally, bales will be wrapped immediately (within 4 hours) of baling. Longer periods of time between baling and wrapping can lead to excessive heating, aerobic deterioration and deformation of forage which can make wrapping difficult.
- **Wrapping.** Some wrappers seal individual bales separately, but there are also inline bale wrappers that prepare several bales for storage (Figure 9). Regardless of method, ensure that enough plastic layers (6 to 8 minimum recommended) are applied to each bale.
- **Bale Storage.** Bales should then be stored in a dry area not prone to flooding and away from potential punctures at both soil surface and above. Stumps, roots, rocks, and hardy weeds can cause bottom punctures that aren't readily visible and cause significant spoilage. Likewise, areas prone to attract small-animal pests (mice, voles, vermin, etc.) that in turn attract birds can cause additional damage.
- **Quality Analysis.** Forage analysis similar to that for hay should be conducted before feeding. Samples can be collected at harvest or as close to feeding as possible. Use a hay corer equipped with a drill to collect samples. Place samples in a sealable, plastic bag and ship immediately for analysis. After collecting the samples, tape the holes in a "+" pattern to provide two layers of protection and to prevent air and wildlife from getting inside the bales which would cause damage and losses of forage quality.
- **Feeding.** When a bale is later unwrapped, the forage should smell bread-like/acidic, and free of excessive amounts of mold. Baling forage at higher moisture level than recommended will lead to issues with bale spoilage and loss of form during storage (Figure 9).

Feeding Stored Forages and Supplementation in Livestock Systems

Steps for Using Stored Forages

- Understand animal nutrient requirements when using stored forages to meet livestock nutritional needs.
- Conduct a forage analysis to determine stored forage nutritional value.
- Match nutrient needs of livestock to forage test results to make informed feeding decisions. For example, the use of high-quality hay may largely meet the needs of growing beef calves and reduce supplementation needs. The use of high-quality baleage might far exceed the needs of dry cows, but could be an excellent feed source for growing or lactating animals.
- Estimate bale size and determine how many bales are needed to meet daily dry matter needs of livestock.
- Reduce feeding waste of stored forages by using a hay ring, cradle, or trailer.
- Consider bale processing, or other alternatives that can increase dry matter intake.

How Do I Know What To Supplement?

- Evaluate locally available feedstuffs. Many feeds can be purchased in bulk, which may help reduce cost of feeding over a defined period of time.
- Consult with an Extension or industry partner to help interpret a forage analysis and develop an appropriate supplementation plan. In many cases, a forage analysis can be used to help reduce feed supplementation in livestock systems!
- Think outside of the box – a 'feed supplement' could also be a high-quality forage that could be limit grazed to help meet nutritional needs. Limit-grazing, or time-restricted access to high-quality forage, helps increase efficiency.

Measuring Nutritional Success

How do you know if your forage program is working for your operation? Animal performance is a key measure of forage success and can help producers understand where improvements can be made in the future. A few items to assess whether nutrition management is on track in beef herds include:

Evaluate animal body condition score – In beef cattle systems, body condition scoring is an on-the-hoof visual appraisal using numbers (1-9) to suggest the relative body fat of the beef cow. With this nine-point scale, a score of 1 represents a very thin body condition and a score of 9 represents extreme obesity. For mature cows, a target BCS score of 5 to 6 is recommended at calving. Condition scoring cows and heifers allows us to properly plan and adjust forage feeding programs. Key times to body condition score beef cattle are at weaning, 60 to 90 days prior to calving, at calving, and the beginning of the breeding season. For more cows, an increase of one body condition score equates to gaining about 100 pounds of body weight.

Keep records on cow performance and reproductive success – Breeding and calving records can assess a cow or heifer's reproductive proficiency by tracking when in the designated breeding and calving season a calf was produced. Cow performance over time can be evaluated for reproductive efficiency by reviewing statistics such as average calving internal or average number of days from one calving date to the next. Calf weaning weights are often collected at 160 to 240 days of age. Adjusted 205-day weaning weights can be used to estimate how efficient a cow is in terms of weaning as a percentage of her body weight (e.g., if she weans a calf that is 40% vs. 50% of her body weight). Changes in animal performance over time can be captured using record keeping and help provide a better picture of where nutritional adjustments may need to be made.

Review your stocking rate – Understanding the stocking rate of pastures is a good starting place for making nutritional adjustments. If a pasture is overstocked, then it may lead to poor individual animal performance because of the lack of forage available for animals. If a pasture is understocked, individual animal performance may be moderate to high because animals can more readily select from the pasture on an as-needed basis, but overall production from the pasture is not being optimized. Stocking rate adjustments, along with visual appraisal of animal condition, can help producers better utilize pasture resources with the view of increased animal production.

Forage Quality

What is forage quality and why is it important?

Forage quality is commonly described as the nutrient concentration of forages and its capacity to support digestible dry matter intake and animal performance. Whereas in the scientific and some technical literature the term forage nutritive value emphasizes nutrient concentration, quality is defined by the nutritive value and digestibility as they relate to voluntary forage intake in the absence of supplementation and is often expressed in terms of animal production such as growth, milk, or wool production. When determining the nutrient concentration, we are interested in the concentration (%) of crude protein (CP), digestibility (represented as invitro true dry matter or organic matter digestibility; IVTDMD or IVOMD), fiber (acid or neutral detergent fiber; ADF or NDF), fat (or ether extract), sugars (water soluble carbohydrates; WSC), ash (minerals), energy (represented as net energy for gain or lactation; NEg or NEl), and calculated total digestible nutrients (TDN) and relative forage quality (RFQ). Other parameters might be available depending on the analysis "packet" requested from the laboratory.

Understanding forage quality is important for predicting animal performance and determining supplementation requirements on grazed pasture or when feeding hay. Most people purchasing supplements will request information on CP and TDN, but many of them never take a forage sample from pasture or hay to assess the quality of the main diet component.

Factors influencing forage quality

Forage quality is affected by multiple factors including plant species, management practices and environment. Intake is determined by forage type (i.e., plant species, associated nutritional value and anti-quality factors, etc.), forage availability (herbage allowance) and canopy structure, composition and arrangement. Plant species and variety are the primary factors determining quality. Generally, legumes have greater concentrations of CP and TDN than most warm-season perennial grasses that usually have greater fiber concentration than annual forages. Another important factor is maturity or the physiological stage of the forage at time of utilization. The longer the (re)growth period, the more mature the plant is. With maturity there is an increase in fiber concentration, increase in senescing material and, at a later stage, appearance of reproductive structures (seedheads). With the exception of forages with high grain production (corn and sorghum), the quality will be at lowest levels during the reproductive phase. There is always a compromise between quantity and quality of forage. The longer the regrowth period is, more forage can accumulate up to a certain point, but the quality will be lower because some of the forage material starts to senesce. Seasonal patterns and environmental stresses also affect forage quality. Extreme heat in the summer can increase fiber accumulation and reduce digestibility, and forages at the end of the season tend to divert carbohydrates toward accumulation of reserves (perennial species) or seeds (annual species), thereby reducing growth and concentration of nutrients in leaves.

Generally, management affects quality in two ways; first, through the influence of regrowth interval on maturity, and secondly the impact of fertility levels on concentration of nutrients in forage tissues. A well-fertilized pasture will be healthier and able to sustain growth best. Limiting nutrients will limit growth, increase fiber concentration (as plants will shift towards reproductive stage earlier) and leave the plant more susceptible to pests and diseases. In general, concentration of nutrients is greater in new growth and at the top of the canopy. The lower the grazing or cutting height, the lower will be the nutritive value of the grazed or harvested forage. When cutting forage for hay, pre-harvest management (i.e., cutting intervaland cutting height) and post-harvesting management (i.e., rate of drying, ash contamination from tedding and raking, and moisture and rain) will affect forage quality. Last, anti-quality factors such as high concentration of tannins, nitrates, prussic acid, alkaloids or other components can have detrimental effects both on intake and on the absorption and utilization of nutrients.

Collecting a forage sample for analysis

The only way to correctly assess forage quality is through a laboratory analysis. For that, we need to collect representative samples of what is being either grazed or cut. For grazed pastures we target sampling the forages at the desirable grazing height (generally the upper half of the canopy height or to the defined stubble with rotational stocking). For hayfields, we need to sample at the desirable cutting height. Collect samples from each pasture separately. For large areas, it may help to collect divide it in smaller fields and collect several samples in a bucket, mixed them thoroughly and send a composite sample to the laboratory for analysis. It is the same approach that we use for soil sampling. Take into consideration differences in forage species, varieties, management, and soil types when dividing the pastures in sections for sampling, as this could help explain the variation in values and understand quality of each paddock/forage species. Delineate a *zig-zag* path to walk and a known number of steps that you will walk and collect a forage sample. Stop after each 20 steps and collect a hand-pluck sample in a bag or bucket and move on. The larger the area is, the more subsamples are needed in order to account for the variability throughout the field. At the end, there will be a composite sample of the whole area. If the sample size is too large, homogenize (mix thoroughly) and take a ~1-lb sample. Ideally, store samples in a paper bag to avoid spoilage and, if not shipping to the lab immediately, let the samples dry in open air or in a warm place. Do not microwave samples (as for determining dry matter) because it will denature protein and affect results. Alternatively, dry samples in an oven for a few hours assuring temperature does not go over 150 °F, which help stops respiration and prevents nutrient losses and spoilage.

Prior to collecting your forage sample, contact the local county Extension agent or testing laboratory to better understand the required procedure to send routine samples for analysis. Also, when shipping the samples to the laboratory, make sure you have stored them properly to avoid losses of forage quality due to spoilage. Prior to hay and baleage feeding, it is useful to analyze the feed to balance the animals' diet as needed. Use a hay probe with a power drill attachment to facilitate sampling from bales. When sampling bales, sample the round side of round bales or short side on square bales. After collecting samples each baleage sample, put heavy duty tape over each hole to avoid air and wildlife from getting inside bales, which may contaminate and decrease baleage quality. Whereas duct tape is convenient, it is not UV resistant and will degrade over time. Samples should be randomly collected from several bales to get an adequate representation of the average quality of the material. For more information, contact your local county Extension agent.

Interpreting a forage analysis report

A forage analysis report generally provides two columns of numbers. One column represents results on a dry matter basis, and the other is on an as-fed or as-received basis. When interpreting a forage analysis report for developing a supplemental feeding strategy, formulation is typically based on the dry matter basis column. Comparing forages on a 100% dry matter basis allows for a more equal comparison among different forages and feedstuff. It is important to understand what each parameter means and what the units represented to assure an equal comparison among parameters, if needed.

Definitions of selected parameters often reported on a forage analysis

1. **Dry Matter (DM), %.** Forage samples are oven-dried to determine the amount of water and dry matter in a sample. The dry matter % influences the stability of stored forages such as hay, baleage, and silage during storage. A goal of 85% dry matter is preferred for hay. Baleage may contain between 40 and 60% dry matter, and silage between 30 and 40% dry matter.

2. **Crude Protein (CP), %.** Crude protein is the total nitrogen in a forage sample multiplied by a 6.25 conversion factor. Protein is important for growth, milk production, and muscle development. A lactating beef cow needs a diet containing 11% CP on a daily basis during the first 60 days after calving. During mid-to-late lactation, CP needs decrease to 9%. A dry, pregnant cow has the lowest CP needs (7%) until the last 60 days before calving, after which nutrient needs begin to increase again.

3. **Neutral detergent fiber (NDF), %.** The NDF value is the total cell wall material, which consists primarily of hemicellulose, cellulose, and lignin. As forage NDF concentration increases, forage intake decreases. A commonly used predictor of dry matter intake by the animal as a percentage of its body weight per day as 120/NDF. For example, if the forage analysis reports a dry matter NDF value of 60%, then dry matter intake (as a % of body weight) = 120/60 = 2.0%. The estimated dry matter intake of this

forage is thus 2.0% of the animal's body weight. This approach may be limited for some forages, more so for warm-season than cool-season grasses and legumes.

4. **Acid detergent fiber (ADF), %.** Acid detergent fiber is an estimation of the component of the forage cell wall that is typically less digestible than NDF for the animal. This value refers to the cell wall portions of the forage that are made up of cellulose and lignin. The greater the ADF, the less digestible forages become to the animal. Both NDF and ADF increase as the forage becomes more mature because of increasing cell wall content. Most widely used perennial forages have an ADF value of 40% or greater. The ADF value is often used to predict forage dry matter digestibility.

5. **Total digestible nutrients (TDN), %.** Energy value of a forage is expressed as total digestible nutrients. Typically, the greater the value, the more digestible energy the forage contains. Low-quality hay is generally 45 to 52% TDN, medium-quality hay is generally 52% to 58% TDN, and high-quality hay is greater than 58% TDN. A dry cow requires a minimum of 48% TDN in its diet, and a lactating cow needs a diet that is at least 60% TDN.

6. **Net Energy.** Some forage reports provide information on net energy of samples submitted. The Net Energy System provides an indication of how the energy provided by the forage will be used by the animal. Energy needs can be divided into maintenance (NE_m), lactation (NE_L) or gain (NE_g). Net energy for maintenance represents the energy required for daily living, such as maintaining body temperature, physical activity and breathing. Net energy for lactation is the energy needed for milk production. Net energy of gain is energy used for production purposes, such as growth. As an example of application of this information, a producer may evaluate the 'net energy of gain' as a measure when trying to target a specific rate of gain.

7. **Relative Forage Quality (RFQ).** A single value that can be used to compare the overall quality of one or more forage samples is RFQ, which integrates a number of forage quality parameters that affect potential animal performance. In general, RFQ

values range from 50 to 300, with the upper end representing the highest-quality forage. The greater the nutrient demands, the higher the forage nutritive value that is needed to support satisfactory animal performance. Table 7 illustrates target relative forage quality values needed to meet the nutrient requirements of livestock in various stages of production.

Table 7. Range of relative forage quality (RFQ) values for livestock in various stages of production.

Animal Class and Stage of Production	**RFQ**
Non-lactating cow/ewe/doe; Idle horse; Dairy heifer, 18 to 24 months	100 to 120
Beef cow with calf; Dairy heifer, 12 to 18 months; Ewe with lamb; Doe with kid	115 to 135
Nursing mare; Hard-working horse	120 to 140
Dairy heifer, 3 to 12 months; Stocker cattle; Growing lambs and kids	130 to 145
High-producing dairy cow	140 to 160

8. **Nitrate-Nitrogen, parts per million (ppm).** Plants under stress can accumulate excessive amounts of nitrates, which at elevated levels (>5000 ppm) can be toxic to livestock. Forage crops such as certain summer annuals and bermudagrass may accumulate nitrates under conditions of high fertility, drought stress, etc. A nitrate-nitrogen range of 0 to 1,500 ppm is generally safe to feed. In the upper range, use caution when feeding pregnant or young animals, and prevent over-consumption (which is sometimes observed in feeding large round bales). When values range from 1,500 to 5,000 ppm, limit forage to half of the total daily dry matter intake. To avoid high-nitrate diet, feed a balanced ration with adequate energy, and do not feed with liquid feed or other common sources of nonprotein nitrogen supplement such as molasses-based tubs. If nitrate-nitrogen values exceed 5,000 ppm, the forage is considered toxic to livestock, and should not be used in a free-choice feeding situation.

9. **Minerals (%).** While some reports will provide calcium and phosphorus values, which are macrominerals, most laboratories require an additional request to provide mineral values and may incur additional feeds. Mineral analyses are typically requested as part of a total nutrition program evaluation. By understanding the components of the forage

and supplemental feeding program utilized on the farm, a mineral analysis may provide additional information on areas for improvement. If forages are sampled for mineral analysis, it is important to obtain samples from across the growing season under similar stage of growth. This is because mineral values in forages will vary throughout the growing season based on management and growing conditions.

10. **pH.** This is a measure of the degree of acidity in ensiled forage crops. Good corn or sorghum silage generally has a pH of 3.5 to 4.5, and baleage from 3.5 to 5.5. This information provided on a forage analysis and provided an indication of how well the fermentation process occurred for conserved feed which should reflect its ability to maintain forage quality over time.

General Rules of Thumb Related to Forage Quality

- As forages reach maturity, nutritional value declines. Therefore, longer (re)growth periods may increase forage quantity but will adversely impact its quality.
- Forage analysis provides a measure of nutritional value and may help reduce supplemental feed needs on the farm.
- Livestock can consume more high-quality forage than low-quality forage due to the lesser fiber concentration of the latter.
- Match the nutritional value of forage to the animal stage of production or growth.

Resources

1. Adesogan, A.; Vendramini, J.; Sollenberger, L. Defining forage quality. Available at https://edis.ifas.ufl.edu/publication/ag332
2. Hancock, D.; Stewart, L.; Saha, U.; Bernard, J.; Smith, B. Understanding and improving forage quality. Available at https://extension.uga.edu/publications/detail.html?number=B1425&title=Understanding%20and%20Improving%20Forage%20Quality
3. Mullenix, K.; Tucker, J. Collecting forage samples for laboratory analysis. Available at https://www.aces.edu/blog/topics/farming/collecting-forage-samples-for-laboratory-analysis/
4. Wallau, M.; Adesogan, A.; Sollenberger, L.; Vendramini, J.; Dubeux, J. Factors affecting forage quality. Available at https://edis.ifas.ufl.edu/publication/ag161

Weed Control

One of the main components of an integrated weed management strategy is proper identification of problematic species. This is especially important when utilizing chemical control options through the use of herbicides. Considering the countless number of weed species that occurs across the Southeast and the many forage-labeled herbicide options, proper weed identification is important to ensure more profitable forage production.

Definitions and the breakdown of weeds: monocots vs dicots

First, the generally accepted definition of a weed is simply a plant growing out of place. Crabgrass is a good example. Crabgrass species are generally a highly nutritious, desirable forage in grazing pastures, but it is usually considered a weed in high quality bermudagrass hayfields because of its varying textures and moisture holding capability. Weed species can be broken down into two broad categories; grasses (monocots) and broadleaves (dicots). Monocots emerge with a single seedling leaf and are usually referred to as weedy grasses. Examples include smutgrass, cogongrass, goosegrass, vaseygrass, and foxtail. Dicots emerge with two seedling leaves. Examples of dicot weeds include thistle, horsenettle, dogfennel, pigweed, and buttercup.

Weeds are further categorized by their length of life. Species may be perennial, biennial, or annual. Perennial weeds have a life span lasting longer than two years and may reproduce by both seed and plant parts like roots and rhizomes. Biennial weeds take two years to complete their life cycle. Biennial plants usually emerge as a seedling and store up root reserves in the form of a rosette during the first year, then produce mature seed during the second year. Annual weeds emerge as a seedling, grow, produce flowers, and set mature seed within one year. The majority of acreage in Southeastern forages consists mainly of grasses like bermudagrass, bahiagrass, tall fescue, or ryegrass. Broadleaf weeds in grass forage are generally most easily recognized. Likewise, unwanted grass weeds may be easily spotted in broadleaf forages like alfalfa and clover. This doesn’t necessarily mean that these weeds will be easily controlled when they occur in forages of opposite growth characteristics. Factors such as growth stage, life cycles, and environmental conditions play a large role in successful management.

Seasonal weeds and control recommendations

Annual broadleaf weeds

Warm season: As spring soil temperatures increase and daylight lengthens southern forages will experience weeds like pigweed, spurge, cocklebur, croton, fleabane, ragweed, sneezeweed, marshelder, sicklepod, and sida.

Cool season: During the fall as air and soil temperatures decrease, weeds like buttercup, chickweed, cress, henbit, horseweed, sowthistle, and vetch begin to emerge.

Generally, this weed spectrum may be most effectively controlled with a foliar-applied herbicide while plants are small and actively growing or with a preemergence herbicide prior to seed germination. Since seedling root systems are relatively weak compared to perennial broadleaf weeds, lower postemergence herbicide rates may be cost effective and provide adequate control when weeds are under two inches tall. In addition to postemergence herbicide options provided below for use in established grass forage crops, effective active ingredients for preemergence weed control include indaziflam (Rezilon) and pendimethalin (Prowl H2O). Preemergence herbicides should be applied prior to weed seed germination. Rainfall is necessary for soil incorporation.

Perennial broadleaf weeds

Warm season: Weeds that will be emerging in the spring from the previous year's root system are species such as dewberry, dogfennel, goldenrod, hemp dogbane, horsenettle, tall ironweed, pokeweed, and vervain.

Cool season: Perennial broadleaf weeds begin to show up as soil temperatures and the warm season forage crop begins to decline during the fall. These include weeds like buttercup, dandelion, dock, plantain, and Virginia buttonweed.

Contrary to the early herbicide timing for annual broadleaf weed control, the most effective application timing for many perennials is when the plant has reached full leaf expansion. Furthermore, utilizing herbicide products with more than one active ingredient often provides more successful control especially when it is active in the soil for root uptake.

Effective herbicide active ingredients for warm season broadleaf weed control *

**2,4-D, aminopyralid, dicamba, fluroxypyr, picloram, triclopyr

*** hexazinone, metsulfuron, nicosulfuron, sulfosulfuron

*These recommendations are solely for weed control in grass forage. Do not use in broadleaf forage crops such as alfalfa or clover unless the label states otherwise.

**Active ingredients are generally safe to use in all established grass forage crops under ideal environmental conditions.

***Intended use of these active ingredients is specifically meant for certain grass forage crops.

Annual grassy weeds

Warm season: Undesirable annual grasses that germinate in the spring and persist throughout the summer months may include barnyardgrass, broadleaf signalgrass, crabgrass, crowfootgrass, foxtail, goosegrass, junglerice, and sprangletop.

Cool season: Those germinating in the fall and persisting throughout the winter months may include annual bluegrass, annual ryegrass, brome, little barley, and rescuegrass.

Many of these may be best controlled by the use of a preemergence herbicide application prior to weed seed germination. For spring-germinating weed seedlings, applications of indaziflam (Rezilon) or pendimethalin (Prowl H2O) during February – March may provide the most effective control while avoiding injury to certain established grass forage crops. For those annual grassy weeds germinating in the fall, these preemergence applications should be made mid-September to early-October. Rainfall is necessary for soil incorporation of these products. Postemergence herbicide active ingredients that may control or suppress these weeds include hexazinone, metsulfuron, nicosulfuron, quinclorac, or sulfosulfuron. These are specifically labeled for use in certain grass forage crops. Clethodim and sethoxydim are active ingredients available for postemergence weedy grass control in broadleaf crops such as alfalfa and clover.

For cool season annual weeds in dormant warm season forage crops, non-selective herbicides like glyphosate or paraquat can be effective without undue injury to desirable forages.

Perennial grassy weeds

Warm season: Established roots of perennial grassy weeds may arguably create some of the most difficult weed management scenarios, especially in grass forage crops. Some warm season perennial grassy weeds present in southeastern forages include carpetgrass, centipedegrass, cogongrass, johnsongrass, knotroot foxtail, smutgrass, and vaseygrass.

Cool season: Tall fescue may be one of the few undesirable, cool season perennial grasses if it occurs in warm season forages like bermudagrass or bahiagrass.

Postemergence herbicide active ingredients that may control or suppress these weeds include hexazinone, metsulfuron, nicosulfuron, quinclorac, or sulfosulfuron. The use of these products by broadcast application is specific to certain forage crops. Consult herbicide labels to avoid crop injury. Glyphosate may be used in spot spray, rope wick or roller/wiper applicators on taller grassy weeds for more selective treatment in sensitive forage crops. Clethodim and sethoxydim are active ingredients available for postemergence weedy grass control in broadleaf crops such as alfalfa and clover. For calibration, consult the **calibration for herbicide application** publication available at ACES.edu > **ANR-2693** publication).

Boom vs. Boomless

Boom sprayers are most often used as tractor-mounted systems in row crop production or by smaller landowners using atv-mounted equipment. Depending on the operation, booms may span a width of 4 feet, up to 60+ feet with multiple nozzles equally spaced along the boom length to deliver a uniform spray pattern. One of the benefits of a boom-type system is the precision and uniformity at which the spray solution is delivered to the target pest and the ability to deliver small spray droplets to newly emerged weeds. A constraint, however, is that booms may lack robustness for rough, undulating terrain, or obstacles like trees or fences that frequently exist in pastures.

Boomless sprayers are often mounted on tractors or atvs for broadcast applications in forage pastures, hayfields, or noncrop scenarios. These systems typically have a single nozzle or may be designed with up to three nozzles that produce patterns that range up to 50 feet swath. These spray designs are useful for tight spaces, uneven terrain, brush control, or chemically side-trimming fence rows and rights-of-way. Unfortunately, boomless nozzles are somewhat limited in precision compared to boom sprayers. For example, when output flow rates are increased or nozzle height above target is raised in order to extend effective swath widths, drift potential also increases. This often isn't the best design for contact herbicides or application to newly emerged vegetation, but can be highly effective for applications of soil-active, residual chemistries and treatment of larger plants typically sprayed in forage systems.

Check your equipment first

- Check all lines, hoses, and tank for dry-rot, cracks, holes, etc.
- Check pumps and connections for leaks
- Remove, inspect, and clean strainers, screens, nozzles, end caps
- Make certain all nozzles are the same size and discharge angle and have the appropriate screen size for the nozzle output
- Flush the entire system with clean water
- Replace all components and use clean water to ensure proper working order
- Gather measuring tape, containers, gloves, stopwatch, and other equipment needed for calibration (Figure 1)
- On boom sprayers catch output from each nozzle to make certain output from all nozzles is within 10% of the average from all nozzles; replace any nozzle outside the average.

Boom Sprayer Calibration

Among the many ways to calibrate a sprayer, the simplest is the 1/128th acre, also called the 'baby bottle' method. We're simply scaling down our calibration course to

1/128th acre (340 ft^2) since there are 128 fluid ounces in a gallon. This means that the spray collected from a single nozzle in fluid ounces directly correlates to gallons per acre (GPA) regardless of the number of nozzles on the boom.

1. Fill the sprayer with clean water
2. Measure nozzle spacing in inches, then convert to feet by dividing by 12.
3. Refer to the following chart to determine calibration course.
4. Measure and stake off the appropriate calibration course based on nozzle spacing. The course should be on the same type of ground as that to be sprayed. (Speeds may be faster on roads than on sod, changing the application rate).
5. Drive the course in the speed, gear, and rpm you will use when actually spraying. Record the time in seconds. Do this twice and get an average.
6. Park the tractor/vehicle and maintain the same rpm.
7. Turn on the sprayer and catch the water from one nozzle for exactly the same time that it took to drive the calibration course (Figure 2).
8. Ounces caught = gallons per acre.

COURSE LENGTHS FOR BOOM SPRAYER CALIBRATION

NOZZLE SPACING (IN)	Length of Calibration Course[1] (ft)
14”	292’
16”	255’
18”	227’
20”	204’
22”	186’
24”	170’

[1] To determine calibration course for a nozzle spacing not listed, First convert the distance between two nozzles from inches to feet. Then divide 340 by the nozzle spacing in feet (1/128th of an acre is 340'). Example: Calibration distance for 19” nozzle spacing = 340 divided by 19/12 = 215 feet.

Boomless Sprayer Calibration

Like the boom sprayer, we need to scale down to a fraction of an acre, in this case 1/8th of an acre (5,445 ft^2) as output will be measured in pints. The sprayer output collected from the boomless nozzle measured in *pints* will directly correlate to gallons per acre (GPA).

1. Fill the sprayer with clean water.
2. Turn the sprayer on and measure the effective swath width in feet. Spray patterns are most visible on dry soil, concrete or gravel.
3. Refer to the following chart to determine calibration course:
4. Drive the course in the speed, gear and rpm you will use when actually spraying. Record the time in seconds. Do this twice and get an average.
5. Park the tractor/vehicle and maintain the same rpm.

6. Turn on the sprayer and use a trash bag or other improvised funnel and bucket to catch the water for exactly the same number of seconds required to drive the calibration course (Figure 3).
7. Pints caught = gallons per minute (GPM).

COURSE LENGTHS FOR BOOMLESS SPRAYER CALIBRATION

EFFECTIVE SWATH WIDTH (FT)	Length of Calibration Course[1]
12’	454’
16’	340’
20’	272’
24’	227’
28’	194’
32’	170’
36’	151’
40’	136’

[1] To determine the length of calibration course for a swath not listed, divide 5,445 ft2 (1/8 acre) by the swath width in feet. Example: Calibration distance for 26' swath width = 5,445 divided by 26 = 209 feet.

Points to Remember:

- If your equipment does not have a pressure gauge, you can affect output (GPA) by changing speed, raising or lowering nozzle above target, or changing nozzles
- If you’re changing GPA by adjusting the pressure gauge (PSI), you must increase or decrease PSI 4x in order to double or half, respectively, GPA
- In order to double the output (GPA), speed (MPH) should be decreased by 50%

Insect Pest Management

There is a diversity of insects in forage crops. Many will be beneficial or incidental, however there are some that can lead to economic losses. Therefore, it is important to know the different insects in your field and how to manage potential pests.

Plant Injury by Pests

There are several factors that determine how a plant responds to injury by pests. Forages are typically able to withstand some injury before damage leads to yield loss. The type and intensity of pest feeding can determine the level of damaged sustained. Forage pests have different types of mouthparts that include chewing and piercing-sucking. They will feed on various parts of the plant, such as the leaves or roots, than can interfere with plant processes including photosynthesis or nutrient uptake. Substantial feeding can cause lodging, stand loss, or delay plant development.

Integrated Pest Management

Integrated pest management (IPM) is a strategy that uses multiple tools to combat pests and minimize economic and environmental risks (Figure 12). Biological, chemical, cultural, and physical controls are all techniques that can work together to manage insect pests effectively. Examples of these techniques include varieties specifically adapted to your area, the use of insect resistant or tolerant varieties, planting within the correct planting date, and insecticides applied at the economic threshold.

A vital component of an IPM strategy is to regularly scout fields. Once or twice a week, the field should be inspected to assess crop growth as well as pest and beneficial insect populations. The easiest way to assess insect levels is with a sweep net (Figure 2). Check several areas of the field and note the number and life stage of pests and also beneficials present. This information will factor into management decisions.

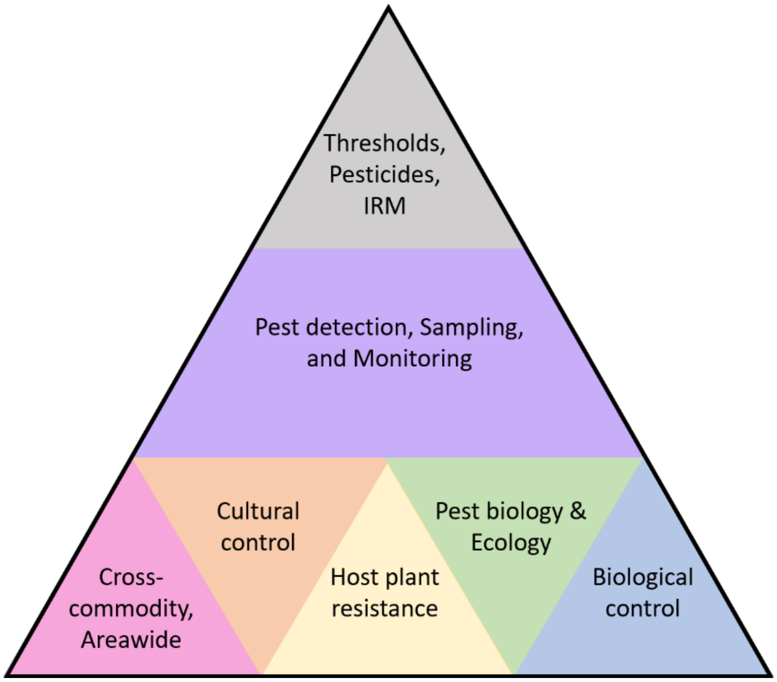


Figure 12. IPM Triangle showing different tactics for pest management

There are many beneficial insects that live in forages and help to keep the pest population down. Common natural enemies include ladybeetles, ground beetles, minute pirate bugs, damsel bugs, spiders, and syrphid larvae. There are also a variety of wasps that parasitize pests. If possible, chose pesticides that are more specific to target pests and less harmful to natural enemies.

Figure 13. Caterpillars caught using a sweep net (left) and on pasture (right).

Management

Chemical control is a useful technique in forages to quickly reduce a pest population. Insecticides should only be used when the plant damage by pests or the pest population approaches levels that will lead to yield loss greater than the cost of treatment. Pests have unique thresholds based on their biology, ability to damage the crop, and the cost to treat. Preventative pesticide applications should not be used. These can decrease beneficial insect populations and promote resistant pest populations. Always read and follow label directions. Insecticides with different modes of action should be rotated. It is important to use chemicals that target pests in a variety of ways so as not to increase the proportion of resistant individuals in the population. If insecticides with the same mode of action are used repeatedly, it will select for resistant insects in the population more quickly. Thus, when choosing an insecticide, multiple factors should be considered. The efficacy, safety, specificity, and timing should all factor into the decision. Refer to the insecticide label for information on pre-harvest or pre-grazing intervals.

Major Insect Pests

Fire Ants

Fire ants are a pest of pasture and hayfields with their ability to damage equipment and aggravate or harm humans. The red imported fire ant, *Solenopsis invicta*, and the black important fire ant, *Solenopsis richteri*, were accidentally introduced into the southern United States and have remained a pest since. They feed on a variety of food, including some pest insects. In hay pastures, tall mounds can damage cutting machinery and ants may consume forage seeds (Figure 14). While uncommon, damage to young livestock and wildlife is possible with fire ants. Economic losses occur when ants interfere with animal operations. For certain operations, the cost to treat may not be economical. Land managers should consider treatment in areas where fire ants are interfering with human and animal activities.

Figure 14. Fire ant mound underneath fencing in a bahiagrass pasture.

Broadcast applications of a bait are the most cost effective and environmentally sound approach for fire ants in large areas. These applications are most suited for areas with more than 20 mounds per acre. Fall is the best time for bait applications and will provide slow-acting control. You can expect control 4-8 weeks after application with control lasting 8-12 months. If there are a small number of individual mounds, or immediate treatment is required, a mound treatment of a registered product can be used. Fast-acting baits are available (2-4 weeks) but do not last as long (3-8 months).

Armyworms

The true armyworm, *Mythimna unipuncta*, is a spring pest of cool-season grasses and tall fescue (Figure 15). Fall armyworms, *Spodoptera frugiperda*, are summer pests of bermudagrass, fescue, and fall-seeded grasses. A cool, wet spring can lead to outbreaks of the true armyworm in cool-season grasses. Fall armyworms are a consistent pest in the southeast, and hot, dry weather can increase the chance of an outbreak.

Figure 15. True armyworm in a sweep net.

Fall armyworms have an inverted “Y” on their head and four raised bumps that form a square on their posterior end (Figure 16). True armyworms have varied coloration but will have a dark spot on each of the abdominal prolegs. Use a sweep net in wheat or pastures to find worms. Avoid scouting in the heat of the day as the worms will be hiding in or on the soil or in leaf litter. Visit several parts of the field when you are scouting to get an accurate representation. Increased bird activity in the field may also be a sign that you have armyworms. An insecticide application should only be made after considering the size of the worms and the growth stage of the hay. If the field is ready for harvest, you can cut and bail rather than applying an insecticide. Larger worms are harder to control than smaller worms using chemical control. Pyrethroids can provide immediate knockdown and work well on small or medium worms but have a shorter residual. Insect growth regulators work best on small worms and will have no effect on larger worms that are ready to pupate.

Figure 16. Head capsule of fall armyworm showing inverted “Y” (left) and posterior end with 4 raised bumps (right). Courtesy of Pat Porter, Texas A&M Agrilife Extension.

Bermudagrass stem maggot

Bermudagrass stem maggots (BSM) are the larval form of an invasive fly pest that is relatively new to the southeast. Bermudagrass and stargrass are the only hosts of this pest. The adult fly is 1/8 inch long with big dark eyes and several dark spots on their yellow abdomen. The larvae are the damaging life stage and will be feeding inside the plant stem (Figure 17). The adults are very active in the field and will be easier to spot than the larvae. The whole life cycle of BSM lasts about three weeks with multiple generations per year. After feeding on the plant, larvae will drop into the soil to pupate before emerging as an adult. BSM feed inside of plant shoots which results in death for the top two or three leaves. These dead leaves give the field a frosted appearance and can easily be pulled from the sheath (Figure 18). The shoot will stop elongating and the plant may put outside shoots; these newer shoots are vulnerable to attack by the next generation of BSM.

Figure 17. Bermudagrass stem maggot larva (left) and adult (right)

Bermudagrass varieties with finer stems tend to have greater infestations. Grazed pastures are less affected by BSM because livestock consume larvae as they graze. If an infested field is within a week of harvest, it can be harvested. However, any surviving larvae will burrow into the soil to pupate and complete their life cycle. Therefore, 7-10 days after cutting, an insecticide application may be necessary. Pyrethroids are current the only option and must be sprayed when adults are present.

Figure 18. Damage caused by bermudagrass stem maggot feeding.

Grasshoppers

Grasshoppers are a sporadic pests, but capable of causing damage during outbreak years. Grasshoppers overwinter as eggs then hatch into nymphs with increasing soil temperatures and spring rains. Nymphs cannot fly and are less mobile than adults. They are usually found in the field margins next to grassy edges or a treeline. If grasshopper populations are found early, a border spray may be effective rather than treating the entire field. However, if the grasshoppers have matured, they are more mobile and have likely moved through the entire field. Larger grasshoppers are also more difficult to kill. Treatment is warranted when populations are heavy and defoliation is occurring. If an entire field is infested, one option is to harvest the field early then apply an insecticide to protect the regrowth.

Chinch bugs

Chinch bugs can be a pest of summer grass forages. They use piercing-sucking mouthparts to suck plant juices from the base of the plant. The result can be brittle stems, discoloration, or wilting. Hot, dry conditions can exacerbate chinch bug problems and populations are hard to control once populations become high. Fields should be scouting early in the season when chinch bugs are easier to control. If an insecticide application is warranted, the spray should be directed at the base of the plants where the bugs are located.

May, June, and green June beetles

There are four types of grubs that can cause problems in forages. Green June beetles, May beetles, southern masked chafers, and Japanese beetles are all pests in the larval stage. Infestations typically occur in mixed populations of these species. They all have various life cycles, damage potential, and response to insecticides, making management decisions difficult.

Figure 19. Typical green June bug damage.

Green June beetle larvae are associated with pastures which use broiler litter or manure as fertilizer. The green June beetles tunnel just below the surface, disrupting the plant-soil interface (Figure 8). The other species of white grubs cause damage through root feeding. Severe infestations can take out a whole field if left unchecked. Currently, there are only insecticides registered for control of green June beetle in pastures. Cultural practices such as proper varietal selection, irrigation, and fertilization can help reduce the risk of problems with white grubs.

Billbugs

The bahiagrass billbug, *Sphenophorus coesifrons*, is a pest of bahiagrass. Adult billbugs lay eggs into the tillers of bahiagrass. Once the larvae hatch, they feed on the rhizomes and result in tiller death. Damage begins as small patches of dead grass that get bigger each year as both adults and larvae feed (Figure 9). Adults cannot fly, so field infestations are from crawling adults or accidental introduction on vehicles or equipment. Billbug larvae are cream colored with a tan head capsule and no legs (Figure 10). The lack of legs is the easiest way to distinguish a white grub from a billbug. We do not have effective tools for managing billbugs in bahiagrass. Spring is the best time to treat for adults before they can lay eggs in the grass. Pyrethroids or carbaryl can be used for the adults, but multiple applications may be necessary.

Figure 20. Damage from bahiagrass billbug. Note discoloration in middle of field that is beginning to form a circle.

Figure 21. Billbug larvae in a bahiagrass pasture.

Blister Beetles

Blister beetles are very distinct looking beetles with a narrow neck and a broad head (Figure 22). They have long skinny legs and their bodies are anywhere from ½ in to 1 in long. Their antennae are about 1/3 the length of their body. Their shorter antennae distinguishes them from another group, the long-horned beetles, which have much longer antennae. Blister beetles come in various colors but gray, black, yellow, or orange is common with various patterns. We are concerned with blister beetles not because of yield loss but rather because of the threat they post to livestock. Blister beetles get their name because they cause skin blistering on humans and animals.

Figure 22. Blister beetles come in a variety of colors but have a distinct broad head and narrow neck. Photo courtesy of Pat Porter, Texas A&M Agrilife Extension

Beetles possess a chemical, cantharidin, which they can squeeze from their leg joints when threatened. This serves as a defense mechanism from potential predators. Blister beetles in hay pose a threat; they can be eaten whole, crushed, or otherwise exude cantharidin. This can lead to internal blistering and inflammation in animals feeding on the hay. While all species of blister beetles do produce cantharidin, the content varies among species, individuals, and locations. Therefore, it is difficult to estimate the number of beetles that are toxic to livestock. Research has shown that horses are the most susceptible while sheep and cattle are more tolerant. The age, size, breed, and overall health of animal play a role in blister beetle toxicity. Proper identification of blister beetles is key. If you are growing your own alfalfa, you can scout for blister beetles. Otherwise, it is important to know your hay suppliers and their management practices. Weeds should be controlled in and around alfalfa so there are not alternative hosts for the beetles. Blister beetles are attracted to flowering pants, so a harvest before or soon after bloom begins would reduce the chances they are present. Before harvest, scout the field. If present, blister beetles may swarm during harvest. If they do swarm, stop harvesting and let them disperse. An insecticide treatment may be necessary prior to harvest; recheck field prior to application.

Forage systems for horses

Good forage management practices and utilization of pasture in equine operations can help reduce feeding costs and environmental impacts while maintaining horse health and welfare. While there are many appropriate forage choices for horses, the most appropriate forage for pasture establishment or improvement of existing pasture(s) depends on many factors including purpose or objectives of the farm, site characteristics, and management level. The following are some important aspects to consider when planning a forage program:

- Which species can be grown in the selected area, depending on adaptation to climate and soils
- Matching growing season with peak demand both in terms of forage quantity and nutritive value
- Purpose or primary use of the forage. For example, will this forage be grazed or used for hay production? will this forage be use for temporary turnout or continuous pasture access; or will this forage be the primary or supplemental source of fiber and nutrients?
- Class or physiological status of horses (maintenance, growing horse, broodmare, breeding stallion, horses in training or various levels of work)
- Level of management required for optimum pasture productivity versus the goals and experience of the manager (available resources such as time and equipment are also important considerations)

Bahiagrass, ryegrass, and white clover are adapted to a wide range of soil drainage types and are more tolerant of wetter areas. Forages such as bermudagrass, perennial peanut, and small grains, however, do not tolerate poorly drained soils. A greater level of management is typically required to produce higher-quality forages (e.g., bermudagrass and small grains often require more management and fertilization compared to bahiagrass since the primary purpose of the bahiagrass is to maintain ground cover). Extending the growing season can be accomplished by mixing and matching forage species and management practices. Cool season forages can be incorporated into warm-season pastures to extend the grazing season, reducing reliance on hay as the sole source of forage during the winter months. Some forage species require a prepared seedbed for establishment while others can be overseeded or drilled into existing forage material. Broadcasting (e.g., ryegrass seed for winter grazing) can also be done when access to equipment is limited.

Forage Species

A brief description of possible forage choices for horses is included here. The nutrient composition of forages commonly utilized in southeastern horse operations is shown in Table 8. The Florida Forage Handbook: Table of Contents (http://edis.ifas.ufl.edu/ag170) provides a detailed discussion of production and management of forage crops.

Table 8. Concentration of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), total digestible nutrients (TDN), and digestible energy (DE) of common pasture forages grown in the Southeast region.

Forage Species	CP (%)	NDF (%)	ADF (%)	TDN (%)	DE (Mcal/lb)
Coastal bermudagrass **	10-14	50	29	52-58	0.89
Bahiagrass	8-11	68	33	50-54	0.97
Tifton-85 bermudagrass	15	77	33	66	1.32
Perennial peanut	14-18	42	32	60	1.1
Ryegrass	18-22	50	22	60	1.2
Oat	14-18	42	22	65	1.3

* Ball, Hoveland, and Lacefield (2002) and Wallau et al. (2019).
** Note that forage quality will vary with level of maturity of plant.

Nutrients Provided by Forages

Horses are non-ruminant grazing herbivores that evolved to consume high-fiber, low-energy diets. They are hindgut fermenters and rely on a symbiotic relationship with hindgut microorganisms to digest and convert forage fiber components to energy. The products from hindgut fermentation can provide the horses up to 80% of their daily maintenance energy requirements. Therefore, forages are the base of their nutrition and, depending on the horse class, they may have their nutritional requirement met by all-forage diets with no supplemental feed needed. Classes of horses with low nutritional needs, such as mature horses doing little or no work, may only need supplemental feed if provided with very low-quality forage. However, the decision on selecting the forage species and whether to use supplemental feeding must be made based on the class of the horse and the forage quality and availability. Horses need to eat sufficient forage to obtain the basic nutrients: energy, protein, vitamins, minerals, and water. Additionally, the fiber contained in forages maintains the health and normal function of the horse's digestive tract. Forages have numerous other benefits including keeping a horse preoccupied, mimicking natural small and frequent meals, providing energy, and aiding in keeping the horse warm during the winter since fermentation in the horse's hindgut naturally produces heat.

Digestible energy. Energy is not an identifiable chemical component; instead, it is released when energy-containing substances are broken down in the digestive tract of horses. The energy ingested is known as gross energy. The portion of the consumed gross energy (feed gross energy) retained in the body after losses of gross energy via feces (fecal gross energy) is known as digestible energy. In horse nutrition, digestible energy is expressed in mega calories (Mcal = 1,000,000 calories) and used to represent the feed available energy, similar to the total digestible nutrients (TDN) terminology, which describes the feed available energy in ruminant nutrition.

The two primary sources of energy for the body are carbohydrates and fat. Protein can serve as an energy source, but to a less extent compared to carbohydrates and fat. Carbohydrates are categorized as structural and nonstructural carbohydrates. The structural carbohydrates, such as hemicellulose and cellulose, are digested by microorganisms in the horse's hindgut resulting in fermentation products (volatile fatty acids) that provide energy to the horse. In forage testing reports, the structural carbohydrates are reported as neutral detergent fiber (NDF) and acid detergent fiber (ADF). The nonstructural carbohydrates, such as starch and simple sugars, are digested in the horse's foregut and result in glucose being absorbed and used as energy fuel by the horse's body. In forage testing reports, the nonstructural carbohydrates are reported in several different fractions, such as starch, ethanol-soluble carbohydrates (ESC), water-soluble carbohydrates (WSC), or simply as nonstructural carbohydrates (NSC). Fats can provide nearly three times as much energy as carbohydrates do. Forages do not contain a lot of fat. In a forage testing report, fat is reported as ether extract and ranges from 2 to 4% in forages. It is important to highlight that although containing low fat levels, forages have greater concentrations of Omega-3 than Omega-6 fatty acids, which is the ideal ratio for providing the horses with health benefits, while most grains have much greater concentrations of Omega-6 than Omega-3.

Crude protein. Proteins are essential for muscle growth and maintenance, the endocrine system, and the transport of nutrients in the body, among other essential roles. Protein is digested to amino acids and dipeptides, and these are then used for protein synthesis. If protein is consumed over its requirement, the exceeding protein is excreted via feces and urine, decreasing the diet's profitability and increasing environmental impacts and potential risks to the horse and human health.

Vitamin and Minerals. A healthy horse on good pasture does not need supplemental vitamins, except for vitamin E if the horse is exercised. Horses fed hay-only may require vitamin A supplementation; however, it is advised to consult a horse nutritionist to avoid toxicity. As for minerals, they are the most variable of all nutrients in forages. Mineral concentrations vary based on soil mineral concentration, plant species and maturity, and conditions at harvesting. Levels of minerals decrease as the plant matures. Regardless of the forage type, a free-choice mineral supplement is recommended. However, not all horses will readily consume these supplements free-choice as horses do not have a mechanism to seek out minerals lacking in their diet, with the exception of sodium and chloride found in salt. Calcium (Ca) to phosphorous (P) ratios in forages are usually 1:1 or greater. Although calcium and phosphorous should be fed in a ratio that ranges from 3:1 to 1:1, adequate intake of P allows Ca:P ratios of up to 6:1 in the diet of most classes of horses.

Recommended forages

In general, high-nutritive value forages should be used in diets of high-nutritional requirement horses, such as young growing horses, lactating mares, and heavy-working horses. Conversely, low- to moderate-nutritive value forages should suffix horses' nutritional requirements with lower nutritional needs, such as adult maintenance horses and non-breeding stallions (Table 9).

Table 9. Range of digestible energy (DE) and crude protein (CP) daily requirements and target concentrations of forage for different classes of horses.

Horse class	**Daily requirements***		**Target value of forage****	
	DE (Mcal/day)	CP (lb/day)	DE (Mcal/lb)	CP (%)
Maintenance	14-16	1.1-1.4	0.68-0.82	5.4-7.2
Moderate Working	21	1.5	1.06	7.7
Intense Working	31	2.0	1.56***	10
Pregnant Mare	15-19	1.3-1.8	0.76-0.97	6.3-8.9
Lactating Mare	24-29	2.5-3.1	1.23-1.44***	12.7-15.3
Growing	14-18	1.4-1.6	1.12-1.63***	10-16

*Adapted from NRC for horses (2007).

**Considering dry matter daily intake of 2% of body weight for a 1,000-lb adult horse or 500-lb growing horse.

***Horses will likely need concentrate feed if forage quality is not limiting.

As in ruminants, forage maturity affects its digestibility by the horse. However, horses have limited ability to utilize poor quality forages as cattle can. Therefore, the selection of good-quality forages is pivotal in horse nutrition for achieving improved performance, such as growing, lactation, and exercise. Usually, high-quality forages are high in digestible energy and crude protein levels and low in fiber components.

Legumes generally have greater nutritive value at the same stage of maturity than grasses, providing greater concentrations of DE, CP, minerals, and vitamins and lower in most fiber components. Digestible energy levels in legumes are 1.11 Mcal/lb DM, while in grasses, DE is approximately 0.94 Mcal/lb DM, with warm-season having lower DE than cool-season grasses. In addition, legumes are usually higher in protein than cool-season grasses, while warm-season grasses are generally the lowest in crude protein. Hemicellulose and NDF are typically greater in warm-season grasses compared to legumes, and cool-season grasses have intermediate NDF concentrations. Although legumes are higher in lignin, their lignin is strategically located in specific tissues of the plans resulting in less consequence to digestibility compared to grasses. Regardless of the forage species, forages in a late stage of maturity are less digestible than immature forages due to higher proportions of stems and hence levels of NDF.

Grazing management strategies

Because horses cannot utilize poor quality forages as efficiently as cattle can, good pasture management or good-quality hay are needed to improve the forage utilization by horses. The foundation of every equine diet should be forage. The daily forage dry matter (DM) intake of horses with no supplemental feed is about 1.5 to 2.5% of their bodyweight. These are averages, as some horses are known to consume over 3% and some miniature horses and ponies up to 5% of their bodyweight. Using these averages, a 1,000-lb horse requires 15 to 25 lb of DM per day, representing 50 to 100 lb of fresh forage with 30% DM and 17 to 28 lb of hay with a 90% DM.

When looking to purchase hay for horses, you may notice that some hay is marketed as “horse quality hay” or “cattle quality hay.” Although there are no set definitions denoting this meaning, there are some general guidelines that can be utilized to assess hay. First and foremost, to truly know the quality of a hay, it should be chemically tested. Your county extension office or state forage or equine specialists can help point you to resources near you to test your hay. Remember that hay from one producer may vary depending on what field the hay was baled from, the cutting, and other factors. If you are purchasing hay that has not been tested, you should visually evaluate the hay. Hay for horses should have the following characteristics: free from dust, mold, and insects; soft in texture; free of weeds; and greater leaf to stem ratio. Ideally, hay should be stored indoors and away from the elements. Green is the most ideal color for hay and indicates ideal curing and storage. Additionally, it is often rich in carotene and vitamin E. Sun can bleach hay and turn it from a green to yellow color. This can decrease the carotene content, indicate over-maturity of the forage when cut, or rain exposure during curing. This does not necessarily mean this hay should not be purchased, but consideration should be given depending on the needs of your horse.

For example, an elite three-day eventer is going to require forage with a greater nutritive value than a mature horse at maintenance.

Evaluating a horse's body condition can help owners determine if their nutritional program is sufficient. The Henneke Body Condition Scoring (BCS) System ranges from 1 to 9 and is a visual and tactile appraisal of fat. For optimal health, most horses should have a BCS of 5 or 6. There are numerous resources available online to help determine a horse's BCS. Estimating a horse's weight can also aid in making informed nutrition decisions. There are numerous commercial weight tapes, equations, websites, and phone applications that can help estimate a horse's weight. There are differences between each method, and some are more accurate than others. Because consistency needs to be maintained, switching between these methods is not recommended. Horses consuming high nutritive value hay or forages will need to consume less than a poorer quality hay to maintain the same condition and weight.

As a starting point, a recommended target feeding rate is approximately 2% of the horse's body weight per day (Table 9). If the horse is dropping weight or BCS, more forage can be added, or concentrates can be supplemented in the diet.

Table 9. Thirty-day forage consumption for horses.

Horse Weight	Forage (lbs)[1]	# of 50-lb square bales	% of 1,000 lb round bale consumed[2]
900 pounds	540	11	68%
1,000 pounds	600	12	75%
1,100 pounds	660	14	83%
1,200 pounds	720	15	90%

[1] at 2% bodyweight; [2] free choice, 2.5% bodyweight.

The gastrointestinal tract of the horse is designed to eat small, frequent meals throughout the day. In order to achieve this, horses can be turned out on pasture 24/7 or offered free choice, or *ad libitum*, forage. Although this mimics a horse's natural diet, some horses may overindulge and become obese which has numerous negative side effects. This may also be cost prohibitive for producers, depending on the number of horses they have to feed and wastage of the offered hay. Feeding hay in a hay feeder–such as a ring or basket feeder–can reduce wastage. Utilizing a round bale net, especially in conjunction with a feeder, also reduces wastage. This can also slow intake to a more reasonable level and prevent horses from diving head-first into round bales, which can expose horses to unnecessary dust or aggravate eyes. Square bales can also be fed in feeders and covered in nets to reduce wastage and extend intake throughout the day. If an owner is feeding smaller amounts at a time–such as flakes of hay– then utilizing a hay net or bag can also be beneficial.

If horses are housed on pasture and are becoming obese, grazing muzzles can be utilized to slow intake and to lose weight. Numerous studies have evaluated the use of grazing muzzle on pastured equids. Many people choose to leave muzzles on during the day and remove them at night. However, if padded properly and attached to a breakaway halter or similar device, they can be safely worn 24/7. It is important to slowly acclimate horses to muzzles to ensure they can drink and eat with them comfortably.

Owners can use pellets and cubes to feed animals. Like commercially available concentrates, pellet and cube manufacturers are required to include guaranteed levels of protein, fat, and fiber on the feed tag. This is advantageous over hay, where quality can change from bale to bale or field to field. In theory, pellets and cubes can be fed as the sole forage component of a diet. However, when a horse's pellet or cube ration is fed in one or two feedings, horses may be left with long periods of idle time. This idle time may lead to boredom-related behaviors such as wood chewing. Producers can remedy this by feeding pellets or cubes in three or more feedings throughout the day or by using a feeder designed for these feed forms.

Many people feel strongly about adding water to pellets and cubes. For horses that bolt their feed or have poor dentition or missing teeth, producers should add water to the feed to make chewing easier and ensure adequate moisture before swallowing. There is no disadvantage to adding water to feed and encouraging a little extra water is beneficial. However, some horses will not consume feed if too much water is added, so it is important to evaluate an individual horse's preference. These feedstuffs should be weighed dry.

Animal health considerations

Figure 23. Foxtail seedheads. Credit: Pixabay

Foxtail. The name "foxtail" covers a wide range of *Setaria* species and are warm-season annuals. Not all foxtail species are considered problematic, but some, including *S. lutescens, S. viridis,* and *S. geniculata*, have been indicated to cause oral irritation in horses. Seed heads from these plants have fine awns that can imbed in the mouth, leading to ulceration of the lips, gums, and tongue, and irritation to the gastrointestinal tract and skin around the muzzle. Horses that suffer from "hay blisters" often exhibit lethargy, excess salivation, difficulty swallowing, red and irritated gums that may bleed, and facial swelling. Additional problems can arise with riding horses because embedded awns can be painful and cause secondary infection. Mouth ulcerations can also resemble the reportable disease vesicular stomatitis which can affect other livestock species and people. Fortunately, these mouth ulcers can improve when horses are removed from feed sources containing foxtail. Not all horses exposed to foxtail are sensitive to the awns, but it is recommended to manage foxtail in pastures and check purchased hay for the tell-tale bushy seed heads. Foxtail seeds from outside hay sources can pass through the digestive tract and infect pastures which can lead to management difficulty. Unfortunately, there are no target-specific herbicides for controlling foxtail without impacting other desirable forage species. To control foxtail, it is recommended to mow or hay pastures before seed heads appear.

Clover slobbers. In wet conditions, the fungus *Rhizoctonia leguminicola*, commonly known as black patch, can grow on some legumes, such as red and white clovers. This fungus looks like black, brown, or gray spots or rings and produces a mycotoxin called *slaframine*. *Slaframine* poisoning is also referred to as slobbers. This poisoning is mostly an aesthetic issue rather than a health threat to horses. Nonetheless, if slobbering is observed, contact your veterinarian to make sure you are dealing with clover slobbers and not with choke, dental issues or any other trauma in the mouth that may cause a life threat to your horse. Alternatives to decrease slobbers with no need to limit horse turnout is overseeding the clover-rich pasture with grass species, such as annual ryegrass and oat. Reducing the pasture clover proportion to less than 50% of the total botanical composition will help keep horses from getting a heavy load of slaframine and hence clover slobbers. Implementation of good pasture management may help keep this fungus away from the pasture. A good example is the use of rotational stocking by bringing clovers to a 3- to 4-inches stubble height and resting the pasture for forage regrowth. Regrowth tends not to harbor the fungus.

Pasture-associated asthma. Summer pasture-associated asthma or severe equine pasture asthma is a seasonal respiratory disease of horses. Also referred to as summer pasture-associated heaves, this disease has most commonly been reported in the southeastern region of the United States, particularly in Florida, Georgia, Louisiana, and Mississippi, although horses in other parts of the world, including the United Kingdom, can be affected. Horses with summer pasture-associated asthma have difficulty breathing due to bronchospasm, hypersecretion of mucous and airflow obstruction (due to thickening of the airway). Signs range from exercise intolerance and coughing to labored breathing and increased exhalation effort, wheezing, and subsequent weight loss. Exposure to pasture conditions during late spring, summer, and early fall and high environmental temperature and humidity exacerbate clinical signs.

Management of horses affected with summer pasture-associated asthma can be challenging and is targeted at eliminating or decreasing exposure to triggers (e.g., aeroallergens including certain mold spores and grass pollens). In the southeastern region, keeping the grass short and removing horses from the pasture during the summer season, allowing them pasture access only in the winter is recommended. Minimizing dust particles in the barn environment while the horse is confined to a stall is extremely important. Soaking hay before feeding, keeping hay stored in a separate area, taking the horse out of the stall during cleaning, and using either low-dust bedding materials or housing horses on rubber mats without bedding can help reduce exposure to dust. Owners are encouraged to observe their horse(s) for early signs of respiratory problems and to consult with a veterinarian about available medications to help improve air flow to the horse's lungs (e.g., bronchodilators and anti-inflammatory drugs).

Blister beetle. Blister beetles are black, elongated insects that may occur in the southeastern U.S. Adult blister beetles feed on flowers and leaves of several plants including alfalfa. These insects contain a toxin, *cantharidin*, which causes irritation to the skin, blisters on the tongue and in the mouth, and irritation in the digestive and urinary tract's lining. Cantharidin is released when the beetle is crushed during haymaking and, because cantharidin is a very stable compound, it can remain toxic in stored hay for more than a year. Horses are more sensitive to *cantharidin*, but ruminants are also affected when ingesting contaminated hay. Although toxic levels have not been determined, no level of ingestion is safe. An estimated minimum lethal dose is 0.5 to 1 mg/kg of body weight. A blister beetle may contain from 0.5 to 5 mg of *cantharidin*. Although it may take a few blister beetles to result in a lethal dose, the ingestion of few insects can cause colic and other problems that may lead to death. If cantharidin poisoning is suspected, contact your veterinarian immediately. Although not commonly reported in the Southeast, contaminated hay may originate from hays shipped from the western states. Proper forage management techniques must be implemented to ensure that the hay is free of beetles. When buying alfalfa (or clovers) hay, learn as much about how it was produced and harvested, avoid hay that was mature or flowering at harvesting, and, although difficult to spot blister beetles in bales, discard any bales you see some dead, crushed beetles.

Fescue toxicosis. Tall fescue is grown on more than 35 million acres and is considered the most important cultivated pasture grass in the United States. This cool-season perennial grass can harbor a fungus called *Neotyphodium coenophialum* which produces ergot alkaloids that are toxic to horses and other livestock species. This fungus is considered an endophyte, meaning that its entire lifecycle is within the plant. This fungus is not visible to the naked eye and has a symbiotic relationship with the plant. In exchange for food, protection within the plant, and dissemination through seed, the plant becomes more vigorous, drought tolerant, and better to withstand some diseases and pests. Surveys across several states estimates that 60 to over 80% of tall fescue pastures are endophyte-infected, with much of this widespread infection due to the planting of Kentucky 31 seed. Although fresh forage has double the amount of ergot alkaloids compared to stored hay, one still must be cautious when feeding hay from infected pastures. Not all tall fescue varieties are indicated in fescue toxicosis. Endophyte-free and novel (non-toxic) tall fescue are both excellent options for pasture and hay but lack the benefits of the mutual relationship with the endophyte.

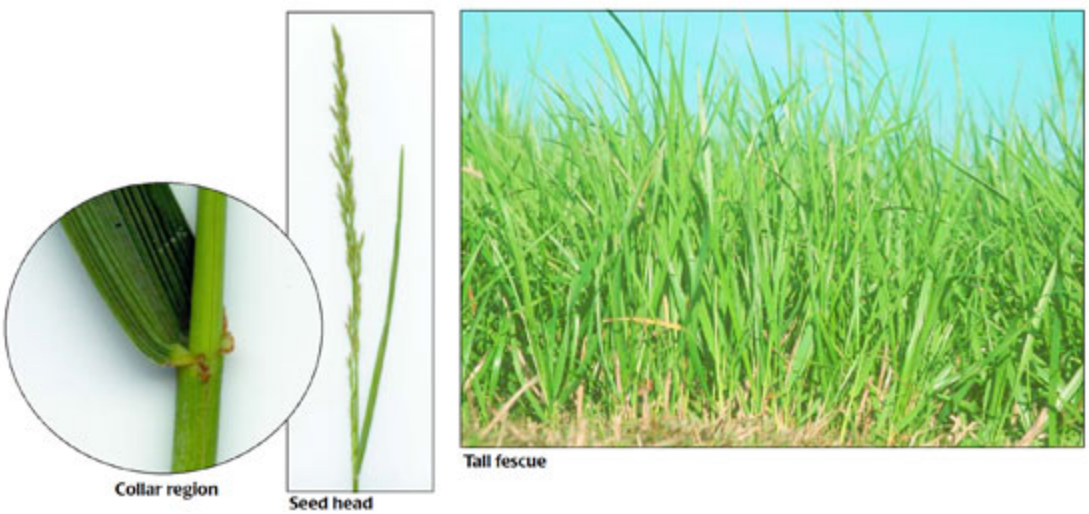


Figure 24. Image Credit: University of Missouri Integrated Pest Management

There is evidence of specific problems in gestating mares including late-term abortions, dystocia (difficult birth), agalactia (little or no milk production), thickened placentas, retained placentas, red bag deliveries, and an increased risk of death of the mare and foal. Mares grazing infected pastures during their last trimester of gestation are at greater risk for complications. Research has shown that removing mares during the last 30 days of gestation can reduce the risk of complications; however, due to the large variability in gestation length in mares, it is safest to remove mares from infected pasture or hay 90 days prior to estimated parturition. Research is more limited in the stallion, but stallions grazing infected pasture have a decrease in ejaculate volume and yearling colts seem to be more susceptible to negative spermatogenic effects and decreased weight gains.

Metabolic disorders. If you spend any time around horses, you will learn that they often like to get into medical trouble. Unfortunately, numerus metabolic disorders can affect horses and require diagnosis by a veterinarian and careful nutrition management. Equine metabolic syndrome (EMS) is a collective term for horses and ponies with a high risk of developing hyperinsulinemia-associated laminitis which varies from other forms of laminitis such as mechanical, supporting limb, and septic laminitis. Horses and ponies with EMS are often younger, display increased general or regional adiposity, are considered “easy keepers”, and suffer from insulin dysregulation (ID). Although these morbidities are common, not all EMS horses display them all. Insulin dysregulation is a combination of elevated resting or basal insulin levels, postprandial or post-feeding/oral sugar test insulin levels, or tissue insulin resistance. Pituitary pars intermedia dysfunction (PPID), formerly known as Equine Cushing’s, affects approximately 20% of equines 15 years of age and older and is a slowly progressive degenerative disease of dopaminergic neurons in the hypothalamus of the brain. This disorder presents with muscle wasting, hypertrichosis (long haircoat that fails to shed), and elevated adrenocorticotrophic hormone (ACTH). Diagnosis requires a veterinarian that will test according to various protocols. Unfortunately, horses can be affected by multiple metabolic disorders at once (Fig. 25).

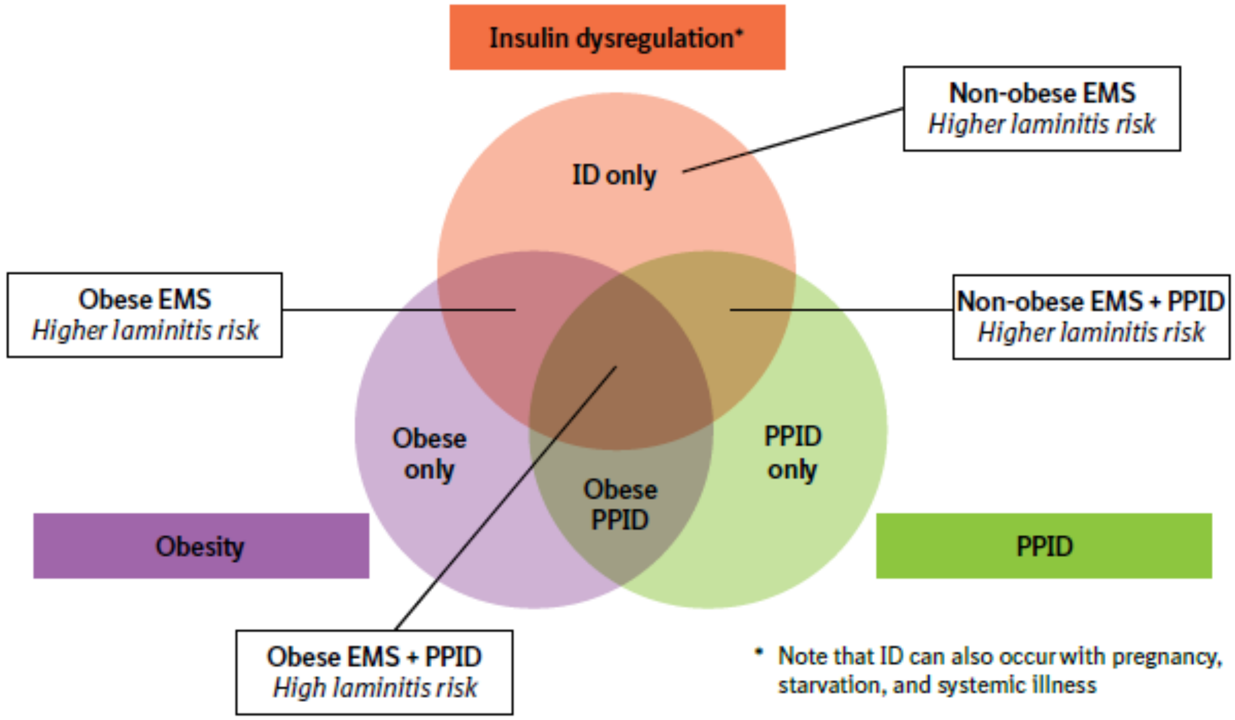


Figure 25. Venn diagram depicting overlaps among equine metabolic disorders. (Equine Endocrinology Group, Tufts University)

If a horse has been diagnosed with a metabolic disorder, producers should be mindful to closely watch their horse's body condition score. Dietary management is key to promote welfare and to control symptoms of the disorder, such as hyperinsulinemia-associated laminitis. Hyperinsulinemia-associated laminitis usually occurs in association with an elevation in blood insulin concentrations due to increased non-structural carbohydrates (NSC) in the diet. Non-structural carbohydrates are simple sugars and starches that should be digested pre-cecally or in the foregut of the horse. Cereal grains are higher in starch and vary on their digestibility in the foregut dependent of processing. Young, growing pasture can have high levels of sugar which can be detrimental to horses with metabolic disorders. Fructans, which are multiple fructose molecules linked together, can also be detrimental because they pass through the foregut and are digested in the cecum. Depending on when hay is cut, sugars can be high. It is recommended that total dietary NSC should be no greater than 10-12% for horses with metabolic disorders.

Cool-season forages, such as annual ryegrass and timothy, tend to be higher in NSC and fructans compared to warm-season forages, such as bermudagrass and bahiagrass. These pastures can still be grazed with a few considerations. Horses should be allowed to graze very early in the morning because it takes several hours after the sun sets for sugar levels to drop. When temperatures drop below 40°F at night the growth rate of plants slow, and less sugar is utilized for growth. Pastures the next morning may still be high in sugar content early in the morning which can be dangerous for metabolic horses. Overgrazed pastures can also be a risk for metabolic horses. Most sugars in grasses are concentrated in the bottom few inches of the plant. Stressed plants and those with only the first few inches available for grazing can be very high in sugar. Waking up at 3 a.m. to allow your horse to graze may not be practical for most producers. Additionally, some very sensitive horses may not be able to graze safely. Horses can be dry lotted and fed through slow-feed hay nets to allow for small, frequent meals throughout the day. If feeding hay, consider testing your forage to determine the concentration of NSC. You can soak hay to remove NSC in a hay net for up to 1 hour, rinse and discard any excess water, and feed to your horse. It is important to discard any uneaten soaked hay so that your horse does not have access to moldy hay.

Resources

National Research Council. 2007. Nutritional Requirements of Horses, 6th edition. Washington, D.C.: National Academy Press.

Johnson, P. J., A. M. LaCarrubba, N. T. Messer, and S. E. Turnquist. 2012. Ulcerative glossitis and gingivitis associated with foxtail grass awn irritation in two horses. Equine Vet. Edu. 24(4):182–6.

Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 2015. Southern forages: Modern concepts for forage crop management. 5th ed. International Plant Nutrition Institute, Peachtree corners, GA.

Fayrer-Hosken, R., A. Stanley, N. Hill, G. Heusner, M. Christian, R. De La Fuente, C. Baumann, and L. Jones. 2012. Effect of feeding fescue seed containing ergot alkaloid toxins on stallion spermatogenesis and sperm cells. Reprod. Dom. Anim. 47:1017-1026. doi: 10.1111/j.1439-0531.2012.02008.x.

Frape, D. 2010. Equine nutrition and feeding. 4th ed. Wiley-Blackwell, West Sussex, UK.

Geor, R. J. and P. A. Harris. 2016. Laminitis. In: R. J. Geor, P. A. Harris, and M. Coenen, editors, Equine applied and clinical nutrition. Saunders, Elsevier, United Kingdom, p. 469-486.

Jensen, K. B., P. Harrison, N. J. Catterton, B. S. Bushman, and J. E. Creech. 2014. Seasonal trends in nonstructural carbohydrates in cool- and warm-season grasses. Crop Sci. 54:2328-2340. doi:10.2135/cropsci2013.07.0465.

Longland, A. C., J. Ince, and P. Harris. 2011. Estimation of pasture intake by ponies from liveweight change during six weeks at pasture. J. Equine Vet. Sci. 31:230-356.

Longland, A. C., C. Barfoot, and P. A. Harris. 2016. Efficacy of wearing grazing muzzles for 10 hours per day on controlling bodyweight in pastured ponies. J. Equine Vet. Sci. 45:22-27. doi:10.1016/j.jevs.2016.04.015.

Davis, K. M., M. E. Iwaniuk, R. L. Dennis, P. A. Harris, and A. O. Burk. 2020. Effects of grazing muzzles on behavior, voluntary exercise, and physiological stress of miniature horses housed in a herd. App. Anim. Behav. Sci. 232.105-108. doi:10.1016/j.applanim.2020.105108.

Forages systems for small ruminants

Recommended forage species for sheep and goats

Goats and sheep, though similar in many ways, differ with regards to foraging behavior and nutrition. Specifically, the anatomy and physiology of goats allow them to browse on a wide range of vegetation, mostly woody plants (brush and shrubs,) and broad-leaf weeds overs grasses while sheep prefer forbs to grasses. Goats are “top down” browsers because they start to browse on the top of the canopy and progressively take the forage down, and they do not like to graze close to the ground like sheep. Also, goats choose woody over herbaceous plants and do not like to graze forage that has been trampled and soiled. Therefore, a better understanding of forage preferences by different animal species should allow producers to control undesired forage species and optimize forage utilization by animals.

Goats can be used as alternative sustainable to control understory vegetation in forestlands instead of using prescribed burning and herbicides applications. Some of the undesired species are:

- ***Woody species***: Blackberry, multiflora rose, honeysuckle, oak, sassafras, persimmon, buckbrush, blackberry, multiflora rose, locust, sumac
- ***Forbs:*** *Sericea lespedeza*, chicory, iron weed, pigweed, queen Anne’s lace, yarrow, thistle, or kudzu.

Figure 26. Goats browsing in woodland. Credit: Valens Niyigena.

Condensed Tannins for Goats

Condensed tannins (CT) can make up to 20% in dry matter in some forage legumes. The CT play an important role in controlling parasites, and reducing bloat, and greenhouse gas emissions. However, when in excess, CT may reduce forage utilization by the animal. Condensed tannins can improve animal health by suppressing gastrointestinal nematodes by inhibiting key parasite enzymes such as glutathione-S-transferases that play a crucial role in detoxification. There are many different forages that contain tannins. One example is *Sericea lespedeza*, a perennial woody legume that is found mostly in the western and southern US. Sericea lespedeza, however, is considered a weed species in some regions in US.

Table 11. Concentration of condensed tannins in different forage species.

Forage	% DM
Birdsfoot trefoil	4.8
Sanfoin	7.7
Sulla	5.1
Alfalfa	0.05
Sericea lespedeza	4.6-12
Perennial ryegrass	0.18
Chicory	0.31
Crabgrass/tall fescue mixture	0.32

Source: National Sustainable Agriculture Information Service, www.attra.ncat.org

Grazing Management Using Goats

Rotational Stocking with Goats

A successful rotational stocking system requires knowledge of animal's nutrient requirement, plants species in the pastures, and soil nutrients necessary to grow desired forages. Rotational stocking allows producers to be more in control of the timing and intensity of forages grazed.

Figure 27. Kiko goats grazing. Credit: Valens Niyigena.

Steps to Establishing a Rotational Stocking System on a Farm

- Determine your forage needs based on nutrient requirements of different animal categories in the operation. Rotational grazing is recommended, and the size of paddocks will need to be defined to properly divide pasture and fencing. Take in consideration the farm location to determine how long the grazing season can be and try to optimize days grazing days once this lower costs of supplementation and hay feeding. Use legumes and cool-season forages if possible, once they have higher forage quality than warm-season grasses and can help improve animal performance and meet higher nutrient requirements of animals lactating, for example.

- Determine forage mass and adjust your stocking rate when moving animals. The resting period for pastures should be based on recommendation for the species or mixtures used.
- Determine the water source and plan to provide water so that animals do not have to walk long distances to the well or tank (daily water consumption for a sheep or goats is between 1.5 - 3.5 gallons per day depending on weather).
- Determine your fencing resources (temporary fence or permanent). Many goat producers prefer to use portable electric net fences. Prefabricated electric nettings come in different sizes. The energizer used to power the fences depends on:
  - number of flexible nettings to be electrified
  - source of power (solar, electricity)
  - species of animals to be contained
  - amount of vegetation around the fence.

Using permanent fencing for rotational stocking offers a method to effectively move animals between paddocks with less effort. Although it may be costly to establish initially, it is less effort to move livestock through an established gate opening rather than moving and establishing the perimeter of areas grazed.

- When goats are browsing on woodland area, do not remove more than about 50% of the leaves and twigs of desirable plant species.
- Maintain forage grazing height above 5 inches tall allow grazed forage to regrow and minimize goats being exposed harmful internal parasites.

Determining Stocking Rate for Weed and Brush Control

The stocking rate will depend on the objectives of the producers regarding vegetation control. Either vegetation eradication or to keep some of the vegetation species and what impact their removal will have on the ecosystem.

Table 12. A guide for stoking rates when goats for weed and brush control.

Pasture Type	% of brush canopy	Cow	Goats	Cows+ Goats
*Excellent pasture	< 10%	1	6-8	1 + (1-2) **
Brush pasture	10- 40 %	1	9-11	1 + (2 to 4)
Bruch Eradication	> 40%		8-12	0.5 + (6-8) ***
Sustainable browse management	Maintaining 10-< 40 % of brush canopy		1-3/ acre	0.25 + (1-2)/ acre

Source: NRCS, 2005 Planning Prescribed Grazing with Goats, Conservation practice information Sheet (IS-MO 528gg).

*The stocking rate for excellent and brush pasture are not on acre basis but on cattle and goat comparison (it will take 6-8 goats on the same amount of land to run 1 cow)

** indicates combined stocking rate of cattle and goats (you can add 1 or 2 goats on per cow without affecting cattle stocking rate due to vegetation difference)

*** indicates stoking rates per acre for brush eradication during 2 to 3 years timeframe. When using goats alone, the stocking rate will be 8-12 goats per acre, or the stoking rate could be reduced to 6-8 goats and add 0.5 cow per acre to obtain the same results.

Multispecies Grazing can help with control of undesired plant species since they have different grazing behaviors and preferences. Multispecies grazing allows effective pasture utilization when vegetation has different heights once sheep will graze shorter vegetation left by cattle and around manure deposits which cows usually avoid. This method can also improve with carrying capacity, and diversification of income for the operation once producers will have different animals to market. Thus, having cattle on the pasture helps to protect sheep or goats against predators.

In terms of animal health consideration with multispecies grazing, gastrointestinal parasite infestation is a major concern in major livestock production species. Most of the parasite lay eggs in the pasture which in turn are ingested by grazing animals in infected pasture. However, most of the parasites are host specific which means some parasite may be infective to cattle but not to sheep or goats. However, goat and sheep share the common parasites especially barber pole worm. Having goat and cattle grazing in the same pasture will reduce parasite infestation by consuming some of the parasites that are infective for goats or sheep.

When managing toxic plants to sheep and goats, toxic plants can be harmful to all livestock species. Eating toxic plants can result in decreased productivity, and even animal. Knowledge of poisonous plants help producers to identify and safely remove them from pastures. Below are some of the main conditions when animals may consume toxic plants:

- In early spring, fall, or dry periods when forages are in short supply, animals may be forced to eat poisonous plants that they would normally avoid.
- Drought makes certain plants accumulate toxins. Slower plant growth due to drought can result in forage shortages.
- Overgrazing in pastures or woodlands can also cause animals to consume forage species they normally avoid when vegetation is more abundant.
- Owners may lack knowledge of toxic plants in pasture or hay and may not survey land for poisonous plants before releasing animals to graze.
- Animals may browse in pastures containing trash or garbage, households, or plant waste discharge areas.
- Turning weaned animals onto rush pasture for the first time in the spring.
- Introducing very hungry animals in a new pasture that contains poisonous plants.
- Turning animal to a pasture following herbicide application.

Figure 28. Goats browsing in forestland. Credit: Shannon Schoeneweis.

Common Symptoms of Plant Poisoning

Symptoms for plant poisoning varies from mild to severe. Among the mild symptoms are reduction in animal movement and normal activities that may last for a few days and reduced feed intake. Severe symptoms may include lack of coordination, convulsion, blindness, vomiting, erratic behavior, and quick death. The severity of symptoms will mainly depend on the quantity of poisonous plant consumed and the stage of production of the animal (e.g., lactating animal). Management of poisonous plants on a pasture can be achieve by implementing a proper management plan.

Avoiding overgrazing helps with keeping the forage stand healthy to compete and suppress weeds poisonous plants, while helping to reduce parasite exposure. Thus, use rotational grazing to help provide proper resting time to pasture to replenish reserves. Also, when animals are new to an area, introduce them to the pasture slowly and scout for any possible poisonous plant prior to turning animals in. It is recommended to conduct soil testing on a regular basis to follow proper fertilization and lime application regimen, based on soil report results. If needed, mechanical control methods as, mowing, burning or hand removal can be used to control poisonous plants.

If you suspect goats ate something poisonous:

- Remove animals from the pasture where toxic plants were found.
- Move animals to a warm, dry, and shaded area.
- Let animals drink clean water.
- Call a veterinarian immediately.

Economics and recordkeeping in forage systems

Managing forages is an integral part of a successful and profitable livestock operation. A key step in successful forage production is to determine the forage resources that are available for your operation and the nutritional needs of your livestock throughout the year. It's important to note that the forage resources and nutritional requirements may vary from year to year and across different areas of the state. Forage availability and nutritional needs should be evaluated throughout the year.

Forage Enterprise Budgets

Enterprise budgets for forages assist in the decision-making process for managing forages. The spreadsheet version of the budgets can and should be customized to reflect costs and practices that utilized in your operation. Budgets for establishment, hay, and grazing are available for the common forages. The Alabama Cooperative Extension System (ACES) enterprise budgets are available at https://www.aces.edu/blog/topics/farm-management/enterprise-budgets-for-forages.

In these spreadsheets, cost estimates are available for the establishment, grazing, and haying costs for Bahia, Bermuda, and fescue. Budgets for winter and summer annuals are provided for consideration as well. It is important to note that the prices and costs included in the budgets are just estimates. Due to the wide variety of factors such as location, alternative inputs, and different production systems, the forage enterprise budgets provide an interactive tool for producers to use values that represent production and costs that are representative of their operation. It is important to note that all your costs should be accounted for to provide the best and most profitable information for your operation. The enterprise budgets for forages separate costs are into variable and fixed. Variable cost, also known as cash costs, or direct costs are a little easier to estimate. Examples of some variable cost items are seed, fertilizer, pest control, fuel, twine or wrap. Fertilization costs are typically the largest variable costs in forage production. Check prices and possible alternative source of nutrients (chicken litter) in your area for the best value. Fixed costs can be more difficult to allocate to a specific enterprise but must be paid. Fixed costs are incurred whether production happens or not. Examples of fixed cost include interest, depreciation, taxes, and general overhead.

Machinery fixed costs is an area to monitor closely. Hiring custom work may be less expensive than an owning equipment that is used only for forage operations.

Forage Production Records

The importance of record keeping in any enterprise can't be overstated. Record keeping is a mechanism that enables producers to gauge output, efficiency and ultimately profitability. There are production records that are directly correlated, and those that are indirectly correlated to the forage itself. Production records directly correlated to forages would focus on the production of forage to include production per acre, storage and feeding losses, and grazing days. Hay production per acre is an easily obtainable value when the weight of each bale of hay is known. The weight of an individual bale of hay is extremely variable based on the size of the bale, compaction of the bale, and forage variety. When available, producers should consider periodically weighing representative bales of hay to maintain the integrity of the record keeping process. An estimate of standing forage in pasture situations can also be valuable but are intrinsically more difficult to assess objectively. Storage and feeding losses of hay can also be difficult to measure but are critical to profitability potential. Storage feeding losses should consider both bale volume lost from deterioration and volume lost from animal refusal, due to quality losses. Grazing days directly tie to feeding costs, which are the largest expense of most livestock enterprises. The number of days livestock can graze quality forages have an inverse relationship with the amount of stored feed required to meet nutritional requirements. When properly managed, grazing will usually be less expensive than stored feed.

Production records evaluate herd and animal performance to make genetic and managerial improvements and are not always directly correlated to forage production. Livestock producers should consider stocking rate, daily gain, weaning weight, gain per acre, market weight, and pregnancy rate, which is directly correlated to quality forage production. Stocking rates dictate how many animal units can be maintained on a given acreage, with a higher rate lending itself to more salable product. This is true of any of the livestock species, including horses and other specialty or companion livestock. Weight gains are directly correlated with both the amount and quality of forage produced and are the basis of profitability in most livestock enterprises. Chart 1 and 2 below (Southern Forages fifth edition, page 267, Table 28.1. Beef steer performance on pastures in the Southern United States) visualize multiple ways to measure gain in livestock. These results show performance of beef steers consuming commonly grazed forages in the southern United States. Comparison of gain associated with different forages, combined with the costs per acre and cost per pound of gain, are the basis of profitability for livestock enterprises.

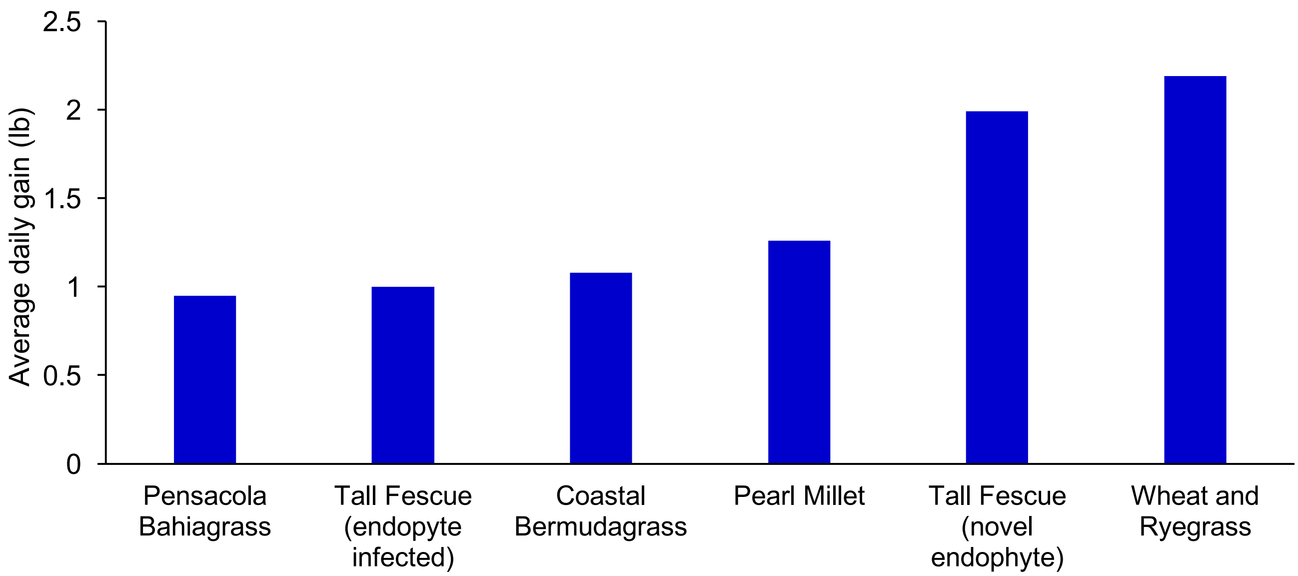


Figure 29. Average daily gain of beef steers on pastures in the Southern United States.

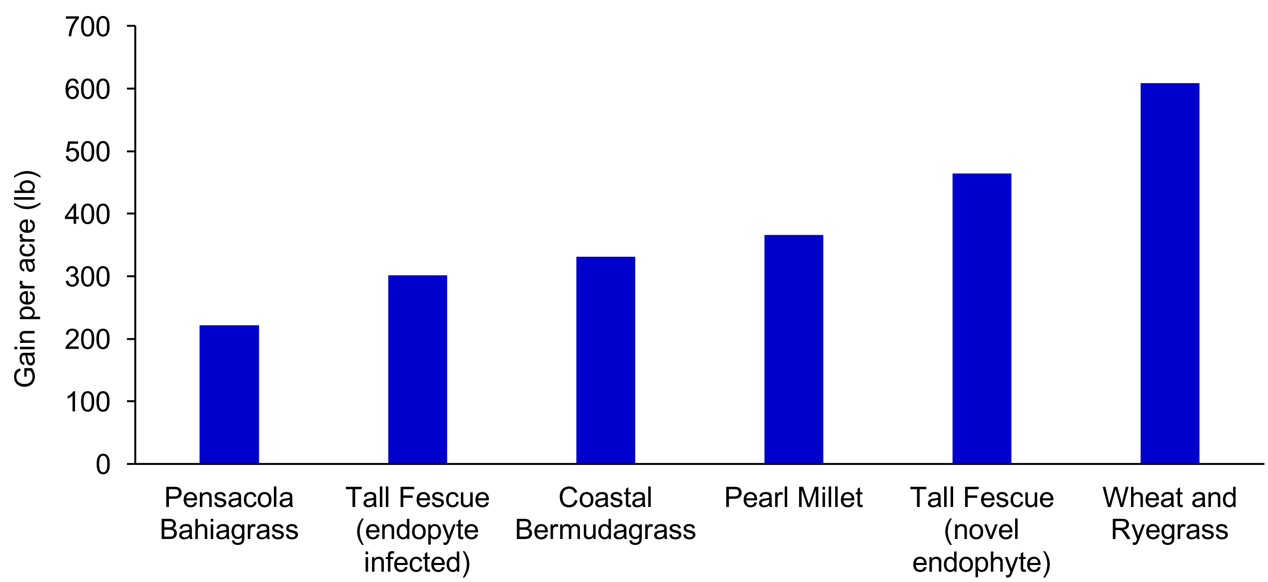


Figure 30. Gain per acre of Beef steers on pastures in the Southern United States

Cow pregnancy rate can also be directly related to forages (chart 3, Southern Forages fifth edition, page 262, Table 27.2, Performance of beef cows and calves on year-round pasture-hay systems in the South). Pregnancy rates of less than 90 % make it difficult for a cow-calf enterprise to be profitable.

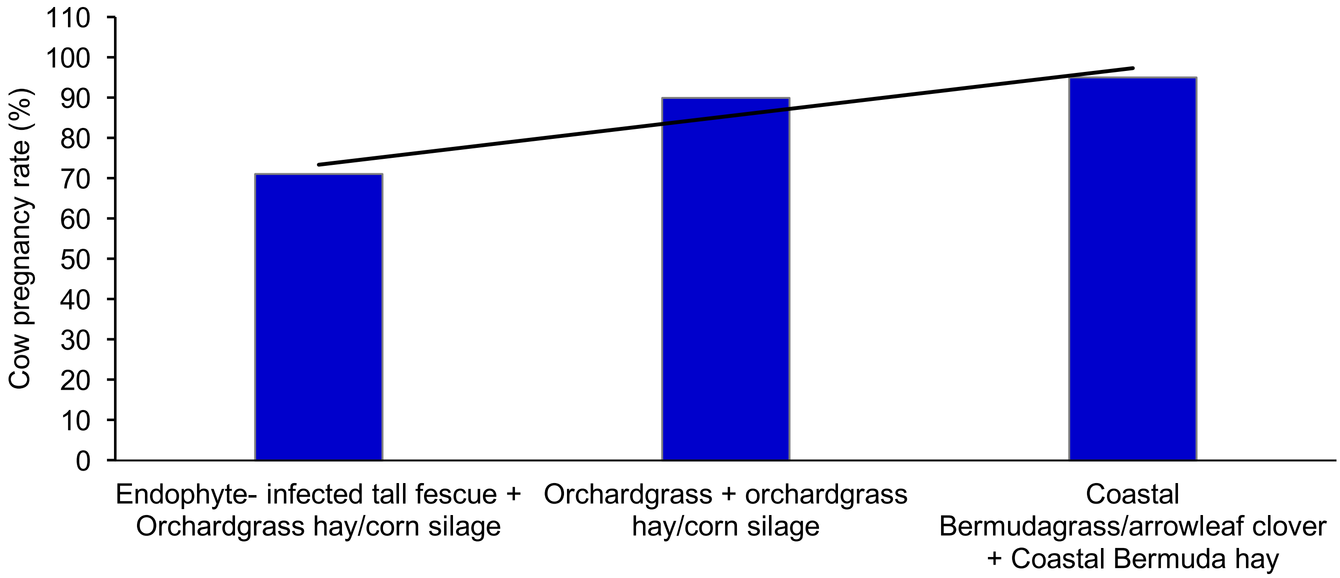


Figure 31. Cow pregnancy rate in response to forage mixtures.

Ultimately production records help producer better manage their agricultural enterprise, and forage production and feeding are a key component that should be measured. Forage cost, production, and feeding dictate overall nutrition costs and have direct influence on other vital production categories such as gain and reproduction.

Pasture, Rangeland, Forage Insurance Program

The Pasture, Rangeland, Forage (PRF) Insurance Program provides subsidized insurance coverage on perennial pasture, rangeland, and forage acres used to feed livestock. This insurance product is designed to protect against yield associated with low moisture conditions. Producers can purchase an area-based insurance policy for a grid that is 0.25 degrees in latitude by 0.25 degrees in longitude (approximately 12 miles by 12 miles) based on where their field is located. Premiums are subsidized between 51% and 59% of the cost, depending on the chosen coverage level. Enrolled producers become eligible for an indemnity payment when the rainfall index (RI) in the covered grid area, over a selected two-month period, is less than the historical precipitation estimate for that area and chosen coverage level. For example, a producer who purchases 90% coverage would receive an indemnity for periods during which the RI is less than 90% of the historical estimate. The RI is calculated by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) using weather stations around the grid area. This calculation is an estimate and not a precise measurement of the rainfall within the grid. Below are the decisions that producers need to make when considering the coverage to purchase:

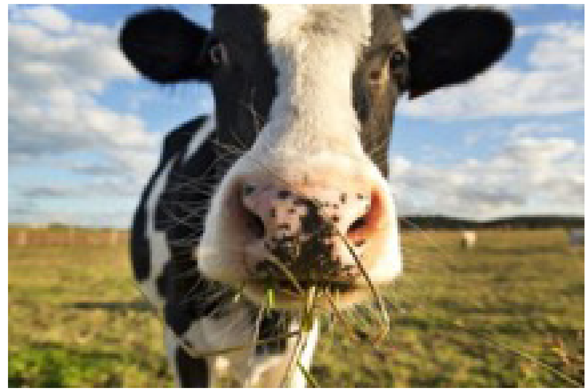
- Number of acres to insure. Producers do not have to insure all their acres and instead might consider insuring the most important acres to their operation.
- Use of the insured acres (either grazing or hay). The same acreage cannot be insured for both grazing and hay in a given crop year.
- Coverage level between 70% and 90%, in 5 percentage-point increments. A 70% coverage level means that indemnities are paid when the RI is less than 70% of the historical estimate for the grid.
- A productivity factor between 60% and 150% to determine the dollar protection relative to the average value for the grid. A chosen factor greater than 100% means that the producer believes their land is more productive than the grid average.
- At least two different, non-consecutive, two-month intervals for coverage. For example, January/February and March/April could be chosen, but January/February and February/March could not be chosen. Up to six intervals can be chosen. The producer must also place a percentage on each interval selected to reflect the percentage of acres insured in each interval, such that the total adds up to 100% for the year. The percentage cannot be less than 10% nor exceed 50% for any interval.

The USDA has a decision tool support online where producers can input information and see protection values, historical RI values, premium rates, and indemnity payments from previous years (Available at https://prodwebnlb.rma.usda.gov/apps/prf). Insurance coverage is purchased through an authorized crop insurance agent by December 1st for the upcoming year. More detail is available on https://www.aces.edu/blog/topics/farming/forage-risk-management-subsidized-insurance-as-a-strategy/.

Ecosystem benefits and soil healthy of grasslands

Worldwide, forages are the main feed source of most livestock production systems due to its low production cost, broad availability, and diversity of species. With the ongoing population growth, agricultural systems have been faced with the challenge to increase food and fiber production while minimizing negative impacts on the environment and further land conversion to agricultural use. Grasslands play an important role in delivering ecosystem services (ES), however, their ability to do it is defined by an array of factors, including management practices.

The definition of ecosystem services is "benefits people obtain from ecosystems" (Milennium Ecosystem Assessment, 2005) and they are classified in four categories: cultural, provisioning, regulating and supporting services. Some examples of ES delivered by grasslands are carbon sequestration, nutrient cycling and pollinators habitat. In this context, practices aligned with sustainable intensification have been increasing and ES provided by grasslands are gaining more importance. Therefore, research has been focusing on better understand how management practices affect forage ecosystems and their ability to deliver ES. Generally, management practices impact stand production, longevity, and resilience of forage stands; therefore, appropriate management can be an ally in keeping it health overtime. Below, we will discuss some of the main impacts and how they influence on stand production and persistence overtime.



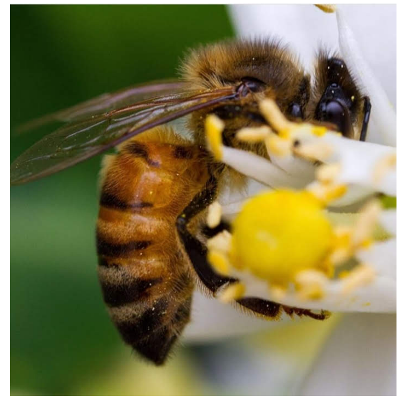
The ability of forages to recover following defoliation. Defoliation frequency (i.e., how often) and intensity (i.e., how closely forage is removed) either by grazing or cutting directly affect sustainability and longevity of forage systems. The use of recommended stubble height and adequate (re) growth period of individual forage species aims to allow for enough leaf area to be left post-harvesting (or accumulated in young plants) for plants to recover without relying as heavily on root reserves for energy. Higher than recommended frequency and intensity of harvest events may compromise the ability of forage species to recover and can lead to loss of forage stand overtime. Under grazing management, rotational grazing can help with more uniform removal of forage mass and to limit animal`s access to individual plants for a given time (resting period). This is particularly important when grazing legumes or legume-grass mixtures once animals tend to visit legume plants more often and can compromise their persistence overtime.

Energy storage for (re) growth is essential. After defoliation (either by grazing or cutting), new regrowth will rely on carbohydrates reserves to supply energy to the plant. These reserves are located on the roots, rhizomes or crowns (lower stem bases) of forage plants. The balance between frequency and intensity of the defoliation will interfere on how much those reserves will need to be used and will be restored at each time. On the long-term, the overuse of reserves without appropriate time for restoration will affect stand longevity. The weakening of the root system will not only compromise the energy supply, but also the nutrient capture which impacts plant health and ability to grow and resilience that can lead to stand thinning. Open spaces in the forage canopy favor weeds to establish and often spread in the area overtime. When weeds increase on pastures, there are risks of toxic weeds to establish which may compromise animal health and overall performance. In this case, it may be necessary to establish a proper control strategy, including use of herbicides to clean pastures from weeds. Overgrazing is one of the most common ways to cause plant depletion and issues with stand persistence overtime. Another point to pay close attention is early spring grazing once perennial forages have just started growing and are heavily relying on the energy storage to regrow.

Nutrient distribution in grassland systems. In hay production systems, we often optimize the removal of forage growth which will be exported to another area for animal feeding. For this reason, there is limited return of nutrient from the forages into the system under hay production, and a greater reliance on off-farm inputs (i.e., fertilizer) to be able to supply nutrient needs by plants. In grazing systems, livestock can return up to 80% of the nutrient consumed back to pastures. Therefore, optimizing the nutrient distribution from animal excretion is important to improve forage accumulation and quality, especially on low input systems. Better nutrient distribution can be achieved by employing rotational grazing since animals remain in the area for a defined period of time, avoiding establishment of exclusion areas or excessive excreta deposition. Livestock can also often cause damage to the growing points of plants, increase compaction, and reduce water infiltration on pastures. Some grasses, such as bahiagrass and bermudagrass, are more tolerant to treading than others, while some legumes are less tolerant. Nutrient return from litter and root contributions either by decomposition or exudation are common to both grazing and cutting systems but may occur in different levels in each. After defoliation events, either by grazing or cutting, it is common for parts of the root system to die and that this plant material be recycled and incorporated back as organic matter and make the some of the nutrient available back to the soil.

Carbon sequestration. Soils under perennial grasslands are major carbon reserves due to limited soil disturbance overtime. Through deposition and decomposition of above- and belowground plant material overtime, there is an incorporation of nutrients into the soil that increases soil fertility, chemical and physical characteristics. Also, some of the material incorporated back into the soil can be added as organic matter content. For example, during grazing, it is common for animals to pull out some plants from the soil and even portion of roots. If not consumed, that material is decomposed and can contribute with nutrients and organic matter being incorporated into the soil. Over the past decades, research has focused on better understand how to improve management strategies to optimize storage of carbon into soil under grasslands.

In grazing systems, adjustments of stocking rate are an ally to maintain a healthy forage stand. The stocking rate (SR) should be adjusted based on forage mass availability. Adjustments will need to take in consideration the animal requirements and be aligned with expected animal performance. Traditionally, farmers may want to stick with historical SR because that is how they have done in the past. However, we need to consider the variations on pasture composition, level of pasture degradation, rainfall pattern changes, animal requirements and expected animal performance, plus the effect of seasonality on forage growth and distribution.



Wildlife habitat and pollinators. Forages are a key component of the diets of grazing and browsing wildlife. They also provide space for habitat, which potentially adds value to farming operations through opportunities for hunting leases, agritourism, and aesthetic value. Grasslands are also an important source of habitat and food for a variety of pollinators. Recent estimates indicated a decline on the worldwide population of pollinators which has increased efforts of using grasslands, especially legume-grass mixtures, to mitigate this issue.

Greenhouse gases emissions. In recent decades, worldwide efforts to quantify emissions of greenhouse gases by the economic sector have led to discussions of the contribution by livestock-forage systems. In this context, efforts have focused on determining inputs and outputs of activities related to the livestock industry through life cycle assessments. Grasslands are able to offset a large portion of emissions by the livestock industry through capture of carbon dioxide from the atmosphere and carbon sequestration in grasslands. Besides, improved management practices can collaborate with reduced off-farm inputs which help decrease emissions. One example is the effort in decrease the reliance on N fertilizer that contributes with greenhouse emissions during its production, storage, distribution, and application, plus the price fluctuation has been decreasing feasibility of many livestock production systems.

Improving soil healthy in pastures

Soil health refers to the soil's ability to perform functions that support life on earth. Without soil, it would not be possible to produce the food, fiber, and energy needed to sustain human life. Soil also helps protect earth's natural resources by filtering water and decomposing harmful chemicals.

There is an increased focus on rebuilding soil health in agricultural lands to conserve soils for use by future generations. In row crop production systems, practices like reduced tillage and cover cropping are used to improve soil health. There are also management practices which can be used in pastures to promote soil health, such as prevention of overgrazing and rotational grazing.

Properties of a Healthy Soil

High organic matter content. Organic matter is comprised of carbon-containing substances from dead and living plant and animal materials (like manure!). Organic matter performs many functions that support soil heath, such as increasing the amount of plant-available nutrients and the amount of water a soil can hold.

Optimal nutrients and pH for plant growth. Routine soil sampling and testing can be used to generate recommendations for fertilizer and lime to ensure pH and nutrients are adequate for optimum plant growth. Rotational grazing can create a more even distribution of nutrients in a field, since nutrient-rich manure is spread more evenly in rotational grazing system.

No compaction layers and stable soil aggregates. Stable soil aggregates (good tilth) increases water infiltration/retention and root growth. Increasing organic matter can improve soil tilth.

Large population of beneficial organisms. One handful of soil contains more microorganisms than there are people on earth. The microorganisms in soils are important for recycling nutrients for plant growth, purifying water, and controlling pathogens.

Practices to Improve Soil Health in Pastures

Provide a continuous cover to the soil. Prevention of overgrazing is the best way keep a continuous cover in pastures. Soil that is overgrazed and left bare is susceptible to water and wind erosion. Having a continuous cover protects soil from erosion and helps to build soil organic matter. A continuous cover can also suppress weeds in pastures.

Keep an active crop growing. When perennial forages are not actively growing, consider overseeding with annuals. Actively growing plants secrete sugars, organics acids, and other compounds that provide a food source for soil microorganisms. The area around plant roots is called the rhizosphere, and this area contains the highest concentration of microorganisms in the soil. By keeping an actively growing crop in the soil, microorganisms can recycle nutrients to promote healthy soil.

Increase plant diversity. Increasing plant diversity can provide distinct benefits to the soil. As an example, consider a mixture of grazed winter annuals that includes a small grain, a legume, and a brassica. Small grains produce a high biomass that can increase soil organic matter storage if managed properly. Legumes can provide high-quality forage that adds nitrogen to the soil. Brassicas have deep taproots that can scavenge for nutrients. Increasing plant diversity can also provide nutritious feed over an extended grazing period.

Resources

Dubeux, J.; Wallau, M.; Vendramini, J.; Silva, L.; Griffin, J.; DiLorenzo, N.; Santos, E. Estimating herbage mass on pastures to adjust stocking rate. Available at https://edis.ifas.ufl.edu/publication/AG434

Hancock, D.; Andrae, J. 2017. Grazing Impacts on grazing composition. University of Georgia, Bulleting 1241. Available at https://secure.caes.uga.edu/extension/publications/files/pdf/B%201243_4.PDF

Milennium Ecosystem Assessment. 2005. Ecosystems and their services. Available at https://www.millenniumassessment.org/en/index.html

Silva, L.; Dillard, L.; Mullenix, K.; Griffin, M. 2020. Grazing management impacts on forage systems. Available at https://www.aces.edu/blog/topics/farming/grazing-management-impacts-on-forage-systems/

Silva, L.; Griffin, M.; Dillard, L.; Mullenix, M. Measuring forage mass to adjust stocking rate. Available at https://www.aces.edu/blog/topics/farming/measuring-forage-mass-to-adjust-stocking-rate/

Vendramini, J.; Sollenberger, L.E. SS-AGR-133 – Impact of grazing methods on forage and cattle production. Available at https://edis.ifas.ufl.edu/ag268

Appendices

A. Common and scientific names of forage grasses, legumes, and forbs.

Common name	Scientific name	Category
Grasses		
Annual ryegrass; rye (annual)	*Lolium multiflorum*	CSA[1]
Bahiagrass	*Paspalum notatum*	WSP
Bermudagrass	*Cynodon dactylon*	WSP
Crabgrass	*Digitaria sanguinalis*	WSA
Corn	*Zea mays*	WSA
Dallisgrass	*Paspalum dilatatum*	WSP
Johnsongrass	*Sorghum halepense*	WSP
Limpograss	*Hermathria altissima*	WSP
Oats	*Avena sativa*	CSA
Orchardgrass (cocksfoot)	*Dactylis glomerata*	CSP
Pearl millet; Millet	*Pennisetum americanum*	WSA
Rye	*Secale cereale*	CSA
Sorghum	*Sorghum bicolor*	WSA
Sudangrass	Sorghum × drummondii	WSA
Tall fescue; fescue	*Festuca arundinacea*	CSP
Triticale	*Triticale hexaploide*	CSA
Wheat	*Triticum aestivum*	CSA
Native grasses		
Big bluestem	*Andropogon gerardii*	NWSP
Eastern gamagrass	*Tripsacum dactyloides*	NWSP
Indiangrass	*Sorghastrum nutans*	NWSP
Little bluestem	*Schizachyrium scoparium*	NWSP
Switchgrass	*Panicum virgatum*	NWSP
Legumes		
Alfalfa	*Medicago sativa*	CSP
Black medic	*Medicago lupulina*	CSA
Clover	*Trifolium*	
Arrowleaf clover	*T. vesiculosum*	CSA
Ball clover	*T. nigrescens*	CSA
Crimson clover	*T. incarnatum*	CSA
Red clover	*T. pratense*	CSA/B*

White clover	*T. repens*	CSA
Cowpea	*Vigna unguiculata*	WSA
Kudzu	*Pueraria lobata*	WSP
Lespedeza, Korean	*Kummerowia stipulacea*	WSA
Lespedeza, strate	*Kummerowia striata*	WSA
Sericea lespedeza	*Lespedeza cuneata*	WSP
Rhizoma perennial peanut	*Arachis glabrata*	WSP
Soybean	*Glycine max*	WSA
Sweetclover	*Melilotus spp.*	CSA
Vetch; hairy	*Vicia villosa* Roth	CSA
	Forbs	
Chicory	*Cichorium intybus*	CSP
Kale	*Brassica oleracea*	CSA
Radish	*Raphanus sativus*	CSA
Rape	*Brassica napus*	CSA
Turnip	*Brassica napa*	CSA

[1] *WS = warm-season; CS – cool-season; A= annual; B= biennial; N= native; P= perennial*

B. Common weights and measures for conversion.

Column 1 Suggested Unit	Column 2 SI Unit	To convert Column 1 to 2, multiply by
inch	centimeter, cm (10^{-2} m)	2.54
acre	hectare, ha	0.405
pound, lb	kilogram, kg	0.454
pounds per acre, lb/acre	kilogram per hectare, kg/ha	1.12
Fahrenheit, °F	Celsius, °C	5/9 (°F – 32)
gram per milliliter, gram/ml	pounds per ounce, lb/oz	15.338
lb per cubic inch, lb/inch^3	gram per cubic centimeter, g/cm^3	27.68

C. Methods to estimate forage mass

Proper forage production estimation is a crucial tool to optimize forage utilization while accounting for plant and animal requirements. Forage mass measurement methods are described below:

a. Canopy height

Measuring canopy height with a pasture ruler (Fig. 32) can give you an estimate of the pounds of grazeable forage mass per inch of standing forage in the field (Table 13). However, this measurement alone does not consider canopy density which can represent an issue in terms of accuracy of estimate.

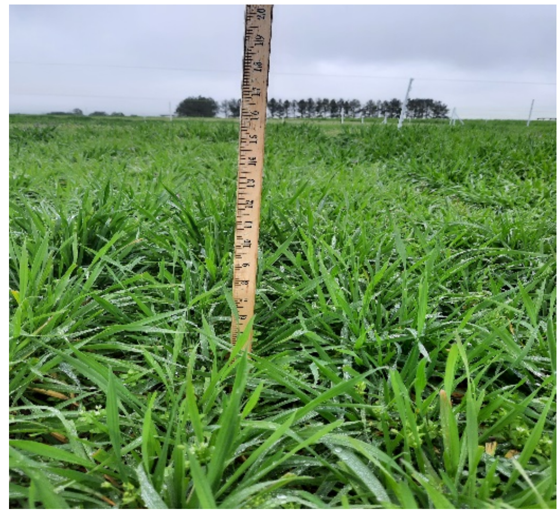


Figure 32. Pasture ruler on field.

Table 13. Pounds of grazeable forage available per inch in the field.

Forage species	Average (lb per inch)	Range (lb per inch)
Alfalfa (grazing types)	225	45 - 400
Annual Ryegrass	250	75 - 400
Bahiagrass	200	100 - 350
Bermudagrass	260	150 - 500
Native warm-season grasses	100	50 - 250
Orchardgrass	180	75 – 300
Small grains	150	75 – 250
Tall fescue	210	100 – 350
Tall fescue + clover	190	80 - 325

b. Cut and Dry Sample Method

Using a Microwave (see *Appendix B*): build a quadrat (an open frame with a known area; Figure 15) using PVC pipe, steel wire or wood. The area of the quadrat must be known because it will be required to calculate forage mass per acre. After the quadrat is built, select few sites on your pastures to cut and dry forage samples. These sites should represent the general pasture condition (canopy height and density), so a good rule of thumb would be to establish a pre-determined number of steps to collect each forage sample from in each pasture to avoid bias. Once the forage is harvested, it can be dried using the microwave method.

Figure 33. Quadrat detail (left) and in use (right) on alfalfa-bermudagrass pasture.

c. Visual estimation

With practice, some people can visually estimate forage mass in a stand. Usually, this skill can be developed with training that requires harvesting few forage samples from an area of known size (see method #2) to check accuracy of visual estimates.

D. Microwave method for drying forage samples

Supplies Needed: a glass of water, plate with samples and a bathroom or kitchen scale.

First, weigh approximately 3.4 oz (100 g) of harvested forage and place on a plate. If weighing plate and the sample together, remember to tare (zero) the scale with the plate beforehand. Then, put the glass of water inside the microwave and set it to high for 2 min. The water helps to avoid combustion and throughout this process, it should be changed if boiling. After 2 min, allow the sample to cool to room temperature and weigh. Repeat this process in increments of 2-min until sample weight remains constant. Keep in mind that samples with higher initial moistures will require a longer time to achieve a constant weight (i.e., silage or baleage samples).

For a more accurate measurement, you can dry a two or more of the forage samples from the same area, then average the weights. To calculate forage mass per area, use the correct formula for the quadrat you used [dry weight (oz)/quadrat area (ft^2)] and then convert to lb/acre (to convert oz/ft^2 to lb/acre multiply by 2,722.5). This method requires harvesting multiple sites in the pasture to obtain a better estimate. Also, one should use a dedicated microwave; *not the one used in your family kitchen*.

E. Adjusting the stocking rate

Measuring forage production is an efficient way to monitor the use of forage and help to estimate pasture stocking rate and carrying capacity. *Stocking rate* (SR) is defined as the number of animals grazing within a unit of land over a specified period of time. When SR is incorrect, it can lead to issues such as overgrazing those compromises stand longevity. *Carrying capacity* is defined as the maximum number of animals or animal units (AU) that a pasture can support over a period without compromising stand health.

It is crucial to maintain a balance between forage available and removal to support goals for animal gain on pasture and allow the stand to replenish carbohydrate reserves (the "engine" for regrowth after defoliation). Once you have measured forage mass on a given pasture, below are simple formulas and steps to make animal stocking decisions on your farm.

1. Number of paddocks (NP): $NP = \frac{\text{days of rest}}{\text{days of grazing}} + 1$

   Example: $\frac{\text{28 days of rest}}{\text{4 days of grazing}} + 1 = 8 \text{ paddocks}$

2. Then, calculate the acres required per paddock (AP**)**:

$$\text{AP} = \frac{\text{weight x DMI x number animals x days per paddock}}{\text{DM available x \% forage utilization}}$$

whereas DMI= dry matter intake; DM = dry matter

   Example: $\frac{\text{(600 lbs x 3\%) x 40 head x 4 days}}{\text{2,700 lbs/ac x 60\%}} = 1.8 \text{ acres}$

3. After, the total acres required per cycle is equal the number of paddocks x acres required per paddock.

   Example: 8 paddocks x 1.8 acres=14.4 total acres required

4. The stocking rate (SR) is calculate using: $\frac{\text{number of animal grazing}}{\text{total acres grazed}}$

   Example: $\frac{\text{40 head}}{\text{14.4 acres}} = 2.8 \text{ head per acre}$

5. Then, stocking density (SD) will be: $\frac{\text{number of animals grazing}}{\text{paddock size in acres}}$

   Example: $\frac{\text{40 head}}{\text{1.8 acre paddock}} = 22 \text{ head per acre}$

F. Genetics selection in beef production

Genetic selection is an important tool in beef production. Setting production goals to define the operational focus is vital and helps with development of a plan of action. Overall emphasis should be given to what type of animal will best to meet the targeted product and market to capture the most value. Understanding market standards, targets, and discounts and the management factors affecting the targeted product and market price can help a cattle producer to capture value. Ultimately, a feeder animal must be able to grow efficiently to produce acceptable beef quality and cutability. In targeting a forage-based finishing system, operational environment and resources, end-product goals, and marketing plans need to be carefully considered to develop operational goals and strategies.

Overall production standards of structural correctness, muscling, growth, adequate frame, and good health are important. Correct structure increases longevity and functionality of the cow herd and feeder calves in the finishing phase. A feeder calf needs average to above average muscling and to grow efficiently to produce a carcass with acceptable quality and cutability. Adequate frame as an indicator of harvest weight in feeder calves, and sound overall health to grow efficiently are essential. In a forage-based finishing system, frame size needs to be carefully considered in reaching harvest targets. Based on the specific forage system, more moderate framed feeder calves will likely reach a finished endpoint for harvest earlier as compared to larger framed calves.

Genetic selection of beef cattle influences performance in all aspects of beef production. Set production goals will provide guidance in the focus and direction of genetic selection. It is more effective to focus on traits pertinent to the production of the chosen end-product. For example, in a cow-calf production system, traits such as calving ease, weaning and yearling weight growth, milking ability, and overall carcass quality should be the focus. With a forage-based finishing system, early maturity, frame score, muscling, growth, rate of gain, cutability or red meat yield, intramuscular fat or marbling and tenderness should be focused on.

To capture the best genetics for an array of traits, crossbreeding, which involves a breeding system to cross two or more genetically different breeds of cattle, increases hybrid vigor or heterosis. Increased heterosis will result in an increase in production traits, such as growth, fertility, and longevity. In planning a crossbreeding system, specific breeds can be used to capture heterosis and complement the strengths and weaknesses of each breed type. For example, breeds can be combined to meet production trait goals for early maturity, moderate frame, sufficient muscling, adequate growth, and high marbling. However, a crossbreeding system should also be designed with overall uniformity in the resulting calves as a goal to meet beef market standards.

Expected progeny differences (EPDs) are genetic prediction tools beef producers can use when making breeding selection decisions. Expected progeny differences incorporate performance records, pedigree information, and can include genomics, while accounting for environmental differences. They predict performance of a bull or cow's future progeny, or offspring, by predicting differences in performance for a given trait. Expected progeny differences are breed specific for use only within one breed. They can be used to compare individuals for multiple traits within a specific breed and determine how an individual animal ranks for multiple traits as compared to the breed average. EPDs are calculated for various traits, such as calving ease, birth weight, weaning weight, yearling weight, milk, carcass weight, ribeye area, marbling, and mature size, among many others.

With a vast number of EPDs available for a broad array of traits, focusing on traits of importance to operational goals and their economic relevance is more effective. For a forage-based finishing system, a focus on production traits and their overall economic relevance might include early maturity, moderate frame, sufficient muscling, optimum rate of gain, and high marbling. Therefore, operational goals should determine the focus of genetic selection tools such as EPDs.

Genetic selection in beef production has a great impact and a plan should be developed to meet the individual goals of an operation. Set production goals will provide guidance in the focus and direction of genetic selection. Crossbreeding is a method to capture the best genetics for an array of traits by complementing the strengths and weaknesses of different breeds. Expected Progeny Differences, or EPDs, are genetic prediction tools to make breeding selection decisions. EPDs are available in a broad array of traits. Focus on traits of importance to operational goals and economic relevance to be more effective.

G. Additional resources for forage and beef producers

USDA Natural Resources Conservation Service
http://www.usda.nrcs.gov

USDA FSA
www.fsa.usda.gov

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