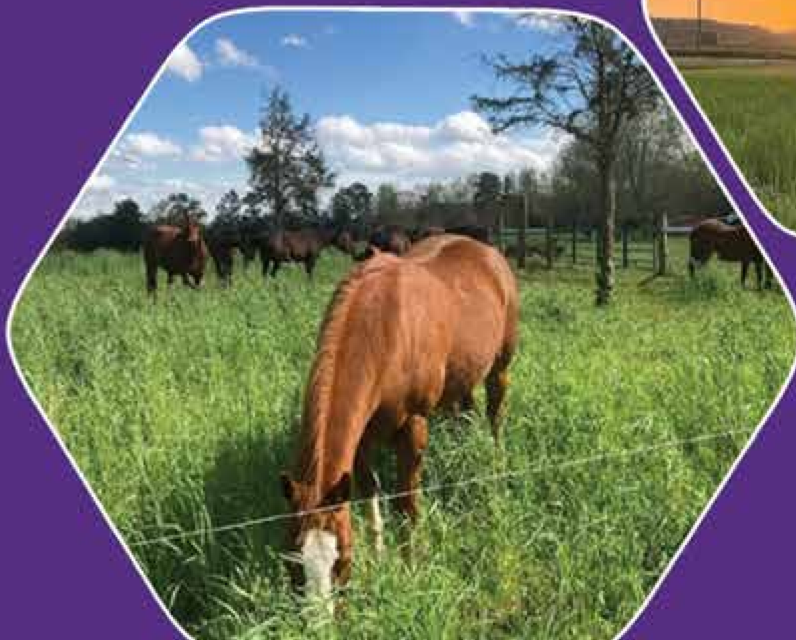



# CONCEPTS AND RESEARCH-BASED GUIDELINES

## FOR SOUTH CAROLINA FORAGE SYSTEMS







**CONCEPTS AND RESEARCH-BASED GUIDELINES FOR SOUTH CAROLINA FORAGE SYSTEMS.**

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College of Agriculture, Forestry and Life Sciences

South Carolina Forage & Grazing Lands Coalition

# PREFACE

This forages handbook provides concepts and research-based information on forages, animals, pests, environment, and soil topics for Extension and agricultural educators, producers, students, and the general public in South Carolina. The goal of writing this book is to provide a practical resource containing the main aspects of forage systems production that any producer can understand and use, regardless of their background or scientific training.

I, Liliane Silva, joined Clemson University as the Forages Specialist in October 2021 and sought out funding to bring this project together. I am thankful to all collaborators for their contributions to enhancing the quality and bringing this publication together. I sincerely hope that the book will be helpful to educators, students, and producers and contribute to improving production, profitability, and sustainability in forage-livestock systems statewide.

All authors are affiliated with Clemson University and/or Clemson University Extension System. The authors do not assume any responsibility, make any guarantees, or offer any warranties regarding the results obtained from using any management strategies included in this handbook.

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# Summary

# 1. Overview of Forage Systems in South Carolina

Liliane Silva, Forages Specialist, Clemson University

The livestock industry is one of the most important agricultural activities in South Carolina. Forages are the primary feed source for livestock due to the favorable climatic conditions for forage plant growth, a wide range of adapted forage species, and regionally available nutrient sources (e.g., poultry litter). Perennial grasses are the primary forage species used, and bahiagrass (*Paspalum notatum*), bermudagrass (*Cynodon dactylon*), and tall fescue (*Festuca arundinacea*) are widely planted. These grasses rely on nitrogen (N) inputs (inorganic fertilizer or animal manures) to sustain forage production and persistence and support animal performance. Seasonality of forage production is a significant challenge for livestock operations and requires planning to provide a year-round supply of feed (e.g., hay, stockpiled forages). If off-farm inputs (e.g., supplements) are required to support the cattle herd, their cost impacts the profitability of operations and limits their ability to implement adequate management and sustainable practices. Due to the favorable weather conditions in the Southeast region, forage systems can be managed year-round to optimize forage production and environmental benefits while decreasing off-farm inputs. There is no 'one size fits all' when planning a forage budget for an operation. It is essential to understand the plant and animal needs, the management skills required, and the goals and budget of the operation.

Expanding our field of view beyond South Carolina to a global scale, increasing population, and limited area for agricultural expansion has led to a growing focus on sustainable intensification. This approach aims to enhance food and fiber production by optimizing resource use efficiency in agricultural areas and decreasing environmental impacts. Within the livestock sector, there is increasing interest in adopting improved practices that can contribute to enhanced forage production and quality, improved soil fertility and health, and reduced greenhouse gas emissions. Forage-based livestock systems can contribute significantly to these sustainability goals because soils under perennial forages store large amounts of organic carbon, a key determinant of soil health and an essential nutrient and water-holding component of agricultural soils.

## 2. Overview of Forage Physiology, Morphology, and Growth

Liliane Silva, Forages Specialist, Clemson University

In this chapter, the focus is on processes associated with the functioning of the forage plants. The goal is to associate the plant physiology concepts with field processes to help producers make better management decisions and optimize the forage system responses. Below you will find some definitions:

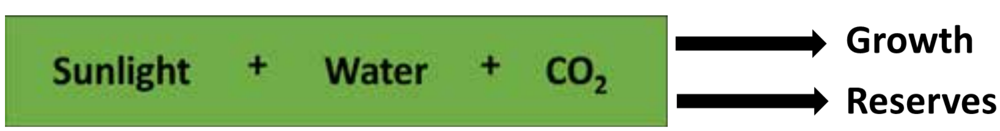
a. **Seeds**: are plant structures containing an embryonic plant, protective coat, and energy reserve for germination. When planting, it is essential to buy high-quality, certified seeds to avoid the introduction of weeds, store seeds correctly, and use the recommended seeding rate and seed depth at planting.

b. **Germination**: consists of the plant's initial growth and is directly affected by environmental conditions such as moisture, oxygen, temperature, and sunlight. Some forage species do not produce viable seeds, and their propagation occurs using plant parts (stems, root-rhizomes, etc.).

c. **Photosynthesis:** is the primary mechanism for energy input in plants and life on Earth. Through light capture, plants can transform water and carbon dioxide into energy for growth, maintenance, and reserves. In essence, photosynthesis occurs in two steps:

i. Energy is harvested from light and produces energy the plant can use;

ii. Uptake of carbon dioxide ($CO_2$) from the atmosphere that is used to produce carbohydrates. This process can be simplified as below.




This process occurs inside specialized cells of plant leaves and can be completed through two carbon fixation pathways which are referred to as C3 and C4. These pathways are associated with specific categories of forage plants. Generally, legumes (e.g., alfalfa and the clovers) and cool-season grasses (e.g., tall fescue and annual ryegrass) are C3 plants, while warm-season grasses (e.g., bahiagrass and bermudagrass) are C4. Some of the main differences between **C3 and C4 plants** are described below.

i. The optimal temperature range for growth is 90 to 95 (C4) and 65 to 75°F (C3).

ii. C4 plants are more efficient photosynthetically and produce more forage per unit of nitrogen and water supplied than C3 plants.

iii. C4 plants have lower digestibility and crude protein concentration than C3 plants.

In pastures, there is a natural cycle of growth and forage accumulation. Plant parts live for specific lengths; if not harvested, senescence starts. During the senescence process, nutrients are redistributed from older structures to new tissues and leaves. The recommendation for target harvest (e.g., grazing, hay production) aims to minimize the amount of senescent material and optimize the balance between forage quantity and quality. After each harvest, the plant regrowth is supported by the residual leaf area and carbohydrate (energy) reserves. Harvesting at the optimal target improves the ability of the canopy to regrow and replenishes energy reserves. When the frequency and intensity of harvests are high (e.g., overgrazing), the reserves can be reduced, compromising the plant persistence, and the stand starts to thin out.

The weather conditions (e.g., seasonal temperature change) directly impact forage growth and accumulation. Plants respond to differences in daylength, light needs, and temperature. For example, temperature changes can induce the dormancy of warm-season perennial grasses in early fall and regrowth in spring. This dormant stage that perennial forage species exhibit is often referred to as the seasonality of production. Perennial species have underground growing points that allow new shoots and roots to grow as weather conditions become more favorable in spring for warm-season perennial plants. For perennial plants, the management implemented during the previous growing season is vital to their ability to survive colder temperatures during the fall and winter and regrow successfully in spring.

## 3. Overview of Forage Species for South Carolina Systems

Liliane Silva, Forages Specialist, Clemson University

When planning a forage system, there is no ‘one size fits all.’ Choice of forage species should be based on site location and climate, plant and animal requirements, goals, and enterprise budget. Before establishing a new forage system, make sure to understand the plant’s needs (e.g., soil fertility, harvest management) to ensure the successful establishment and longevity of the stand. Always use high-quality, certified seeds and conduct proper land preparation and weed control when planting. This section will focus on common annual and perennial forage species used in South Carolina.

**Warm-season grasses**

Warm-season perennial grasses are the basis of most forage-livestock systems in South Carolina. They are well adapted to our environmental conditions and can be utilized for grazing, hay, baleage, or silage. Below is an overview of the most-planted species and their establishment recommendations statewide.

**Perennial grasses**

**Bahiagrass**

Bahiagrass is native to South America and widely used in the southeastern USA. It is adapted to sandy loam soils with optimal pH ranging from 5 to 6.5 and can grow 12 to 25 inches tall. Bahiagrass is established by seeds and can tolerate drought, sporadic flooding, low soil fertility, and close grazing. It is a dense, prostrate grass with shallow and horizontal stems (rhizomes) that form a thick mat (sod). It can be managed for grazing, hay, or seed production, and most of its forage production occurs from April through September. There are diploid and tetraploid bahiagrass types, and they differ in several characteristics, including seasonality of production and cold tolerance. Diploid types (e.g., Pensacola, UF Riata, Tifquik, Tifton 9, Sand Mountain) are more cold tolerant than tetraploids and are adapted to the northern areas of the Coastal Plains. Tetraploid types (e.g., Argentine) are mostly confined to warmer regions of the state. For bahiagrass establishment, the planting window is during spring, and seed quality is important to avoid introducing weeds, especially brunswickgrass (*Paspalum nicorae*). The recommended seeding rate is 15 to 20 lbs. pure live seed (PLS)/acre. Seeds can be either broadcast or drilled to ¼ to ½ inch depth. Between 7 to 10 days after seedling emergence, the stand should be fertilized using 35 to 50 lbs. nitrogen (N)/acre. Potassium (K) and phosphorus (P) rates should be applied based on soil report recommendations. After 30 to 50 days, apply another 50 to 75 lbs N/acre.

**Bermudagrass**

Bermudagrass is adapted to moderate to well-drained soils with optimal pH ranging from 5.5 to 6.5. Its canopy height ranges from 6 to 25 inches, and varieties are propagated through seeds or vegetative material. Hybrid varieties have higher forage production and quality potential and are propagated vegetatively. The most common hybrids are Russell, Tifton 44, and Tifton 85, although new varieties have been released recently (Newell and Mislevy). Among the seeded

varieties, the most widely used are Common and Cheyenne. The seeding rate is 8 to 15 lbs. PLS/acre, and the planting depth is ⅛ inch. The planting window is throughout spring. Hybrid varieties are planted using root-rhizome material at a rate of 30 to 50 bushels of sprigs per acre. Due to challenges related to getting sprigs, some varieties can also be planted using the aboveground parts (tops) at 1000 lbs of fresh stems per acre.

Generally, bermudagrasses have high forage production and quality potential relative to bahiagrasses. Bermudagrass can be managed under grazing or hay production and, during fall, can either be stockpiled or overseeded with cool-season forages in early fall to extend the grazing season. The bermudagrass stem maggot [BSM; *Atherigona reversura* Villeneuve (Diptera: Muscidae)] was first reported in 2010 by hay producers in South Georgia and has spread throughout the Southeast region. It can cause substantial damage to fields because of its short life cycle (21 d), and its feeding kills the growing point of the plants, causing upper leaves to be yellow and senesce.

**Johnsongrass**

Johnsongrass (*Sorghum halepense*) is a rhizomatous bunchgrass that can grow up to 6 ft tall. It is best adapted to clay soil, spreads by rhizomes and seeds, and is drought tolerant. It has high forage quality for cattle but is often considered a troublesome weed in hayfields. Johnsongrass is not grazing tolerant and does not survive under continuous grazing management. When managed under grazing, producers need to be aware of practices to avoid prussic acid and nitrate toxicity in animals. Prussic acid can build up in the leaves of plants in the sorghum family that are stressed by prolonged drought, frost, or the application of herbicides (e.g., 2,4-D). It is recommended to wait up to two weeks after a drought or frost event has occurred before turning the animals in to graze to allow time for restoring plant growth and metabolic functions and diluting these compounds. An accumulation of nitrates typically occurs following a drought or cool and cloudy weather that stunts growth. Unlike prussic acid, nitrates do not degrade over time, so it is crucial to test heavily fertilized or drought-stressed johnsongrass hay for nitrates before feeding.

**Dallisgrass**

Dallisgrass (*Paspalum dilatatum*) is a bunchgrass used primarily as a volunteer grass in the Southeast. It has excellent tolerance to poor drainage and is adapted to clay and loam soils with optimal soil pH ranging from 5.6 to 8. The recommended seeding rate is 10 to 15 lbs. PLS/acre with a seeding depth of ¼ to ½ inch. It has low forage production potential and limited seed production with the risk of ergot infection. When seed onset occurs in late summer and early fall, ergot can cause toxicity in cattle called dallisgrass staggers. Seed heads should be clipped to eliminate the ergot problem if it develops.

**Native Warm-season Grasses**

Native grasses refer to those species native to the USA region before European colonization. They are widely adapted to the Southeast region and can be managed under grazing or hay production. They are deep-rooted bunchgrasses, can have rhizomes, and can grow up to 6 ft tall. Generally, most forage production occurs from late March through mid-summer, then their growth slows down, and they go dormant in October. Typically, they have a slow establishment; therefore, management practices to reduce weed pressure and ensure persistence are essential. Big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), eastern gamagrass (*Tripsacum dactyloides*), and switchgrass (*Panicum virgatum*) are the most common native grasses used for forage. They are drought tolerant, can be grown under low input systems, and are adapted to burning cycles.

## Annual grasses

### Crabgrass

Crabgrass is native to South Africa and requires well-drained soils with a pH ranging from 5.5 to 7.5. It produces relatively high-quality forage and can be managed under grazing or hay production. The most used crabgrasses are large or hairy crabgrass (*Digitaria sanguinalis*) and smooth crabgrass (*D. ischaemum*). The seeding rate and depth recommended for establishment are 3 to 5 lbs. PLS/acre and ¼ to ½ inch, respectively. Crabgrass requires adequate soil fertility, including N fertilizer, to sustain forage production and quality. At the end of each growing season, it can be managed for reseeding for the following growing season.

### Pearl millet

Pearl millet (*Pennisetum glaucum*) has high forage production and quality potential and is reasonably tolerant to drought. It is adapted to well-drained and fertile soils and can be used for grazing, hay, or silage production. The recommended seeding rate is 15 to 25 lb PLS/acre, and the seeding depth is ½ to ¾ inches. Scouting for diseases and insects is essential, and control should be applied as needed. Attention should be given to weather conditions that favor the accumulation of nitrate (e.g., drought), elevating the probability of the occurrence of toxicity in animals.

### Sorghum

Sorghum (*Sorghum bicolor*) is a high-yielding forage mainly used for silage but can also be grazed. The optimal soil pH ranges from 6 to 6.5. Recommended seeding rate and seeding depth are 8 to 12 lbs. PLS/acre and 1 to 2 inches, respectively. The planting window starts when the soil temperature reaches 65°F at the 4-inch soil depth, and planting can occur well into the summer for fall grazing. It is important to scout for insects and diseases and control them as needed. Sugarcane aphid (*Melanaphis sacchari*) is a significant pest in *Sorghum* spp compromising forage production and quality. Numerous hybrids in the market offer sugarcane aphid tolerance. Limited insecticides are available to control the sugarcane aphid in forage sorghum and sorghum-sudangrass varieties. When growing forages in the sorghum family, caution should be used because of potential prussic acid poisoning or nitrate toxicity, primarily associated with drought or frost during the fall.

### Sorghum sudangrass hybrids

Sorghum × sudangrass [(*Sorghum bicolor*) × (*Sorghum × drummondii*)] is a cross between sorghum and sudangrass. It is tolerant to heat and drought and can be used for grazing, hay, or silage. It is adapted to fertile soils with a pH of 5.8 or higher. The recommended seeding rate is 12 to 15 lb PLS/acre, and the seeding depth is one to two inches. It is vital to understand the potential for prussic acid poisoning or nitrate toxicity when using these hybrids, particularly when drought and frost events lead to the accumulation of these compounds.

### Cool-season grasses

Cool-season forages are used statewide, and tall fescue is the perennial cool-season grass predominant in northern South Carolina. Below is an overview of establishment recommendations for the most planted species statewide.

**Perennial grasses**

**Tall fescue**

Tall fescue is a perennial, cool-season forage that can be managed under grazing or hay production. It grows from February to June and September to November. Recommended seeding rate is 15 to 20 lbs. PLS/acre and seeding depth is ¼ to ½ inch. In general, tall fescue should be planted from September to October. It is recommended to plant novel endophyte varieties because the older varieties infected with the endophyte *Epichloë coenophiala* can fescue toxicosis in animals. This condition happens due to the production of an ergot alkaloid.

**Orchardgrass**

Orchardgrass (*Dactylis glomerata*) is used under grazing or hay production. It grows 2 to 4 ft tall and is less tolerant to drought and poor drainage than tall fescue. Usually, it is one of the earliest grasses to initiate growth during cool weather conditions and requires a pH ranging from 5.8 to 7 for good establishment and stand persistence. The planting window is September to October, and the recommended seeding rate ranges from 15 to 20 lbs. PLS/acre and seeding depth is ¼ to ½ inches.

**Annual grasses**

**Annual ryegrass**

Annual ryegrass (*Lolium multiflorum*) requires fertile soil and tolerates poorly drained soils better than small grains. Its peak forage production occurs around March and April, and it is a good companion forage to be planted in a mixture to extend the grazing season in spring. The recommended seeding rate is 15 to 30 lbs. PLS/acre and seeding depth is ½ to ¾ inch. It is a high-quality forage that tolerates close grazing and can also be used for hay. Annual ryegrass is often overseeded into perennial warm-season grass stands; therefore, the management of its end-of-the-season growth is crucial to avoid delaying the onset of growth of the warm-season perennial. Annual ryegrass can be planted alone or in a mixture with other cool-season species. It is important to remember that annual ryegrass and cereal rye are not the same species.

**Oat**

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

**Cereal rye**

The majority of cereal rye (*Secale cereale*) grown in the US is used as a cover crop, pasture, or hay. Rye is well-adapted to sandy or acidic soils, and the optimal pH ranges from 5.8 to 6.5. 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 the 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 stubble height.

**Triticale**

Triticale is a cross between wheat and rye and 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 tests indicate that triticale often produces DM yields similar to rye but with a heading date later than rye. Triticale is typically used to produce hay or silage, but it 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 utilized predominantly for human consumption, wheat is also grown as a feed source for animal production. Wheat shows active growth in the fall, winter, and spring. It grows well under a soil pH range of 5.5 to 8.0. Recommended seeding rate is 90 to 120 lbs. PLS/acre and seeding depth should be one to two inches. Wheat is usually a choice in western and northern areas of the SE region and has limited productivity and more incidence of diseases in southern areas. The hessian fly can be an issue, and there are varieties more tolerant to the insect.

## Warm-season legumes

Legumes can capture nitrogen from the atmosphere and transform it into compounds available for plants. This process is called biological nitrogen fixation and occurs through a symbiotic association between the legume plant and microorganisms. All legume seeds should be inoculated before establishment. Below is an overview of establishment recommendations for planted species adapted to South Carolina.

### Perennial legumes

#### Rhizoma perennial peanut

Rhizoma perennial peanut (*Arachis glabrata*) 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 can be used for hay production or under grazing management. New varieties and technologies have helped decrease establishment costs and cope with its slow establishment rate. Soil pH and fertility should be tested, and proper land preparation should be conducted before planting. Adequate weed control should occur throughout the establishment period. It is established by vegetative propagation using rhizomes, and the planting rate is 80 bushels of rhizomes per acre. Ideally, rhizomes should be planted at a 1-inch depth. The planting date should generally be late March through early July.

#### Sericea lespedeza

Sericea lespedeza (*Lespedeza cuneata*) is deep-rooted and grows well on medium- to well-drained clay-to-loamy soils. It can be used for hay production or managed under grazing conditions. Generally, it grows from April through November 1st, and its forage production peaks from June through August. The seeding rate is 20 to 30 lb PLS/acre, and the planting window runs from March 15 to May 1st. 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 livestock rumen, contributing to more efficient feed use. Sericea helps reduce internal parasite loads in small ruminants, including *Haemonchus contortus* (barber pole worm).

**Annual legumes**

**Cowpea**

Cowpea (*Vigna unguiculata*) can grow under relatively poor soils and dry conditions. Planting dates vary from mid-March to late August. Typically, growers should wait until soil temperatures reach 60°F to plant. The recommended seeding rate and depth are 30 to 40 lbs. PLS/acre and ¾ to 1¼ inches with row spacing of 30 or 36 inches. 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).

**Hairy indigo**

Hairy indigo (*Indigofera hirsuta*) is adapted to well-drained, sandy soils and has moderate tolerance to drought. It is mainly used under grazing management and can be managed to reseed. It can be used in a mixture with other warm-season annual as an option to increase the input of organic nitrogen into the forage system. Seeding rate and depth are 5 to 8 lbs PLS/acre and ¼ inch, respectively. It is resistant to the root-not nematode. The planting date should generally be late March through June.

**Sunn hemp**

Sunn hemp (*Crotalaria juncea*) tolerates drought and relatively low-fertility soil. The optimal soil pH ranges from 5 and 8.4, and it grows best in sandy, well-drained soils. Sunn hemp should be planted into a prepared seeded when soil temperature has reached 65°F. The recommended seeding rate and depth are 25 to 30 lbs. PLS/acre and ¼ to one inch, respectively. It can accumulate biomass rapidly within 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 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.

**Striate lespedeza and Korean lespedeza**

Both striate annual lespedeza (*Kummerowia striata*) and Korean lespedeza (*Kummerowia stipulacea*) have shallow taproots 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. 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 than hay production. Korean lespedeza is less competitive than striate lespedeza with companion grasses.

**Cool-season legumes**

Cool-season legumes are often used in a mixture with grasses to add nitrogen to the system, improve animal diets, and increase soil fertility for the current or next crop in rotation. The incorporation of legumes into forage systems has been increasing, including alfalfa (*Medicago sativa*).

**Perennial legumes**

**Alfalfa**

Alfalfa is well-suited for hay, silage, baleage, and grazing. It requires well-drained, high-fertility soils and has limited pest and disease pressure tolerance. Soil samples to a 15-inch depth should be collected by dividing the soil profile into two layers, surface (0 to 8 inches) and subsoil (8 to 15 inches), before planting to determine pH and fertility. Soil pH should range from 6.5 to 7.0 on the surface and 5.5 to 6 on the subsoil. Adequate levels of boron (B) and molybdenum (Mo) are essential for nodule formation. If seeds purchased are not inoculated, inoculant (Type A, *Rhizobium meliloti*) should be applied according to label instructions. Alfalfa seeding rate and depth are 20 to 25 lbs. PLS/acre and ¼ inch.

**White clover**

White clover (*Trifolium repens*) is tolerant of grazing and often planted in a mixture with other cool-season forages. The optimum pH ranges from 5.5 to 6. Before planting white clover, it is vital to ensure no herbicide residual in the soil because that can lead to stand establishment failure. The recommended seeding rate and depth are 2 to 3 lb PLS/ace and ¼ to ½ inches. The planting window ranges from August 25th to Nov 1st.

**Annual legumes**

**Arrowleaf clover**

Arrowleaf clover (*Trifolium vesiculosum*) requires soil pH ranging from 5.8 to 6.5 and can be planted in mixtures with other cool-season forages. The planting window is late September through early November. The recommended seeding rate and depth are 5 to 10 lbs. PLS/acre and ¼ to ½ inch. Recommended stubble height is 4 inches, and when harvesting hay, it should be cut at the bloom stage.

**Ball clover**

Ball clover (*Trifolium nigrescens*) has non-hairy leaflets, white flowers, and late maturity. It is widely adapted and can tolerate poor drainage. The seeding rate and depth recommended are 2 to 3 lbs. PLS/acre and ¼ to ½ inch. The production peak ranges from late March through May and can be managed for reseeding under grazing.

**Berseem clover**

Berseem clover (*Trifolium alexandrinum*) 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 lbs. PLS/acre for broadcast and drilling, respectively. Seeding depth should be from ¼ to ½ inch. Recommended stubble height is 4 inches and can be used in a mixture with other cool-season forages.

**Crimson clover**

Crimson clover (*Trifolium incarnatum*) has pubescent leaves, stems, and crimson flowers. It requires well-drained soils and does not tolerate calcareous soils. The recommended seeding rate and depth are 20 to 30 lbs. PLS/acre and 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.

**Red clover**

Red clover (*Trifolium pratense*) 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. The recommended seeding rate and depth are 6 to 15 lbs. PLS/acre and 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 and established and can be planted with other cool-season forages.

**Hairy vetch**

Hairy vetch (*Vicia villosa*) requires well-drained, fertile soils with a pH ranging from 6 to 7. It is winter hardy, and the planting window is late August through October. The recommended seeding rate and depth are 15 to 20 lbs. PLS/acre and ½ to 1 inch. It can be managed under grazing or single-cut hay production and in a mixture with other forages. Its peak production is in late March through late April/May.

**Winter peas**

Winter peas (*Pisum sativum*) require well-drained loam to sandy loam soil. The planting window is September through October. The recommended seeding rate and planting depths are 30 to 40 lbs. PLS/acre and ¼ inch. It can be used for a single cut of silage in April or managed under grazing.

**Non-leguminous Forbs**

**Brassicas**

Brassicas are cool-season annuals that can be used for fall or spring production. They include rapeseed (rape; *Brassica napus*), radish (*Raphanus sativus*), turnip (*Brassica napa*), kale (*Brassica oleracea*), and hybrids. Brassicas are quickly maturing and can be grazed 60 to 120 days after planting, depending on the species. Forage production averages 4 tons of dry matter/acre.

Varieties of turnip, radish, and swede produce a highly palatable and nutritious tap root that can be grazed during the last rotation of the season. The seeding depth should be ¼ inch, and seeding rates range from 4 to 5 lbs. PLS/acre for kale, rapeseed, radish, and 2 to 3 lbs PLS/acre for swede and turnip. Seeding rates should be reduced when planting brassicas in a mixture with other forages. Brassicas should not be more than 50% of the diet to minimize chances for Cu and I deficiency.

**Why should I consider using Forage Mixtures?**

Using forage mixtures can be an option to balance forage production, quality, and distribution and to reduce the input of inorganic nitrogen fertilizer. The latter is possible using legumes once they can establish symbiotic relationships and fix nitrogen biologically. When using mixtures, the seeding rate must be adjusted to account for the proportion of each species in the stand. The harvesting management strategy must be adjusted to improve species' use efficiency and regrowth. Examples of warm- and cool-season forage mixtures will be presented below.

**Alfalfa-bermudagrass mixture**

In the Southeast region, seeding alfalfa into bermudagrass is a viable option for improving forage production and quality and extending the production season. Both species have similar soil drainage and fertility requirements, and alfalfa supplies biologically fixed nitrogen to the system.

Before sowing alfalfa, soil testing should be conducted and amendments applied based on the soil report. Then, the bermudagrass stand should be mowed or grazed to ~ 2 inches before planting to remove excessive forage mass. The recommended alfalfa seeding rate and depth are 12 to 15 lbs. PLS/acre and ½ inch with a 14-inch row spacing.

It is recommended to soil test annually and apply P and K according to recommendations. Potassium fertilization is critical, and rates up to 300 lb/acre are recommended in split applications throughout the season. Boron and molybdenum should be applied. After established, harvest events should occur when the stand is at 10% bloom or generally every 28 to 35 days. The recommended stubble height is 4 inches, and if using the mixture under grazing, rotational management should be applied to allow for a proper resting period. Scouting the fields for insect and disease pressure will be necessary from spring through fall.

### Rhizoma perennial peanut-grass mixture

Rhizoma peanut can be planted in strips into warm-season grass stands, such as bahiagrass, to decrease inorganic nitrogen input and improve forage production and quality, especially in low-input systems. This practice is called strip-planting and involves using a herbicide to control the grass in strips, then planting rhizoma peanut into the strips. Over time the legume will spread horizontally into the field. Proper weed control will ensure the best chances of establishing the rhizoma peanut. Both species go dormant during the fall and winter months, and this mixture can be overseeded to cool-season forages during that period to extend the grazing season. This mixture is often used under grazing management, and rotational grazing is recommended to help optimize the excreta distribution.

### Warm-season annual forages

Summer annuals are fast-growing, high-quality forages that can be used as supplemental feed for grazing or as conserved feed. They can be an excellent option to produce additional biomass to complement tall fescue, bahiagrass, or bermudagrass systems. They can be used to meet higher nutrient requirements for specific animal categories (i.e., stockers, replacement heifers) or to fill the gap in forage production due to weather conditions (i.e., prolonged drought). There are several species of annual warm-season forages available, as previously mentioned. The use of legumes in mixtures has been increasing, and they help balance the forage quality and the residual nitrogen that can remain available to the next crop in the rotation in the field.

**Cool-season annual forages**

Annual cool-season forages have high quality and can extend forage production and distribution, decreasing the need to feed hay. Selecting the proper forage species adapted to your location, weather, soil type, and animal nutrient requirements is essential. A mixture of forages improves forage production and distribution throughout the season, and when including legume(s), it helps to provide nitrogen into the forage system.

The residual nitrogen added during this period will improve the growth and production of the warm-season forages when they regrow during spring if overseeding a warm-season grass stand. This is a viable option to provide proper nutrition to animals grazing, including weaned calves. Moreover, a year-round system allows for nutrient cycling and continuous input of biomass that contributes to carbon sequestration and delivers additional environmental benefits that will increase soil health and fertility.

## 4. Soil Sampling and Fertility Management

Liliane Silva, Forages Specialist, Clemson University

### Collecting soil samples

Routine soil sampling is essential to monitor soil pH and fertility. These parameters can vary widely throughout a field, requiring a representative sample for testing. Samples should be taken to a 4-inch depth using a soil auger or a shovel. The recommendation is to randomly take around 15 to 20 sub-samples for an area of up to 10 acres. These subsamples should be placed inside a bucket and mixed thoroughly to form a composite sample from a field, then placed into a sample box to send for testing.

In pastures, it is essential to avoid areas where animals congregate intensively, such as around water sources, hay rings, feeding areas, and under-shaded areas. Generally, these areas tend to have a higher nutrient concentration due to the animal excreta deposition and will not be representative of the average fertility of the field. Soil samples should be collected yearly for pastures and hayfields to monitor soil amendment needs and promote soil fertility and nutrient availability for plants. Following the soil test recommendations for lime and nutrient applications helps to improve forage production and quality to meet livestock requirements. The fertility requirements and management plan will vary according to the soil and forage type.

### Interpreting soil reports

In the soil report, there will be three sections providing important information. The **lime recommendation** provides the amount of lime (ton/acre) needed to correct soil pH. Then, the **nutrient concentrations** and **fertilizer recommendations** (lb/acre) for nitrogen (N), phosphorus (P), and potassium (K) are provided. It is important to remember that different fertilizer sources contain different percentages of each nutrient so the appropriate amount will depend on the fertilizer source used. It is crucial to emphasize that upon soil sample submission, the form should contain the correct forage(s) established in the area currently or to be planted in the area. This is critical because fertilizer recommendations are based on the crop(s) being grown. The recommendations provided by the laboratory will be based on information from previous research studies. It is essential to use a reliable testing laboratory and always consult your local extension agent for fertilizer rates and sources to be used in case you need help. The last section will be the comments which give special instructions regarding the fertilization plan and/or recommendations for the timing and placement of fertilizers, among other information.

**Nutrient deficiencies**

In addition to soil testing, visual observation is commonly used to diagnose nutrient deficiencies in the field since plant symptoms, such as yellowing and stunted growth, are associated with specific nutrients. This approach may be helpful for trained observers, but more than one nutrient may often 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 the main macro and micronutrients within the plant. It is recommended to take plant tissue samples randomly throughout a field to get a representative sample of the canopy strata of interest for tissue analysis. 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 should be carried out when soil test results have been inconclusive.

## 5. Tips for Proper Stand Establishment

Proper land preparation and stand establishment are crucial to ensure successful forage establishment. Below are a few essential tips to follow:

1. Soil test before planting to amend pH and apply fertilizers based on soil report recommendations. Soil sampling should be conducted up to six months before planting to allow for lime application and its incorporation into the soil.
2. Conduct proper weed control. Identify weed species in the area and plan to use required herbicides to control them.
3. Land preparation is crucial before sowing seeds:
   a. When using a clean seedbed, land should be well prepared (disked, harrowed, etc.) to achieve appropriate planting conditions.
   b. When overseeding into perennial warm-season grass stands, removal of excessive forage mass is required to allow for proper seed-soil contact.
4. Use certified, high-quality seeds to avoid introducing unwanted plants into your pastures.
5. Using proper seeding rate and seed depth is critical.
6. Use mixtures to improve forage distribution and quality throughout the season. For example, well-established perennial grass fields can be overseeded with cool-season forages to be grazed in fall and winter. Adjustments to the individual seeding rates will be necessary when mixing species. For help in adjusting the seeding rates, please consult your local Extension agent.
7. Incorporating legumes can improve diet quality and helps with the input of biological fixed N into the forage system. Legumes can be used in association with grasses in

annual or perennial systems. The choice of species, establishment, and management of the system must be correctly made to improve the chances of success.

8. Once the stand is established, plan to split the total fertilizer rate for nitrogen and potassium to optimize plant use and decrease losses and runoff.

Below is an overview of the seeding rates and dates for commonly planted forages in South Carolina (Table 1).

Table 1. Seeding rate and common planting window for forage species.

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

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

### Overseeding perennial forage pastures to extend the grazing season

A practice 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 it requires some practices before the establishment to ensure seed germination and establishment of the cool-season species.

In preparation for sowing, the excessive vegetative growth of the warm-season species 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 optimize seed-soil contact. Generally, in bahiagrass and bermudagrass pastures, the planting date will be in late September to early December, depending on where the site is located and when the warm-season forage goes dormant.

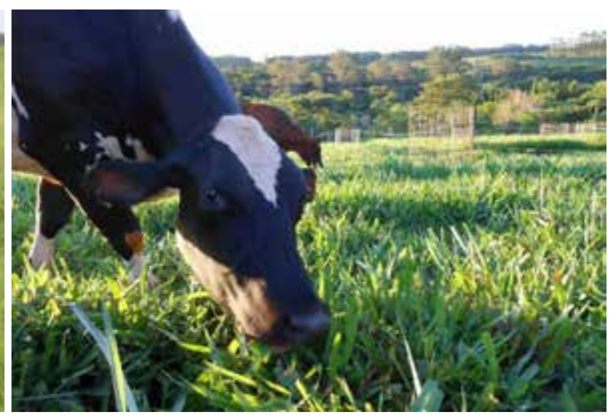
## 6. Forage Harvest Management Strategies

Liliane Silva, Forages Specialist

The use of proper forage management strategies is essential to achieving adequate forage production and forage quality and to meeting animal performance goals. Following research-based management recommendations for each forage species helps optimize stand longevity and improve forage use efficiency. Good decisions regarding approaches taken for **grazing** and **conserved forage** (hay, baleage or stockpiled) production are of critical importance.

### Grazing methods

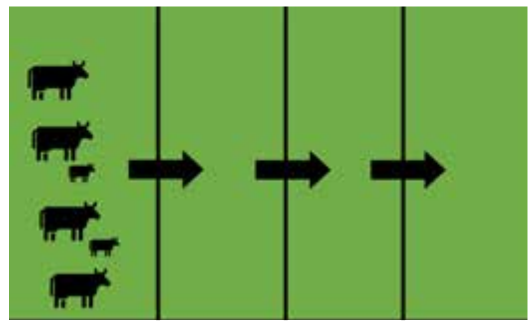
Grazing management is crucial in the production, quality, and persistence of forage crops and significantly impacts animal performance. When making a grazing plan, it is essential to consider animal and plant requirements, management skills, the operating budget, and enterprise goals. Increasing the number of grazing days should be considered because it reduces costs associated with supplemental feed.

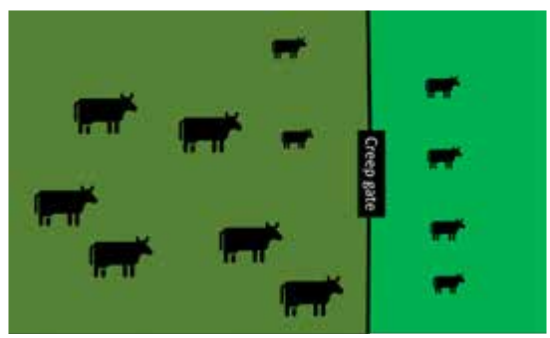
**Continuous stocking**- animals have unrestricted access to a specific unit of land during the grazing season. Animals can selectively graze unless the stocking rate is high. If overstocked, animals may deplete plant storage reserves and also damage growing points leading to overgrazing and compromising stand persistence.

**Rotational stocking-** the pasture is subdivided into paddocks on which there will be alternate grazing and rest periods during the grazing season. This method requires a higher management level and more labor but can provide better distribution of recycled nutrients and more rapid plant recovery.

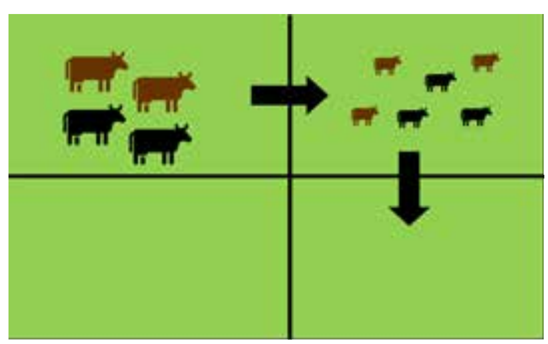
**Strip grazing-** consists of using temporary fencing to have animals graze an area for a short period and progressively move to the next strip forward. This is commonly used in stockpiled forage systems (e.g., bermudagrass, tall fescue) and cool-season annual foragesAnother possible use is to restrict access to given areas to break disease cycles and reduce their occurrence, for example, in small ruminant systems.



**Creep grazing**- can be used on cow-calf systems to allow calves access to higher forage quality feed adjacent to the forage base where the mothers are grazing. The creep gate (openings) will connect the areas and should be large enough for calves to move through.




**First-last grazers**- allows animals with higher nutritional requirements to graze a given pasture area first to remove the higher quality forage and move forward in a rotation ahead of the second group. This method can be used with different animal classes (e.g., mature cows and yearlings) or species (e.g., cows and goats).



**Limit grazing** - provides animals with limited access to a forage crop field for a short period, commonly a few hours per day. This method provides access to higher-quality forage for short periods to allow animals to meet their daily nutrient requirements.

## Conserved forages strategies

One of the main challenges of perennial grass-based systems is the seasonality of production. Conserved forages are a reliable way to meet forage quantity and quality requirements of livestock herds while perennial forages are dormant.

## Hay production

The moisture level of the forage is an essential consideration for hay production. As a rule of thumb, for safe bailing, the moisture levels should be <20%, ≤18%, and ≤16% for small rectangular, large round, and large rectangular bales, respectively. There is a fire risk when baling hay over the proper moisture range. Internal hay temperature should be observed after bailing, and if the internal hay temperatures reach over 140°F, bale (s) should be removed from the barn.

Recommendations for harvest stage, frequency, and stubble height are specific to each forage species and essential to good forage production and persistence. After forage is cut, drying time varies based on the forage species and environmental conditions. Tedding helps to decrease the time until bale, and the initial tedding should occur within 4 hours of cutting if the moisture level is adequate. However, avoid tedding legumes with moisture above 50% to decrease leaf loss.

Hay bale storage plays a crucial role in conserving the forage quality of the harvested forage material. If done incorrectly, storing hay bales can lead to losses of dry matter and quality and promote animal health issues. Hay bales should be stored in well-drained areas, without contact with soil, and preferably inside a barn or other covered structure. Before feeding, hay samples should be taken and sent to the laboratory for analysis. Supplementation of animals consuming hay must be based on a forage quality report to meet nutrient requirements.

**Baleage**

Baleage (or haylage) is a fermented forage product that is stored in the absence of oxygen. After harvest, the forage is baled at high moisture (40 to 60%), reducing the drying time and exposition of material to the environmental conditions. In the Southeast region, this can be an advantage during the rainy season when it can be hard to have several days of clear weather in a row to dry the material. The wilting time will depend on forage species and environmental conditions. In Appendix E, you will find an explanation of how to determine forage moisture level using a microwave which is a quick test and can help decide when to bale and wrap the forage.

When the moisture is appropriate, the forage is baled and sealed in several layers of plastic using a bale wrapper. Then, bales should be stored in a dry area. The fermentation process can take between 4 and 10 weeks to complete. Upon bale opening, the feed should smell bread-like and be free of excessive mold growth. When

forage is baled under excessive moisture (> 60%), spoilage can happen associated with loss of bale shape, as in the picture. If unfit to feed, bales should be discarded to avoid compromising animal health.

**Silage**

For silage, harvested forage is baled between 60 and 80% moisture. Generally, the forage is chopped, then compacted into silos to eliminate oxygen. An appropriate bulk density is required to optimize the conditions for proper fermentation. Different types of silos can be used, while the most common ones are the open-style concrete bunker and the plastic silage bags. Corn, sorghum, pearl millet, and small grains are often used as silage.

**Stockpiling forages**

Stockpiling is a management practice that defers forage availability for later use when growth is limited or null. This practice helps to decrease costs associated with feeding hay in livestock operations. In the southeast U.S., perennial grasses such as bahiagrass, bermudagrass, and tall fescue are used to close the forage gap and extend the grazing season.

To begin the stockpiling period, the recommendation is to graze or cut the field to 4-inch stubble height for the perennial grasses mentioned above. Then, apply up to 50 lb of N and K and let the forage accumulate for four to six weeks, depending on when the period started. For example, for bermudagrass, the stockpiling period should be initiated in late Aug, and grazing starts around mid-October.

For stockpiled forages, grazing management should be designed to optimize grazing efficiency. Generally, strip grazing is used, and animals have access to a given area for a short time and then progressively move forward. This practice allows for the adjustment of the size of strips based on the forage mass available, allowing animals to spend 2 to 3 days in each strip optimizing the forage removal. When using strip grazing, it is essential to plan for the placement of water throughs and mineral feeders before the rotation is initiated. The forage quality declines as time passes, but this is an economical way to extend the grazing season until animals are moved into the cool-season forages or start being fed hay.

# 7. Understanding the Basics of Forage Quality

Liliane Silva, Forages Specialist, Clemson University



Forage quality is commonly described as the nutrient concentration of forages and their capacity to support animal performance. It is important to emphasize that in the scientific literature, forage nutritive value relates to nutrient concentration, while forage quality is defined by nutritive value and intake in the absence of supplementation.

When referring to nutrient concentration, we consider crude protein, digestibility, fiber components, sugars, and energy concentrations, among others. Thus, when receiving forage quality reports from the laboratory, total digestible nutrients and relative forage quality are calculated, while other parameters might also be available in the analysis packet.

The main factors affecting forage quality are plant species, management practices, and the environment. Warm-season grasses are C4 plants and have less crude protein and higher fiber concentration than legumes. These characteristics impact animal intake and their ability to meet nutritional requirements daily. Management practices directly impact responses through maturity of forage, fertility levels, and forage composition, among others. For example, a growing practice has been the incorporation of legumes into grass systems. This helps balance out forage quality and production due to the organic N input from the biological fixation promoted by the legumes.

**Collecting a forage sample for analysis**

The only way to assess forage quality is through laboratory analysis. For this reason, collecting a representative sample of the forage is essential. For live plants (pasture or hayfields), the forage should be randomly sampled throughout the area at the target stubble height. It is recommended to split larger areas into smaller fields. Then, several sites within the same field should be collected into a bucket, mixed thoroughly, and a composite sample sent to the laboratory. It is a similar approach to what is used for soil sampling. Before collecting the samples in the field, consider slope, feeding area (if any), management practices differences, etc. A zig-zag pattern is recommended when collecting samples to represent the area better. It is essential to follow the recommendations from the laboratory for the size of the forage sample and the package arrangement to send the sample inside.

It is vital to sample hay and baleage before feeding animals to balance the animal`s diet. When sampling hay or baleage, you will need a hay probe with a power drill attachment to facilitate the sampling process. Bales should be sampled at the round size of round bales or the short side of square bales. After collecting baleage samples, use heavy-duty UV-resistant tape to cover each hole to prevent air and wildlife from getting inside the bales. Samples should be randomly collected from several bales within the same harvest date to obtain representative samples. For more information, please contact your local Extension agent or testing laboratory.

**Interpreting a forage analysis report**

Below, you will find definitions for selected parameters reported on a forage analysis.

a. **Dry Matter** (DM), %. Forage samples are oven-dried to determine the amount of water and dry matter in the sample.

b. **Crude Protein** (CP), %. Crude protein is the total nitrogen in a forage sample multiplied by a 6.25 conversion factor. Animal species and categories have different protein requirements, and supplementation can be adjusted to meet daily requirements.

c. **Neutral detergent fiber** (NDF), %. It consists of hemicellulose, cellulose, and lignin. As NDF% increases, forage intake decreases.

d. **Acid detergent fiber** (ADF), %. An estimation of the indigestible component of the forage (cellulose + lignin). The greater the ADF%, the less digestible forages become.

e. **Total digestible nutrients** (TDN), %. Typically, the greater the value, the more energy-dense the forage is considered. Ranges for low-quality hay (45 to 52%), mid-quality hay (52 to 58%), and high-quality hay (greater than 58%).

f. **Relative forage quality** (RFQ). A single value that can be used to compare overall quality among forage samples. It ranges from 50 to 300, with the upper representing the highest-quality forage. Most animal species require RFQ ranging from 100 to 160.

g. **pH**. This is a measure of the acidity in the ensiled forage. For silage, it should range from 3.5 to 4.5, while for baleage, from 3.5 to 5.5.

h. **Minerals** (%). Mineral analyzes are typically not included in the basic packet.

# 8. Considerations for Developing a Strategic Nutritional and Supplementation Program

Matthew Hersom, Professor and Director at the Piedmont REC

The concept of strategic nutrition or supplementation is the art and science of providing appropriate feedstuffs and supplement feed for animals at the right time. Generally, strategic nutrition and supplementation programs address what, when, how much, and for how long we will use a given feedstuff, plus what it will cost. Creating strategic nutritional and supplementation programs requires synthesizing three concepts: planning, animal biology, and economics.

**Planning**

Most activities in a cattle production system operate on a seasonal cycle. Cattle production cycles, pasture growth, and environmental conditions occur in semi-regular patterns. Unfortunately, the challenge in many production scenarios is implementing management practices accordingly. Having resources and procedures in place and ready is the strategic portion of a supplementation plan.

**Forage cycle.** The forage production cycle is an essential consideration for strategic supplementation. Cool- and warm-season perennial grasses have seasonal forage production and quality variations that contribute to the need for supplementation. From a forage standpoint, quantity and quality are crucial considerations when establishing a strategic supplementation, and they will directly impact animal performance. Management practices implemented in forage-based systems should follow the proper harvest guidelines to balance forage quantity and quality. Deficiency of energy and ruminal degradable protein certainly limit cattle performance.

In many cases, the matrix of energy and protein available to support rumen function, feed intake, and performance will respond favorably to strategic supplementation. Forages also supply minerals and vitamins, which will impact animal performance and health when deficient. Phosphorus (P), sodium (Na), copper (Cu), zinc (Zn), and selenium (Se) available are generally less than sufficient to meet animal requirements during parts of the season. In this case, strategic supplementation of minerals would support cattle performance. The ability of any grazed forage to provide adequate nutrients for cattle production forms the basis for beef cattle production.

**Cow production cycle.** Cattle nutrient requirements are not static and exhibit a great deal of variation during the productive cycle of any beef animal. Therefore, not only do requirements change, but the response to nutrient supply is physiological state dependent. A cursory appreciation of cow nutrient requirements indicates changes in cow intake potential, energy, protein, and mineral requirements to meet nutrient requirements.

**Biology**

Emerging work indicates critical times in the cow's productive cycle when the nutritional environment can profoundly affect fetal programming, directly impacting the calf's subsequent life. As this field produces more evidence, the biological impact of strategic nutrition and supplementation decisions will increase. Implementation of a supplement program must have a measurable outcome to maintain its biological relevance and continued use. Supplementation of livestock makes little sense if it does not affect animal performance in some manner. Therefore, supplementation practices must have some positive biological function for the animal.

**Body weight-condition score.** Body condition score (BCS) can be used as an indirect indicator of nutritional status as it estimates the amount of fat an animal contains. Body condition score or shifts in body condition is a more reliable guide to evaluate the nutritional status of an animal when compared to live weight due to factors such as gut fill and pregnancy influencing what is read on the scale. When taken regularly, body condition score and other significant factors, such as lactation status and forage quality, can be an important tool to a producer when determining the management of nutrition and supplementation to the cow herd, for example.

**Reproduction**. Body condition score and nutritional status at calving tend to be the most influential factor in the resumption of estrous. Additionally, body energy reserves are related to the reproductive function of postpartum cows. Most studies suggest a minimum BCS of ≥ 5 at calving is needed to ensure adequate body stores so peak reproductive performance can be attained during the subsequent breeding season. The total nutritional program and strategic supplementation that supports reproduction link the biological functions to the beef enterprise profitability.

**Economics**

Feed resources cost money. Whether that money is invested in the pasture to produce grazable forage, spent to conserve forage for times of decreased pasture availability, or as a supplement outlay to address nutritional deficiencies, a financial decision is made. How and how many financial resources are dedicated to feeding and supplementing the cow herd is an enterprise-specific decision. Regardless, approximately 45 to 55% of the annual maintenance cost for a cow is consumed by feed. The key is to find the point at which cattle performance and cost outlays are optimized. Many variables will affect this, including expected cow performance, previous cow condition, forage conditions, supplement type, and environmental conditions.

**Overview of feedstuffs**

Cattle are primarily grazing animals, and most nutritional programs for the cow-calf sector should emphasize grazing as the primary means to provide nutritional inputs. However, cattle can use an array of feedstuffs to meet their nutritional requirements. Forages, grains, and byproducts of other industries constitute the primary feedstuffs categories encountered by most cattle producers. Table 2 provides a simple classification for common feedstuffs.

Table 2. Classification of feedstuffs.[1]

| Classification | Description |
|---|---|
| **Roughage** | Alfalfa cubes, Beet pulp, Cottonseed hulls, Cotton gin trash, Hay, Silage, Stockpiled forage |
| **Grains** | Corn, Oats, Barely, Wheat, Milo /Sorghum, Rye, Soybeans, Flax seed |
| **Protein Meals** | Soybean meal, Cottonseed meal, Corn gluten meal, Dried distiller's grains, Peanut meal, Linseed meal |
| **By-Products** | Bread, Brewers' grains, Citrus pulp, Corn gluten feed, Cull vegetables, Dried distiller's grains, Hominy, Molasses, Rice mill feed, Rice bran, Soybean hulls, Wheat middlings, Whole cottonseed |
| **Additives** | Antibiotics, Flavors, Insect control, Ionophores, Prebiotics, Probiotics, Salt, Trace minerals, Vitamins, Urea, Vegetable oil |

[1] Some feedstuffs can be classified into multiple categories and/or processed. This classification is used for illustrative purposes only and is not exhaustive. Consult a nutritional professional for more information and ration balance for your operation.

**Forages.** Options for grazing cattle include many options, each with benefits and challenges. The specifics of many of those grazing options are discussed in detail elsewhere in this book. Forage grazing systems can include annual or perennial grasses, legumes, or mixed stands.  Regardless of the specific forage available for grazing, the seasonality of the environment, plant growth, soil fertility inputs, and many other characteristics results in variable forage quantity and quality. This forage variability causes the need for strategic nutrition and supplementation programs.

**Conserved forages are another feedstuff option for cattle.** Conserved forages are harvested to provide forage material for later consumption by livestock. Conserved forage can help bridge the forage gap in grazing systems or replace grazed forages in cattle diets. Conserved forages encompass hay, silage, baleage, and stockpiled forages described previously (chapter 6). Some forage species are more amenable to specific conservation methods than others, and their suitability should be considered carefully to ensure the best results. Additionally, conserved forages require machinery input for cutting, preparation, harvest, feeding, and facilities for storage.

**Grains, oilseeds, and concentrates.** Grain, oilseeds, and other similar feedstuffs are used as supplements and are fed in amounts less than forages. Familiar grain sources feed to cattle include corn, sorghum, barley, oats, rye, and wheat. Familiar oilseeds include soybeans, cottonseed, sunflower, linseed, and peanuts. Other concentrated feedstuffs applied to feeding cattle include fats from vegetable sources or tallows. Grains, oilseeds, and other concentrate sources can be fed individually or in mixed feeds. Grains and oilseeds may be processed to some extent before feeding cattle to improve the digestibility of the product.

**Byproducts.** Byproduct feedstuffs result from other industries or ingredient processing methods. Many byproduct feedstuffs result from the processing of grains or oilseeds, or food manufacturing industries. In the Southeast, typical byproducts include corn grain, cereal grain, cotton, fruit and vegetables, and food manufacturing residues. Byproduct feedstuffs can be fed individually or as part feeds, and there are considerations and limitations to their use. Many of the byproduct feedstuff have concentrated nutrients or properties that limit their inclusion in cattle diets. Examples include, but are not limited to, the amount of water, concentrations of minerals and fat, anti-nutritional factors, and excessive starch. These considerations should be part of the decision process when selecting byproducts to feed cattle. Many byproducts are excellent sources of energy, protein, fiber, and nutritional components. Regardless of the source, by-product feeds are a resource to meet beef cattle's nutritional and supplemental needs and, often, a cheaper alternative than many feed ingredients.

### Considerations for strategic nutrition and supplements

The first consideration in designing a strategic nutritional and supplement program is providing enough for cattle to eat. Ensuring that dry matter intake requirements are met through grazing, stored forages, supplements, or combination is the first step in a successful program. Through the supply of enough dry matter intake, energy intake requirements can be addressed. The requirement for energy supplied in the diet is the greatest in terms of nutritional needs. Overall, the energy supply drives the productive outputs of a beef cattle enterprise. Strategic supplementation of energy can positively affect animal performance. Next in amount and importance is the supply of crude protein, which provides the necessary nitrogen for ruminal microbes. The strategic supplementation of protein can improve the utilization of low-quality forages.

Vitamins and minerals are essential to many metabolic life processes. Grazed and conserved forages are often deficient in one or more important vitamins and minerals. Likewise, numerous single-source feedstuffs are low or imbalanced in several minerals. Consistent and strategic supplementation to meet mineral deficiencies is imperative to support animal performance. Finally, considerable evidence exists supporting the application of feed additives and feed technologies in nutritional and strategic supplementation programs. The list includes ionophores, animal health additives, bioactive compounds, rumen modifiers, and anti-nutritional inhibitors that can be applied strategically to improve cattle health and performance.

**Selecting supplements.** Part of strategic nutrition is that the supplement program complements the overall feeding strategy and meets current nutritional needs and performance goals. Selection of a supplement and initiating a strategic supplementation program requires consideration of several variables. Initial considerations include the concentration of nutrients in the supplement, cost, convenience, and appropriateness of the supplement. There is no perfect supplement that addresses every scenario's needs. The evaluation of single-source or manufactured feeds should consider the following characteristics.

- The primary source of energy comes from fiber, starch, or fat. Depending on the application and feeding level guides the appropriateness or proportion of the energy-supplying ingredients.
- What form is the protein supplied. Differences in the rumen degradability and inclusion of non-protein nitrogen influence what and how much of a feed is appropriate.
- What minerals and concentrations of minerals occur in feedstuffs. By-product feeds can be concentrated sources of minerals; this can be beneficial or lead to detrimental mineral antagonisms.

- What other unique or special characteristics the feedstuff possesses. Some by-products have greater concentrations of fats, anti-nutritional properties, or other properties that limit the inclusion or feeding level of the feedstuff.
- The suitability and convenience of the feed will be impacted by how the supplemental feed will be stored, handled, and fed. Many feedstuffs look great on paper, but producers may be limited in their ability to store the product, handle and load the product, or feed out the feedstuff.

**Comparing supplements.** Strategic nutrition and supplementation should result in an evaluation of multiple options to supply nutrients to cattle. To effectively evaluate multiple supplement options, a few things need to be understood about each feed or feedstuff.

- Understand the formulated or appropriate amount of supplement consumption. Manufactured supplements often list the expected feeding amount on the feed tag; bulk commodities require knowledge and experience to predict intake.
- Determine the concentration of the key nutrients that are being supplemented. Understand how much is being provided to the animal in the recommended amount.
- Determine the cost of the nutrient supplemented. Calculate the cost on a bulk amount or the actual amount supplemented to the animal.
- Consider all costs and benefits associated with providing the supplement and ensure an economic and biological return on the investment.
- Evaluate the suitability and convenience of the supplement under consideration. Evaluate if the feedstuff be stored, handled, and fed in a manner compatible with the operation.

The task of meeting cow requirements and correcting deficiencies is complicated by changing cow requirements, forage conditions, and environmental conditions. The least variable aspect of this scenario may be the supplemental feedstuffs. However, the ongoing interactions between cattle and their environment imply that strategic supplementation is a moving target for cattle production. Understanding forage dynamics, cattle nutrition requirements, and economic evaluations are essential to strategic supplementation success.

## 9. Forage-Finished Beef Production for South Carolina

Susan K. Duckett, Professor, and Ernest L. Corley Jr. Trustee Endowed Chair

The Covid-19 pandemic significantly impacted meat processors and the distribution of meat products to retailers, leading to an increase in the demand for locally raised, pasture-finished, and forage-fed beef products. In the Southeast, many producers are finishing beef cattle and marketing directly to consumers. Producers typically utilize many different finishing systems that range from all forage-fed to hybrid systems that include both forage and supplementation. This chapter presents results from several forage-finishing studies on cattle performance, carcass quality, meat composition, and palatability and consists of a frequently asked questions section.

**How does forage-finished beef compare to grain-finished beef**

A large, collaborative research project between USDA-ARS, Virginia Tech University, West Virginia University, and Clemson University was conducted for several years to examine how finishing system, grass versus the grain, altered cattle performance, carcass quality, and composition of the beef (Neel et al., 2007; Duckett et al., 2007, 2009, 2013). Angus-cross steers (n =326; 6 yr study) were randomly allotted to one of two finishing systems, grass (mixed pastures consisting of bluegrass, orchardgrass, tall fescue, white clover, triticale/Italian ryegrass) or grain (76% corn, 18% silage, 6% soybean meal and minerals). All steers were slaughtered at the same number of days (150-174 d/year) on forages or grain to avoid possible confounding of animal age or seasonal effects between finishing systems.

The finishing system altered the rate of gain with grain-fed steers gained over 1.1 lb/d more than forage-finished steers (Fig. 1). Grain-finished steers finished 160 pounds heavier than forage-finished steers when harvested at a similar time endpoint.

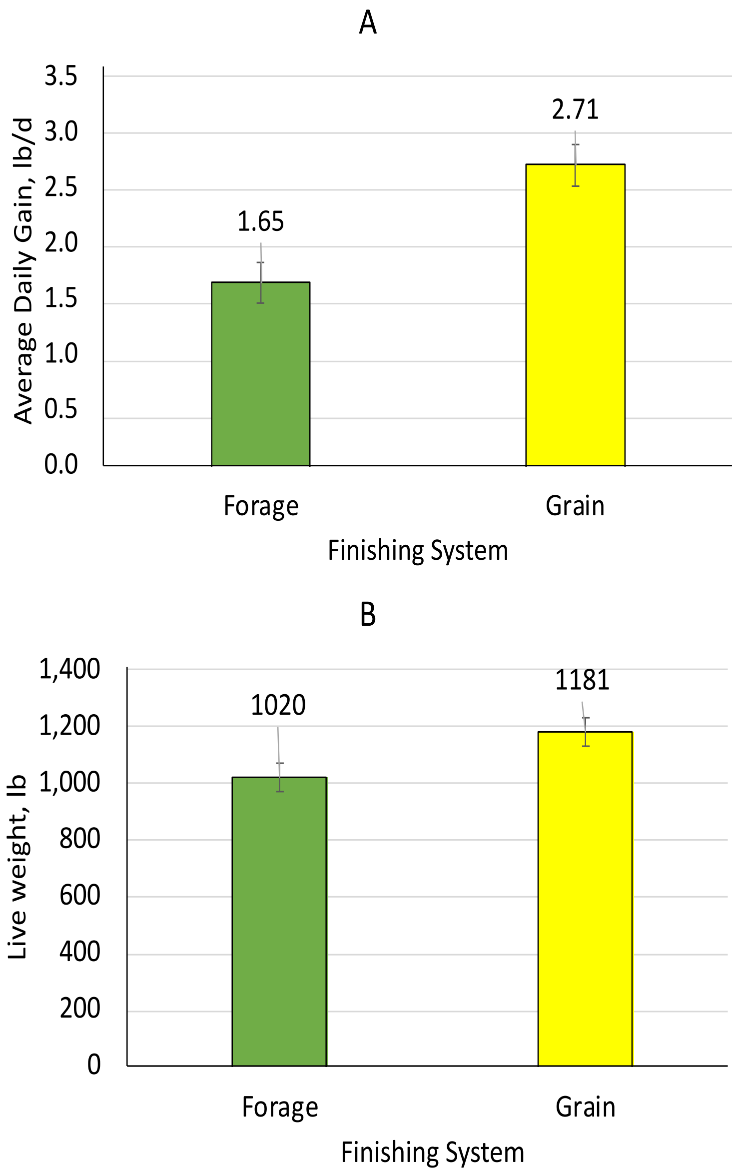



Figure 1. Average daily gain (A) and live weight (B) of Angus-cross steers finished on forages or grain for the same number of days before slaughter.

Grain-finished steers had a higher dressing percentage (62%) than forage-finished steers (54%; Table 3). These differences in live weight at slaughter and dressing percentages resulted in carcasses from grain-finished being 181 pounds heavier than those finished on forages. About half of this difference in carcass weight was due to the greater leanness of the forage-finished beef (86 lb less fat on carcass or 47.5% reduction in fat deposition). Quality grade and percentage grading choice were lower for forage-finished steers compared to grain-finished. However, the Warner-Bratzler shear force values (WBS) and trained sensory panel tenderness scores were similar between forage and grain-finished beef. Overall, the greatest difference in grain-fed versus grass-fed finishing systems is the leanness of the carcass and beef cuts when animals are finished on forages instead of high concentrate grain diets before slaughter.

Table 3. Carcass composition and quality by finishing system.

| Characteristic | Grain | Forage |
|---|---|---|
| Dressing percent, % | 62 | 54* |
| Hot Carcass Weight (HCW), lb | 732 | 551* |
| Ribeye area, $in^2$ | 12.34 | 10.29* |
| Carcass Lean, lb | 426 (58% of HCW) | 349 (64% of HCW)* |
| Carcass Fat, lb | 162 (22% of HCW) | 76 (14% of HCW)* |
| Carcass Bone, lb | 142 (19% of HCW) | 124 (22% of HCW)* |
| Quality grade[a] | 5.2 | 3.8* |
| Percentage Choice, % | 88 | 7* |
| Yield grade | 2.3 | 1.6* |
| Warner-Bratzler shear force, d14, kg | 2.71 | 2.56 |
| Sensory overall tenderness score[b] | 5.16 | 5.14 |

[a]Quality grade code: 3 = low select, 4 = high select, 5 = low choice, 6 = average choice, 7 = high choice; [b]Sensory Tenderness Score; *Grain-finished versus forage-finished differ ($P < 0.05$).

**Fatty acid composition**

The total lipid and fatty acid content in steaks are lower for forage-finished compared to grain-finished beef when finished to a similar endpoint. The fatty acid composition can be presented in two ways: 1) as a percentage or concentration of total fatty acid content (Table 4) or 2) on a gravimetric basis as the total amount of each fatty acid consumed when eating a steak (Table 5). Finishing on forages increases the concentration of omega-3 (n-3) fatty acids, trans-11 vaccenic acid, conjugated linoleic acid and saturated fatty acids; whereas, finishing on grain increases monounsaturated fatty acid concentrations. These differences result in a lower, more desirable, for human health, ratio of omega-6 to omega-3 fatty acids in forage-finished beef (1.54) compared to grain-finished beef (5.01).

Table 4. Fatty acid percentage of the ribeye steak from steers finished on a high grain diet or forages.

| Characteristic | Grain | Forage |
|---|---|---|
| Total lipid content (TL), % | 5.39 | 2.48* |
| Total fatty acid content (TFA), % | 4.87 | 2.03* |
| Saturated fatty acids (SFA), % | 42.94 | 44.49* |
| Monounsaturated fatty acids (MUFA), % | 43.95 | 34.95* |
| Polyunsaturated fatty acids (PUFA), n-6, % | 3.45 | 3.64 |
| Polyunsaturated fatty acids (PUFA), n-3, % | 0.68 | 2.50* |
| Ratio of n-6 to n-3 fatty acids | 5.10 | 1.46* |
| Trans-11 vaccenic acid (TVA), % | 0.24 | 3.41* |
| Conjugated linoleic acid (CLA), cis-9 trans-11, % | 0.31 | 0.71* |

*Grain-finished versus forage-finished differ ($P < 0.05$).

On a gravimetric basis (g/steak), the differences between finishing systems are altered due to the higher total fat content of the grain-finished steak (10.5 g/steak) compared to the forage-finished steak (3.6 g/steak). The leanness of the forage-finished steak also reduces the amount of saturated, monounsaturated, and omega-6 (n-6) polyunsaturated fat contents per steak. Omega-3 polyunsaturated fat content is 89 and 71 mg/steak, respectively, for forage-finished and grain-finished. The actual amount of CLA provided by both finishing systems is similar and meets the recommended daily consumption levels. However, CLA can also be produced in humans via the desaturation of trans-11 vaccenic acid (TVA) to CLA (about 19% conversion).

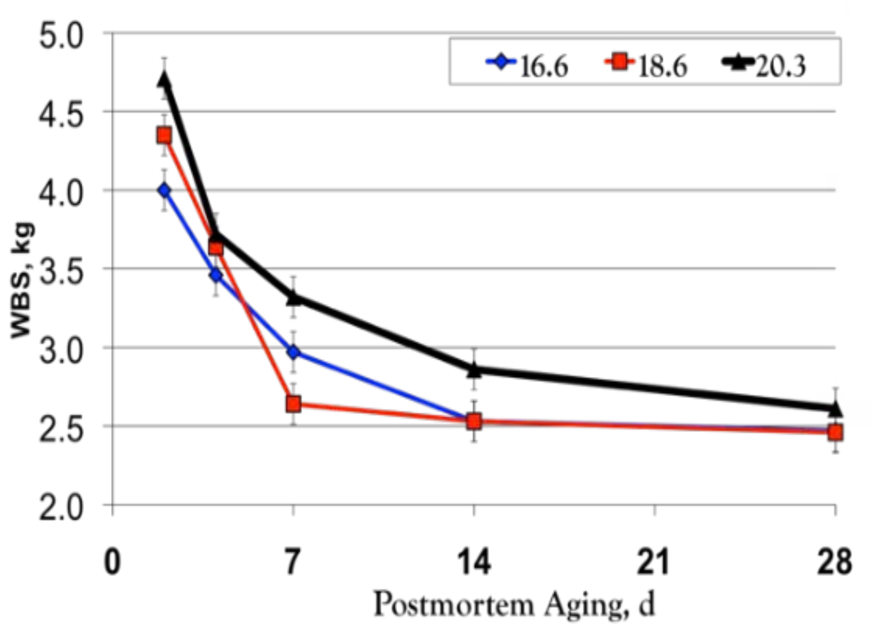
Table 5. Gravimetric fatty acid content (g/steak or mg/steak) by finishing system.

| Characteristics | Grain | Forage |
|---|---|---|
| Cooked steak weight, g (1" thick) | 162 (5.7 oz) | 136 (4.8 oz) |
| Total fatty acid content, g/steak | 10.48 | 3.57* |
| Saturated fatty acids (SFA), g/steak | 4.50 | 1.59* |
| Monounsaturated fatty acids (MUFA), g/steak | 4.61 | 1.25* |
| Polyunsaturated fatty acids (PUFA), omega-6, mg/steak | 361.5 | 129.9* |
| Polyunsaturated fatty acids (PUFA), omega-3, mg/steak | 71.3 | 89.2* |
| Trans-11 vaccenic acid (TVA), mg/steak | 25.1 | 121.7* |
| Conjugated linoleic acid (CLA), cis-9 trans-11, mg/steak | 32.5 | 25.3 |

*Grain-finished versus forage-finished differ ($P < 0.05$).

**Frequently asked questions**

***What is my end point for finishing in a grass-based system?*** There is no established endpoint (i.e., specific animal weight, age, or fat thickness) in a forage finishing system. My recommendation is to slaughter forage-finished animals when forage availability decreases and animal gains start to decline. We do not want animals to stay at the same weight for long periods of time or lose weight due to low forage availability. These fluctuations in gain and performance can impact beef quality and palatability. In most of our studies, we slaughtered the steers about 16 to 18 months of age, and the tenderness of the beef was highly acceptable. As animal age increases, initial tenderness (d 1 postmortem) is higher (tougher) and a longer postmortem aging time is required to achieve the same level of tenderness (Figure 2). As grazing time and animal age advance, the percentage of steaks that are 'tough' (above the 3 kg threshold for guaranteed tenderness) increases (Duckett et al., 2014). In other words, the older an animal is at slaughter, the tougher the meat will be. This is true for both grain and forage finishing systems.



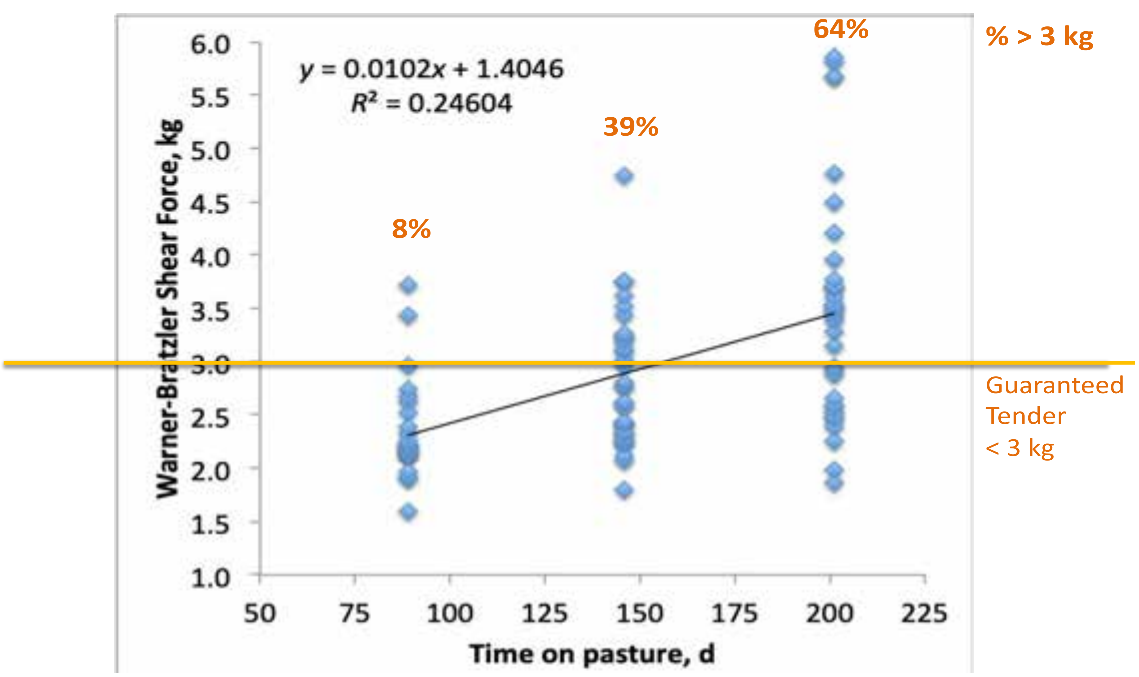




Figure 2. Warner-Bratzler shear force (WBS) of steaks from steers finished on forages and slaughtered at different animal ages (16.6, 18.6 and 20.3 mo of age) during postmortem aging. Percentage of 'tough' steaks (WBS > 3 kg; aged for 14 d) from steers finished on forages for different lengths of time (89, 146, 201 d) which advanced animal age (16.6, 18.6, and 20.3 mo of age) at slaughter.

***How long should the carcass age after slaughter?*** Postmortem aging is the process of proteolysis (breakdown) of accessory proteins in the muscle fiber. Postmortem aging should always be conducted at refrigerated temperatures to avoid issues with food safety. The greatest improvement in tenderness with postmortem aging will be observed in the first 7-10 d after slaughter (see figure 2). There can be additional improvements with extended aging (14-28 d), but they are smaller than the initial 10 d. Aging of carcasses reduces carcass weight due to shrinkage (loss of moisture). Long postmortem aging times (> 14 d) take up cooler space and limit the number of carcasses a processor can chill. In commercial meat plants, carcasses are fabricated after 24 h, and beef cuts are aged in vacuum-packaged bags ('wet' aging) and stored in boxes (i.e., boxed beef) for shipment to the retailer.

***What is the average dressing percentage for forage-finished beef?*** The average dressing percentage for forage-finished beef is 54-58%. This means that hot carcass weight will be 54-58% of live animal weight. If your steer weighs 1000 lb at slaughter, you would have an estimated hot carcass weight of 550 lb (55% dressing percentage).

***How much meat will I have to sell?*** This depends on how it is cut and how much bone and fat remain after the fabrication of the carcass to retail cuts. If you look at Table 3, you will find that approximately 64% of hot carcass weight is carcass lean, and this should all become retail cuts. Then you will likely have some bone and fat that remains on the retail cuts, but this depends on the cut order (boneless, semiboneless, or bone-in cuts) and how much fat trim is removed from the carcass.

- Here is an example of a forage-finished steer: **<u>For a 550 lb HCW</u>**
  - Cooler shrink = 2.5% (normal aging time)
  - Cold carcass = 536.25 lb
  - 64% lean = 343 lb of lean meat

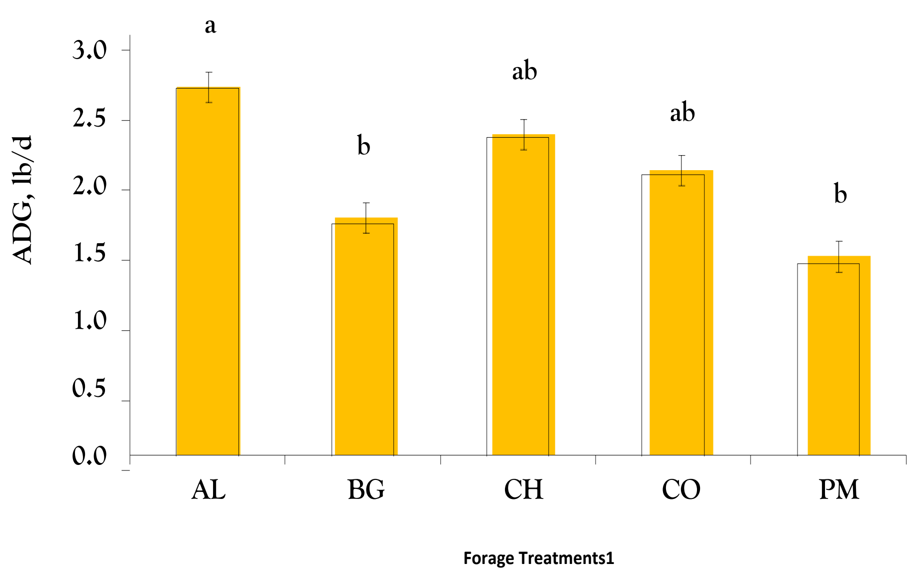
○ 11% bone = 59 lb of bone (assuming semi-boneless; ~half of the bone remains on retail cut)

○ 10% fat = 54 lb of fat (assuming 1/3 of fat is trimmed from carcass)

○ Total = 456 lb retail cuts (based on assumptions above; about 83% of hot carcass weight).

Additional information can be found at: ‘How Much Meat to Expect from a Beef Carcass,’ University of Tennessee, Extension PB-1822. Available at: https://extension.tennessee.edu/publications/documents/pb1822.pdf

***What forage works best for finishing?*** At Clemson University, we evaluated finishing beef cattle on alfalfa (*Medicago sativa* L.), bermudagrass (*Cynodon dactylon*), chicory (*Cichorium intybus* L.), cowpea (*Vigna unguiculata* L.), and pearl millet (*Pennisetum glaucum,* L. R Br.) during the summer (Schmidt et al., 2013). Average daily gains (ADG), grazing days, and hot carcass weights were different between the forage types. Steers grazing alfalfa had higher ADG than bermudagrass and pearl millet. Dressing percentages were higher for alfalfa, chicory, and cowpea-finished steers compared to grasses (bermudagrass or pearl millet). Forage species utilized for finishing did not alter the total lipid, fatty acid, saturated, monounsaturated, or polyunsaturated fatty acid content of the LM.




[1]Treatment: AL = alfalfa, BG = bermudagrass, CH = chicory, CO = cowpea, PM = pearl millet

| | Alfalfa | Bermudagrass | Chicory | Cowpea | Pearl Millet |
|---|---|---|---|---|---|
| Grazing days, d/ha | 168 | 219 | 135 | 115 | 277 |
| Hot carcass wt, lb | 710* | 719* | 676 | 752* | 665 |
| Dressing percent, % | 60.9* | 57.6 | 60.4* | 62.3* | 58.9 |
| Fat thickness, in | 0.20* | 0.14 | 0.19* | 0.18* | 0.11 |
| Marbling score | 4.50 | 4.55 | 4.33 | 5.13 | 4.73 |
| Quality grade | 3.50 | 3.75 | 3.17 | 4.42* | 3.83 |

Marbling score: 4.00 = Slight (select); 5.00 = small (Choice-)

Figure 3. Average daily gains (ADG) and carcass quality of steers grazed on alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM) pastures prior to slaughter.

The only forage type that I **do not** recommend for the finishing of beef cattle is Kentucky-31, toxic tall fescue (Realini et al., 2005). Toxic tall fescue reduces animal performance significantly (57% reduction in ADG) and hot carcass weights compared to the novel, non-toxic tall fescue.

***Does the forage type used during finishing affect beef flavor?*** Yes, it can. Consumer panels rated for tenderness and gave their preference for steaks from steers finished on alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM) and also listed their preference for the best steak. The consumer panel was conducted at an SC Cattlemen's Association meeting in a blind taste test. Alfalfa finished beef received the highest preference score of the forage types (Schmidt et al., 2013).

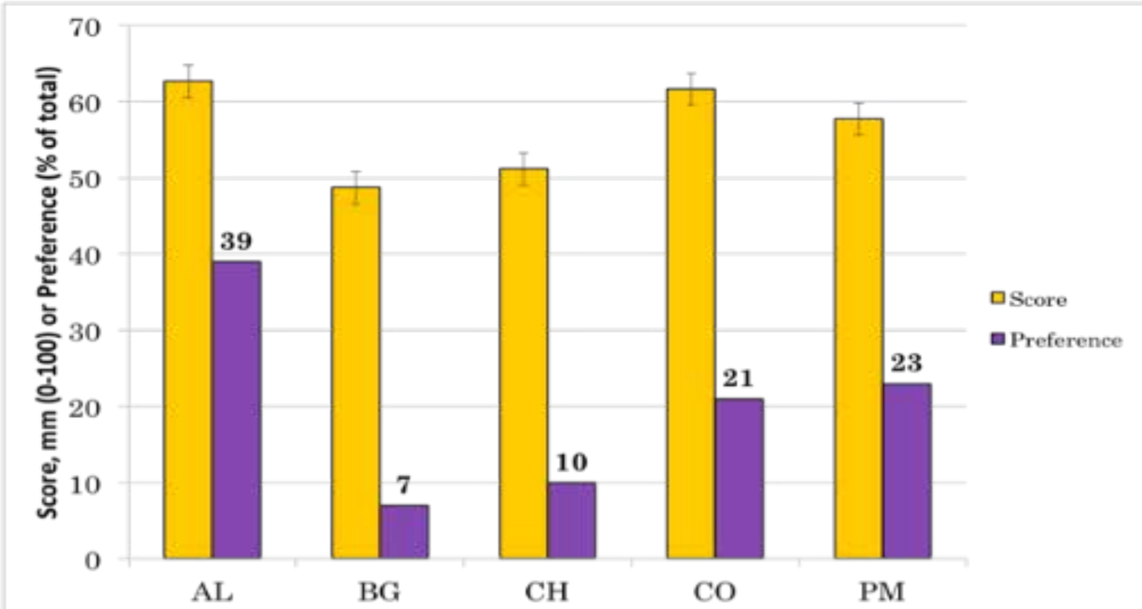



Figure 4. Consumer sensory panel evaluation of tenderness scores and preference of steaks from steers grazed on alfalfa (AL), bermudagrass (BG), chicory (CH), cowpea (CO), and pearl millet (PM) pastures before slaughter.

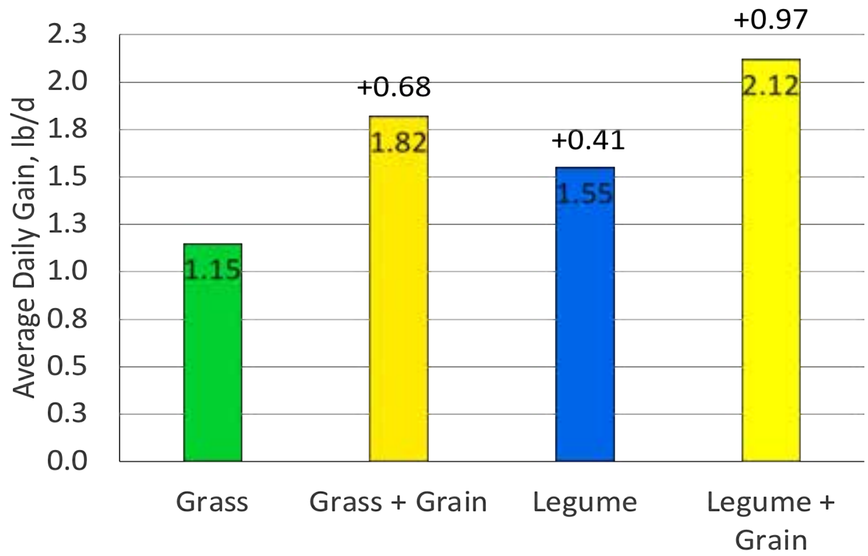
***Should I finish smaller frame cattle on forages?*** We evaluated frame size (large or medium framed steers) on animal performance and carcass quality in forage finishing systems. Large-framed steers had greater ADG, live weight, hot carcass weight, and ribeye size than medium-framed steers, but no differences in carcass quality, meat composition, or tenderness values were detected between frame scores (Duckett et al., 2014; Volpi-Lagreca et al., 2018).

***Will my carcasses have yellow fat?*** Animals finished on forages will have a higher b* score (14.0 feedlot vs. 18.0 forage), which is measured using a colorimeter on the subcutaneous fat and reads the yellowness (0 [white] – 100 [yellow]) of the fat color (Duckett et al., 2007, 2013). However, we may not be able to distinguish this small difference visually from the naked eye.

***Can I supplement while grazing?*** This is a personal preference for your production system and depends on how you market beef to the consumer. Most consumers assume that grass-fed beef means that it was finished on forages only. The USDA had a definition for grass-fed beef at one time and then removed it. American Grassfed Association (AGA) does have standards that include a 100% grass diet from weaning until harvest, raised on pasture without confinement, no antibiotics or added growth hormones, and family farm origin (https://www.americangrassfed.org/about-us/our-standards/ ). AGA does conduct certifications of your farm and production practices. If you market local, pasture-raised beef, then you may be able to supplement in this type of system, but I recommend transparency with your customers. Supplementation will decrease forage intake due to a substitution effect, and this may help to extend grazing when forages are limited or the weather is an issue.

***Corn Grain Supplementation on Grass or Legume Pastures***

Thirty-two Angus x Hereford steers were used to evaluate the effects of grazing legumes (alfalfa and soybeans) versus grasses (non-toxic tall fescue and sudangrass) with or without daily corn supplementation (0.75 % of body weight/d of corn grain) on animal performance and beef quality in a 2-yr study (Wright et al., 2014). Average daily gains were increased by 0.40 lb/d for grazing legumes, 0.68 lb/d for corn supplementation on grass, and 0.97 lb/d for corn supplementation on legume pastures. On a gravimetric basis, omega-3 polyunsaturated fatty acid and conjugated linoleic acid (CLA) content were not altered with corn grain supplementation, indicating the corn gain can be supplemented at this level in a forage-finishing system without negative consequences on perceived beneficial fatty acids.




| | Grass | Grass + Corn | Legume | Legume + Corn |
|---|---|---|---|---|
| Final wt, lb | 1134 | 1144+ | 1146 | 1172+ |
| Hot carcass weight, lb | 655 | 682+ | 678 | 718+ |
| Dressing percent, % | 58.0 | 59.1+ | 59.0* | 60.7+ |
| Fat thickness, in | 0.28 | 0.39 | 0.37 | 0.38 |
| Marbling score (5.0 = small, Ch-) | 4.82 | 5.45 | 5.14 | 5.16 |

* Forage system effect (*P* < 0.05) +Supplementation effect (*P* < 0.05)

Figure 5. Average daily gains and carcass quality of steers grazing grasses or legumes with or without corn gain supplementation during finishing.

***Do forage-finished steers have lower cholesterol content?*** No. Cholesterol content in beef muscle is similar between forage (57.27 mg/100 g) and grain (56.29 mg/100 g) finishing systems (Duckett et al., 2009).

***Is my beef 'hormone free' if I do not use anabolic implants?*** No. Non-implanted beef has basal levels of some natural hormones in the meat and is not 'hormone free' (Hoffman and Eversol, 1986). No meat is hormone free because all living animals produce many different hormones that regulate growth, reproduction, and fattening.

***Do forage-finished beef have a lower carbon footprint?*** It depends. Researchers in California conducted a life cycle assessment for different finishing systems (CON = feedlot finished, GF20 = grass-fed for 20 mo., GR45 = grass-fed for 20 mo with 45 d of grain finishing, and GF25 = grass-fed for 25 mo; Klopatek et al., 2022). Global warming potential ($CO_2$ equivalents) was lowest for feedlot finished (CON) and highest for grass-fed at 25 mo (GF25). Energy usage (MJ) was highest for feedlot finished (CON) and lowest for grass-fed at 20 mo (GF20). Another study conducted in Michigan evaluated the impacts of soil carbon sequestration on life cycle greenhouse gas emissions for adaptive multi-paddock grazing systems (Stanley et al., 2018). They found that the adaptive multi-paddock grazing system can contribute to the mitigation of climate change through soil organic carbon sequestration.

***What about forage finishing heifers instead of steers?***One issue that can arise when finishing heifers is that they may be in estrus around the time of slaughter. When heifers are in estrus, they spend more time riding other heifers and typically reduce grazing time. This can produce a dark-cutting condition in the meat where beef color remains dark after slaughter due to a high pH. In the feedlot industry, heifers are typically fed melengestrol acetate (MGA), suppressing estrus so that heifers have an increased rate of gain and fewer negative issues with carcass quality. We ran a research study with heifers (n = 40) and found that 10% were dark cutters at slaughter. There is nothing wrong with the beef product, but consumers will notice the dark color of the beef and may be concerned about perceived quality problems.

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# 10. Overview of Forage Systems for Dairy Cattle

Matias Aguerre, Assistant Professor, Clemson University

The Southeast's favorable climate allows dairy producers to grow and utilize forages year-round. Forages are the foundation upon which nutritionally sound, economical, and rumen healthy dairy diets are formulated. They comprise about 50 to 60% of dairy feeding systems' ration (dry matter basis) and introduce variability in nutrient supply. However, high fiber concentration and low digestibility in some forage species restrict dry matter intake (especially in high-producing cows) because of increased feed bulkiness and slow passage through the digestive tract. Thus, maximizing the production of highly digestible forages is a tool to increase the utilization of forage in dairy diets with concomitant improvements in the efficiency of nutrient utilization and lactation performance.

## Cool-season annual forages

Due to the potential benefits of soil fertility, erosion control, and weed suppression, the adoption of cool-season annuals has increased significantly in the last decade. Cool-season forages are a cost-effective option to support recommended body weight gains for replacement dairy heifers and/or as a component of the lactating cow diet. Also, annual cool-season crops can be harvested for hay, baleage, or silage to complement the traditional summer forage crops (i.e., corn silage) in dairy systems.

To maximize the use of cool-season crops in dairy diets, it is necessary to properly synchronize the nutrient composition of the forages with the nutrient requirements of the animals that will be fed. For example, grasses should be harvested at the boot stage due to the balance of proper quantity and superior fiber digestibility. As forage matures, the grain filling will increase the energy density of the forage material, but overall, there is a decrease in forage quality. Under extreme conditions, farmers may not be able to harvest grasses at the proper time. In this case, producers can allocate this feed to animals with lower nutrient requirements, such as late lactation cows, dry cows, or heifers.

Under a grazing management scenario, implementing proper strategies will help dairy producers to get the most from their forages. Overgrazing will reduce carbohydrate reserves and tillering, which impacts forage production the following spring. Spring grazing should start when the grasses are 6 to 8 inches tall, and cattle should be removed when the average stubble height is 4 inches to maintain sufficient residual leaf area for regrowth. For high-quality grass silages, winter annuals should have an adequate level of sugars (10-15% of the dry matter), and the optimal harvesting moisture is 60-65%. The recommended stubble height when cutting is 4 inches to promote rapid regrowth and reduce soil contamination. A flail conditioner and a wide swath should be used to speed up the drying process. In addition, optimal material compaction during the ensiling process is achieved with a cutting length of ¾ to 1 inch.

**Warm-season annual forages**

Corn harvested for silage is usually the primary forage source for dairy farming systems. This forage provides an excellent combination of high dry matter yield per acre and the quality of biomass produced. Several management practices are available for dairy producers when planning to maximize the yield and quality of corn silage. For hybrid selection, the production potential of different hybrids can be obtained from performance tests. The Clemson Agronomic Crop Variety trials provide information on corn silage yield and quality from tests conducted at several locations in South Carolina. Besides yield, farmers can select corn hybrids with increased fiber digestibility. Brown midrib (BMR) is a natural mutation found in various forages such as corn, sorghum, and pearl millet. The visual manifestation of this trait is a light to dark brown coloring of the leaf's midrib that tends to disappear in intensity with increased plant maturity. As a result of this mutation, BMR forages are known for their significant reduction in lignin content and higher fiber digestibility compared to conventional hybrids. Numerous controlled feeding trials have shown that this increase in forage digestibility has translated into greater dry matter intake and milk production. These quality improvements make the BMR trait a very attractive forage for high-forage diets and the herd with high milk production potential. In general, BMR may yield less than conventional corn silage hybrid. To reduce the risk of yield reduction, producers should consider growing BMR hybrids in soils with the highest yield potential.

A general recommendation is to target a planting population between 26,000 and 32,000 plants per acre. Higher plant populations are best suited on the most fertile soils. Under optimal growing conditions (abundant rain and high soil fertility), increasing the planting population to the higher range will likely boost dry matter yield with minimal impact on forage quality. However, producers might face an increase in the price of the corn silage that they feed if that additional yield is not obtained due to the greater production cost associated with the extra seed required to raise the plant population. The recommended cutting height for corn silage is usually 6 to 8 inches; however, some producers may choose to increase it to 18 to 20 inches. In a summary of studies, Penn State University researchers reported a 7.4% reduction in biomass yield when the cutting height was raised from 7 to 19 inches. Therefore, more acreage would be required to yield the same tonnage as the low-cut silage approach. However, the high-cut silage shows lower fiber content, higher fiber digestibility, and energy-dense grain proportion.

One of the most important factors in silage production is the moisture content at harvest. The fermentation process during ensiling involves bacteria that convert plant-soluble carbohydrates into lactic acid. The lactic acid bacteria responsible for the fermentation processes require an anaerobic environment with a dry matter content of the standing crop ranging from 32 to 36%. Harvest considerations should also focus on obtaining the correct particle size distribution and the need to process the crop. Proper particle length is fundamental for proper silage packing, while kernel processing increases the silage's starch availability. The current recommendation for the cut length for processed silage is ¾ inch with a 1- to 2-millimeter roller clearance.

Other warm-season annual grasses such as sorghum, sudangrass, sorghum × sudangrass or pearl millet are highly productive forages species frequently used during the “summer slump” to fill yield and quality gaps often found in perennial forage systems during summer months. They are a potential option to corn silage in dairy diets due to their reduced establishment costs and can provide tolerance to heat and drought stress. Under grazing management, it is important to follow recommendations in order to optimize forage utilization and plant regrowth after each grazing event.

Pearl millet is a popular warm-season annual forage in South Carolina. It is mainly used for grazing but can be conserved as hay or silage. Pearl millet has thick stems and is more difficult to conserve than sudangrass but can be slightly faster to conserve than sorghum-sudangrass hybrids. Sudangrass is suited to medium to heavy textured soils and can be a good choice for hay production as it has finer stems than pearl millet or sorghum-sudangrass. Sorghum-sudangrass hybrids are crosses between sorghums and sudangrass. These hybrids are often used in the central and upper portions of South Carolina and on heavy soils in the Coastal Plain. They are typically more productive than either sudangrass or pearl millet in optimal conditions.

Mixing annual summer grasses and legumes can increase the protein concentration of the forage, making the mixture a viable option to increase dietary crude protein intake. Vine climbing legumes like cowpea can tolerate shade and fill-in rows in stands of annual summer grasses. Some studies have shown that a mixture of legumes with corn or grain sorghum has no impact of forage yield. However, due to the poor regrowth, cowpea might leave empty spaces when mixed with multi cut species like pearl millet or sudangrass. Thus, cowpea may be a better option for forage mixes with one-cut forages like sorghum or corn.

**Perennial grasses**

The main perennial grasses utilized in South Carolina are bermudagrass, bahiagrass and tall fescue. Despite the slower rate of fiber digestion, compared to legumes, high quality perennial grasses can be successfully used as a source of fermentable fiber in dairy cow diets with a concomitant increase milk components levels and a reduction of feeding cost. Bermudagrass is an important source of digestible fiber in beef and dairy cow rations in the Coastal region of South Carolina. Research conducted at the University of Georgia has shown that bermudagrass hybrids with high fiber digestibility, such as Tifton 85, can be fed to dairy cows at 10 to 15% of dry matter with no impact on milk production, but it is important to harvest the grass when it is in an early stage of maturity. Tall fescue is the main cool-season perennial grass used in the piedmont and mountain regions of South Carolina. Tall fescue grass can contain more than 50% NDF but with high levels of fiber digestibility. Most tall fescue fields contain an endophyte that produces ergot alkaloids that exert a negative impact on milk production, pregnancy rates, and animal health. The novel tall fescue varieties is also infected with a naturally occurring endophyte that provides the plant with drought and grazing tolerance but does not produce toxins which decrease animal performance. Thus, incorporating novel tall fescue can allow for increased digestible fiber in a ration fed to lactating dairy cattle.

**Alfalfa**

Along with corn silage, alfalfa has been one of the most important forages feeds in dairy cattle systems in the U.S.A. Despite being a very versatile forage crop, alfalfa remains an underutilized forage resource in South Carolina. Establishment and management recommendations for alfalfa were covered previously in this book. Alfalfa harvest at proper maturity stage contains high levels of crude protein with rapidly digested fiber. This complements well the slower fiber digestion but high soluble carbohydrates (starch) fermentability of corn silage. Several studies have shown that a wide range of alfalfa to corn silage ration can fed to dairy cows without affecting milk production. These findings give dairy producers the flexibility to decide how much corn silage or alfalfa they need to grow based on the cost of production, soil fertility, water availability, and other management variables. When budgeting the amount of alfalfa to growth, consider that although will produces during the summer and into the fall, 60% of the annual yield is obtained during the first harvests

# 11. Overview of Forage Systems for Horses

Liliane Silva, Forages Specialist

Proper forage management in horse operations can support forage production, quality, and persistence while maintaining animal health and welfare. In chapter 3, we provided an overview of forages for operations, and many of them can be used for horses. Among them are bahiagrass, ryegrass, bermudagrass, perennial peanut, small grains, etc.

The choice of forage species should be based on weather conditions, soil type, location, management skills, and goals of the operation. Generally, a perennial grass pasture might be used as the basis for grazing, and annual forages can be used to complement the forage production distribution and quality required to meet the nutritional requirements of animals. Extending the grazing season is a viable tool to cut costs by feeding hay to animals. Mixtures of forage species are recommended when planting annuals to help with extending the forage distribution and improving forage quality, especially if you are able to include legumes, such as clovers, in the mixture.

Grazing management is a crucial tool to balance proper forage production and the quality and persistence of fields in horse operations. Horses can selectively graze the new growth of plants in pastures if given unrestricted access to an area. Therefore, rotational grazing is recommended to allow plants to restore their energy reserves and growth prior to the next grazing event. As a rule of thumb, on well management pastures, the stocking rate should be 1 to 1.5 acres per horse; otherwise, there will be a high reliance on hay feeding. When feeding hay, the best approach is to conduct testing prior to balancing the supplementation each animal category requires. Knowing the forage quality of the hay can help save on costs of additional supplements that the animals may not require. Content on grazing management, hay quality, and how to collect a forage sample was covered previously in this book. For further information on horse systems, I highly recommend you download this book below and read the "Forage Systems for Horses" chapter.

**More information about horse systems can be found at:**

1. Silva, L.S.; Dillard, S.L.; Mullenix, M.K; Vasco, C.; M.; Wallau, Russell, D.; Tucker, J.J; Keishmer, K.; Kelley, K.; Runge, M.; Prasad, R.; Gamble, A.; Elmore, M.; Burns, M; Stanford, K. et al. Chapter: Forage Systems for horses in the book: *Concepts and research-based guidelines for forage-livestock systems in the SE region.* Available for download at: https://projects.sare.org/information-product/concepts-and-research-based-guidelines-for-forage-livestock-systems-in-the-southeast-region/

## 12. Overview of Forage Systems for Small Ruminants

Liliane Silva, Forages Specialist

Goats are "top-down" browsers and select higher-quality leafy forage when grazing. They thrive on pastures containing shrubs and small trees and do not like to graze forage that has been trampled and soiled. Goats can be used to control undesired vegetation instead of using prescribed burning or herbicides. Goats and sheep differ concerning forage behavior and nutrition. Sheep prefer forbs to grasses and require forage quality adjustment to meet nutritional requirements throughout the season.

Planning your forage budget to extend the grazing season improves the profitability and sustainability of forage systems. The choice of forage species adapted to the soil and climatic conditions and compatible with costs, management requirements, and the level of animal production desired are essential. A better understanding of forage plant requirements, growth patterns, and management requirements will help you achieve your goals. More information about these topics can be found in previous chapters of this book. In small ruminants systems, a proper parasite control plan is essential. Management practices, such as rotational grazing, can support this by breaking the parasite cycles when animals are rotated out of a paddock, and the area remains under resting for a few weeks. There is a growing interest in the use of forage species containing condensed tannins in small ruminant systems due to their essential role in controlling parasites while supporting reduced bloat and greenhouse gas emissions. For further information on small ruminant systems, I highly recommend you download this book below and read the “Forage Systems for Small Ruminants” chapter.

**More information about small ruminants systems can be found at:**

1. Silva, L.S.; Dillard, S.L.; Mullenix, M.K; Vasco, C.; M.; Wallau, Russell, D.; Tucker, J.J; Keishmer, K.; Kelley, K.; Runge, M.; Prasad, R.; Gamble, A.; Elmore, M.; Burns, M; Stanford, K. et al. Chapter: Forage Systems for Small Ruminants in the book: *Concepts and research-based guidelines for forage-livestock systems in the SE region.* Available for download at: https://projects.sare.org/information-product/concepts-and-research-based-guidelines-for-forage-livestock-systems-in-the-southeast-region/

## 13. Most Common Forage-related Livestock Disorders in South Carolina

Patty Scharko, Professor and Extension Veterinarian

The following are the most common forage-related livestock disorders occurring in South Carolina.

### Bloat

Bloat is caused by an abnormal collection of gas in the rumen, and the animal cannot "belch up" gases produced in the process of rumen fermentation. Pasture (frothy) bloat usually occurs in cattle grazing lush legumes, such as alfalfa, ladino, or clover. The danger of bloat is greatest when pasture plants are young, lush, and high in soluble protein. Bloat results from the production of a stable foam that does not allow gas bubbles to form free gas and be "belched" off. This disorder is due to the foaming properties of soluble leaf proteins, which are more prevalent in legumes. The fear of bloat should not keep you from using high-quality legumes, such as alfalfa and clover, in your pasture program. Management adjustments will be an ally on avois bloat.

An animal's inability to expel the gas allows pressure to build up in the rumen. As the pressure increases, the rumen becomes distended on the cow's upper left side between the last rib and the point of the hip. As the bloat becomes more severe, breathing becomes difficult. Once the animal can no longer stand, death follows within a few minutes. In these severe cases, a stomach tube (¾-inch to 1-inch rubber hose) can be passed through the mouth (using a metal tube/speculum to prevent chewing the tube) into the rumen to provide relief. Since pasture bloat is frothy, a tube to the rumen may not be sufficient. If it is not adequate, a defoaming agent (oral bloat treatment medicine, vegetable oil, or dish detergent) may be added through the tube. As a last resort, relief can be obtained by making a surgical hole in the rumen large enough to release the foam. For this, an incision is made on the left side at a point halfway between the last rib and the hook bone; then, a rumen trochar can be placed to maintain an opening. The best plan is to prevent bloat. Antifoaming agent bloat-preventing products, such as Bloatguard®, are effective if consumed daily in adequate amounts. Rumensin® (monensin) has been demonstrated to reduce a large percentage of bloats. Management practices can also be an ally in preventing bloat:

• Allow animals to feed on grass hay or pasture before turning them on to alfalfa or clover pasture. Do not turn hungry cattle on lush, immature alfalfa or clover, especially for the first grazing of the season or their first time exposed to those legumes.

• Once cattle are turned onto pasture, remove them at the first signs of bloat. Some animals may be prone to bloat, identify them and avoid exposing them to situations on which bloat can occur.

• Consider incorporating a grass-legume mixture into your forage operation. This helps with providing a balance of fiber and crude protein available in the forage the animals are consuming.

**Grass Tetany (hypomagnesemia, grass staggers)**

Grass tetany is caused by an abnormally low amount of magnesium (Mg) in the animal's blood. In South Carolina, beef cattle producers have successfully reduced tetany incidence with daily Mg supplementation. However, the potential still exists in most herds for this disorder to become a problem. Grass tetany occurs most often in cows grazing lush spring forages, especially small grains and cool-season perennials, such as tall fescue. It is most common in spring-calving cows, especially if they are high producers in their third to fifth lactation. Several factors contribute to the increased incidence of tetany at this time, including the higher magnesium requirement, which doubles from late gestation to early lactation (from 9 grams to 21 to 22 grams). When this rapid change in magnesium needed by the cow is coupled with lowered magnesium in the plant, along with specific components that reduce the availability of magnesium (such as high applications of nitrogen and potassium fertilizers), tetany can develop. Weather can also have an effect; the most significant threat is when temperatures are between 40°F and 60°F. Temperatures above 60°F for a week markedly decrease the incidence of tetany. Generally, legumes are high in magnesium but might not be available in the early spring.

Animals with grass tetany should be isolated from the herd. As the disease progresses, they may exhibit extreme nervousness, rapid breathing, and muscle trembling, becoming aggressive and charging anyone. In the most severe stage, the animal collapses to the ground with muscular spasms. Treatment must be given rapidly, as death can occur within an hour after the onset of convulsions. To prevent relapse, recovered animals should be removed from the pasture and fed a hay/concentrate mixture supplemented with magnesium oxide for at least a week. For the prevention of grass tetany, about 2 ounces of magnesium oxide magnesium daily is recommended. Cows grazing spring grass pastures should have higher magnesium in the mineral mixture, typically 12 to 14% Mg; in high-risk situations, it may be supplied as a supplement. Many commercial mineral mixtures are available in various forms to prevent tetany. Before you make a purchase, determine if the product will give adequate magnesium intake - usually 4 ounces of 12 to 14% Mg. This depends on the magnesium content and the expected consumption of the product. This information should be listed on the tag. If magnesium intake appears to be inadequate, a product with more or greater intake should be used. In high-risk situations where tetany is a frequent problem, magnesium oxide can be included in a grain or protein supplement.

**Nitrate Toxicity**

Nitrate toxicity can affect cattle that consume forages containing excessive amounts of nitrate. It also might occur if animals (especially those hungry for salt) have access to nitrate fertilizer. Under normal conditions, low levels of nitrate consumed by cattle are converted to ammonia and then to protein. However, high nitrate levels interfere with red blood cells' ability to carry oxygen. Thus, the animal dies from nitrate poisoning because of a lack of oxygen. Forage crops most likely to present a buildup of nitrates concentration are annual grasses, such as sorghum-sudangrass hybrids, sudangrass, corn, pearl millet, corn, oats, and wheat. Avoid grazing these grasses when growth ceases due to drought or cold damage, especially those heavily fertilized with high amounts of nitrogen. It is recommended to wait around 15 days before turning the animals back into these areas. If uncertain about the nitrate levels on a forage, collect a forage sample and get it tested. Consult your veterinarian or local Extension agent for agriculture for information concerning sampling and how to send samples to a diagnostic laboratory. The results are reported on a percentage or parts per million (ppm) of nitrate on a dry matter basis. If cattle were fed or grazed on suspect forages, watch them closely for the following signs:

- Labored breathing
- Frothing at the mouth
- Diarrhea, convulsions, or staggering
- Frequent voiding of colorless urine
- Brown color of the membranes (mouth, vagina)

**Table 6.** Management considerations based on the concentration of nitrate forms in feed, in dry matter basis (DM). Adapted from Poore et al., 2000.*

| **Concentration (DM)** | | | **Feeding Precaution** | |
|---|---|---|---|---|
| **Nitrate (% ion)** | **Nitrate (ppm)** | **Nitrate Nitrogen (ppm)** | **Unadapted Animals** | **Adapted Animals[1]** |
| 0.0 to 0.25 | 0 to 2,500 | 0 to 568 | **Safe:** Generally considered safe for all animals. | **Safe** |
| 0.26 to 0.50 | 2,500 to 5,000 | 569 to 1,136 | **Slight risk:** Should not make up more than 50 percent of total intake for pregnant animals. | **Safe** |
| 0.51 to 1.00 | 5,000 to 10,000 | 1,137 to 2,272 | **Moderate risk: Do not feed to pregnant** animals. Limit to less than 50 percent total intake for all other animals. | **Slight risk** |
| 1.01 to 1.50 | 10,000 to 15,000 | 2,273 to 3,409 | **High risk:** Exercise extreme caution when feeding. Limit to 33 percent of the ration. | **Moderate risk** |
| 1.51 - 2.00 | >15,000 | 3,410 to 4,544 | **Severe risk:** Do not feed to any animals free choice. If using in a mixed ration, limit to 25 percent of the ration. | **High risk** |

[1] Use the same feeding precautions given for the risk category for unadapted animals.

* Adapted from Poore, M. et al. *Nitrate Management in Beef Cattle*. 2000. AG-606. North Carolina State University Cooperative Extension Service.

**Prussic Acid (Cyanide) Poisoning**

Prussic acid poisoning occurs in animals that have consumed plants containing cyanide-yielding compounds. The prussic acid (hydrocyanic acid) poisoning potential is affected by species, plant variety, weather conditions, and soil fertility. Plants of the sorghum family (sudangrass, johnsongrass, and sorghum-sudangrass hybrids) and leaves of wild cherry trees have the potential to produce prussic acid poisoning. Pearl millet does not produce prussic acid. Prussic acid occurrence is most likely at dangerous levels immediately after a frost. Symptoms from small amounts of prussic acid can be labored breathing, frothing at the mouth, and staggering within 10 to 15 minutes after ingestion. To lower the risk of prussic acid poisoning, follow these management practices:

- Do not graze sorghum or sorghum-cross plants until they are at least 15 inches tall.
- Do not graze wilted plants.
- Do not graze these plant species during or shortly after prolonged drought periods when growth is retarded.
- Do not graze for two weeks after a nonkilling frost event.
- Do not graze until at least 48 hours after a killing frost (until plant material is dry).
- Do not graze at night when a frost is forecast.
- Do not allow cattle (or any livestock) access to wild cherry leaves.
- Check pastures after storms for fallen wild cherry trees or limbs.

**Less occurrent livestock health problems in South Carolina**

**Acute Bovine Pulmonary Emphysema** and Edema (ABPEE) (aka fog fever bovine atypical interstitial pneumonia) is a sudden onset of acute respiratory distress in cattle, particularly adult beef cattle. This is observed by open-mouth breathing, Extension of the tongue, and drooling, which can be fatal. Typically occurs in fall, 5 to 10 days after a change to a better, lush pasture. There is no specific treatment, and caution is advised when removing cattle from offending pastures to prevent immediate death. Prevention is to avoid sudden changes in diet. This can be achieved by feeding hay before turning out on pasture, limiting grazing time and increasing exposure, using pastures before they become lush, grazing younger cattle, or using strip grazing.

### Ergot Toxicosis

Ergot toxicosis is caused by fungus (*Claviceps purpurea*) that grows in the seed heads of dallisgrass (most common), small grains, ryegrass, tall fescue, or bahiagrass. The alkaloid toxin interferes with circulation, resulting in reduced blood flow to the extremities and gangrene. It can result in lameness and loss of feet, tail, and/or ears. There is no specific treatment for ergot toxicosis, and the recommendation is to remove animals from the infected field and provide adequate bedding. Also, another recommendation is to mow pastures when needed to limit seedhead development.

### Bermudagrass Staggers

Bermudagrass Staggers is a nervous disorder of cattle caused by alkaloids from fungal infection of bermudagrass. It can occur on cattle grazing tall, mature bermudagrass during autumn and winter, following a period of cloudy, damp weather that promotes the growth of the fungus. Infected cattle twitch, tremble, become stiff legged in the hind quarters and uncoordinated. These symptoms are similar to ergot toxicosis. There is no specific treatment, and the recommendation is to remove animals from infected pastures and feed alternative feed sources.

### Poisonous Plants

Poisonous Plants are of natural occurrence in some areas and can become part of pastures, especially in overgrazed and degraded areas. It is important to learn to identify the poisonous plants in your area and inspect pastures frequently for their occurrence before turning animals into them for grazing. Below are some considerations to avoid issues with poisonous plants in your herd:

- Do not allow hungry or thirsty animals to graze areas heavily infested with poisonous plants. This is especially important in early spring and late summer when normal forages are scarce.

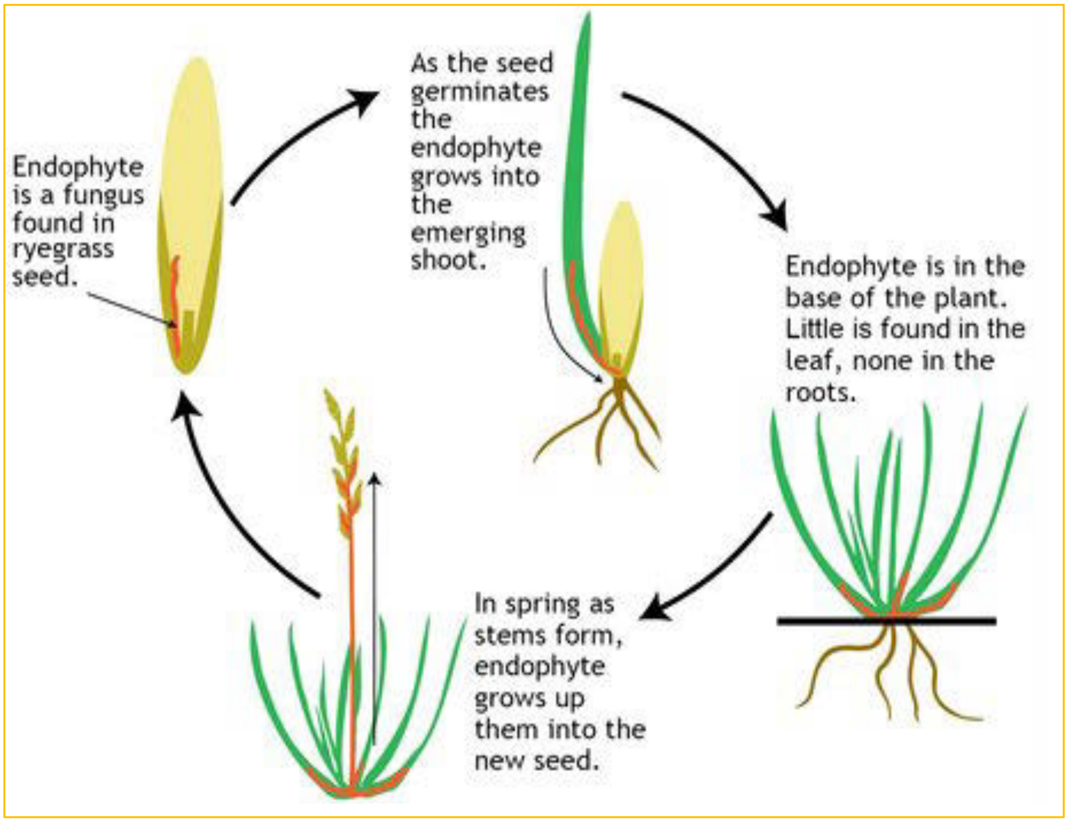
- Supplement animals throughout the year with salt and phosphorus and ensure they have access to clean water.
- Do not put new animals in a pasture or range without feeding them a salt and phosphorus supplement for two weeks.
- Plan the grazing program so areas with poisonous plants can be used when the plants are least toxic.
- Herbicides are seldom cost-effective over large areas but can be used to control poisonous plants in small areas selectively.
- Plowing, selective digging, and mowing before seed maturity can be used to control poisonous plants.
- It is also crucial to consider the use of chemicals to eliminate the occurrence of those plants in the pastures. If the percentage of plants is elevated in a given area, it may be worth considering renovation or re-establishment of pastures.

# 14. Fescue Toxicity in Grazing Systems

Matthew Burns, Livestock Specialist

Toxicity problems in livestock due to forage can be traced back as far as 50 A.D. and can affect cattle, sheep, and horses. Fungus-infected seed of darnel, a ryegrass species, has long been associated with psychotoxic effects in humans and animals (Thomas et al., 2016). With the cultivation of cereal grains thousands of years ago, darnel spread along with crop domestication and became known as "wheat's malign twin." The notable effects of darnel are now attributed to a fungus that infects the plant's seed (Howard et al., 2016). Although fungal toxicity problems have been researched for hundreds of years, we still have limited knowledge of exact mechanisms and causative agents leading to decreased animal performance and other negative associative effects. While sever toxicosis can lead to death, other effects of toxicosis can be less visible and difficult to detect. A great example of a forage with wide-ranging severity and impacts that we still do not fully understand is Kentucky 31 tall fescue (used interchangeably as "wild-type" fescue throughout).

Tall fescue is a cool-season perennial grass popularly used for soil reclamation, turf, grazing, and hay production across the southeastern United States. With its broad use of applications and adaptation to a wide geographic range, from the mid-Atlantic states through the Southeast, tall fescue is established on well over 40 million acres. It grows best during September and May in the Southeast and can be stockpiled during winter. Stockpiled fescue retains its quality during the winter months, decreasing the amount of hay required to meet the nutritional needs of livestock during this time. In practice, rotational grazing can strategically use stockpiled fescue during specific times of the year. In addition, wild-type fescue is drought-tolerant and insect resistant. Wild-type fescue's highly adaptive nature and hardy properties are provided by a mutualistic symbiosis with an endophytic fungus *Neotyphodium coenophialum*, formerly *Acremonium coenophialum*. Endophytes, which can be fungi or bacteria, reside in plants and often provide a protective advantage to the plant (Figure 1). The endophytic fungus in wild-type fescue produces compounds called ergot alkaloids, giving grass resistance to environmental stressors. The benefits of the alkaloids led to tall fescue's widespread use and prevalence, making it the most abundant cool-season perennial forage in much of the southern United States. It is estimated that 8.5 million cattle graze 32 million acres of wild-type endophyte-infected fescue (Hoveland, 1993). Most well-established pastures in the Southeast (lacking recent planting or re-establishment) will include wild-type toxic tall fescue.




Despite the advantages of the ergot alkaloids produced by the fungal endophyte in wild-type fescue, these alkaloids can also cause significant deleterious effects in livestock (Hill et al., 1991). It is estimated that the U.S. beef industry loses from $600 million to over $1 billion annually from performance losses due to fescue toxicosis (Allen and E. Segarra, 2001). While death loss due to fescue toxicosis is rare in cattle, it is much likelier in pregnant horses. Symptoms of toxicosis are particularly evident in broodmares when grazing on wild-type fescue in the peripartum period. These symptoms can include abortion, prolonged pregnancy, agalactia (lack of milk), and foaling issues (positional and size dystocia, thickened placenta, retained placenta, or premature separation of the chorion called "red bagging"). In other species, signs are often less restricted to reproduction and less overt. Observed symptoms of fescue toxicosis include livestock retaining winter hair coats, standing in creeks/ponds during mild to hot weather, and decreased growth performance, particularly in summer months, especially on "summer slump."

These physiologic effects of wild-type fescue on livestock are attributed to the disruption of normal metabolic processes by ergot alkaloids, primarily as dopamine agonists that stimulate vasoconstriction. Fescue toxicosis decreases blood flow to the extremities and increases core body temperature (Porter, 1995). With limited ability to sweat, decreased blood flow greatly reduces cattle's ability to dissipate heat through the fine capillary system of the skin, increasing heat stress during summer months. The interactive effects of heat and vasoconstriction from toxicosis further decrease livestock performance in the summer. The negative impacts of toxicosis on weight gain and reproductive performance in cattle are greatly reduced in the fall/winter months. However, in colder climates, restricted blood flow to extremities in winter months can allow gangrene to set up in the foot, sometimes called "fescue foot," and even tail switch. Therefore, toxicosis is still present.

A significant economic impact of toxicosis in cattle is on cow-calf production. Reproductive efficiency in beef cattle is a critical component of any cow-calf operation. Decreased reproductive performance while grazing toxic tall fescue has been documented in cattle (Burns et al., 2012; Porter and Thompson, 1992; Brown et al., 2000; Looper et al., 2009; Looper et al., 2010); however, specific mechanisms of how or at what stage of the reproductive cycle infected fescue negatively impacts reproductive performance is unknown. Many Southeast operations, where wild-type fescue is abundant, have a spring breeding season that coincides with fescue seed head emergence. Seed heads contain higher alkaloid levels than typical foliage. Increasing temperatures and exposure to high alkaloid concentrations exacerbates the impact on reproductive performance, seen in decreased reproductive rates and increased time to conception.

Since fescue toxicosis was identified, many applied research studies have attempted to create solutions to attenuate the effects of wild-type fescue on livestock. For example, administering domperidone (dopamine antagonist medication) to pregnant mares effectively reduced the impacts of grazing toxic tall fescue. Alternatively, removing broodmares from wild-type fescue pastures 45-90 days (about 3 months) prior to parturition (or approximately day 300 of gestation) prevents toxicosis-associated reproductive issues. Several researchers have explored modifications to fescue plants and their endophytes to keep the advantages of wild-type fescue on the plant but remove the harmful endophyte's effects on livestock. These have resulted in the following categories of fescue/endophyte:

| **Fescue Type** | **Description** | **Contains Endophyte** | **Provides benefits to plant** | **Causes fescue toxicosis** |
|---|---|---|---|---|
| Wild-type | described throughout this chapter; Kentucky 31 tall fescue | Yes (wild-type) | Yes | Yes |
| Endophyte-free | removal of the endophyte from the plant/seed | No | No | No |
| Novel Endophyte-infected | after the removal of the toxic endophyte, a novel endophyte that does not produce toxic ergot alkaloids is used to inoculate the plant/seed | Yes (novel) | Yes | No |

Other management strategies used to decrease the impact of fescue include:

•**Pasture renovation**: Partial or full removal of wild-type fescue from the grazing system will reduce the impact of toxicosis. Replanting alternative forages (annuals or other non-toxic forages) provides non-toxic grazing during critical points in the production cycle. Novel endophytes work by providing the plant with positive attributes of the wild-type endophyte but not decreasing livestock performance. Many novel endophyte forage cultivars are available to fit a wide range of production environments.

•**Dilution**: Introduce other forage types (i.e., legumes), which may increase the quality of biomass but also "dilute" the intake of wild-type fescue, therefore decreasing effects.

•**Grazing management**: Stockpile fescue to utilize under rotational grazing during strategic times of the year (fall/winter) will reduce the impact of toxicosis during warm seasons. Producers may consider grazing alternative forages during a spring breeding season or stocker calves on non-toxic forage to increase gain potential.

In conclusion, wild-type fescue has serious health, performance, and economic impacts on the livestock industry. The toxic ergot alkaloid-producing endophyte in wild-type fescue causes problems with body temperature regulation, growth, reproductive performance, etc. Other than Domperidone in horses, fescue toxicosis is not directly treatable. However, the amount of harmful forage can be reduced, especially at crucial times in the production cycle, or it can be removed entirely. Novel endophyte-infected fescue is a hardy alternative to wild-type fescue. Managing this deleterious forage is possible, and several strategies are effective at reducing the negative impacts. Since toxic fescue is such a large part of most cow-calf grazing systems, grazing management strategies need to be examined to determine if animal reproductive performance can be improved; however, knowledge of when tall fescue grazing impacts reproductive performance would lead to better grazing strategies. Even with the uncertainty of how fescue decreases reproductive performance, alternative grazing systems have been proposed to attenuate female reproductive problems associated with fescue grazing.

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# 15. Genetic Selection in Beef Production

Brian Bolt, Livestock Specialist

The selection of parent animals (bulls, cows and/or heifers) is an important aspect of beef production. Identifying animals and their genetics that will perform in your environment, under your management, all while producing marketable offspring, is critical for successful seedstock and commercial cow-calf operations. Operations that can match their cows to their environment and their bulls to their markets are well-positioned for success.

**Starting with the basics**

The basic principles underlying genetics concepts are straight forward. In practicality, they are a complex system of multiple traits balanced in relevance to your operations. Within genetics, there are only two tools available: deciding who becomes parents and how those parents are paired. More simply stated as selection and mating.

Selection for cattle producers involves deciding how to expand or sustain your operation. All operations will need to source bulls (be that producing, buying a bull, or utilizing artificial insemination (AI). Additionally, to maintain cow herd sizes, a producer elects to purchase additional females or retain replacement heifers. All combinations of the above can be successful if approached as a systems approach. Available resources, management experience, and expertise, along with critical evaluation of the existing herd and future goals, will help decide the best approach for individuals. Regardless of the method, decisions and investments will need to be made at some point.

Genetic change or progress describes how quickly desired changes in a herd can be made. The rate of genetic change or progress varies between traits and is based on an individual operations approach to selection and mating. The relative speed or amount of change toward an operation's genetic goals is governed by three factors.

- **Heritability** ($h^2$) is a numerical representation of the amount of total phenotypic variation that is explained by the effects of individuals' genes controlling that trait.

Phenotype is defined as the physical appearance and performance of an animal. There are heritability estimates for all "inheritable" traits that range from 0 to 1.0, with 0 representing that none of the variations in the trait is explained by the individual genes and 1.0 representing all the variation is due to the individual genes. It is important to note that heritability accounts for individual gene effects on the trait, not the effects of how those gene combinations affect the outcome.

Table 7. Heritability rates, examples or traits, and values associated.

| Rate | Example Traits | Value |
|---|---|---|
| Lowly | Reproductive and Fitness Traits | < 2.0 |
| Moderate | Growth | 2.0-4.0 |
| Highly | Linear Measurements (hip height, etc.) | > 4.0 |

- **Selection Intensity** (S) is a combined value representing how intense you can be in selection pressure(i) and how much variation exists. This means how choosy you can be as you select your parents. Selecting only one bull from several hundred one can be very specific in selecting for performance in a trait of interest. The second factor of interest here is how much variation in phenotype/performance exists within a given population. An operation can select extremes in a trait of interest and make fast genetic progress. The downside to this extreme change is the potential unintended effect on all other traits.
- **Generation Interval** (L) is a term used to represent how fast genetics are turned over in a herd. Lowering the average age of your herd by culling and replacing parents faster has an impact on the time in which change is made. This is often difficult given the costs of replacement females

**Selecting the right animals**

Historically, producers were left to select animals based on their phenotype. Phenotype is a product of the animal's genetics and how the environment has impacted the relative performance of those genetics. When choosing animals raised in different environments, performance can vary based on their relative impacts on the animal's genetics. Unique environmental interactions can occur where a high-performing animal in one environment is a poor-performing animal in another. Consider the animal performance of an animal bred to thrive in hot, humid environments and how those traits may or may not perform in a colder climate. Given the nature of these interactions, it is worth finding animals with a history of performance in environments like yours.

In genetics, the concept is represented by Phenotype(P)=Genetics(G) +/x Environment(E). The addition symbol denotes the effects of both genetics and environment being cumulative. A multiplier symbol reflects the unique environmental interactions, such as the climate impact referenced earlier. Selection on phenotype/performance alone can be difficult as the goal is to select the desirable genes that can be paired in combinations to thrive in your environment. Fortunately, producers have multiple tools available that assist in filtering out performance differences because of the environment and the effects of combing genes (earlier referred to as mating).

Accounting for known sources of environmental variation is one of the better strategies available to identify reasons for variation in performance. Consider a scenario where you desire to improve weaning weight performance only (single trait selection is risky, this is just an example) in your commercial cow herd, and you are selecting replacement heifers from your weaned calves. Suppose you select the heaviest 10% based on their actual weaning weight (the weight recorded at weaning.) Assume you have a 90-day calving season and assume all calves are weaned on the same day. It stands to reason that the first calf born is expected to weigh more than the last calf of the season. It also is fair to assume that a calf born to a first calf heifer will weigh less than a calf born to a six-year-old cow. By simply employing an adjusted weaning weight calculator, you can control for variation based on age at weaning and the dam's age. The tool also controls for variations in performance between males and heifers. You may find compelling reasons not to select heifers born late in the season (considering all cows had the opportunity to breed during the first 21 days of the season and, for whatever reasons, the late calvers did not.) There may also be reasons not to select replacement heifers from first calf heifers because of a desire to select only females from older, proven cows. In this example, adjusting weights allows a more accurate comparison of growth performance.

The use of EPD's (expected progeny differences) is a great example of just such a tool that does allow for measurement of how you expect performance to differ between animals as a result of the genes received from a parent animal. The EPD's may be difficult (not impossible) to generate on a herd of commercial cows but are a great answer to most bull selection decisions. From a practical standpoint, the current EPD systems allow for the comparison of animals within a breed. Comparing bulls of different breeds is possible but more challenging.

Take a scenario where you have two bulls (of the same breed) that you are deciding between as a new herd sire. The EPD's allow you to describe expected differences in the performance of calves between the two animals. Assuming you have an idea of areas that you would like to improve on, you can take the respective EPD profiles to decide between the two.

Table 8. Example scenario.

| **Bull Name** | **Calving Ease Direct (CED)** | **Birth Weight (BW)** | **Weaning Weight (WW)** | **Milk** | **Yearling Weight (YW)** |
|---|---|---|---|---|---|
| **Bull A** | +12 | -3.1 | +54 | +28 | +108 |
| | (0.63) | (0.66)[a] | (0.66) | (0.26) | (0.57) |
| **Bull B** | +8 | +1.0 | +21 | +19 | +54 |
| | (0.73) | (0.75) | (0.74) | (0.50) | (0.67) |
| **Diff** | +4 | +4.1 | +33 | +9 | +54 |

[a] Accuracy for the EPD

If mated to a group of genetically similar cows, on average, you would expect calves sired by Bull A to be:

- 4% more likely to calve unassisted (than B's calves)
- 4.1 pounds lighter at birth (than B's calves)
- 33 pounds heavier at weaning (than B's calves)

- Produce daughters that wean calves 9 pounds heavier as a result of their milking ability (than B's calves)
- 54 pounds heavier at one year of age (than B's calves)

Underneath each respective EPD is an accuracy value. Accuracy values reflect the amount of confidence that the predicted value is the actual value. Accuracies range from 0-.99. Accuracies are improved by additional pedigree data (performance from relatives), performance data (an individual's own performance), and, most importantly, progeny data (performance of offspring.) The more data reported on a bull, the more accurate the EPDs for that bull become. Genomically enhanced EPDs are the result of genomic data enhancing the accuracy of EPDs before additional performance information can be collected.

Genomic selection tools are an additional tool that allows producers to submit genetic material (generally a skin punch, hair, or blood) to a testing lab and have the genetics analyzed. Results provide a prediction of animal performance relative to herd mates for a variety of performance categories. When choosing replacement animals, consider other means to help you best identify the right genetics that allows you to make progress toward operational goals beyond simple phenotypic selection.

The EPD's have changed since their inception in the early 1980s. Not only have the underlying animal models improved and become more accurate, but the number of available EPD's has also expanded. In recent years the trend has been to include index EPD's. Indices are numerical tools to pull information from multiple sources (in this case, multiple EPD's) to generate single values that should make a selection for improvement easier. For example, the American Angus Association generates a $Weaned Calf Index that includes the Birth Weight, Weaning Weight, Maternal Milk, and Mature Cow Size to generate a single EPD in dollars that would allow comparison of the economic differences in calf weaning weight for different Angus parents. These models use some underlying assumptions (based on historical data) on base calf price, feed costs, cow size, and cow/heifer ratio in a herd.

**Mating Systems**

The discussion above is all relevant to selecting the right animals with the right genes that move an operation toward its goals. The second part is how those animals are paired to create the most desired outcomes. Heterosis is the tendency of crossbred individuals to show qualities superior to those of both parents. Utilizing heterosis or hybrid vigor to increase performance is a valuable tool for most economically relevant traits. In the discussion about heritability above, the reference was made that the higher the heritability value, the faster genetic progress can be achieved. For those traits lower in heritability (especially those associated with fertility, calf survivability, and longevity), the use of crossbreeding is a tool that will show increases in performance in those areas. There are multiple types of mating systems. The following is not an extensive list, but it helps illustrate the underlying principles.

Table 9. Mating system types and characteristics.

| Type of System | Characteristics | Level of Calf Heterosis | Level of Maternal Heterosis |
|---|---|---|---|
| Straight | Use of the same breed of bulls and cows. | Low | Low |
| Crossbreeding (A X B) | Use of bulls and cows of different breeds | High | Low |
| Rotational Crossbreeding (C X AB) | Use of a bull of a different breed on crossbred cows | High | High |
| Rotational Crossbreeding (C X ABC) (B X ACB) (A X BCA) | Use of different breeding groups to mate a bull of a breed the most different from the crossbred cows. The females of the lowest percentage of breed A are bred to bull from breed A. | High | High |

| | | | |
|---|---|---|---|
| Terminal | Regardless of the mating system, all offspring are sold, and replacements are purchased | Potentially high depending on parent breeds | Potentially high depending on source breeds |
| Composite | Use of crossbred parents (bulls, cows, or both) to incorporate multiple breeds at one time | Potentially high depending on parent breeds | Potentially high depending on source breeds |

Regardless of the mating system you choose, it is best to consider the marketability and the respective performance profiles to ensure an outcome consistent with your operational goals. Heterosis and crossbreeding are effective tools when used in commercial operations. In summary, the tools outlined above can all be employed in a systems approach to improving an operations sustainability, economic outcomes, and long-term success strategies. These tools are like other tools outlined in this handbook. They are to be logically paired together in a systems approach to manage all your available strengths and resources. They are also to be routinely evaluated to ensure that new technologies, tools, and strategies are considered for application in your operation. Keeping records, writing down goals, and critical evaluation are sound practices to be employed in your cattle operation.

## 16. Basics of Weed Management in Forage systems

Michael Marshall, Assistant Professor, and Extension Specialist

Weeds can be a major determinant of sustainable and profitable forage production. In addition, some weeds can be toxic to animals when consumed. As part of a holistic management plan, managing weeds in forage production is critical to reducing potential yield loss. In addition, weeds can influence grazing patterns in the forage system, where animals will avoid grazing certain weeds, increasing their prevalence through seed or vegetative propagation in the field. This increase in overall weed populations to the desirable forage(s) leaves less for the animals to consume. Therefore, it is essential to prevent and/or control these troublesome weeds before competition reduces the forage stand. The following are the most troublesome weeds in forage systems in SC (Table 5).

Table 10. Troublesome weeds in South Carolina forage production systems.

| Weed | Scientific name | Lifecycle |
|---|---|---|
| Crabgrass | *Digitaria spp.* | Annual |
| Dallisgrass | *Paspalum dilatatum* | Perennial |
| Dogfennel | *Eupatorium capillifolium* | Perennial |
| Horsenettle | *Solanum carolinense* | Perennial |
| Knotroot foxtail | *Setaria parviflora* | Perennial |
| Maypop passionflower | *Passiflora incarnata* | Perennial |
| Rescuegrass | *Bromus catharticus* | Annual |
| Sandburs | *Cenchrus echinatus* | Annual |
| Vaseygrass | *Paspalum urvillei* | Perennial |
| Texas panicum | *Panicum texanum Buckl* | Annual |
| Thistles | *Cirsium spp.* | Biennial |

**Plant lifecycle.** Weeds can be grouped by lifecycle: annuals, biennials, and perennials. Annuals complete their lifecycle within one year or growing season. There are two types of annuals, depending on what time of year they are found: warm-season and cool-season. Crabgrass and sandburs are examples of warm-season annuals. Annual bluegrass and henbit are examples of cool-season annuals. Annuals rely on seed production for dissemination in the environment; eliminating or minimizing seed production is the most effective strategy for reducing these populations over time. Seed size and production vary where small-seeded annual weeds, such as pigweeds, can produce up to 500,000 seeds per plant in a single growing season. In contrast, large-seeded annual weeds tend to produce fewer seed (e.g., cocklebur) per plant. Biennials are plants that complete their lifecycle in two growing seasons. Bull thistle is an example of a biennial weed. During the first season, the seedling forms a rosette which is composed of a whorl of leaves at the soil surface that overwinters, and the following spring/early summer, it bolts (forms a stalk) on which the reproductive organs (flowers, fruits, and seed) are produced. Successful management of biennial weeds is achieved during the first year of the lifecycle.

Weeds that have lifecycles longer than two years are perennials. Perennials can reproduce by seed and/or vegetative structures. Johnsongrass is an example of a perennial weed that reproduces by seed and underground stems (e.g., rhizomes). Perennial weeds can be classified into two groups: simple and spreading. A simple perennial produces new shoots each year from reproductive buds located on the crown of a taproot. Common pokeweed is an example of a simple perennial. In contrast, spreading perennials often form colonies using aboveground stems (e.g., stolons), underground stems (i.e., rhizomes), or creeping roots, which produce new daughter or clonal plants from the mother plant. Horsenettle is a broadleaf perennial weed that reproduces using creeping roots, which gives rise to new daughter plants. Other perennial reproductive structures include tubers (e.g., yellow nutsedge) and bulbs (e.g., wild garlic). Perennials are the most difficult and challenging to control once established in a pasture. A combination of several different management practices is needed.

**Scouting.** Documenting what weed populations are present in your forage production fields is critical. This practice will help detect changes over time in weed populations and possible herbicide-resistant weeds before they are a significant problem in your fields. Herbicide selection is based on proper weed identification;

therefore, documenting weed populations over time is critical in weed management decision-making.

### Cultural Practices for Weed Management in Forages

- **Mowing -** Mechanical control can be an effective option for reducing or eliminating seed production in weeds. In the case of annual weeds, this practice can reduce weed seed returning to the soil seed bank each year. Clipping can also reduce or “starve” the root systems of some perennial weeds. For example, mowing perennial weeds, such as Johnsongrass or dogfennel, in the late summer or early fall can force the weed to regrow and expend storage carbohydrates in the root system needed for overwintering. This practice can make the weed susceptible to winter kill. However, mowing is not effective on perennial weeds with relatively small above-ground leaves/stems compared to their belowground root system (for example, horsenettle, maypop passionflower, and trumpet creeper).
- **Pasture Renovation and Rotation**- When a forage stand is in decline, or the producer decides to rotate to a new forage cropping system, this is a good opportunity to manage difficult-to-control weeds before the new forage is planted. For example, perennial grass weeds are often difficult to control selectively in a grass forage. The use of a non-selective herbicide (for example, glyphosate) during this renovation period would control and eliminate these weeds. A well-planned renovation can reduce and eliminate weed problems before the next forage is planted.
- **Tillage-** Mechanical preparation before seeding or sprigging the forage is an effective method for preparing the field and eliminating most weeds. The downside to tillage is some weeds can propagate by stem or root fragments (for example, Johnsongrass and horsenettle). Again, non-selective herbicides would be a better option for those weeds while leaving the soil undisturbed.

### Herbicide use for Weed Management in Forages

Herbicides should be part of the solution to weed problems in forages. Assessing why weeds are a problem in the forage system is critical (for example, fertility, low pH, overgrazing, etc.). Correcting these issues before using herbicides is highly recommended; otherwise, the weeds will return. Compared to other practices, herbicides are cost-effective options for weed management. When purchasing and using herbicides, it is essential to read and follow the instructions on the product label. Herbicide selection should be based on the weeds present. As discussed previously, scouting and correct weed identification in forage fields are essential because herbicides are selective for certain weeds or groups. Most herbicides available for forage systems are selective to broadleaf weeds. There are a few available for grass weeds in forage grass pastures (examples, Facet and Pastora). In forage legumes, more grass control options are available, but fewer for broadleaf weeds. Herbicides are available for several different application timings relative to the time of year and age of the forage crop.

**Newly sprigged/new seedings -** For new sprigged forages, weed control during establishment is critical for a successful stand. Typically, weedy grass control is challenging during this time as there are no over-the-top herbicides available. In new forage seedings, product labels recommend delaying herbicide application until forage is well established, usually indicated by tillering and/or the presence of a well-developed root system.

**Dormant season/between cuttings in established forages-** Applying herbicides during the dormant season can reduce the likelihood of crop injury the next season. For example, Prowl H2O (pendimethalin) is a soil-active herbicide that can be applied during the winter for the control of annual weeds, such as sandburs, during the following growing season. Non-selective herbicides, such as glyphosate or paraquat, can be used to control weeds between forage cuttings, provided there is enough foliage left on the weed for the herbicide to be absorbed into the plant. Consult the herbicide product label for specific details on timing and application rates.

**Postemergence in established forages-** Many of the weeds in forage production are managed with herbicides during the production season. As mentioned earlier, most herbicides used in grass forages are selective for broadleaf weeds. Removal of these weeds is critical to minimize competition with the forage crop and prevent seed production. There are more grass herbicides available in broadleaf forage crops (for example, alfalfa and clover). Select the correct herbicide based on the weed present in the forage system. Glyphosate-tolerant alfalfa varieties are available and allow the over-the-top use of glyphosate for weed management. The growth stage of the weed greatly influences the success of a postemergence herbicide. Small, actively growing weeds are easier to control compared to large and/or drought-stressed weeds, which often need retreatment for satisfactory control. Consult the product label for information on recommended spray additives and adjuvants, effective weed spectrum, and other application parameters.

**Herbicide persistence and carryover -** The potential for a herbicide to persist in the soil and potentially impact the seeding of the next forage crop is a concern. For example, picloram (Tordon) is a long-lived herbicide once applied to the soil. This soil activity is a benefit for controlling difficult weeds, such as horsenettle; however, these residues in the soil can injure or kill any new forage crop. The product label recommends a bioassay before planting the desirable forage crop. These bioassays involve seeding the forage crop in small strips across the herbicide-treated field and evaluating crop response after a certain period of time. Be sure to consult the product label regarding waiting periods before spraying the herbicide on the forage crops. This is important if you plan on seeding a temporary forage in an established forage stand.

**Herbicide drift and sensitive crops -** Auxinic herbicides, including 2,4-D and dicamba, have the potential to volatilize and move from the treated forage to a sensitive crop, such as cotton and tobacco. Avoiding the use of these herbicides and selecting alternative herbicides for forage weed control when these sensitive crops are growing is highly recommended.

**Herbicide use precautions**

Following herbicide application, waiting intervals are required before grazing, haying, animal withdrawal, or planting a new forage crop. In Tables 11 and 12, these intervals are provided for herbicides used in forages.

Table 11. Interval after herbicide application before grazing, haying, or removal for slaughter.

| Herbicide | Time Interval (days)[1] | | | | |
|---|---|---|---|---|---|
| | Grazing Management | | | Removal prior slaughter[3] | Hay Cutting |
| | Lactating Cow | Beef | Other Animals[2] | | |
| Aim | 0 | 0 | 0 | 0 | 0 |
| Arsenal | 0 | 0 | 0 | --- | 7 |
| Banvel/Clarity | | | | | |
| up to 1 pt/A | 7 | 0 | 0 | 30 | 37 |
| up to 2 pt/A | 21 | 0 | 0 | 30 | 51 |
| up to 4 pt/A | 40 | 0 | 0 | 30 | 70 |
| Chaparral | 0 | 0 | 0 | 3 | 14 |
| Cimarron Max | 7 | 0 | 0 | 30 | 37 |
| Cimarron Plus/Chisum | 0 | 0 | 0 | 0 | 0 |
| Crossbow | Next Growing Season | 0 | 0 | 3 | 14 |
| Diuron | 70 | 70 | 70 | --- | 70 |
| DuraCor | 14 | 14 | 14 | 3 | 14 |
| Facet | 0 | 0 | 0 | --- | 7 |
| Freelexx | --- | --- | --- | --- | 7 |
| Garlon 3A | Next Growing Season | 0 | 0 | 3 | 14 |
| GrazonNext HL | 0 | 0 | 0 | 3 | 14 |
| Gramoxone SL | --- | --- | --- | --- | 40 |
| Glyphosate | --- | --- | --- | --- | 0 |
| Graslan | 7 | 0 | 0 | 3 | 30 |
| Huskie | 7 | 7 | 7 | --- | 7 |
| Impose/Panoramic | --- | --- | --- | --- | --- |
| Metsulfuron | 0 | 0 | 0 | 0 | 0 |
| Milestone[4] | 0 | 0 | 0 | 3 | 14 |
| Outrider | 0 | 0 | 0 | --- | 14 |

| | | | | | |
|---|---|---|---|---|---|
| Pastora | 0 | 0 | 0 | 0 | 0 |
| PastureGard HL | Next Growing Season | 0 | 0 | 3 | 14 |
| Prowl H2O | 0 | 0 | 0 | 0 | 0 |
| Remedy Ultra | Next Growing Season | 0 | 0 | 3 | 14 |
| Rezilon | 0 | 0 | 0 | 0 | 0 (40 if >3.0 fl oz/A) |
| Sandea | 0 | 0 | 0 | 0 | 37 |
| Spike | 0 | 0 | 0 | --- | 365 |
| Stinger[5] | 0 | 0 | 0 | --- | 0 |
| Starane Ultra | 0 | 0 | 0 | 2 | 7 |
| Surmount[7] | 14 | 0 | 0 | 3 | 0[8] |
| Velpar | 60 | 60 | 60 | --- | 60 |
| Weedmaster | 7 | 0 | 0 | 30 | 37 |
| Yukon | 0 | 0 | 0 | 0 | 37 |
| 2,4-D (various) | 7 | 0 | 0 | 3 | 7 |

[1]--- no information provided by the product label.
[2]Other animals include goats, horses, and sheep.
[3]For the removal period indicated animals for slaughter should be withdrawn from treated areas or consumption of hay harvested from treated areas.
[4]Do not use or transfer treated plant residues, including hay or straw from treated areas, or manure from animals that have grazed forage or eaten hay harvested from treated areas within the previous 3 days, in compost or mulch that will be spread to areas where broadleaf crops may be grown. Manure from animals that have grazed forage or eaten hay harvested from treated areas within the past 3 days may only be used pasture grasses, grass grown for seed, and wheat.
[5]Do not transfer livestock from treated grazing areas (or feeding of treated hay) to sensitive broadleaf crop areas without first allowing 7 days of grazing in an untreated area (or feeding of untreated hay), manure and urine may contain enough clopyralid to cause injury to sensitive broadleaf crops.
[6]Do not harvest hay from the treated area until the next growing season for consumption by lactating dairy cattle.
[7]Do not transfer livestock from treated grazing areas (or feeding of treated hay) to sensitive broadleaf crop areas without first allowing 7 days of grazing in an untreated area (or feeding of untreated hay), manure and urine may contain enough picloram to cause injury to sensitive broadleaf crops
[8]Do not harvest hay from treated area for consumption by lactating dairy animals within 14 days after application.

Table 12. Planting restrictions following herbicide application due to soil residual activity in forage systems.

| | Time Interval (months) | | | | |
|---|---|---|---|---|---|
| **Herbicide** | **Clovers[1]** | **Wheat** | **Oats** | **Tall Fescue** | **Annual Ryegrass** |
| Aim | 0 | 0 | 0 | 0 | 0 |
| Arsenal | 12 + Soil Assay[10] | 12 + Soil Assay[10] | 12 + Soil Assay[10] | 12 + Soil Assay[10] | 12 + Soil Assay[10] |
| Banvel/Clarity | 12 | 4 | 4 | 4 | 4 |
| Chaparral | Soil Assay[9] | 0 | 12 | 0 | 4 |
| Cimarron Max | 4 | 1 | 10 | 4 | 4 |
| Cimarron Plus/Chisum | 4 | 1 | 10 | 4 | 4 |
| Crossbow | Soil Assay[7] | 3 weeks | 3 weeks | 3 weeks | 3 weeks |
| Diuron | 24 | 24 | 24 | 24 | 24 |
| DuraCor | Soil Assay[9] | 45 days | 45 days | 15 days | 15 days |
| Facet | 10 | 0 | 10 | 10 | 10 |
| Freelexx | None indicated on label | | | | |
| Garlon 3A | Soil Assay[7] | 3 weeks | 3 weeks | 3 weeks | 3 weeks |
| Glyphosate | None indicated on label | | | | |
| GrazonNext HL | Soil Assay[2] | 4 | 4 | 4 | 4 |
| Graslan | Soil Assay[5] | 2[4] | 2[4] | Soil Assay[5] | Soil Assay[5] |
| Huskie | Soil Assay[9] | 1 | 1 | 1 | 1 |
| Impose/Panoramic | | | | | |
| <4 oz/A | 26 | 12 | 18 | 26 | 26 |
| 5-8 oz/A | 30 | 12 | 22 | 30 | 30 |
| 9-12 oz/A | 36 | 12 | 24 | 36 | 36 |
| Metsulfuron | Soil Assay[9] | 1 | 10 | 18 | 6 |
| Milestone[4] | Soil Assay[2] | Fall[3] | Fall[3] | Fall[3] | Fall[3] |
| Outrider | 12 | 0 | 12 | 12 | 12 |
| Pastora | 12 | 4 | 10 | 4 | 4 |
| PastureGard HL | 1 | 4 | 4 | 3 weeks | 3 weeks |
| Prowl H2O | 12 | 4 | 12 | 10 | 10 |
| Remedy Ultra | Soil Assay[7] | 3 weeks | 3 weeks | 3 weeks | 3 weeks |

| | | | | | |
|---|---|---|---|---|---|
| Rezilon | Soil Assay[11] | 22 | 22 | Soil Assay[11] | Soil Assay[11] |
| Sandea | 9 | 2 | 2 | 2 | 2 |
| Spike | 24 | 24 | 24 | 24 | 12 |
| Stinger | Soil Assay[6] | 0 | 0 | 0 | 0 |
| Surmount | 12[8] | 0 | 0 | 0 | 0 |
| Velpar | None indicated on label | | | | |
| Weedmaster | 4 | 4 | 4 | 4 | 4 |
| Yukon | 9 | 2 | 2 | 2 | 2 |
| 2,4-D (various) | 12 | 4 | 4 | 4 | 4 |

[1]Clover species include red, white, and sweet.

[2]Do not plant forage legumes until a soil assay has been conducted to determine if aminopyralid residues remaining in the soil will adversely affect establishment.

[3]If GRAZONNEXT HL or MILESTONE is applied in the spring or early summer, grasses may be planted the following fall when conditions are favorable for grass establishment.

[4]Wait 60 days or 2 months with temperatures above 40 F during that period.

[5]Do not plant any crop except small grains until a soil assay has been conducted to determine if picloram residues remaining in the soil will adversely affect rotational crop establishment.

[6]Do not plant a rotational crop until a soil assay has been conducted and shows that no clopyralid residues remain in the soil.

[7]Do not plant forage legumes until a soil assay has been conducted to determine if triclopyr residues remaining in the soil will adversely affect legume establishment.

[8]After 12 months, a soil assay should be conducted before seeding forage legumes to verify no picloram residues remain in the soil.

[9]Do not plant forage legumes until a soil assay has been conducted to determine if herbicide residues remaining in the soil will adversely affect legume establishment.

[10]Following 12 months after ARSENAL application and before planting any crop, a successful field bioassay must be completed. See label for more information.

[11]Following 22 months after REZILON application, a successful field bioassay must be completed. See label for more information.

## 17. Basics of Insect Control in Forage Systems

Jeremy Greene, Associate Professor and Extension Specialist

There is a diversity of insects occurring in forage systems. In this context, it is crucial to identify insect pests versus beneficial ones and manage pests as needed using integrated pest management (IPM) strategies. The IPM uses multiple approaches to control and reduces economic and environmental losses. Tactics of IPM are varied and include, but are not limited to, mechanical, cultural, biological, and chemical control. Mechanical or physical control of insects includes sanitizing the field of anything that might attract insects. For example, pulling weeds that might be attractive to some insect pests, such as blister beetles on pigweeds, or using barriers, nets, or traps for insects. Cultural control can often be achieved by altering planting dates or using resistant or tolerant varieties.

In comparison, biological control strategies include conserving natural enemies of insect pests by only spraying insecticides when necessary and can consist of augmentative releases of beneficial arthropods into the forage crop area. Chemical control should be the last resort when using IPM appropriately, with all other strategies deployed in advance. Although effective in controlling targeted pests, insecticide sprays can kill non-target arthropods, such as predators, parasitoids, pollinators, and other transient insects. Therefore, insecticides must be used only when insect pests reach treatment thresholds. Proper selection of insecticides is crucial, so knowledge of insecticide mode of action and activity on target species is essential. For help on this, always consult your local Extension agent.

### Major insect pests

### Alfalfa weevil

The alfalfa weevil, *Hypera postica* (Gyllenhal), is a significant pest on alfalfa fields, and reports of its occurrence in North America date back to the 1900s. Adults of the alfalfa weevil are small (about one-fourth inch long), light brown beetles with a darker stripe on the top and down the length of the body. The chewing mouthparts on the tip of a snout are used to feed on leaves and chew holes in stems for laying eggs. The larvae are green with a light line running down the “back” of the insect. Larvae of the alfalfa weevil can cause significant defoliation with their chewing mouthparts. Management of the alfalfa weevil with insecticides in alfalfa is based on treatment thresholds (number of weevils by plant height or with a sweep net, damaged terminals, or a combination) (Table 13) (Greene et al. 2022).

Larva and adult of alfalfa weevil (*Hypera postica*). Source: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org.

Table 13. Treatment thresholds for alfalfa weevil occurrence in alfalfa fields.

| Number of weevil larvae | Alfalfa growth Stage, Sweep-Net, or Damage Threshold |
|---|---|
| 0.5 | 3 to 8 inches tall |
| 1.0 | 9 to 14 inches tall |
| 1.5 | 15+ inches tall |
| 20 | Per sweep |
| - | 30% damaged terminals |

**Blister beetles**

Several species of the genus *Epicauta* can occur in alfalfa and pose a risk if consumed. The toxic chemical cantharidin, produced by blister beetles (Capinera et al. 1985), can be poisonous to livestock. Proper timing of cuttings for harvest, control of weeds attractive to blister beetles, and scouting are all critical to reducing the risk of blister beetle presence in alfalfa. Control is recommended when a threshold of two beetles per square foot is achieved (Buntin, 2022). Blister beetles occurrence in the Southeast USA in alfalfa fields has been limited.



Adult of margined blister beetle (*Epicauta funebris,* left) and striped blister beetle (*Epicauta vittate*, right). Source:Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org**.**

**Grasshoppers**

Grasshoppers can eat leaves and cause significant losses of yield and even stands. These opportunistic, plant-feeding pests can proliferate in and around agricultural fields, especially during hot and dry periods. Because adult female grasshoppers lay eggs in pods placed in the soil, developing and emerging nymphs benefit from reduced tillage. Treatment thresholds vary by forage crop but usually involve defoliation or stand reduction estimates. In the picture is an adult redlegged grasshopper (*Melanoplus femurrubrum*). [Source: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org].

**Fire ants**

Fire ants are from the genus *Solenopsis.* Ants are typically beneficial insects in many agricultural crops because they serve as important predators of economic pests. For example, fire ants can reduce or suppress populations of major insect pests in row crops, such as cotton. However, in forage crops, in addition to their usual beneficial role, their presence can cause problems for equipment and livestock. The large mounds of soil built by colonies can damage farm machinery, especially under drought conditions when soil hardens. Delayed operations and repairs due to mounds as obstructions can be costly. In addition, rare but possible interactions with livestock or humans can make fire ants medically essential pests. Insecticides applied for ants, or other insect pests can provide control of fire ants, and there are bait products that will reduce populations of ants.  However, dedicated applications of insecticide for ants can be expensive and might not be economically justified. The costs of controlling fire ants should be carefully weighed with the potential benefits.

Mounds of the fire ant (*Solenopsis invicta*). Source: USDA APHIS PPQ - Imported Fire Ant Station, USDA APHIS PPQ, Bugwood.org (left) and Liliane Silva, Clemson University (right).

**Bermudagrass stem maggot**

The bermudagrass stem maggot [BSM; *Atherigona reversura Villeneuve* (Diptera: Muscidae)] is invasive species to the southeastern U.S.A. After hatching, the fly maggots feed on plant apical meristems, which results in dead leaves/plants and reduced forage yields. Bermudagrass and stargrass are the only hosts of this pest. The whole life cycle of BSM lasts about 21 days, with multiple generations in one year, which difficults its control. Management practices can be used to try to reduce losses caused by BSM. Generally, under grazing, injuries can be less visible once livestock is grazing and might consume some of the maggots, but the adults are unaffected and will continue to reinfest the pasture. Applications of insecticide (pyrethroids are the main option) target the exposed adults. A second application should be conducted within 7 to 10 days after the first one, aiming to control surviving larvae and adults.


Damage caused by bermudagrass stem maggot (*Atherigona reversura*). Sources: Will Hudson, University of Georgia, Bugwood.org (left) and Liliane Silva, Clemson University (right).

**Armyworms**

Generally, the fall armyworm (*Spodoptera frugiperda*) occurs in summer. They have an inverted “Y” on their head, which is the most distinguished mark to identify them. The true armyworm (*Mythimna unipuncta*) can be a problem during the spring in cool-season grasses. These species can be quite numerous (hence the name ‘armyworm’) and voracious defoliators after the migratory adult moths move into an area. Significant losses are observed in forage fields affected by them, and weather conditions can contribute to several occurrences in a single year, compromising the season forage production. Scout the fields frequently when armyworms are expected to occur. Avoid scouting the field in hotter periods of the day, and they will be hiding in the forage canopy. Upon identifying their presence on fields, it is crucial to determine if the threshold was achieved using the bucket or sweep net method to determine how many armyworms per area and their sizes. If the field is close to being harvested for hay or grazed, proceed with it as soon as possible. If not, an insecticide application is recommended as soon as possible to control the damage. An additional insecticide application may be needed 7 to 10 days after the first is conducted.

Larva of fall armyworm (*Spodoptera frugiperda*). Source: Chazz Hesselein, Alabama Cooperative Extension System, Bugwood.org (left) and Liliane Silva, Clemson University (central and right).

# 18. Introduction to the Economic Impact of Forage Production on South Carolina

Matthew Fischer, Extension Specialist, and Nathan Smith, Extension Specialist

In South Carolina, the agribusiness industry corresponds to $46.2 billion in annual economic impact. The United States Department of Agriculture (USDA) reports hay production valued at $79 million to the agriculture economy in the state, not accounting for pasture or silage production. Therefore, it is crucial to understand better single concepts and how to apply them to your operation, aiming to improve profitability.

**Understanding Costs**

a. **Direct cost or variable cost-** These are expenses that can directly affect the amount of production within a given production cycle. These expenses can fluctuate given various levels of production.

b. **Indirect cost or fixed cost-** These expenses can be incurred across multiple production cycles and are typically based on the size of the production method.

In a forage system, achieving proper production and quality results from multiple management factors. Similarly, the profitability of an operation will be a function of input cost management and marketing. To better understand input cost management, inputs should be defined in the correct cost definition. The following are some examples of direct and indirect cost categories of forage production inputs.

**a. Direct costs:**

i. Fertility (fertilizer and lime)
ii. Herbicide and insecticides
iii. Seed (annual plantings, i.e., ryegrass, clovers, etc.)
iv. Labor
v. Equipment repairs
vi. Fencing repair
vii. Twine, net wrap, plastic wrap
viii. Irrigation operation cost

**b. Indirect costs:**

i. Fencing
ii. Equipment depreciation

iii. Forage depreciation (perennial species)

iv. Taxes

v. Land rent

vi. Irrigation depreciation

While most of these costs can occur between pasture production and harvested forage production (hay, haylage, and silage), it is vital to enterprise independently. Enterprise is best described as a defined production practice that directly results in some production quantity. For example, suppose you are producing bermudagrass round bale dry hay. In that case, you only want to assign the fertilizer bill to make hay, not the fertilizer bill for your bermudagrass pasture.

**Budgeting**

Budgets should be utilized throughout any business practice as a planning tool. There are two types of farm enterprise budgeting: partial and complete budgeting. The partial budgeting will look at income above direct cost and provide insight into the cost of production and revenue generated within a production cycle. Complete budgeting is the partial budget, including the indirect cost. This budgeting will provide the production cost and revenue generated for a production, including the cost that are incurred across multiple production cycles.

The number of budgets you should create should equal the number of enterprises you are currently farming or planning. Budgeting also provides the opportunity for producers to compare alternative production and marketing methods. The following examples, Fig 1. and Fig 2., illustrate partial budgeting. It is important to note that cost and production practices will change. For your individual enterprise(s), you should make the appropriate changes to account for all direct costs. Figure 1 accounts for bermudagrass small square bale hay production, while figure 2 accounts for bermudagrass grazing (pasture) enterprise. As mentioned before, both are partial budgets, and they account for all costs that directly affect the amount of production, direct cost.

| HYBRID BERMUDAGRASS FOR HAY | | | | | | |
|---|---|---|---|---|---|---|
| | ESTIMATED MAINTENANCE COSTS AND RETURNS PER ACRE | | | | | |
| | 5 TON YIELD FROM 4 CUTTINGS (SMALL SQUARE BALES) | | | | | |
| | | | | PRICE OR | TOTAL | YOUR |
| | | UNIT | QUANTITY | COST/UNIT | PER ACRE | FARM |
| **1. GROSS RECEIPTS** | | | | | | |
| | BERMUDAGRASS | TON | 5.00 | $240.00 | $1,200.00 | |
| | TOTAL RECEIPTS: | | | | **$1,200.00** | **$0.00** |
| **2. VARIABLE COSTS** | | | | | | |
| | FERTILIZER | | | | | |
| | NITROGEN | LBS | 150.00 | $0.77 | $115.50 | |
| | PHOSPHATE | LBS | 70.00 | $0.49 | $34.30 | |
| | POTASH | LBS | 210.00 | $0.33 | $69.30 | |
| | LIQ. NITROGEN (SPREAD) | LBS | 140.00 | $0.40 | $56.00 | |
| | LIME (SPREAD) | TON | 0.50 | $45.00 | $22.50 | |
| | HERBICIDES | ACRE | 1.00 | $98.19 | $98.19 | |
| | CUSTOM SPREAD | ACRE | 1.00 | $10.00 | $10.00 | |
| | TWINE | BALE | 200.00 | $0.15 | $30.00 | |
| | TRACTOR/MACHINERY | ACRE | 1.00 | $75.45 | $75.45 | |
| | LABOR | HRS | 15.82 | $9.50 | $150.29 | |
| | INTEREST ON OP. CAP. | DOL. | $330.77 | 5.0% | $16.54 | |
| TOTAL VARIABLE COSTS: | | | | | **$678.07** | **$0.00** |
| **3. INCOME ABOVE VARIABLE COSTS:** | | | | | **$521.93** | **$0.00** |

Fig 1. Budget for bermudagrass small square bale hay production.

| HYBRID BERMUDAGRASS FOR GRAZING | | | | | | |
|---|---|---|---|---|---|---|
| | ESTIMATED MAINTENANCE COSTS AND RETURNS PER ACRE | | | | | |
| | MAY-OCTOBER GRAZING | | | | | |
| | | | | PRICE OR | TOTAL | YOUR |
| | | UNIT | QUANTITY | COST/UNIT | PER ACRE | FARM |
| **1. VARIABLE COSTS** | | | | | | |
| | FERTILIZER | | | | | |
| | NITROGEN | LBS | 100.00 | $0.77 | $77.00 | |
| | PHOSPHATE | LBS | 25.00 | $0.49 | $12.25 | |
| | POTASH | LBS | 50.00 | $0.33 | $16.50 | |
| | LIME (SPREAD) | TON | 0.50 | $45.00 | $22.50 | |
| | CUSTOM SPREAD | ACRE | 1.00 | $10.00 | $10.00 | |
| | TRACTOR/MACHINERY | ACRE | 1.00 | $2.66 | $2.66 | |
| | LABOR | HRS | 0.74 | $9.50 | $7.03 | |
| | INTEREST ON OP. CAP. | DOL. | $73.97 | 5.0% | $3.70 | |
| TOTAL VARIABLE COSTS: | | | | | **$151.64** | **$0.00** |

Fig 2. Budget for bermudagrass pasture managed under grazing.

Enterprise differences can be visualized when observing these budgets side by side. The budget in figure 1. is a revenue-producing enterprise; therefore, we have a gross receipts line item. Figure 2 is a production method that does not generate revenue until grazing animals are sold, which is a separate enterprise. Therefore no gross receipts are in this budget.

**Marketing**

Forage marketing can have its challenges. Unlike grain marketing, forage marketing can be influenced by non-tangible factors, such as “I don’t like the way it looks” or “This bale is loose and not tight,” which are examples of what a hay producer might hear. Hay testing should be a tool to support proper marketing, and when done correctly, this information provides both the seller and buyer with complete details on the expected product delivered. Opportunities for producers to differentiate themselves from other sellers will be related to the management and quality of the material they can provide. Therefore, investments in proper hay storage under a barn, for example, can pay off eventually. Any forage producer must remember that you must differentiate yourself and your product (forage or animal product) and remember the quality will bring customers back.

## 19. New Technologies for Use in Forages and Livestock Systems

Kendall R. Kirk, Precision Agriculture Engineer

### Guidance and Application Technologies

New agricultural technologies enter the commercial market every year, and many of these can benefit forage and livestock production systems. Some of these will be described below.

***GPS tractor guidance systems*** can be used to replace foam markers to assist in the reduction of overlap and/or underlap when applying chemicals or fertilizer. At the most basic level, generally requiring no subscription service, GPS guidance systems cost about $2,000 or less and maintain an accuracy of better than three feet. Some GPS guidance systems provide a light bar to show how close a tractor's path is to a set of parallel guidance lines, but many GPS guidance systems provide an in-cab display to also "paint" areas of a field where a product has been applied. Most of today's systems support guidance along parallel passes of straight lines and curved lines. If replacing a foam-marker system, accuracies are similar, and the reduction in maintenance can be substantial since GPS guidance systems require little to no servicing. Any reduction in application overlap directly translates to a decrease in product costs, and a reduction in application underlap will translate to improved forage management. At the high-end among guidance solutions, GPS autosteer systems currently cost about $20,000 or less to retrofit to a tractor and will automatically steer the tractor along guidance lines, generally requiring an operator to turn on the ends of each pass manually. A vital factor to consider when selecting a GPS guidance system includes whether the system is compatible with potential future add-ons, such as automated section control, discussed below.

***Manual section control and automated section control*** on a sprayer imply two different functionalities. Manual section control divides a spray boom into multiple sections, for example, dividing a 45 ft boom into three 15 ft sections. With manual section control, each section of a boom is turned on and off by a valve, which can be toggled by the operator with a switch in the cab. A great deal of operator attentiveness is required to benefit substantially from manual section control. Automated section control is a technology used in combination with GPS guidance systems, where each sprayer section is automatically turned on and off, depending on the current position of the sprayer section. For example, if field boundaries have been set and a given section of the sprayer is outside of these boundaries, then the section will be automatically turned off. Or, if a section of the spray boom overlaps an area of the field that has already been sprayed, then it would also be turned off. The benefits of section control come in the form of reduced application overlap and therefore reduced waste and product costs. Benefits are least on rectangular fields and most substantial on irregular-shaped fields, with typical product savings ranging from 3% to 10%. Savings are greater when more sections are employed since they result in smaller sections and therefore reduced overlap.

Other sprayer technologies that could benefit forage production systems include ***pulse-width modulation (PWM) and turn compensation***. PWM sprayer controls allow improved flow rate management and function by pulsing a valve to control product flow rate and, therefore, application rate. The valve is pulsed (turned on and off) at a high frequency and a particular duty cycle, which represents the percentage of time that the valve is open. At a 100% duty cycle, the valve is open 100% of the time, and the PWM system operates at the highest flow rate achievable for the sprayer configuration. At a 50% duty cycle, the valve is open 50% of the time, and the PWM system produces 50% of the flow rate for the sprayer configuration. A PWM system is generally configured to automatically maintain a specified application rate (gal/ac) while compensating for ground speed. A primary advantage of a PWM sprayer controller is that it allows for relatively constant pressure, and therefore droplet size, across a range of ground speeds and therefore, liquid flow rates. Turn compensation systems often pair PWM controllers with GPS positioning systems and section control (or individual nozzle control) to provide more accurate application rates along the length of a sprayer boom. When spraying through a turn, the innermost boom section, relative to the turn, covers less area than the outermost section. Because of this, the innermost boom section requires a lower flow rate than the outermost section to achieve the same application rate.

***Variable rate application (VRA) technologies*** allow products to be applied at different rates in different areas of the field and can be implemented with just about any agricultural input, including those applied with planters, sprayers, and spreaders. VRA technologies utilize a controller to change the material flow rate as a product is being applied. The most commonly employed form of variable rate management is for fertilizer application with a spreader, where the speed of the conveyor chain on the spreader is regulated to control the amount of fertilizer applied to a specific area of the field. VRA can demonstrate substantial product savings over uniform rate application, but only if the rates dictated for different areas of the field are well-prescribed. VRA is most often a map-based technology, where “prescription maps” are developed to dictate the rates that should be applied in each area of the field. These prescription maps generally divide a field into several zones or grids.

For instance, a 30 acres field may be divided into three 10 acres zones. Soil samples would be collected independently from each zone, demonstrating different fertilizer recommendations in each zone, and the prescription map would reflect these recommendations. As a spreader is operated in the field, a GPS positioning system compares the current position to the rate assigned for that position and accordingly communicates a material flow rate to the application controller. VRA is not intended to reduce total inputs; instead, it moves inputs from areas of the field that would have otherwise been over-applied to areas of the field that would have otherwise been under-applied. Therefore, the outcome of adequately applied VRA is to maximize input use efficiency or to get a greater return on investment per unit input (e.g., fertilizer) applied. So, the return on investment from VRA increases as a function of crop value and input cost. Many fertilizer companies will perform variable rate applications for a nominal surcharge, which is economically justifiable in many cases in South Carolina, given the large degree of variability in our soils.

**Clemson Web Applications (Apps)**

In recent years, Clemson has developed several web applications that may be useful to forage and livestock producers as decision aids and management tools. They can be used from any device with a web browser and an internet connection.

The ***Clemson Lime Rate Calculator*** is designed to work with Clemson soil test results, allowing farmers to adjust target pH or mixing depth and customize lime recommendations for specific lime sources, compensating for product effectiveness in adjusting soil pH. This tool was developed to make it easy to customize lime recommendations for various needs. The lime rate calculator also determines the total quantity required for a specified acreage and allows producers to determine cost per unit area and per unit of lime. This can be useful for comparing various lime products or various lime suppliers. Available at:
https://precisionag.sites.clemson.edu/Calculators/Fertility/LimeRec/

The ***Reverse Lime Rate Calculator*** was designed similarly to the lime rate calculator, although instead of calculating the amount of lime required to achieve a target soil pH, the Reverse Lime Rate Calculator estimates a final soil pH as a function of the amount of lime applied. This tool was developed in the 2022 crop year when sourcing adequate lime quantities were challenging for some farming operations. Soil test results are also used with the Reverse Lime Rate Calculator, using the current soil pH and buffer pH as the basis for determining the final pH. Available at
https://precisionag.sites.clemson.edu/Calculators/Fertility/ReverseLime/

The ***NPK Recommendation Calculator*** allows farmers to obtain Clemson Extension fertilizer recommendations for nitrogen, phosphate, and potash based on soil test results. This tool was developed in cooperation with Clemson's Agricultural Service Lab to ensure that outputs were consistent with soil test report recommendations. The calculator is useful if crops selected for the submitted soil analysis need to be changed, but it is also designed and useful for pushing outputs to the Fertilizer Blend Calculator, discussed below. User inputs include soil type, crop name, and soil test $P_2O_5$ and $K_2O$ levels. The output includes Clemson Extension fertilizer recommendations, and crop-specific comments may also be viewed. The laboratory uses tabulated recommendations as a function of soil test level, and the calculator uses algorithms that approximate the lab's tabulated values, so slight differences in recommendations can be expected. Available at: https://precisionag.sites.clemson.edu/Calculators/Fertility/npkRec/

The ***Clemson Fertilizer Blend Calculator*** was designed to stand alone or work alongside the NPK recommendation calculator. There are two application rate entry modes: guided (use worksheet) and direct NPK entry. When recommendations are pushed here from the NPK recommendation calculator, the guided mode is set by default. In guided mode, an Application Rate Worksheet is provided, allowing the user to tally deductions from the recommendation, for instance, to account for manure application, for a nitrogen credit when following a legume, or for other fertilizer applications. The worksheet determines the remaining NPK needs after taking into account deductions specified by the user. In the next step, cost- and rate-optimized fertilizer blends can be calculated for a given application. In direct NPK entry mode, the application rate worksheet discussed above can be bypassed. Up to eight fertilizer raw materials can be specified, along with prices, and the calculator determines blends of these raw materials that meet or nearly meet the desired application rate. The resulting blends are sorted by closeness in matching the target rates and then by price if provided. Available at: https://precisionag.sites.clemson.edu/Calculators/Fertility/fertBlend/

The ***Clemson Feed Ration Calculator*** was developed as a tool for livestock producers to determine the nutritional value of feed rations and build mix sheets for those rations. Percentages containing up to eight different feedstuffs can be analyzed. General nutritional information for over 500 feed ingredients is built-in to the calculator, but the tool also allows the user to adjust nutritional information if, for example, they have results from a lab analysis. The calculator determines crude protein, total digestible nutrients, crude fiber, fat, net energy for maintenance, net energy for gain, lactation, calcium, and phosphorous for any specified ration. The mix sheet allows the producer to set a batch weight or total weight to be mixed, and the mixed sheet automatically displays the weight to be added for each ingredient. Cumulative weight is also provided if, for instance, a feed mixer with a built-in scale is used and ingredients are added in the order specified. Outputs can be emailed to the user so that the same ration can be easily used in the future for different batch weights or other minor adjustments. Available at: https://precisionag.sites.clemson.edu/Calculators/Livestock/RationCalculator/

The ***Clemson Feed Ration Optimizer*** was built in response to user feedback from the Feed Ration Calculator. By default, the Feed Ration Optimizer uses species and classification to provide cited nutritional recommendations. Users may also opt to manually set criteria for ration analysis by setting the criteria entry mode to manual entry. Current species supported include beef cattle, goat, and sheep. Recommendations for dairy cattle, poultry, and swine do not align with the feedstuff database used to support the tool. After selecting the animal species, the animal classification must be specified, for example: bred heifers, bull calves, mature cows, etc. Animal species and class is used along with other user inputs to generate nutritional recommendations for the ration. The next step involves the entry of feedstuffs to consider for constructing the rations. Custom feedstuffs may be entered, or feedstuffs may be selected from a list of over 500 ingredients with nominal nutritional values. After all feedstuffs to be considered have been entered, suitable rations to meet nutritional recommendations are determined and displayed. Each row in the output is a ration and can be pushed to the Feed Ration Calculator to make adjustments or build mix sheets. Rations are sorted by as-fed cost by default, but other sort orders are provided. Available at: https://precisionag.sites.clemson.edu/Calculators/Livestock/RationOptimizer/

## 20. Improved Management Strategies to Support Ecosystem Services Delivery in Forage Systems

Liliane Silva, Forages Specialist, Clemson University

Worldwide, forages are the primary feed source for livestock production systems due to low production costs, adapted species, and diversity. With the growing population, agricultural systems are facing challenges in increasing food and fiber production while minimizing negative environmental impacts. Forage systems play an essential role in delivering ecosystem services, and their management directly affects their ability to do so. Ecosystem services (ES) are defined as the "benefits people obtain from ecosystems," and they are classified into four categories: cultural, provisioning, regulating, and supporting benefits. Some examples of ES provided by grasslands include carbon sequestration, nutrient cycling, and wildlife and pollinators' habitat. In recent years, the focus of forage research has expanded to understand better how management practices affect forage ecosystems and their ability to deliver ES. Generally, management practices affect forage stand production, longevity and resilience, nutrient cycling, animal performance, soil fertility, and health, among others. Therefore, appropriate management can be an ally in keeping a healthy forage stand over time. Below, a few key points related to ES from forage systems will be briefly discussed.

**Energy storage is crucial for recovery and growth after each harvest event.** Harvest frequency (i.e., how often) and intensity (i.e., how closely forage is removed), either by grazing or cutting, directly affect the productivity and persistence of forage systems. The use of research-based recommended stubble height and adequate (re) growth period of forage species aims to allow residual leaf area to be left for plants to recover without reducing energy reserves stored. Higher than recommended frequency and intensity of harvest events may compromise the ability of forage species to recover and lead to standing decline and loss over time. Under grazing management, rotational grazing can help with the uniform removal of forage mass, limiting animals' access to individual plants for a given time (resting period). This is particularly important when grazing legumes or legume-grass mixtures since animals tend to visit forage legumes more often, which might compromise their persistence over time.

**Energy storage for (re) growth is essential.** After harvest (either by grazing or cutting), new regrowth will rely on carbohydrate 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 with how much those reserves need to be used and will be restored each time. In the long-term, the overuse of reserves without appropriate time for restoration will affect stand longevity. The weakening of the root system will compromise the energy supply and nutrient capture, which impacts plant health, growth, and resilience, frequently leading to stand thinning. Open spaces in the forage canopy favor weeds encroachment. When weeds increase in 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 using herbicides to clean pastures of weeds. Overgrazing is one of the most common ways to cause plant depletion and issues with stand persistence over time. Another point to pay close attention to is early spring grazing, once perennial forages have just started growing and rely heavily on energy storage to regrow.

**Nutrient cycling and redistribution in forage 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 a limited return of nutrients from the forages into the system under hay production and a greater reliance on off-farm inputs (i.e., fertilizer) to supply plant nutrient needs. 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 vital to improve forage accumulation and quality, especially in low-input systems.

Better nutrient distribution can be achieved by employing rotational grazing since animals remain in the area for a defined period, avoiding the establishment of exclusion areas or excessive excreta deposition. Also, when feeding hay on pastures, the recommendation is to alternate feeding areas throughout the field to help with better excreta distribution.

Livestock can also damage the growing points of plants, increase soil 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 grazing and cutting systems but may occur at different levels. After defoliation events, either by grazing or cutting, it is common for parts of the root system to die. This plant material is recycled and incorporated as organic matter, releasing nutrients into the soil.

**Carbon sequestration and soil health.** Due to limited soil disturbance, soils under perennial grasslands are significant carbon sinks over time. Over time, nutrients are incorporated into the soil by deposition and decomposition of above- and belowground plant material, increasing soil fertility and 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 a portion of their roots. If not consumed, that material is decomposed and can contribute to nutrients and organic matter being incorporated into the soil. Over the past decades, research has focused on better understanding how to improve management strategies that optimize soil carbon storage under grasslands.

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 to protect the 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 that can promote soil health in pastures, such as utilizing rotational grazing and avoiding overgrazing. Some parameters that determine proper soil health include, but are not limited to, organic matter content, adequate fertility and pH, and fauna biodiversity.

**In grazing systems, stocking rate adjustments are an ally to maintaining a healthy forage stand.** The stocking rate (SR) should be adjusted based on forage mass availability. Adjustments must consider 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 in pasture composition, level of pasture degradation, rainfall pattern changes, animal requirements, and expected animal performance, in addition to 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, potentially adding value to farming operations through opportunities for hunting leases, agritourism, and aesthetic value. Grasslands are an important source of habitat and food for various pollinators. Recent estimates indicated a decline in pollinators' worldwide population, which has increased efforts to use grasslands, especially legume-grass mixtures, to mitigate this issue.

**Greenhouse gases emissions.** In recent decades, worldwide efforts to quantify greenhouse gas emissions by the economic sector have led to discussions about the contribution of livestock-forage systems. In this context, efforts have focused on determining the inputs and outputs of activities related to the livestock industry through life cycle

assessments. Grasslands can offset a large portion of livestock industry emissions by capturing carbon dioxide from the atmosphere through carbon sequestration. Besides, improved management practices can collaborate with reduced off-farm inputs, which can help to attenuate emissions. An example of this effort is the decrease in reliance on N fertilizer, which contributes to greenhouse emissions during production, storage, distribution, and application. Moreover, the price fluctuation of N fertilizer has affected the feasibility of many livestock forage systems.

**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
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- 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

# 21. 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 |
| Oat | *Avena sativa* | CSA |
| Orchardgrass | *Dactylis glomerata* | CSP |
| Pearl millet; Millet | *Pennisetum americanum* | WSA |
| Rye | *Secale cereale* | CSA |
| Sorghum | *Sorghum bicolor* | WSA |
| Sorghum 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 |
| Clovers | *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 |
| 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 |
| 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. Grazing management recommendations for most used forages

Table B.1. Guidelines for rotational stocking. Adapted from Ball et al. (2015).

| Forage species | Target Height (inches) Begin Grazing | Target Height (inches) End Grazing | Regrowth interval (days) |
|---|---|---|---|
| **Perennial grasses** | | | |
| Bahiagrass | 10-12 | 4-6 | 25-32 |
| Bermudagrass | 10-12 | 4-6 | 25-30 |
| Dallisgrass | 8-10 | 4-5 | 20-25 |
| Jonhsongrass | 15-18 | 6-8 | |
| Tall Fescue | 8-12 | 4-6 | 15-30 |
| **Annual grasses** | | | |
| Annual Ryegrass | 6-12 | 4-5 | 20-30 |
| Crabgrass | 8-12 | 4-6 | 20-30 |
| Pearl Millet | 20-24 | 10-14 | 20-30 |
| Small Grains | 8-12 | 4-5 | 20-30 |
| Sorghum/Sudangrass hybrids | 20-24 | 10-14 | 20-30 |
| **Legumes** | | | |
| Alfalfa (for hay or grazing) | 10-16 | 4 | 28-35 |
| Clovers | 8-10 | 4-5 | 25-35 |
| Rhizoma Perennial Peanut | 8-10 | 4-5 | 28-42 |
| Sericea Lespedeza | 8-15 | 4-6 | 28-30 |
| White Clover | 8-10 | 4-5 | 25-35 |

## C. Methods to estimate forage mass

Measuring forage mass is crucial to estimating production and adjusting the stocking rate on grazing systems. This helps to reduce the chances of overgrazing or undergrazing pastures and improves forage utilization while accounting for plant and animal requirements. Below are methods of estimating forage mass.

### a. Canopy height

Measuring canopy height with a pasture ruler can estimate the pounds of grazeable forage mass per inch of standing forage in the field. However, this measurement alone does not consider canopy density which can represent an issue regarding the estimate's accuracy.

Pasture ruler on the field.

Table C.1. Average 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

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 a 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 in each pasture to avoid bias. Once the forage is harvested, it can be dried using the microwave method (see *Appendix D*).

Figure C.1. 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 a few forage samples from an area of known size (see method b- cut and dry sample) to check the accuracy of visual estimates.

### D. Microwave method for drying forage samples

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

First, weigh approximately 3.4 oz (100 g) of harvested forage and place it on a plate. If weighing the 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 it. Repeat this process in increments of 2-min until the 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 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 multiple harvesting 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. Common weights and measures for conversion.

| Column 1<br>Suggested Unit | Column 2<br>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 |

## F. 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. When SR is incorrect, it can lead to overgrazing; those compromises stand for 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 harvest). 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 to 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 calculated 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: $\frac{\text{40 head}}{\text{1.8 acre paddock}} = 22 \text{ head per acre}$

## G. Additional resources for forage and beef producers

**Clemson University Extension System – Livestock and Forages team**

**Webpage:** https://www.clemson.edu/online/programs/extension/livestock-and-forages.html

**Meet the team:** https://www.clemson.edu/extension/livestock/team.html

**South Carolina Cattlemen's Association**

https://sccattlemen.wildapricot.org/

**South Carolina Farm Bureau**

https://www.scfb.org/

**USDA Natural Resources Conservation Service**

http://www.usda.nrcs.gov

**USDA FSA**

www.fsa.usda.gov

**The Carolina Cattle Connection**

https://www.nccattle.com/news-events/the-carolina-cattle-connection

**Forage Drops** – Dr. Liliane Silva`s educational page with weekly content released on forage and livestock systems topics.

**Youtube:** https://www.youtube.com/channel/UC2fj2-Vnat-_GR6rFmLz8Ag

**Facebook:** https://www.facebook.com/foragedrops

## Notes

**Notes**