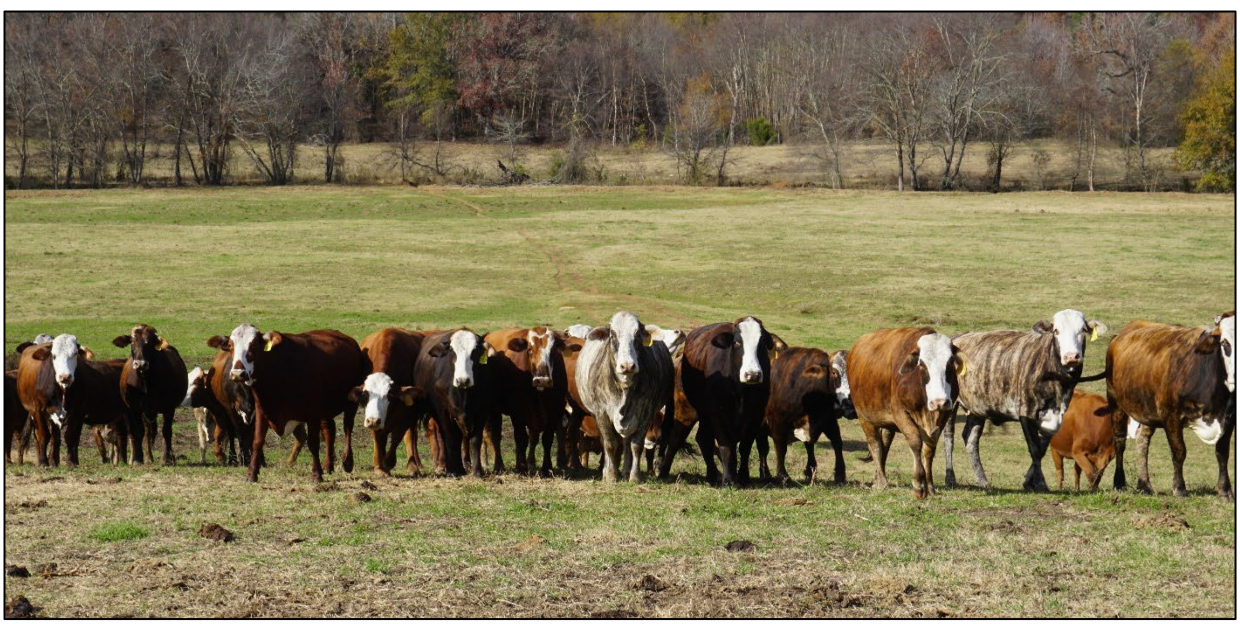
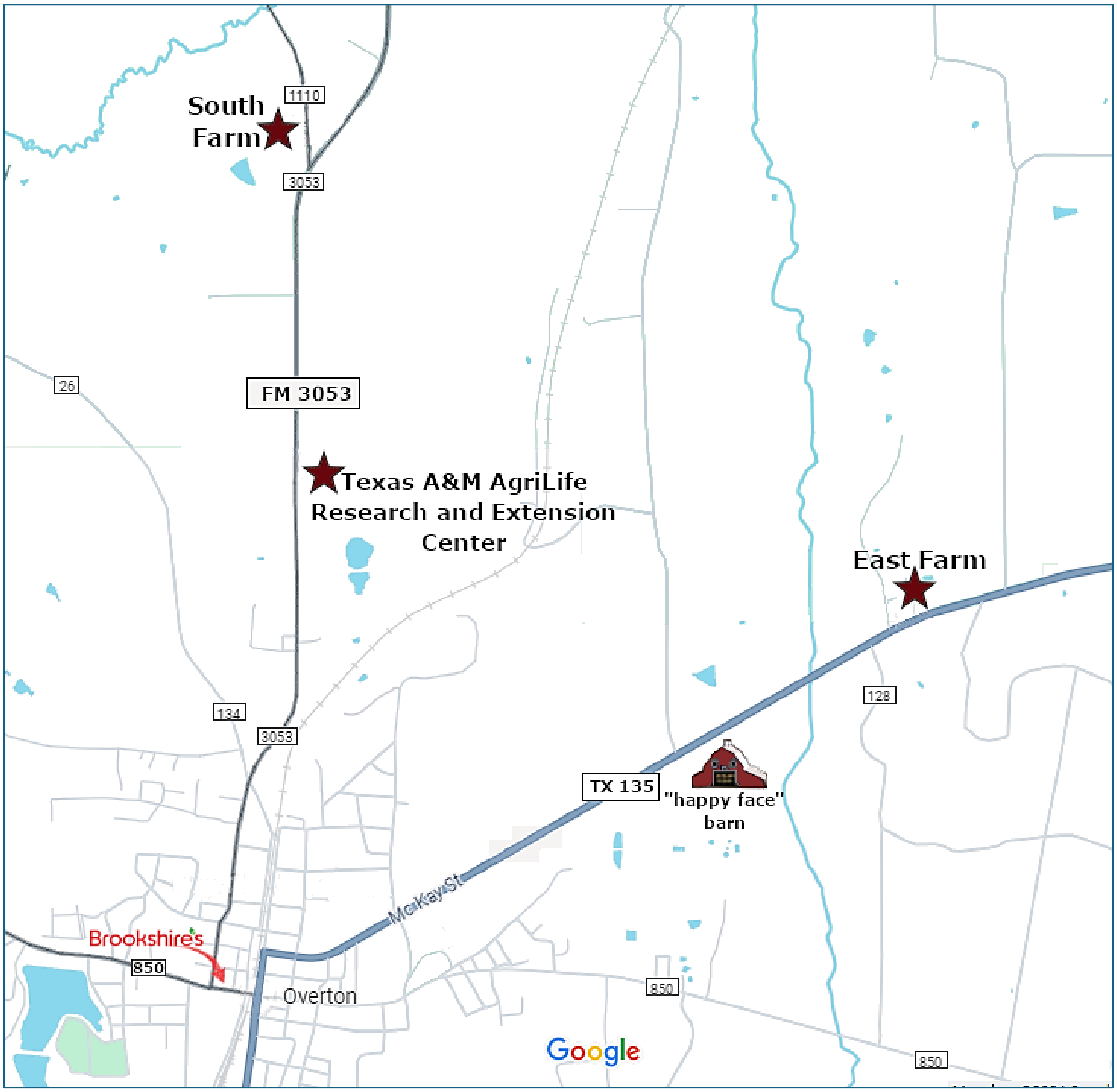
BEEF CATTLE & FORAGE FIELD DAY - 2025

Texas A&M AgriLife Research and Extension Center at Overton

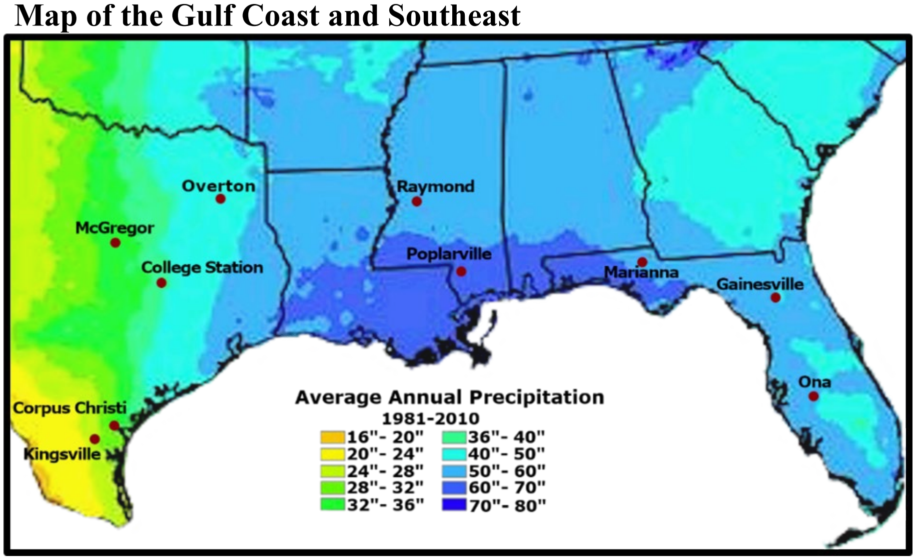
April 11, 2025 - Center Technical Report 25-1



Map to Concurrent Field Sessions at South Farm and East Farm



Map of the Gulf Coast and Southeast



Rainfall averages in the Gulf Coast and Southeastern regions of the United States are reduced as one travels from East to West. Shown are averages for the years 1981 to 2010.

BEEF CATTLE & FORAGE FIELD DAY - 2025

1710 FM 3053N, Overton, TX 75684
Friday, April 11, 2025

PROGRAM

8:00 AM – Registration

8:30 AM – Welcome & Introductions

8:45 AM – **Soil Health Management in East Texas**
Dr. Anil C. Somenahally, Associate Professor

9:15 AM – **Improvement of Forage Legumes and Grasses for East Texas**
Dr. Gerald Smith, Professor & Regents Fellow

9:45 AM – **Forage Utilization for Cow-calf and Stockers**
Dr. Monte Rouquette, Jr., Professor & Regents Fellow

10:15 AM – BREAK

10:30 AM – **Beef Cattle Fertility - The Impact of the Bull**
Dr. George A. Perry, Professor

11:00 AM – **Impact of Forage Quality on Beef Cattle Nutrition**
Dr. Jason Banta, Professor & Extension Beef Cattle Specialist

11:30 AM – Introduction of Sponsors

NOON – **Lunch - Will be provided**

1:00-2:00 PM & 2:30-3:30 PM
Concurrent Field Sessions - Scheduled 1:00-2:00 PM & 2:30-3:30 PM
Map provided on facing page for participants to attend the first session of one topic and the second session of the other with time to travel between the sites.

Bull Management & Fertility - East Farm (2211 State Hwy. 135)
Breeding soundness examinations and other bull management decisions.

Forage Utilization and Management - South Farm (401-499 County Road 1110)
Soil fertility; Forage options; Grazing management decisions.

Faculty and Staff at Overton

Name	Position
Aguilar, Chastity	Research Assistant
Attia, Ahmed*	Postdoctoral Research Associate
Banta, Jason*	Professor & Extension Beef Cattle Specialist
Carson, Chloey	Research Assistant
Clary, Colby	Information Technology
Coffman, Lauryn	Research Associate
Cole, Judy	Senior Administrative Coordinator I
Goldman, Mary	Senior Custodial Worker
Harkless, Judson	Agricultural Research Worker
Harris, Shelia	District Extension Administrator
Keese, Tyson	Extension Program Specialist Pond Management
Khan, Rafia *	Asst. Professor & Extension Specialist
King, Andrew*	Assistant Professor - Horticulture
Knight, Baker	Research Assistant
Laird, Katie	TCSI Ambassador
Law, Dustin	Manager, Operations
Long, Charles*	Resident Director of Research
Long, Garret	Research Assistant
McBride, Heather	Research Assistant
McLendon, Marcellus	Research Technician I
McSwain, Jheri-Lynn *	4-H Specialist
McSwain, Mason	Research Technician I
Mendoza, Taylor	Research Technician I
Metcalf, Shelly	Administrative Associate II
Neupane, Prajina	Graduate Student
Newburn, David	Technician I
Norman, Kelli	Systems Administrator II
Oli, Prem*	Assistant Professor - Production Systems Modeling
Olson, Vanessa*	Professor & Extension Forage Specialist
Perry, George*	Professor - Reproductive Physiology
Perry, Jancy	Research Assistant
Pierce, Larry	Regional Program Leader, AGNR & 4-H
Portley, Reggie	Senior Custodian
Putnam, Tami	Regional Project Specialist, BLT
Robatjazi, Javad	Graduate Student
Rouquette, Monte*	Professor & Regents Fellow - Forage Management
Sarker, Tushar*	Postdoctoral Research Associate
Schaefer, Zach	Disaster Assessment Recovery Specialist
Sensing, Michelle	Administrative Associate III
Shanmuhasundaram, Vikram	Research Assistant
Slater, Garett*	Assistant Professor, Apiculture/Entomologist
Smith, Gerald*	Professor & Regents Fellow - Legume Breeding
Snowden, Scott	Research Technician II
Somenahally, Anil*	Associate Professor - Soil Microbiology & Health
Taylor, Eric*	Silviculturist V, Texas A&M Forest Service
Thorn, Ross	Research Assistant
Turner, Kyle	Senior Research Associate
Velvin, Jay	Maintenance Worker II
Walton, Carolyn	Administrative Associate II
Watson, Rhonda	Administrative Associate II
Weidman, Haley	Graduate Student
Welch, Sandra	Senior Business Administrator II

* PhD

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Forages and Grazing Research:

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Pictures from the Past at Overton

The Overton Press

"The Fastest Growing and the Most Widely Read Weekly Paper In East Texas"

. XXXV — OVERTON, TEXAS 75684, FRIDAY, JANUARY 22, 1965 — No. 3

VERTON IS SITE FOR RESEARCH CENTER

others To March ext Monday Night

on mothers will embark on nnual march against Polio ippling birth defects next night, January 25, it was ced this week by Mrs. Honeycutt, chairman of the

Honeycutt said some 44 will assemble at 7 o'clock evening at the home of . A. Piercy to pick up materials and assigned ies. The city has been di- nto 22 sections, Mrs. Hon- said, and with the 44 working in pairs they be finished the entire city than an hour.

ents who are willing to ute to the annual March of through this drive, are to have their porch lights n 7 until 8 o'clock Monday make the volunteers' jobs easier.

ing in the drive will be the es C. T. Allen, Arthur C. P. Hall Jr., Allen Rich, Cliff Tyler, Bob Benbow, Ralph DeGuerin, Paul Monaghan, G. H. Osburn, W. H. Harper, Mickey Butts, Gene Laughlin, Ralph Ward, Gene Minor, Joe Trus, Jack Moore, Bill Brown, A. D. Biggerstaff, Pat Sharrer, and Jack Berry.

Also Mesdames Aaron Phillips, Floyd Sartors, Robert King, Jim Hamilton, Graham Savage, Dudley Young, L. M. Streeter, Sidney Fleming, Jack Wall, Raymond Estes, J. S. Lamb Jr., Milborn Cohagen, Bob Ragsdale, Leo Silvey, John Cragar, Judson Turner, Walker Wilson, King Riley, Bill Young, Baily Jarvis, D. R. Wimberly, Hayden Hicks, and Gene Shamburger.

Bucket Brigade, Too

In addition to the Mothers March, Overton Boy Scouts will conduct a "Bucket Brigade" in downtown Overton on Saturday, January 23rd, to supplement the MOD campaign.

Mrs. L. M. Streeter, general chairman of the Overton campaign, announced that Bill Young has been named to head the "Business Men's" drive.

In a joint announcement Monday afternoon in the Blackstone Hotel at Tyler, officials of Texas A&M University and the Bruce McMillan, Jr. Foundation released details of their plans for an agriculture research center to be established in Overton. Taking part in the announcement, as they appear from the left, are Donald Leverett, Foundation board member; Ralph Ward, managing trustee; Ralph Shank, vice president of the board; John L. Pope, president of the board; Dr. R. E. Patterson, dean of Agriculture at Texas A&M; and E. M. Trew, assistant dean.

Dr. R. E. Patterson, Dean of the College of Agriculture at Texas A&M University, and John L. Pope, president of the Board of Trustees, Bruce McMillan, Jr. Foundation of Overton, jointly announced Monday, a plan for the development of an East Texas Research-Extension Center. The Center, to be located at Overton, will use 1,220 acres of land being leased by the Foundation to the University for the sum of $1 per year.

Twenty acres of land inside the Overton city limits on Farm Road 1639 will be deeded to the University for the construction of principal permanent buildings for the center.

A grant of $300,000 from the Foundation will allow establishment of the Center as a base of operations for the University's research and extension programs in East Texas. "This area Center will enable us to conduct a wide variety of research and educational efforts," Patterson said; "developed in cooperation with The Build East Texas program."

Foundation money will be used toward payment of costs for design and construction of buildings and other improvements. Included will be an office building and laboratory building, named the "Moore-McMillan Building" in honor of Dr. Bruce McMillan and his wife, Mary Moore McMillan, who established the Foundation in 1951, and her father Walter P. Moore.

Patterson said that other facilities to be developed with the grant will include a shop and labora-

Foundation, in that during his lifetime he accumulated vast acres of land and a great wealth which was inherited by his daughter, Mary Moore McMillan."

"The Bruce McMillan, Jr. Foundation was created in Overton by Bruce and Mary Moore McMillan in memory of their son, Bruce McMillan, Jr., who passed away in July, 1951 at the age of 8. The Foundation was formally established by an agreement and Declaration of Trust made on October 15, 1951.

"About three and one-half years after the Foundation was established, in April, 1954, Mary Moore McMillan passed away. Dr. Bruce McMillan was the Managing Trustee of the Foundation from the date of its inception until his death in April, 1960.

Pope said that since the Foundation was established in 1951, it

Continued on Back Page)

Mustangs Score Two Victories

The Overton Mustangs traveled to Arp Friday of last week to tame the Tigers 55-44. The Mustangs had little trouble as Roger Cooper, Robert Raney, and Johnny

Rotary Club To Stage Annual Pancake Supper

London-Gaston School Boards Launch Consolidation Effort

--OUR-- OLUMN

Rev. Leland Herrin, Former Arp Pastor Dies At LaMarque

Decision to establish Overton Center is announced - January 22, 1965

F1 Brahman-Hereford heifers at Overton purchased from Rocker B Ranch about 1967

2024

Texas A&M AgriLife Extension

EAST REGIONAL OVERVIEW

- **Agriculture & Natural Resources**

ANR PROGRAM OVERVIEW

AgriLife Extension teaches agricultural producers to adopt best management practices based on new scientific knowledge that will help them increase production, enhance sustainability, and conserve natural resources. Also, by educating the public about agriculture and food production,

AgriLife Extension creates a partnership with all Texans that can improve food safety and security, reduce the prevalence of food insecurity, and improve diet and human nutrition throughout the state.

Additionally, safeguarding our precious natural resources and maintaining a clean and healthy environment are among AgriLife Extension's top priorities.

We encourage production practices and the use of technologies that promote sustainability in agricultural production, conduct conservation programs that reduce drought impacts, improve, and preserve water quality, minimize wildfire risks, and help maximize water supplies through more efficient irrigation and conservation.

We also help to promote the safe and reduced use of pesticides through the pesticide use training, and the integrated pest management program.

EAST REGION

44 REGIONAL COUNTIES

52 ANR AGENT POSITIONS

Larry W. Pierce, Jr.
Regional Program Leader - ANR
Texas A&M AgriLife Extension Service
903.834.6191 | lpierce@ag.tamu.edu

FY 2024

2,631
EDUCATIONAL ACTIVITIES

305,615
PEOPLE REACHED
including volunteers engaged

1,032,520
EDUCATIONAL CONTACTS
including events, one to one, newsletters & media

Texas A&M AgriLife Extension programs targeted to large and small scale producers help generate safer food and fiber products with maximum efficiency.

"Thanks for helping us stock our place properly. We didn't realize how much damage we were doing to the value of the land and wildlife."

Grayson County Landowner

2024

TEXAS A&M AGRILIFE EXTENSION

PROGRAM HIGHLIGHTS

Beef Cattle and Forages

- **36 - Counties Involved**
- **278 Events**
- **9,881 Participants**
- **100,533 contacts**

1591 of 1926 (83%) participants responded to surveys at 36 educational programs evaluated for regional outcomes. 1437 of 1591 (90%) participants increased their understanding of one or more items discussed at these educational programs. 1180 of 1290 (92%) participants anticipated a total economic benefit of $4,878,914.00. Respondents managed a total of 101,755 head of livestock and 473,866 acres.

Home and Community Horticulture

- **27- Counties Involved**
- **1,243 Events**
- **52,298 Participants**
- **235,225 Contacts**

1216 of 1348 (90%) participants responded to surveys at 40 educational programs evaluated for regional outcomes. 1154 of 1348 (95%) participants increased their understanding of one or more items discussed at these educational programs. 627 of 840 (75%) participants anticipated a total economic benefit of $528,836.00. Respondents managed a total of 17,348 acres.

Small Acreage and New Landowners

- **19 - Counties Involved**
- **136 Events**
- **3,023 Participants**
- **10,559 Contacts**

282 of 367 (77%) participants responded to surveys at 18 educational programs evaluated for regional outcomes. 275 of 282 (98%) participants increased their understanding of one or more items discussed at these educational programs. 138 of 237 (58%) participants anticipated a total economic benefit of $10,787,652.00. Respondents managed a total of 3,520,440 acres.

Priorities of Texas A&M AgriLife Research and the Overton Center

Charles R. Long, PhD, PAS, Diplomate ACAG
Resident Director of Research and Professor

Strategic Priorities of Texas A&M AgriLife Research

Strategic priorities are areas that AgriLife Research will emphasize over the coming years to make measurable progress toward enhancing the resilience of agricultural systems and ensuring an abundant supply of high-quality, nutritious foods for our citizens. These are described in detail in the Agency Strategic Plan.

Strategic Priority One: Leading-Edge Research and Innovations

Discover new innovations, technologies, and science-based solutions to enhance agricultural and ecological systems and the life sciences.

Strategic Priority Two: Sustainable Production Systems

Provide the translational research necessary to develop and produce high-quality, safe, and sustainable food and fiber systems with local, national, and global impacts.

Strategic Priority Three: Economic Strength

Enhance the efficiency, profitability, and resiliency of agriculture, natural resources, and food systems in the state of Texas and around the world.

Strategic Priority Four: Healthy Living

Discover, disseminate, and facilitate the adoption of scientific evidence at the intersection of nutrition, human health, and agriculture.

Synergistic Interactions Among Priorities

These four research priority areas interact synergistically to deliver healthy living to Texans. Innovative research is the foundation of this strategy, which empowers the nexus between agriculture and human health by cultivating science-based solutions to develop sustainable, profitable, and resilient agriculture that provides affordable, high-quality, nutritious food.

Mission of Texas A&M AgriLife Research at Overton

The mission of the Texas A&M AgriLife Overton Center is to generate, learn and share knowledge about agriculture and the life sciences that nourishes health, strengthens communities, protects natural resources, supports economies and enhances the well-being and quality of life of people.

This mission is accomplished by conducting research targeting Agency Strategic Priorities and the numerous outreach activities to transfer knowledge and technology to colleagues and stakeholders.

Current Research Programs at the Overton Center

Research at the Overton Center targets specific needs of East Texas that must be addressed in the East Texas ecosystem. Major contributors to East Texas' annual agricultural farm-gate income are livestock (primarily beef cattle), nursery crops, poultry and timber; other agricultural income is from feed crops (including hay), vegetables, recreation and dairy. Texas A&M AgriLife Research programs at Overton address beef cattle, hay and forage crops and horticulture with some attention to forestry and rural recreation. Center research focuses on 1) Forage-Based Beef Cattle Production Systems and 2) Horticultural Production.

Research simultaneously addresses issues of production parameters plus economic and environmental sustainability. The subject matter disciplines of soil science, plant physiology, plant and animal breeding and genetics, animal physiology and production system science are focused on fundamental, translational and applied research targeting highest priority issues. The discovery of new agricultural principles and the technology transfer of these principles and production applications are key components of research and outreach goals.

Areas of Research and Outreach

Soil Microbiology and Health – Led by Dr. Anil Somenahally

Horticultural Crop Production – Led by Dr. Andrew King

Forage Crop Breeding - Led by Dr. Gerald Smith

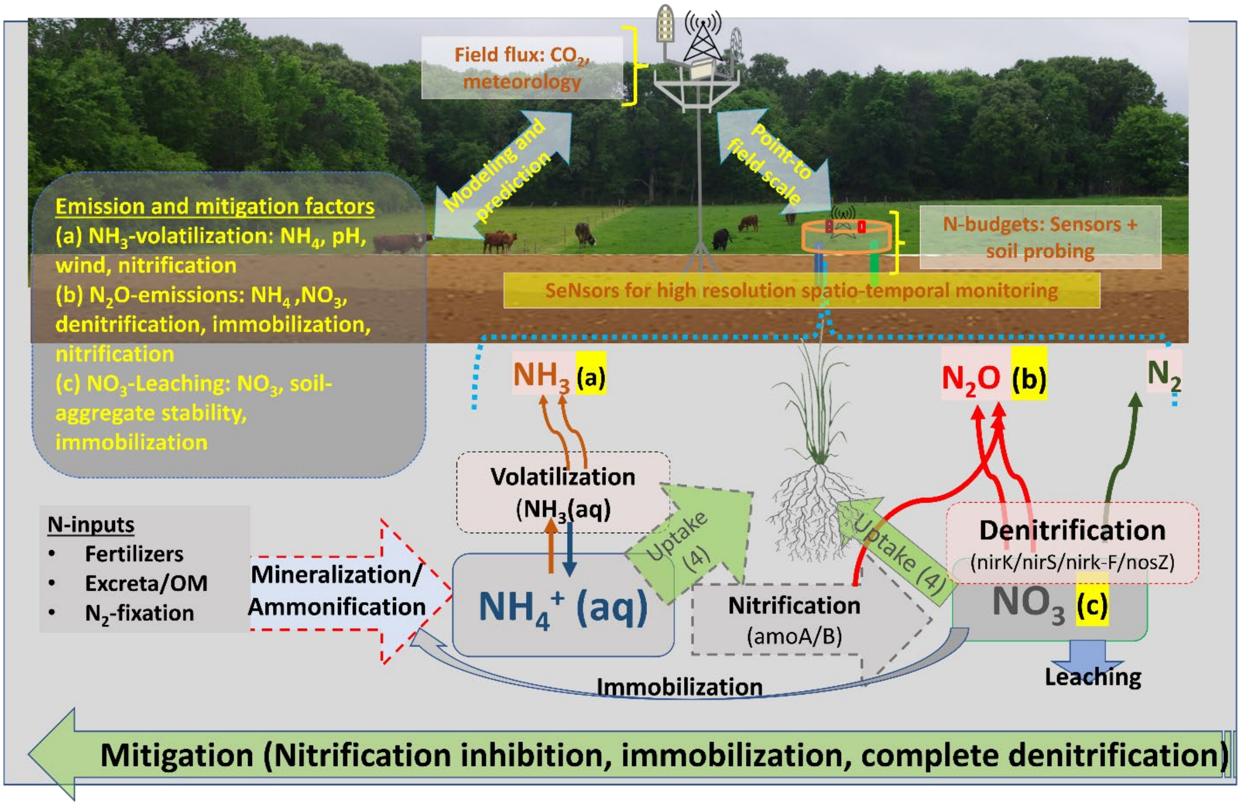
Forage Production and Utilization - Led by Dr. Monte Rouquette

Biomathematical Modeling of Production Systems - Led by Dr. Prem Oli

Animal Physiology and Management - Led by Dr. George Perry

Research Teams – Composed of faculty from Overton and cooperating units

Soil Microbiology and Health



Research and outreach activities in this project area will address the Strategic Priorities as indicated.

Strategic Priority One: Leading-Edge Research and Innovations
Program applies leading edge research within soil biogeochemistry and soil health management for improving soil ecosystem services and reducing environmental impacts of crop and livestock

production systems. Research innovations within soil microbiome interactions and soil functional responses to agronomic management practices were applied to improve key soil functions such as carbon sequestration and soil fertility. New research collaborations are focused on combining big data analysis and biogeochemical modeling, and developing a digital tool for soil health assessment, to predict soil health properties, soil carbon sequestration potential and subsequently for identifying effective climate-smart management practices in forage and grazing lands, range lands and cropping systems. Additional interdisciplinary collaborative research is validating novel soil sensing technologies for in-situ monitoring and reporting of soil health properties.

Strategic Priority Two: Sustainable Production Systems

Many research outcomes resulted in reduced use of chemical inputs, improved soil health, productivity, and sustainability of natural resources. Project works have identified effective soil health management practices with most impacts on improving beneficial plant-microbiome interactions in acidity and salinity stressed lands, which led to improvement in soil fertility and plant nutrition. Project outcomes have also benefited regional and national stakeholders through innovative management strategies for effectively increasing soil carbon sequestration and greenhouse gas mitigation. Current projects are focusing on adopting soil health management guidelines for enhancing climate smart agriculture initiative by regional stakeholders.

Strategic Priority Four: Healthy Living

Collaborative projects are in progress with an aim to discover linkages between soil health management and food quality and apply novel food safety risk mitigation practices in organic and conventional production systems. Projects are also focusing on identifying effective soil microbiome management practices to reduce soil disease pressure, reduce food safety risks and increase micronutrient density.

Horticultural Crop Production

The green industry comprised a significant portion of the U.S. economy in 2018, producing over $348 billion in total output contributions (Hall et al. 2020). In 2019 Texas green industry sales reached $22.4 billion while the industry provided over 260,000 jobs. East Texas has a rich horticultural history including production of woody ornamental trees and shrubs, roses for landscape use and cut flowers, bedding plant production, fruit and fruit tree production and many other endeavors. The 36-county area generally known as East Texas boasted green industry sales of more than $1.6 billion and more than $2 billion in value added in 2019. Horticultural research efforts in Overton present an open door for the Texas A&M System because of the acid soils and ample rainfall found in East Texas. These provide a unique opportunity for researchers in Overton to participate in the large and vibrant green industry in the southeastern U.S. while also serving the whole of Texas and beyond.

Due to the diversity of horticultural operations in East Texas, the research efforts in Overton are also diverse. They include ornamental and fruit breeding, enhancement of cultural practices in the greenhouse and nursery industry, enhancement of landscape establishment of woody plant materials, screening new varieties of fruit and vegetables and trialing new and improved bedding plants from around the U.S.

Research and outreach activities in this project area will address the Strategic Priorities as indicated.

Strategic Priority One: Leading-Edge Research and Innovations
The horticultural research and innovations from the Overton Center will include breeding for resource use efficiency and unique aesthetics in herbaceous perennials, improved nursery and landscape establishment of woody trees and shrubs, enhanced resilience of nursery stock through improved cultural practices, screening varieties in fruit crops like muscadine and vegetable crops like tomato and pepper, and conducting a large bedding plant trial including new selections from across the U.S. in addition to more exhaustive trials of select species. All of these efforts are designed to make the Texas green industry more competitive, decrease the amount of water, fertilizers and other inputs required to grow healthy greenhouse and nursery crops, ensure that homeowners and other end users are more successful with the crops that they plant and improve the selection of ornamental, fruit and vegetable plants that are available to Texans.

Strategic Priority Two: Sustainable Production Systems
Research is currently underway to determine the adaptability of new seedless muscadine varieties for commercial and homeowner use in Texas. Efforts like this one are important since muscadine can be grown in East Texas with minimal inputs (pesticide, water and fertilizer) when compared to conventional table and wine grapes. Introduction of these seedless varieties will increase the number of Texans with interest in the crop based on previous consumer preference data. Ultimately this research, and other efforts like it, can decrease the inputs required to produce a high-quality, sustainable fruit crop.

Strategic Priority Three: Economic Strength
The economic standing of our stakeholders is made stronger by providing improved crops for them to grow (e.g. breeding drought and heat tolerant herbaceous perennials; screening seedless muscadines), enhanced methods with which to grow these crops (e.g. optimizing fertilizer programs to decrease sunburn on the bark of nursery-produced maples; studying the effect of pruning practices on pest pressure in crapemyrtle), reducing the amount of costly inputs that the grower needs to apply to produce a healthy crop (e.g. less fungicide on muscadines than conventional table or wine grapes; less fertilizer on crapemyrtles) and ensuring that producers are aware of new selections of their crop of interest (e.g. the annual Overton bedding plant trial).

Strategic Priority Four: Healthy Living
Horticultural research in Overton can encourage healthy living in a number of ways. 1) Screening fruit and vegetable crops can lead to an increased number of Texans participating in growing their own food. This allows the consumer to experience the joys and physical activity of gardening while knowing what has been applied to their food 2) Texas has the conditions required to produce many medicinal crops. Research on a number of these crops will be conducted in Overton in the future. 3) Gardening, even if only for ornament, has proven to be an activity that improves the health of an individual from a physical, psychological and emotional perspective.

Forage Crop Breeding

Legumes and cool season grasses are very important forage crops in East Texas. These same forage crops also function as cover crops, wildlife browse and pollinator crops with big impacts in sustainable cropping systems, wildlife stewardship and natural resource conservation. For the past several years, the conservative total economic impact of forage legume cultivars developed at Overton is $16 million per year. This includes seed sales, nitrogen fertilizer replacement, beef cattle calf gain, wildlife stewardship value and pollinator crop value.

Forage Legume and Grass Breeding program activities will address specific Strategic Priorities as indicated:

Strategic Priority One: Leading-Edge Research and Innovations
Germplasm evaluation, traditional plant breeding and marker assisted selection are all used to develop improved cultivars of forage legumes and grasses to enhance livestock-forage production systems for Texas and the US southern region. A team approach, including plant breeding, molecular biology, plant physiology, nematology and plant pathology, is implemented to ensure that new cultivars will function as expected. Grazing animals are often used in both selection and evaluation of new forage cultivars. Partnerships with Texas and US seed companies are actively pursued to enhance commercialization and licensing of new cultivars. A new cooperative agreement with USDA-ARS is now in place to enhance breeding and research directed at forage winter pea improvement for Texas.

Strategic Priority Two: Sustainable Production Systems
Improvement and cultivar development of forage legumes are major goals of this breeding program; legumes in forage or cover cropping systems are key components of sustainable agriculture. Legumes through symbiosis with Rhizobium and related bacteria can fix atmospheric nitrogen into compounds usable by plants. This biological N fixation can then fuel the N cycle in pastures and other cropping systems, eliminating or reducing the requirements for fertilizer N.
Annual ryegrass is a valuable cool-season forage used in warm-season perennial grass systems as a overseeded winter/spring grazing crop. Overseeded ryegrass extends the grazing season of warm-season perennial grass pastures and provides high forage yield in combination with high nutritive value. Our breeding program on annual ryegrass seeks to improve forage yield, seed yield, acid soil tolerance and disease resistance in this important annual forage.

Strategic Priority Four: Healthy Living
We have an active program in improvement and cultivar development in forage cowpea with two cultivars released in the last four years. The Southwestern US does not have a widely used summer legume grain crop to use in crop rotations or double cropping systems. Improved multi-use cowpea cultivars could fill that void with a heat tolerant and low water use crop. We have expanded our investigations to develop multi-use cowpea with a variable suite of phenotypes that could fit forage systems, cover crops, double crop systems and human edible pulse crops for Texas and the Southwestern US. Both marker assisted selection and wide hybridization are used in this breeding program.
Cowpeas and other dry beans are one of the most nutritionally complete foods available. They are an inexpensive source of complex carbohydrates, protein, minerals and soluble fiber. Expanded production of multi-use cowpeas in Texas will provide a new, locally produced crop with potential to enhance agricultural production systems and to provide more healthy food choices for all consumers.

Forage Production and Utilization

This research program combines the soil-plant interface of sustainability and environmentally compatible impacts of nutrient cycling under grazing and stocking conditions with the plant-animal interface that assesses biological components of efficiency of utilization and birth-to-harvest attributes of beef cattle. The pasture-animal research targets utilization strategies of forages in various grazing systems for conception-to-consumption of beef production and has focused on: a) evaluation of forage cultivars for dry matter, nutritive value, persistence, and sustainability for livestock; b) effects of stocking rate, forage species, and fertilization regimens on soil nutrient status, forage stand maintenance, biodiversity of forages, and nutrient cycling in pastures under grazing; c) effects of stocking rates and strategies, stocking methods, and forage utilization systems on forage persistence and cow-calf and stocker performance; d) describing biological efficiencies of pasture systems and project economic implications on lifetime performance of tropically-adapted beef cattle breed types.

The on-going, long-term (>35 yrs) stocking experiments on bermudagrass overseeded with ryegrass + N vs clover without N are one-of-a-kind in the US. Primary contributions have included documentation of soil nutrient status via nutrient cycling. This was the first research in the US to quantify and identify bermudagrass ecotype diversity under long-term stocking with cows and calves.

Stocking rates, stocking methods, and stocking strategies using cow-calf and stocker cattle with bermudagrasses and ryegrass, clover, or small grain + ryegrass pastures have defined Forage Allowance and Average Daily Gain relationships. This research was one of first to document the effects of Forage Allowance on ADG of both lactating cows and suckling calves.

Supplemental protein and/or energy for stockers at levels of 0.25% BW on bermudagrass or small grain + ryegrass pastures was shown to be the optimum level for biological and economic returns for stockers.

Soil nutrient status of pastures has documented carbon sequestration and soil P, N, K, Mg, Ca, and pH dynamics. The long-term cow-calf nutrient cycling on pasture database has served to re-direct fertility inputs, document sustainable use of legumes in pastures, and develop stocking strategies for environment-compatible and economic sustainable pastures in East Texas and the Southeastern US.

Pasture-animal performance studies have been conducted with Horses, Corriente and Mexican steers, Holstein heifers, and Tropically adapted cattle breedtypes including Brahman, Bonsmara, Tuli, Senepol, and Romosinuano with English and Continental sires that has benchmark standards of production systems for stakeholders. This is the only project in Texas and perhaps in the US that evaluates component performance of beef cattle from birth through cow-calf and post-weaning stocker-grazing systems to feedlot to carcass attributes to sensory evaluations of meat.

The Forage x Animal Modeling Team at Overton has produced the first model that predicts forage nutritive value of bermudagrass pastures on a dynamic, daily basis. Other models with bermudagrass includes effects of rainfall events of El Nino, La Nina, and Neutral conditions in addition to nitrogen application rates on DM production.

Research and outreach activities in this project area will address the Strategic Priorities as indicated.

Strategic Priority One: Leading-Edge Research and Innovations

Forage Germplasm Evaluation for Forage Production.

These Forage Project activities are involved as a collaborator in evaluation of forage germplasm for seed production traits, forage mass and nutritive value, cover crop alternatives, persistence under fertility regimens, and stand maintenance under grazing conditions.

Development of new Forage-Animal Simulation Models.

Novel forage-animal simulation models have been developed in Decision Support System for Agrotechnology Transfer. The modeling team was first to publish a model that predicts forage nutritive value of bermudagrass on a dynamic, daily basis. Two additional modeling "firsts" include modifications of the summative equation for estimating total digestible nutrients (TDN), and modifications of the NRC model for predicting stocker calf gains from bermudagrass pastures. These new and modified equations-models will have direct application for forage-animal nutritionists and commercial forage laboratory analysis interpretations. Extramural funding will create opportunities for decision support systems for biological and economic demands.

Strategic Priority Two: Sustainable Production Systems
Long-term nutrient cycling under grazing experiments at Texas A&M AgriLife Research at Overton represent the longest continuous stocking research of this kind in the US and will serve to redirect and reduce fertility inputs for more environmentally friendly pastures in East Texas and the southeastern US. Soil analysis data have confirmed sod-seeding and stocking regimens for impacts on the soil-pasture ecosystem, and the most effective soil health, efficient carbon sequestration, and N dynamics on pastures. An archival database, BeefSys, was created to incorporate more than 45 years of the soil-plant-animal data from this research program. This has resulted in complete birth-to-harvest histories for over 6500 cattle, and documentation of long-term soil and pasture profiles.

Current cropping systems modeling efforts are targeted at sustainable production systems using double-cropping and cover cropping cowpeas to project production without N fertilizer. The grazing and cropping production systems will provide the background documentation of confirmational evidence to secure extramural funding.

Strategic Priority Three: Economic Strength
Collaborative team research has led to the release of 11 forage cultivars for livestock and wildlife and 5 disclosures-licenses for Texas A&M AgriLife. Three annual ryegrasses have been used to sod-seed about 4.5 million acres. Farm Gate seed and calf sales from these three ryegrasses have been about $2.3 Billion. Farm Gate legume seed and calf sales plus fertilizer savings from N fixation totaled about $0.5 Billion. Total Economic Impact and Value Added for ryegrass and legume cultivars from Overton has been about $5.5 Billion. With the expected release of new forage germplasm as new varieties, there will be an increased demand by commercial seed companies and stakeholders for these enhanced forages.

Strategic Priority Four: Healthy Living
Pasture-animal experiments and management strategies have resulted in food products from Pasture-Finished and Grass Fed Beef Systems. Some previous experiments that have documented forage production, utilization, and carcass traits for Healthy Living include the following:

Carcass characteristics of calves at weaning and on 3 stocking rates;
Effects of electrical stimulation and stocking rate on carcasses of calves;
Forage systems for producing slaughter calves at weaning;
Natural Beef production of steers stocked on rye and ryegrass;

These previous team-member experiments will provide the baseline for opportunities to secure extramural funding for the increasing concerns of the public sector for safe, nutritious, and healthy foods.

Biomathematical Modeling of Production Systems

Increasing agricultural productivity sustainably, adapting agroecosystems to climate change, and mitigating climate change are the three intertwined challenges that need to be addressed together for food security and agricultural development. In Texas, the prevalent agroecosystems that significantly contribute to its economy are cotton-, grain sorghum-, and wheat-based cropping systems; warm-season perennial grasses- and cool-season annual forages-based pasture systems; and grazing- and beef-based livestock production systems. The production approaches and practices adopted in these agroecosystems are primarily conventional: highly productive, but also highly resource-demanding. Conventional systems have degraded much of our land and accelerated ecological meltdown. To stop this process, agricultural production systems need to be sustainable. To sustainably increase the productivity of above-mentioned agroecosystems in Texas, farming methods and practices that can enhance resource-use efficiency and farming approaches that are sustainable, regenerative, and climate-smart must be explored and adopted. Climate change is impacting agriculture as a result of increased prevalence of extreme events and increased unpredictability of weather patterns. To achieve agricultural production security, adaptation to climate change without depleting the natural resource base is necessary. To help our agroecosystems adapt to climate change, techniques and practices that can build their resilience to the climate change-related risks have to be identified and applied. Conventional agriculture has been a net producer of greenhouse gas emissions. To switch from current agroecosystems that use conventional production practices to agroecosystems that are more productive, more resource-use efficient, and more resilient to risks, shocks, and long-term climate variability and can help mitigate climate change, innovative farming approaches and practices that can reduce the intensity of agricultural emissions and enhance soil carbon sink must be discovered and implemented.

The goal of the agroecosystem modeling team at the Overton center (AMTO) is to identify or develop innovative practices, methods, or approaches that can (i) help sustainably increase the productivity of the various agroecosystems mentioned above that have significant contribution to the economy of Texas and beyond (ii) assist these agroecosystems to adapt to climate change; and (iii) contribute to reducing agricultural emissions from and enhancing soil carbon sink in these agroecosystems through modeling and simulation.

The vision of the AMTO is to create and utilize novel mathematical models and critical metrics for assessing the performance of the various agroecosystems stated above. This specialty will enhance the crop and livestock industries associated with these agroecosystems in Texas and beyond through developing and disseminating information and strategies to stakeholders for optimizing the performance of the agroecosystems.

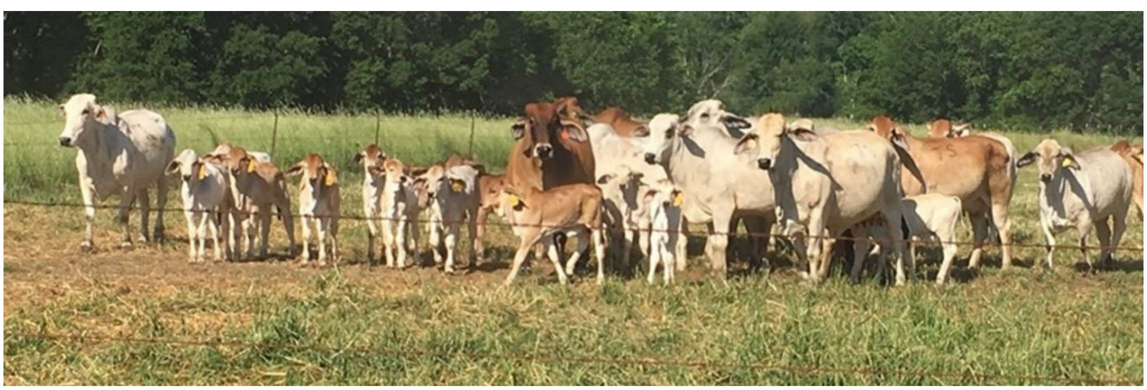
Strategic Priority One: Leading-Edge Research and Innovations
New innovations, technologies, and science-based solutions associated with the above-stated agroecosystems will be discovered to enhance their productivity and sustainability through computer simulation and modeling. The AMTO will work with other Texas A&M AgriLife units and various state, federal, and international collaborators to strengthen its research- and engineering-oriented modeling capabilities in the areas stated above.

Strategic Priority Two: Sustainable Production Systems
Using simulating modeling approach, the translational research necessary for developing and producing high-quality, safe, and sustainable agroecosystems across Texas and beyond will be provided. Through developing collaborative linkages with various relevant state, federal, or international agencies, the AMTO will develop and disseminate authentic and reliable decision support tools that could be used by stakeholders for improved management of agroecosystems.

Strategic Priority Three: Economic Strength
The efficiency, profitability, and resiliency of agroecosystems in Texas and beyond will be enhanced through simulation modeling studies. Working with relevant state, federal, or international agencies, the AMTO will conduct modeling studies on the economic effects of changes in farming system, production practice, climate change, price, and other economic and policy variables associated with the above-mentioned agroecosystems.

Strategic Priority Four: Healthy Living
The adoption of scientific evidence at the junction of agriculture, nutrition, and human health will be discovered by way of modeling and disseminated and facilitated by working with relevant extension agencies and stakeholders. Collaborating with relevant agencies, such as the Texas A&M University College of Medicine, the AMTO will develop a system to predict the effects of various management and environmental factors, such as fertilizer application-induced water pollution and climate change, on various disease vectors and human health.

Animal Physiology and Management



Beef cattle are a major contributor to the Texas and the U.S. agricultural economy. In 2019, U.S. per capita retail beef supply represented 30% (over 19 billion pounds of retail product) of total retail meat (USDA, 2022), and the retail value of beef production was $123.3 billion (USDA, 2020). The Beef industry makes up roughly 22-24% of the total meat produced worldwide, and with it being estimated that the world's population will exceed 9 billion by 2050; food production must more than double to meet the growing world demand. The greatest benefit for the beef industry is its ability to convert low quality forage (which is not usable for human food) into a high-quality food source for humans. However, as the world population increases, resources available for beef production become even more limited. Therefore, the efficiency of

beef production must increase to meet the rising demand. It has been estimated that a 5% increase in the number of cows that conceive in the first 21 days of the breeding season would increase the pounds of beef weaned by 1,550 pounds per every 100 cows. Thus, to enhance the sustainability of cattle production, further efforts to understand reproductive efficiency are essential. *Therefore, the long-term goal of Animal Physiology and Management research at the Overton Center is to discover, develop and disseminate management practices that improve reproductive efficiency of cattle in Texas and around the world.*
Research and outreach activities in this project area will address the Strategic Priorities as indicated.

Strategic Priority One: Leading-Edge Research and Innovations
New innovations, technologies, and science-based solutions associated with increasing the efficiency of beef cattle production will be studied and developed. Development of new methods for evaluating key factors may enhance sperm survival and fertilization. As new information is gleaned from this research, improved technologies to store semen and increase conception rates through AI may be developed. Furthermore, pregnancy loss after a single service is 40 to 50% for beef cows and heifers through day 30 of gestation. This is the single greatest economic loss for beef cows. Development of new methods for evaluating what factors may influence embryo survival will greatly impact the beef industry. These potential findings could be a game changer for the beef industry.

Strategic Priority Two: Sustainable Production Systems
Data collected on over 10,000 cows/heifers synchronized with recommended fixed time AI protocols identified a 27% improvement in conception rates among animals with elevated concentrations of estradiol. Those results mean estradiol prompted the opportunity for an extra 27 calves out of every 100 cows. Combining increased control of follicular development with improved conception rates will result in the development of management strategies that improve the percentage of cows that conceive in the first 21 days of the breeding season thus increasing the sustainability of beef cattle operations.

Strategic Priority Three: Economic Strength
If pregnancy maintenance can be increased by just 10%, beef production would be increased by ~3,100 pounds per 100 cows (31 lbs/cow). This would increase the number of pregnant beef cows in Texas by 0.39 million head (3.9 million x 0.10 = 0.39 million) and translate into an economic impact of roughly $181 million in Texas (31 lbs/cow x 3.9 million cows = 120,900,000 lbs x $1.50/lb = $181,350,000 million).

Strategic Priority Four: Healthy Living
In both cattle and humans, stress can have harmful consequences on reproductive success; not only for the current pregnancy but possibly for subsequent generations. Collaborative research between Texas A&M AgriLife Overton, Texas A&M Department of Animal Science, and the University of Wisconsin has been investigating the role of a mild stress during pregnancy on embryo development and transgenerational impacts. Understanding how stressful events during pregnancy may not only impact the current pregnancy but may impact pregnancy success for years/generations to come will benefit not only the beef industry but also human health.

Research Teams

The six areas of research and outreach will operate as directed by the respective research leaders. They will train graduate students and publish research findings in order build national and international reputations.

In many cases, feasible solutions to production problems require multidisciplinary teams that address the issues in a systems context. The Overton Research Program has a history of developing and supporting teams of faculty members and graduate students from Overton and from other units in AgriLife and beyond. This approach has been very effective and rewarding and will continue to be encouraged and supported. Overton research faculty members will continue to collaborate as appropriate in these teams.

The Bruce McMillan, Jr. Foundation board along with local leaders were instrumental in convincing the Texas A&M administration in the 1960s to establish the East Texas Research & Extension Center in the vicinity of Overton rather than somewhere else in East Texas. At that time and during the past 59 years, the Foundation has provided tremendous financial and in-kind support to the Center and its research and extension programs. The sign shown here is at the East Farm which was provided for conducting research beginning in 2016.

Forage Legumes for Texas 2025

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The successful use of forage legumes in Texas livestock production systems and as supplemental forages for Texas wildlife is influenced by: seasonal rainfall; competition with grasses and weeds; soil type; drainage; and ecoregion location.

Grasslands are primarily composed of grasses and legumes. Forbs and shrubs are also part of the grassland ecosystem on rangeland. Species in the grass and legume families are divided into annuals, perennials, and biennials, and each of these categories is further divided into cool- and warm-season forages. Annuals germinate, grow, and mature in one growing season and therefore must be established from seed each year. Perennials have the ability to live more than one year under appropriate climatic conditions. They usually die back (go dormant) sometime during the year and then initiate new growth from roots, rhizomes, or stolons. Biennials require two growing seasons to complete their life cycle, with the first season devoted to vegetative growth, and flowering occurring in the second season. Warm-season forages begin growth in the spring and die or go dormant in the autumn with the first killing frost. Cool-season forages generally begin growth in autumn and mature or go dormant in late spring or early summer. A general description of each forage legume class and adaptability of each species and a list of varieties follows.

Cool-Season Annual Legumes

Cool-season annual legumes are the most extensively used legumes in the southeastern United States. They are usually overseeded on warm-season perennial grasses either alone or in mixtures with annual ryegrass. In addition to providing forage with high nutritive value during the spring, they can add nitrogen to the pasture system through N_2-fixation in association with Rhizobium bacteria. Other benefits are spring weed control, nitrogen source for organic farming systems, and as supplemental forages for wildlife. They are more soil specific than grasses and generally require a minimum soil pH of 6.0. They must establish from seed each autumn, but some of the species have a high percentage of hard seed that permits volunteer reseeding if managed properly.

Annual Medics - The annual medics are a group of species belonging to the Medicago genus that are native to the Mediterranean region. They are annual relatives of alfalfa. Most species are best adapted to soils with a pH of 7 and higher and persist in lower rainfall areas than most clover species if rainfall occurs in late autumn and winter. Annual medics are more active winter growers than most annual legumes, but most annual medic species also lack cold tolerance, which limits their northern adaptation. They produce small yellow flowers that mature into pods. Some of the species found in the United States form spines of various lengths, and some do not. Individual plants may produce over a thousand seed pods.

Annual medics are dependable reseeders because they produce a high level of hard seed and have excellent seedling vigor. This excellent seedling vigor makes them one of the easiest winter annual legumes to establish. Annual medics can easily establish with a light disking, broadcast seeding, and then dragging the pasture to cover the seed. These hard seed can remain viable in the soil for several years. Annual medics do have a high bloat potential. However, this can be overcome by proper management of livestock and providing other forage to the grazing animals such as frosted mature grass, hay, or planting ryegrass with the medic.

Annual medics are excellent winter forages for domestic livestock and wildlife. One thing that makes medics well adapted as a grazing crop is that they generally have a prostrate growth habit and will flower and set a good seed crop even under heavy grazing pressure. Most commercial varieties in the world have been developed in Australia, and as a general rule, most Australian varieties lack winter hardiness needed to persist in Texas.

Burr medic, or burr clover, *(M. polymorpha*) was introduced sometime in the ninetieth century and has become naturalized in South Texas and the West Coast. 'Armadillo' burr medic, was selected from a naturalized ecotype in South Texas and was released by the Texas Agricultural Experiment Station at Beeville in 1998. Armadillo is adapted south of I-20 in Central and South Texas. Recommended seeding rates are 5 to 10 lbs per acre. Armadillo does well when grown with bermudagrass and kleingrass providing the perennial grasses are managed to be grazed short in the autumn to allow the seedlings to establish.

Barrel medic (*M. truncatula*) is less winter hardy than Armadillo burr medic, but some Australian varieties perform well in South Texas. The barrel medics are somewhat better adapted to the high pH sandy soils of Central and South Texas than Armadillo burr medic. The old variety 'Jemalong' has been recommended in South Texas for 10 or more years. There is a new cultivar, 'Jester', that was selected out of Jemalong, and it has been performing nearly like Jemalong. Jester and Jemalong mature about 2 weeks later than Armadillo and are recommended from about Austin southward. Another cultivar that is only recommended in deep South Texas is Parabinga. Parabinga is a very active winter grower and matures 2 weeks before Armadillo, so has performed well in the hot drier areas of deep South Texas. Recommended seeding rates on barrel medic are similar to Armadillo.

Spotted burr medic (*M. arabica*) is more cold tolerant and better adapted to sandy soils that are slightly acid than most other medics. At the present time there are no commercial varieties available.

Black medic (*M. lupulina*) is common from South Texas north to Canada. It is the predominant annual medic on much of the blackland soils of Texas. Black medic develops a smooth black cluster of pods with normally only one seed per pod. The only commercial varieties currently available are not well adapted to Texas as they were developed for more northern regions. However, if you have a naturalized stand of black medic, it can be encouraged to contribute to your winter and spring forage base if you manage to allow it to reestablish itself in the autumn.

Button medic (*M. orbicularis*) has a large flat smooth pod and is best adapted to North Central Texas. 'Estes' button medic is currently being marketed for North Central Texas. A problem unique to this species is that the pod is very large and fleshy, and it is highly palatable to deer. Nearly complete removal of all pods has been observed when using this legume in deer food plots.

Little burr medic (*M. minima*) has become naturalized in the Texas Hill Country and has smaller leaves and smaller seed than most medics. The pods have long spines, and the plant is very pubescent. Devine little burr medic was released in 2005 by Texas Agricultural Experiment Station at Beeville. Devine originated from a kleingrass pasture near Devine, TX, and is best adapted in the I-35 corridor from south of San Antonio to nearly the Oklahoma border. Recommended seeding rates are 3 to 5 lbs per acre. Devine grows well with most perennial grasses provided the grasses are managed to be grazed short in the autumn to allow the seedlings to establish.

Annual Clovers.

Arrowleaf clover (*Trifolium vesiculosum* Savi) is one of the major annual clover species grown in the southeastern U.S. It has large white flowers with a pinkish cast and can grow over 4 ft tall if not grazed or cut. Arrowleaf clover is best adapted to well drained loam and sandy soils but is more sensitive to soil pH than other legumes with a preference of 6.5 to 7 pH. Iron chlorosis can be a problem on soils with a pH above 7.5. Arrowleaf clover is the latest maturing and usually the highest yielding annual clover with growth continuing through June if moisture is adequate. Seedling growth is slow, with seedlings staying in a rosette stage until late February. This results in very little forage production until early March. Arrowleaf clover has excellent reseeding potential with up to 90% hard seed. Volunteer stands may be poor the first reseeding year because of the low percentage of soft seed. Only scarified seed should be planted at 8 to 10 lb/acre. Planting an additional 4 to 5 lb/acre of scarified seed the first reseeding year will ensure that an adequate amount of soft seed is present to obtain a good stand.

Virus diseases are a major problem with older varieties like Yuchi. Leaves of affected plants will be crinkled, have a light and dark green mosaic pattern, and a chlorotic appearance. Root rots have also been a problem. Early symptoms are poor stands in the autumn because of seedling loss. Surviving plants will do poorly during the winter because of root damage and may die when grazing begins. Leaves of arrowleaf clover may turn red because of stress due to disease, low temperatures, or other environmental factors. Early planting from mid-September to mid-October has also improved seedling survival against these diseases. 'Apache' arrowleaf clover released in 2001 has tolerance to bean yellow mosaic virus disease. 'Blackhawk' arrowleaf clover was released in 2012 and is tolerant to both bean yellow mosaic virus and fungal seedling diseases. Both Apache and Blackhawk are recommended varieties.

Ball clover (*Trifolium nigrescens* Viv.) has small ovate leaflets and small white to yellowish-white flowers. If not cut or grazed, stems can grow up to 3 feet and are prostrate to partially erect, often forming a thick mat. This prevents using ball clover for hay and makes harvesting seed difficult unless it is grazed before flowering. Seed are very small (approximately 1,000,000 per lb) with a recommended seeding rate of only 2 to 3 lb/acre. Ball clover does best on loam and clay soils but has done well on relatively level sandy soils near creek or river bottoms that maintain good soil moisture. It does not have good drought tolerance, and growth will be reduced in a hot, dry spring. It prefers a soil pH of 6 or higher. Ball clover can tolerate wet soils but not as well as white clover. It is medium maturity, flowering about a month later than crimson with yields usually slightly less than crimson.

Ball clover has excellent reseeding. Hard seed content is about 60% and it will produce some flowers even under close grazing. Ball clover does have a high bloat potential and should be managed accordingly. Since there are no commercial varieties at this time, only common ball clover seed is available.

Berseem clover (*Trifolium alexandrinum* L.), also called Egyptian clover, is believed to have originated in Syria. It was introduced into the Nile Valley in Egypt in the 6th Century and is now grown on half the cultivated land in that country as a winter cover and green manure crop. It has oblong leaflets, hollow stems, large white flowers, and can grow up to 2.5 ft. tall. Berseem clover is not as cold tolerant as the other annual clovers. Bigbee berseem, a joint release by the USDA and the Mississippi Agricultural and Forestry Experiment Station in 1984, has improved cold tolerance. However, even Bigbee berseem is considered less cold hardy than most of the other annual clover species.

Berseem clover is well adapted to river bottoms and clay soils with a pH of 6 to 8. Berseem clover has medium size seed with 207,000 seed/lb. Recommended seeding rate is 12 to 16 lb/acre. Bigbee berseem has excellent seedling vigor with growth 8 to 10 inches tall by December if planted on a prepared seedbed in late September or early October along the Gulf Coast. Grazing should begin when it is 6 to 8 inches tall to stimulate tillering and limit frost damage. New cultivars of berseem are available with improved reseeding and cold tolerance. Lightning is a new cultivar of berseem with improved cold tolerance and reseeding and is available from Smith Seed, Halsey, OR.

Crimson clover (*Trifolium incarnatum* L.) is native to Europe and is the most widely adapted annual clover species grown in the southeastern United States. It has scarlet or deep red flowers and is used extensively for roadside stabilization and beautification throughout the southeastern United States. Crimson clover grows on soils ranging from sands to well-drained clay soils with a pH of 5.5 to 7. Best growth occurs at a pH of 6 to 7. Iron chlorosis has been a problem on calcareous soils at a pH of 7.3 or higher. Recommended seeding rate is 16 to 20 lb/acre. Crimson clover is one of the larger seeded annual clovers with 150,000 seed/lb and has excellent seedling vigor. If planted early, it can produce some forage in the autumn and has earlier forage production in the spring than the other clover species. However, winter temperatures about 15°F or lower have caused some top kill that will reduce early spring growth.

Crimson clover is the earliest maturing annual clover. The combination of good seedling vigor and early maturity makes it ideal for overseeding warm-season perennial grasses. Present crimson clover varieties are considered poor reseeders because hard seed levels are only about 10%. Most soft seed germinate with the first rain after seed matures in May. Range in maturity of present varieties is about 12 days. Flame and AU Robin are early varieties, and Tibbee and Dixie are late varieties.

Persian clover (*Trifolium resupinatum* L.) is native to Asia Minor and the Mediterranean region. The actual time of introduction into the United States is not known, but it was found growing in Wilcox County, Alabama in 1923. Common Persian clover has small leaves and reaches a height of 8 to 12 in. with small, light purple flowers. It is found on loam and clay soils, especially on poorly drained soils with soil pH of 6 to 8. Seedling growth is best at a pH of 7 to 8. Persian clover spreads during flooding because the calyx swells at seed maturity and serves as a float, allowing the seed to move to other flooded areas. It does have high bloat potential. Recommended seeding rate is 6 to 8 lb/acre. The seed are small with 600,000 seed/lb. The only available varieties are from Australia.

Rose clover (*Trifolium hirtum* All.) is native to the Mediterranean region and Asia Minor and is one of the few clover species that is adapted to lower rainfall areas. Most of the rose clover acreage is on the California rangelands that receive at least 10 in. of rain during the winter growing season. Overton R18 was selected for climatic and soil conditions in the southeastern US at the Texas A&M University Agricultural Research and Extension Center at Overton. It matures 4 weeks later with twice the production compared to the early varieties grown in California and Australia. Rose clover is adapted to all soil types with a pH of 5.5 or higher but does not tolerate poorly drained soils. Some iron chlorosis problems have been reported on calcareous soils with soil pH near 8.0. Optimum pH for seedling growth is 5.5 to 7.0. Recommended seeding rates are 12 to 16 lb/acre. Rose clover has a medium size seed with 164,000 seed/lb. Poor seedling growth and nodulation is a major limitation of rose clover that results in later spring growth than the other legume species.

The greatest success with rose clover has been in North Central Texas and Central Oklahoma where the annual rainfall is 25 to 30 in., which limits the growth of most other clovers. The good drought tolerance is due to a deep rooting depth. Rose clover is an excellent reseeder because of a hard seed percentage of 90%. California data have shown that if volunteer clover stands are lost to drought or insects several years in a row, there would still be sufficient hard seed remaining to reestablish the rose clover stand.

Subterranean clover, also called subclover, is native to the Mediterranean region. Subterranean clover is the common name for three Trifolium species, subterraneum, brachycalcycinum, and yanninicum. Most varieties grown in the United States are subterraneum species. Subclover is best adapted to soils ranging from a fine sandy loam to clay with a pH from 5.5 to 7. Like arrowleaf, it usually becomes chlorotic and stunted on soils with a pH above 7.3. The brachycalycinum species of subterranean clover is adapted to soils with pH above 7.0 but has less cold tolerance. Subclover has a low growth habit which forms a dense sod that seldom exceeds a 10-in. height. Its short height is deceiving. Forage yield of a 5- to 6-in. high subclover pasture is similar to a 12-in. high arrowleaf clover pasture. Reseeding of subterranean clover is generally poor in Texas.

Annual Sweetclover (*Melilotus albus* Medik.) is not a true clover but is an excellent forage legume. At one time, it was the most widely grown forage legume in the United States. It is one of the most drought-tolerant legumes and was grown for forage and soil improvement, particularly in the Great Plains and the Corn Belt. Sweetclover will grow almost anywhere there is a minimum of about 17 in. of rainfall and soil pH is 7.0 or higher. The three general cultivated types of sweetclover are biennial yellow flower, biennial white flower, and annual white flower. Hubam and Floranna are annual white flower types that were grown in the southern US. In the late 1940s and early 1950s, over 9 million pounds of sweetclover seed were produced in Texas annually. The advent of cheap nitrogen fertilizer after World War II and the spread of the sweetclover weevil (Sitona cylindricollis) eliminated most of the sweetclover acreage in the United States. However, it is still grown in Canada. Both white and yellow flower types are found growing along roadsides throughout the United States.

Sweetclover can be planted in the southern states in October at 12 to 16 lb seed/acre. Successful stands have been obtained in Central Texas when seeded in late January and February. It has a medium seed size with approximately 260,000 seed/lb. Sweetclover plants are 3 to 7 feet tall at maturity depending on variety. Annual sweetclovers are late maturing, flowering from May through June in the southern United States. Sweetclovers contain coumarin that causes a bitter taste to which animals become accustomed. If sweetclover is baled at too high a moisture level and fungal molds develop, the coumarin changes to dicoumarol, a blood anticoagulant. Cows eating the moldy hay can die of internal bleeding. Dicoumarol is not a problem when sweetclover is grazed by cattle or browsed by deer. Dicoumarol can cause toxicity problems only when high coumarin sweetclover is consumed as moldy hay or silage.

Genes for low coumarin have been found in a wild sweetclover type but none of the annual sweetclover varieties contain the low coumarin gene. A breeding program has been initiated at Texas A&M AgriLife Research and Extension Center at Overton to transfer the low coumarin gene to annual sweetclover. Seed increases and evaluations of low coumarin experimental cultivars are in progress.

Silver River is a rust resistant cultivar of white-flowered, annual sweetclover (Melilotus albus Medik.) developed by Texas A&M AgriLife Research at Overton with excellent adaptation to south and central Texas. Sweetclover rust (Uromyces striatus Schroet.) causes a range of plant disease symptoms, including leaf drop, reduced seed and forage yield, and premature plant death. The evaluation of Silver River for rust resistance was conducted at Beeville, TX under severe epiphytotics of sweetclover rust. Two cycles of mass selection at Beeville were used to improve the rust resistance of a sweetclover plant introduction line from Uruguay. The original plant introduction population had 21% rust resistant plants. Silver River averaged 91% resistant plants at Beeville in 2014 and 2015, compared to 'Hubam' with a 2-year average of 7% resistance. Silver River is similar to Hubam in forage yield and maturity. This new cultivar will improve the reliability of annual sweetclover in cattle grazing systems and wildlife supplemental forage plantings in south and central Texas. Silver River was released in 2016.

Vetch (*Vicia* spp.) There are many different species of vetch including 15 that are native to the US. Cold-hardy vetch species such as hairy vetch are adapted over a wide area of the US. Common vetch is less cold-hardy and is limited to areas with mild winters such as the Gulf Coast area. Vetch is adapted to a wider range of soil types and pHs than most other forage legumes. It grows on sand, loam, and clay soils from pH 5 to 8. It also has excellent seedling vigor because of its large seed. There are approximately 16,000 seed/lb for hairy vetch with a recommended seeding rate of 20 to 25 lb/acre. Optimum planting depth is 1 to 2 inches because of the large seed. Stems bear leaves with pinnate leaflets and terminate in tendrils that attach themselves to stems of other plants. White or purple flowers, depending on the species, are borne in a cluster or raceme. Hairy vetch flowers during April and May. Seed and pod characteristics vary with species.

The main use for vetch is for a green manure crop because it maintains a high nitrogen concentration through plant maturity. A mature crop of hairy vetch will contain about 150 lb nitrogen/acre. Vetch does not tolerate close grazing and should not be grazed shorter than 6 in. Insects are the main disadvantage of vetch. Pea aphids, corn earworm, fall armyworm and spider mites can be problems. The vetch bruchid or weevil destroys the interior of the seed reducing seed yields, which is the main reason for poor reseeding.

Austrian Winter Peas (*Pisum sativum*) may produce a moderate amount of dry matter used for grazing, as a hay crop, or as a green manure. Winter peas are often used as companion crops with cereal grains and are high in nutritive value. Winter peas are easily established on well-drained loam or sandy loam soils and should be planted during September or October at 20 to 30 lbs of seed/acre in mixed stands with cereal grains or ryegrass and 30-40 lbs/acre in pure stands. Austrian winter peas are adapted to low pH soils.

Cool-Season Perennial Legumes

A few cool-season perennial legume species are grown in the southern United States. Their acreage in the southern United States is limited by preference for loam and clay loam soils. Perennial clovers often act like annuals in this region because of poor summer survival.

Alfalfa (*Medicago sativa* L.) is the best-known forage legume in the United States and is referred to as the "Queen of the Forages". It is the only forage known to have been cultivated before the era of recorded history. Although classified as a cool-season legume, it grows throughout the summer if moisture is available. Because of this long growing season it has the capacity to produce large yields of high quality forage. It is best adapted and grown most extensively in the mid-west US. However, varieties have been developed that are adapted to most climates throughout the United States.

Alfalfa does best on deep, well-drained loam to clay loam soils with a pH of 7.0 or higher. In the eastern half of Texas, the optimum sites are well-drained river bottoms of the Brazos, Colorado, and Red Rivers. Alfalfa can be grown on any soil with good internal drainage and a subsoil pH of 5.5 or higher. Lime can be added to raise the surface soil pH to near 7 and nutrients limiting for optimum growth can be applied. When sandy acid soils are limed to pH 7, boron is critical for alfalfa if soil boron is less than 1.0 ppm. Autumn planting dates are preferred over spring because of fewer weed problems. Recommended seeding rates are 16 to 20 lb/acre planted at ¼ in. depth in clay soils to ½ in. depth in sandy soils in a clean, firm seedbed.

Alfalfa can be a very profitable forage crop, but it requires a high level of management. Chemical weed control is required to obtain good clean stands. Most disease problems have been solved by selecting for resistance. Alfalfa weevil and three-cornered alfalfa hopper are the main insect problems, but all can be controlled with insecticides. Its primary use is hay for dairy cows and horses. With the development of grazing tolerant varieties, more alfalfa is being used for grazing.

<u>Red clover</u> (*Trifolium pretense* L.) is a weak perennial with stands lasting 2 to 3 years in the northern 2/3 of the United States but usually only 1 year in the Lower South (35 N latitude southward). Red clover is best adapted where summer temperatures are moderately cool to warm with good soil moisture conditions. It prefers loam to clay loam soils as long as they are well drained. It will grow on flat sandy soils (flatwoods) with good moisture. Soil pH needs to be above 6. In the South, red clover reaches a height of 2 to 2.5 ft. with numerous leafy stems rising from the crown. Hairs are present on both leaves and stems. Flower color varies from light pink to rose purple to magenta. It has a tap root that gives it some drought tolerance on loam soils, but red clover is sensitive to low soil moisture on sandy soils.

Recommended seeding rate is 10 to 12 lb/acre planted at a ¼ to ½ in. depth. Red clover will grow into June and July if moisture is available. Cherokee red clover is the only variety developed in the South, so it begins spring growth earlier than other varieties. Red clover can be used for both hay and grazing but does not tolerate close grazing.

<u>White clover</u> (*Trifolium repens* L.) is a perennial legume grown in the eastern half of the US. While perennial in nature, white clover in the southeastern US generally persists as a re-seeding annual. There are small, medium, and large (ladino) white clover types. Although a shorter stature, short and medium types are better seed producers than large types, which is important for reseeding in the south. Recommended varieties are Louisiana S-1, Neches and Durana. White clover requires good soil moisture, is usually found on clay loam, bottomland soils, and is not productive under droughty, upland conditions.

White clover is often planted at 3-4 lbs/acre into existing tall fescue or bermudagrass stands. Best production will be obtained on fertile, well-drained soils if rainfall is favorable. White clover will tolerate wet soil conditions better than most legume species. Because it is often found on wetter sites, white clover may survive a drought during the summer months better than other forage legumes.

White clover does not exhibit the same erect growth habit as red clover, and mixed grass-clover stands should be grazed at a 4-to-6-inch height to prevent competition for sunlight from becoming a limiting factor in white clover production. When cattle graze pure stands of white clover, bloat potential may be reduced using Bloat Guard blocks, feeding grass hay or grown in grass mixtures.

Warm-Season Annual Legumes

Both annual and perennial warm-season legumes are used more for wildlife than livestock. It is difficult to grow warm-season legumes in association with warm-season perennial grasses because the warm-season grasses are so well adapted and competitive.

Cowpea (*Vigna unguiculata*) is an annual viney plant with large leaves. The species is fairly tolerant of drought, heat, low fertility, and moderate soil acidity. Cowpeas, however, do require adequate levels of P and K to be productive. Forage nutritive value is generally high and plants are easily established from May through June. Many times cowpeas are used as a warm-season food plot for white-tailed deer to offset the negative effects of summer stress. Cowpeas do not cause bloat in ruminants, but are not found immediately palatable by cattle.

'Ace' is a small seeded (9000 seed/lb) cultivar of forage cowpea developed for use in wildlife supplemental plantings, cover cropping systems and legume hay production. Ace was developed in the Texas A&M AgriLife Research Forage Legume Breeding Program at Overton and released in May 2018. Ace was evaluated at Texas A&M AgriLife RECs at Overton and Vernon, TX. Ace has full season forage production and flowers in late August.

'Iron & Clay' is an old forage-type cowpea cultivar (technically a variety mix) that remains vegetative during most of the summer and flowers in mid September. Both Ace and Iron & Clay are recommended for Texas.

Lablab (*Lablab purpureus* [L.] Sweet) is a vining, annual tropical legume with high nutritive value as a forage for cattle and goats and browse for deer. The qualities of this tropical forage include: drought tolerance, high palatability, high nutritive value, excellent forage yields and adaptation to diverse environmental conditions.

Currently, seed of the Australian lablab cultivar 'Rongai' is imported into the US primarily for supplemental forage plantings for white-tailed deer. Rongai was released by the New South Wales Department of Agriculture in 1962. Rongai is very late maturing and generally does not flower in northeast Texas before frost.

'Rio Verde' lablab was developed through selection for tolerance to defoliation, forage production potential and Texas seed production. Rio Verde was developed at the Texas A&M University Agricultural Research and Extension Center at Overton, Texas and released by the Texas Agricultural Experiment Station (TAES) in 2006. Rio Verde was the first lablab cultivar developed in the US. Currently (2020) no Rio Verde seed are produced in Texas due to anthracnose disease in west Texas seed production areas. Texas A&M AgriLife Research at Overton has identified resistance in lablab to this foliar and stem blight, but new cultivars are still in evaluations.

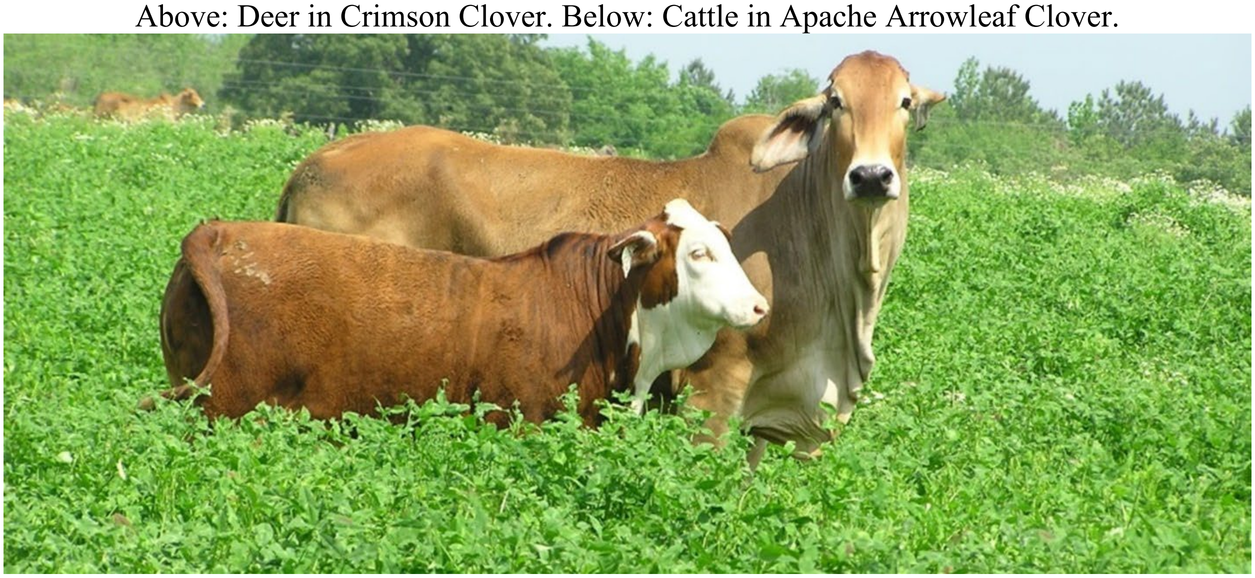
Soybean (*Glycine max*) is a temperate grain legume that can be used as a grazing and hay crop. This plant is not as tolerant of heat and drought as cowpea and lablab and does not regrow well after defoliation. Soybean is better adapted to heavy clay soils and wet soils relative to cowpea and lablab. There are forage type soybean varieties that require short days (late fall) to flower and mature. They remain in a vegetative stage during the summer in contrast to grain-type soybeans that begin to flower 2 to 3 months after planting. 'Tyrone' is the best adapted forage soybean variety for the southern states.

Warm-Season Perennial Legumes

Bundleflower: There are several species of bundleflower (Desmanthus) that are native to Texas and surrounding states. Two species have been commercialized for use in Texas. ‘Sabine’ Illinois bundleflower (Desmanthus illinoesis) is adapted to North and Central Texas from about Austin northward. ‘BeeWild’ bundleflower (D. bicornutus) was developed at Beeville and released by the Texas Agricultural Experiment Station in 2003. BeeWild consists of four (4) different cultivars that are produced as monocultures for seed production purposes and then blended to produce BeeWild. The four different cultivars have a 100% range in seed size and a broad range in flowering and seed maturation time. BeeWild is best adapted south of about Waco in Central Texas. All bundleflowers are poorly adapted to acid sandy soils, so their use is restricted to soils that are sandy clay loams and heavier with a pH near neutral and above. All bundleflowers contain tannin which reduces palatability and essentially eliminates the potential for bloat. Recommended seeding rates for bundleflower is 3 to 5 lbs per acre.

For more information contact Dr. Gerald R. Smith for more information. (g-smith@tamu.edu; 903 834-6191; aggieclover.tamu.edu)

Above: Deer in Crimson Clover. Below: Cattle in Apache Arrowleaf Clover.



Giant Forage Cowpea

Silver River Sweetclover

Impact of FSH and LH treatment on dominant follicle growth and estrus expression in Bos indicus fixed-time artificial insemination protocol.

Ana Clara D. Mattos[1,2], Jaclyn N. Ketchum[2,3], Lacey K. Quail[2,3], Sarah Blaske[2,3], Chloey Guy[2], George A. Perry[2,3]

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[3]Texas A&M Department of Animal Science, College Station, TX

Application: Reproductive success in cattle is critical to profitability of any cow/calf operation. Therefore, the objective of this study was to evaluate the effects of administering FSH and/or increasing LH on follicular growth (FG), EE and pregnancy per FTAI in synchronized beef cows.

Introduction: Pregnancy success in cattle depends on several factors, such as dominant follicle growth (DF) and estrus expression (EE) at fixed time-artificial insemination (FTAI). Thus, the need for strategies to increase follicular diameter and estrus expression in bovine females is critical to improve reproductive success.

Materials and Methods: Brahman cows (n=129) averaging 74±6 days post-partum (DPP) were enrolled in the PG 6-d+CIDR protocol (Replicate1: n=100, Replicate2: n=29). On d-12 $PGF_{2\alpha}$ (25mg Lutalyse i.m; Pfizer Animal Health) was administered, 100µg GnRH (Cystorelin, i.m; Merial) and insertion of a CIDR (Pfizer Animal Health) on d-9, 25mg $PGF_{2\alpha}$ and CIDR removal on d-3 and insemination on d0 with 100µg GnRH. Females were assigned to one of four treatments according to age, DPP, presence of a corpus luteum (CL) and DF on d-12: **Control group** (no additional treatment; n=32), **FSH group** (20mg FSH [Folltropin, i.m; Vetoquinol] on d-3; n=33), **LH group** (20µg GnRH on d-0.5; n=33) and **FSH+LH group** (combination of FSH and LH treatments; n=31). Ovaries of all females were evaluated by ultrasonography on d-12, d-3 and d0 for presence of CL, DF size (mm), and FG (mm) from d-3 to d0, and EE was evaluated on d0. Pregnancy diagnosis occurred on d36 after FTAI (PD36). Analysis of FG and DF by PROC GLM, and EE and PD36 by PROC GLIMMIX (SASv9.4).

Results: There was no difference in FG between treatments (Control: 0.9±1.2mm; FSH: 0.7±0.6mm, LH: 0.7±1.0mm, FSH+LH: 0.7±0.8mm; P=0.88); however FG was greater (*P*=0.01) in females with a CL compared to females with no CL on d-12 (0.9±0.9mm vs 0.4±1.0mm, respectively). There was no significant difference in EE between treatments (P=0.65); however, Replicate1 had greater EE compared to Replicate2 (P=0.05; 55±5% vs 23±8%, respectively). There was no difference in d0 DF between treatments (P=0.88), although Replicate1 had a greater DF compared to Replicate2 (12.4±2.5mm vs 11.3±2.3mm; P=0.05). There was no difference in PD36 between treatments (P=0.32); however, animals that expressed estrus had greater pregnancy rates than those that did not (66±7% vs 27±06%; P<0.01). In conclusion, administering FSH and/or LH did not increase PD36; however animals with a CL on d-12 had greater FG and estrus expression improved pregnancy rate.

Conclusions: In conclusion, administering FSH and/or LH did not increase estrus expression, diameter of the dominant follicle and pregnancy rate, however animals with a CL on d-12 had greater follicular growth and estrus expression improved pregnancy rate.

Acknowledgments: FAPESP (2023/00864-7).

Figures and Tables:

Table 1. Estrus expression, follicular growth, dominant follicle size on d0 and pregnancy rate in Brahman cows submitted to a FTAI protocol treated or not with FSH and LH. Results are expressed as mean ± SEM or proportion (%).

	Treatments				***P*-value**
	Control	**FSH**	**LH**	**FSH+LH**	
Estrus expression (%)	39	43	29	41	0.65
Follicular growth (mm)	0.9±1.2	0.7±0.6	0.7±1.0	0.7±0.8	0.88
DF on d0 (mm)	12.2±2.3	12.0±2.8	12.3±2.5	11.8±2.2	0.88
Pregnancy rate (%)	53	32	45	54	0.32

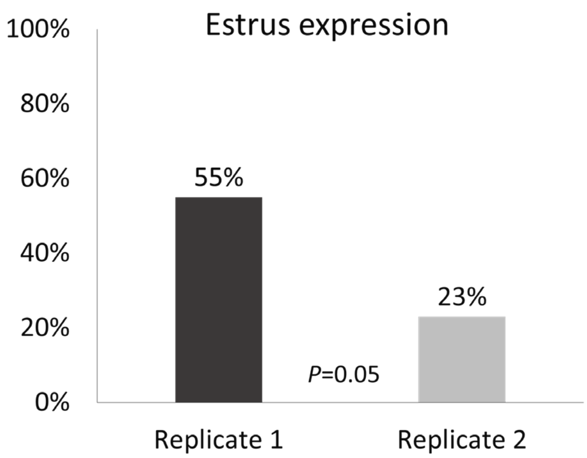

Fig 1. Estrus expression at the time of insemination (d0) among the replicates.

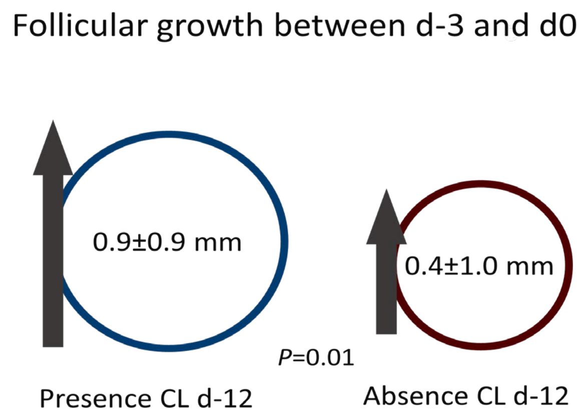

Fig 2. Follicular growth (mm) between d-3 and d0 according to the presence or absence of CL on d-12.

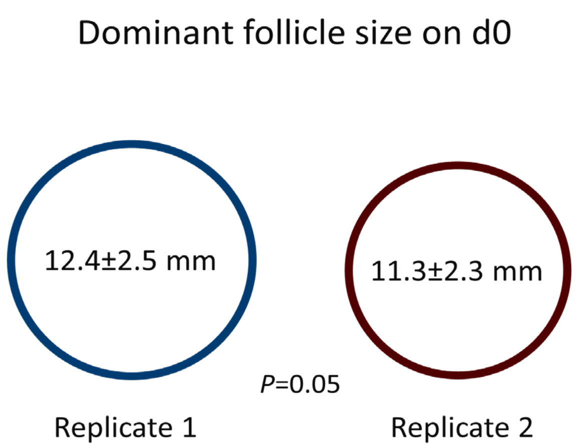

Fig 3. Dominant follicle diameter (mm) at the time of insemination (d0) among the replicates.

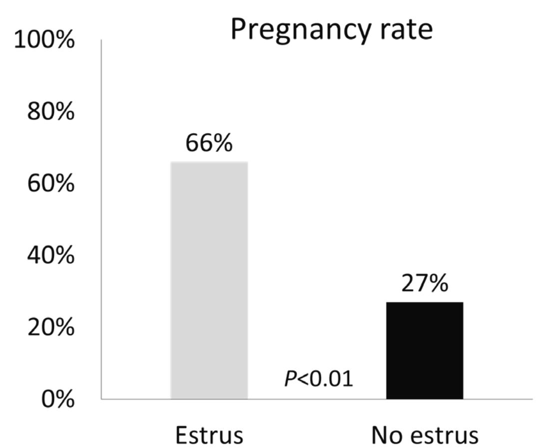

Fig 4. Pregnancy diagnosis at 36-37 days after insemination (d0) among animals that expressed or not estrus.

Impact of a Controlled Internal Drug Release device on circulating and local concentrations of progesterone.

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Application: Controlled Internal Drug Release (CIDR) devices have become an important component of reproductive management programs in many beef herds. Therefore, the objective of this study was to determine the impact of a CIDR device on circulating and uterine tissue concentrations of progesterone.

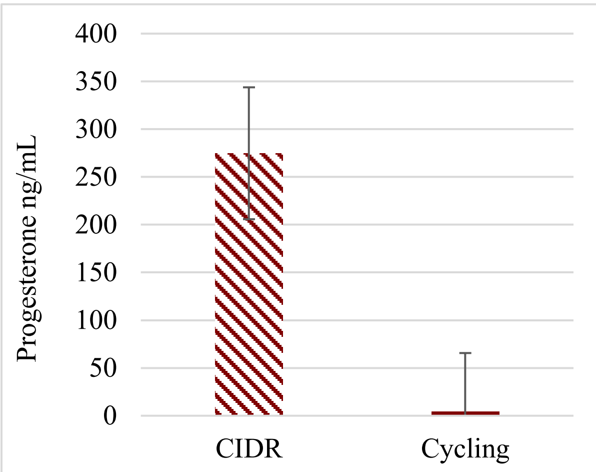
Introduction: When a CIDR is inserted into a cow, circulating concentrations of progesterone mimic a functional corpus luteum. Some data; however, suggests that concentrations of progesterone following insertion of a CIDR might have negative consequences on fertility in Bos indicus animals, and concentrations that are detected by the uterus can have a direct impact on gene expression and the subsequent estrous cycle.

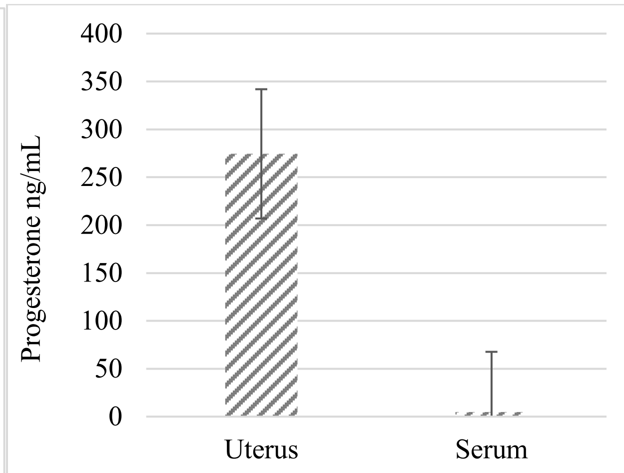
Materials and Methods: A blood sample and a uterine biopsy were collected from non-suckled postpartum cycling Brahman cows (n = 10; Cycling) during the midluteal stage. A blood sample and a uterine biopsy were also collected from non-suckled postpartum cycling Brahman cows (n = 9; CIDR) after a CIDR had been in place for five days. To collect uterine biopsies from CIDR cows, the uterine biopsy tool was placed inside a plastic covering, both were passed into the cervix of the cow before the tool was extended through the covering and into the uterus. After the biopsy was collected, the tool was carefully removed to prevent sample contamination. Blood samples were centrifuged, and serum was collected to determine concentrations of progesterone. Uterine biopsies were snap frozen until extraction. Biopsies were weighted, thawed, and homogenized in assay buffer. Samples were then extracted with Methyl tert-Butyl Ether and resuspended in assay buffer. Serum concentrations are reported as ng/mL and uterine concentrations are reported as ng/g. Statistical analysis was performed using the GLM procedure in SAS with treatment (CIDR vs Cycling), tissue type (uterine vs serum) and their interaction included in the model.

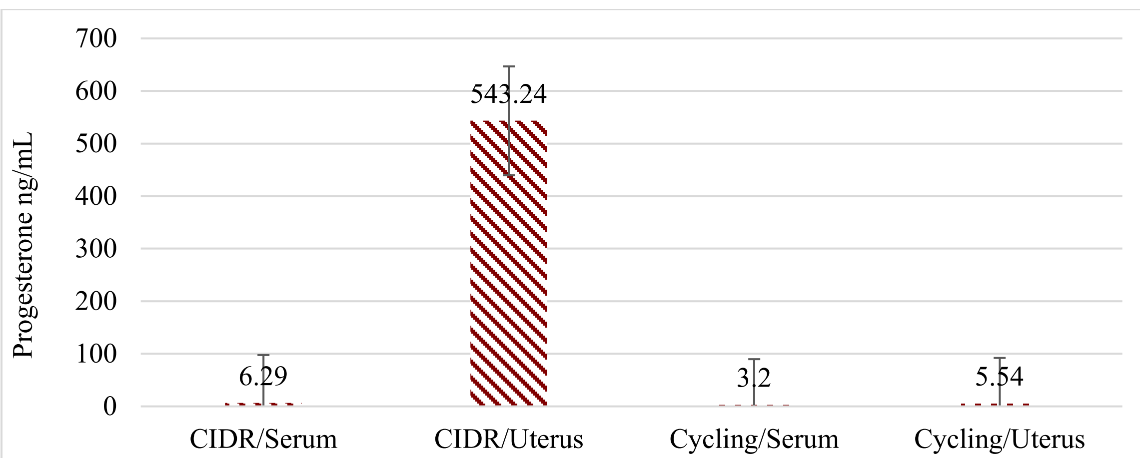
Results: There was a significant effect of treatment ($P = 0.0062$), tissue ($P = 0.0063$) and a treatment by tissue interaction ($P = 0.0068$). Animals with a CIDR had greater concentrations of progesterone than Cycling animals (274.77 vs 4.37 ng, respectively). Uterine samples had greater concentrations of progesterone than serum samples (274.40 vs 4.74 ng, respectively). These increased concentrations of progesterone were mainly from CIDR uterine samples (543.24 ng/g) which had greater ($P < 0.001$) concentrations of progesterone compared to all other samples, which did not differ from each other ($P > 0.98$; CIDR Serum 6.29 ng/mL, Cycling Serum 3.2 ng/mL, and Cycling Uterus 5.54 ng/g).

Conclusions: In summary, CIDRs increased circulating concentrations of progesterone sufficient to keep animals from exhibiting estrus and was not different from cows in the midluteal stage of their cycle. Local concentrations in uterine tissue; however, were significantly greater when a CIDR was in place compared to uterine tissue collected during the midluteal phase. The implications of these significantly greater concentrations of progesterone in uterine tissue warrant further investigation.

Figures and Tables:







Changes in Cytokine Concentration among Beef Cattle that had a Normal and Abnormal Estrous Cycle after Vaccination with a Modified Live Viral Vaccine: A Meta-Analysis

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[2]Texas A&M AgriLife Research and Extension Center, Overton, TX
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[5]USDA, ARS, U.S. Meat Research Center, Clay Center, NE

Application: Infectious reproductive diseases are vaccinated against annually to improve herd health; however, these annual vaccinations may be causing unintended consequences that outweigh their benefits. This meta-analysis summarized changes in cytokine populations following pre-breeding vaccinations around the time of estrus.

Introduction: Vaccination with a modified live viral vaccine (MLV) has been reported to negatively impact reproductive cyclicity in cattle. In previous studies, it has been determined that MLV combination vaccination upregulates the immune system, resulting in an increase in cytokine concentrations, negative consequences to the corpus luteum, and abnormal estrous cyclicity. This meta-analysis aimed to identify specific cytokine populations following vaccination with an MLV.

Materials and Methods: Data from three studies were compiled and analyzed to determine differences in cytokine concentrations between animals with normal and abnormal cycles following vaccination. In all studies, $PGF_{2\alpha}$ was administered on d-3 to regress corpora lutea and bring cattle into estrus. Animals were vaccinated on d 0 with a MLV (n=50) or saline (n=11). Blood samples were collected on d 0, 2, 4, 6, , 10, 12, and 14 to analyze INF-γ, IL-1α, IL-1β, IL-4, IL-6, IL-8, IL-10, IL-17A, IL-36A, MIP-1α, MIP-1β, MCP-1, IP-10, TNFα, and VEGF-A concentrations by a MagPix multiplex machine using a MILLIPLEX Cytokine Magnetic Bead Panel. Differences in cytokine concentrations between animals with normal (n=42) and abnormal (n=19) cycles were analyzed using repeated measures using PROC MIXED (SAS v9.4).

Results: There was a significant effect of cycle status (P = 0.01) and time (P = 0.01) on IL-1β, with increases concentrations in animals with abnormal cycles compared to animals with normal cycles. An increase in IL-1β occurred from d 0 to d 4 among animals with abnormal cycles, but no difference occurred among animals with normal cycles. There was a significant effect of cycle status (P < 0.01) and time (P < 0.01) on INF-γ, with concentrations increased from d 0 to d 2 in animals with abnormal cycles. There was an effect of cycle status (P < 0.01) and a cycle status by time interaction on VEGF-A, where concentrations were greater on d 8 and d 10 among animals with abnormal cycles compared to animals with normal cycles. Furthermore, animals with abnormal cycles had greater (P = 0.01) concentrations of IL-4 compared to animals with normal cycles. There was no impact (P > 0.0) on cycle status, time, or cycle status by time on IL-1α, IL-6, IL-8, IL-10, IL-17A, Il-36A, MIP-1α, MIP-1β, IP-10, and TNFα concentrations.

Conclusions: MLV combination vaccination resulted in abnormal cycles and increased concentrations of IL-1β, IL-4, VEGF-A, and INF-γ among animals with abnormal cycles.

Figures and Tables:

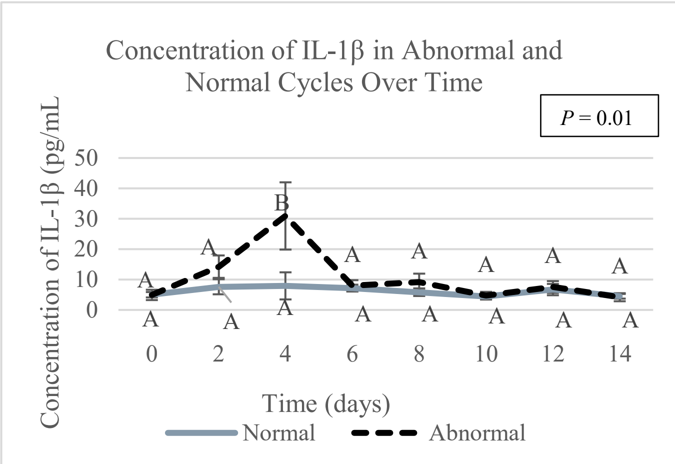

Figure 1. Changes in IL-1β concentrations in abnormal and normal cycles following vaccination with saline or MLV. Treatments within a day that have different superscripts are different (P < 0.05).

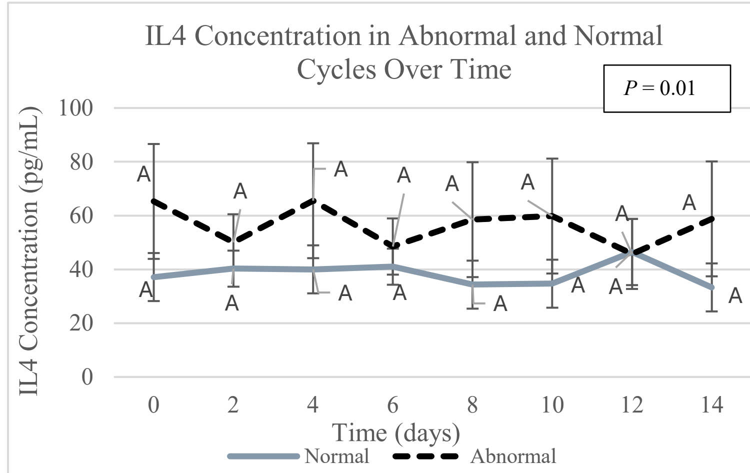

Figure 2. Changes in IL-4 concentrations in abnormal and normal cycles following vaccination with saline or MLV. Treatments within a day that have different superscripts are different (P <0.05).

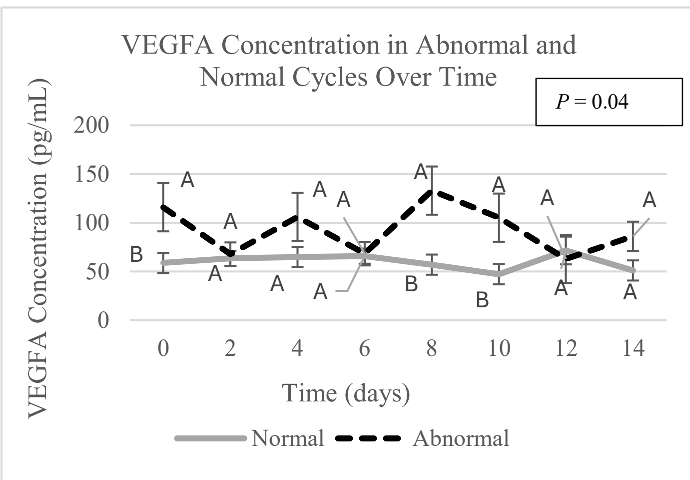

Figure 3. Changes in VEGFA concentrations in abnormal and normal cycles following vaccination with saline or MLV. Treatments within a day that have different superscripts are different (P < 0.05).

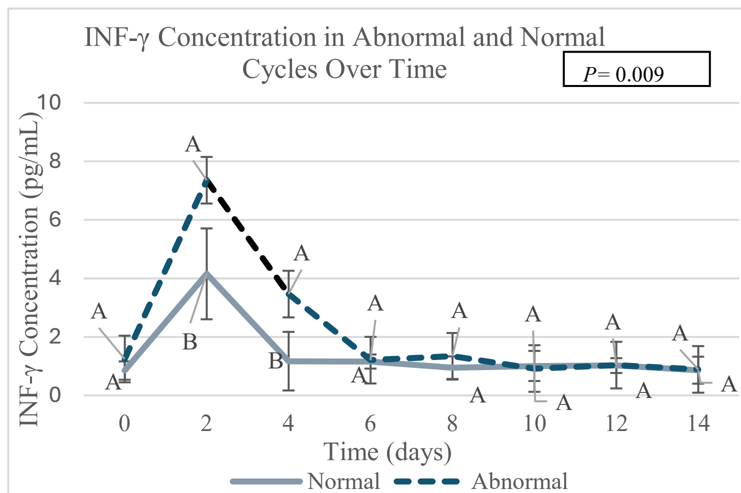

Figure 4. Changes in INF-γ concentrations in abnormal and normal cycles following vaccination with saline or MLV. Treatments within a day that have different superscripts are different (P < 0.05).

Evaluation of sire vs dam influences on age at first parturition in Brahman heifers.

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Application: For selection purposes, knowing if early pubertal attainment is influenced greater by the sire or dam is important for herd management. Therefore, the objective of this study was to determine if sire or dam had a stronger impact on age at first parturition of Brahman heifers (n=833) born between 2000-2021.

Introduction: Typically, in *Bos taurus* heifers, puberty occurs between 10-12 months of age leading to parturition of the first calf occurring around 24 months of age. However, in *Bos indicus* cattle, puberty is achieved between 15-17 months of age leading to a first calf around 36 months of age. The ability of heifers to achieve pubertal status earlier plays a vital role in reproductive success.

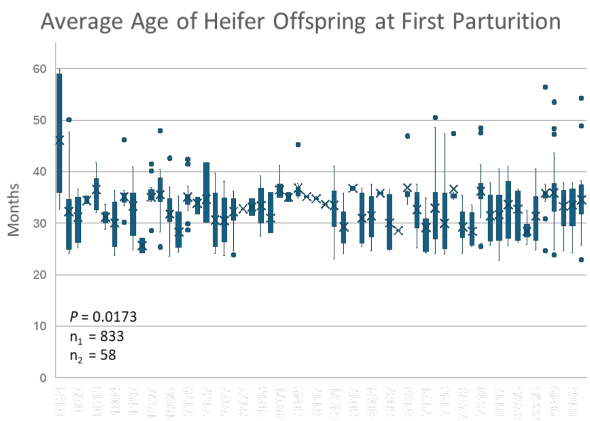
Materials and Methods: For this study, in order to minimize any epigenetic and environmental changes, all heifers originated and were developed at the Texas A&M AgriLife Research Center at Overton. Sire groups (SG) and dam groups (DG) were established based on the number of offspring utilized in the study. Sire groups were comprised of SG-1 (1+ calves sired; n=58 sires), SG-2 (5+ calves sired; n=44 sires), SG-3 (10+ calves sired; n=31 sires), SG-4 (15+ calves sired; n=23 sires), SG-5 (20+ calves sired; n=17 sires), and SG-6 (25+ calves sired; n=12 sires). Dam groups consisted of DG-1 (1+ calves; n= 489 dams), DG-2 (2+ calves; n= 215 dams), DG-3 (3+ calves; n= 81 dams), DG-4 (4+ calves; n= 38 dams), and DG-5 (5+ calves; n=9 dams). Statistical analysis (PROC GLM; SAS 9.4) included the fixed effect of sire group (dam group) and all dams (sires) utilized in that grouping. Significance for age at first calving was considered at $P < 0.05$. Mean separation for age was performed using LSmeans.

Results: Sire significantly impacted age at first calving in SG-1 (P=0.0173) vs dam effect (P=0.3993; n=489 dams), SG-2 (P=0.0159) vs dam effect (P=0.5476; n=481 dams), SG-3 (P=0.0023) vs dam effect (P=0.2532; n=439 dams), SG-4 (P=0.0022) vs dam effect (P=0.3997; n=400 dams), SG-5 (P=0.0002) vs dam effect (P=0.0602; n=361 dams), and SG-6 (P=0.0005) vs dam effect (P=0.1058; n=305 dams). The dam impact on age at first calving was never significant in the dam groupings but sire did impact age at first calving in two groups: DG-1 (P=0.3993) vs sire effect (P=0.0173; n=58 sires), DG-2 (P=0.4823) vs sire effect (P=0.0173; n=56 sires), DG-3 (P=0.3011) vs sire effect (P=0.3420; n=49 sires), DG-4 (P=0.3911) vs sire effect (P=0.6278; n=40 sires), and DG-5 (P=0.3042) vs sire effect (P=0.9159; n=23 sires). In summary, evaluation of sire and dam influences on age at first parturition for female offspring demonstrates that the ability to calve at an earlier age is influenced by the sire but not the dam. Further studies into the mechanisms for the transmission of this trait are warranted.

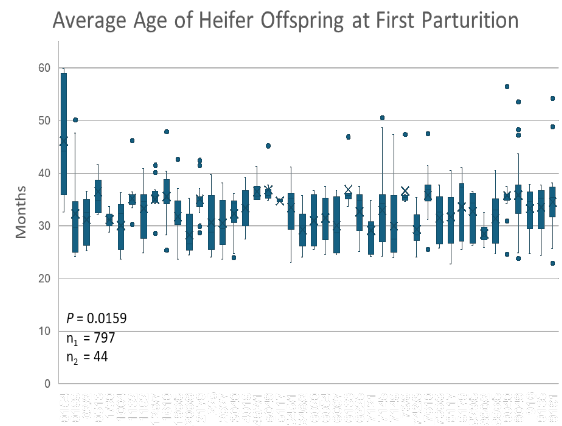
Conclusions: Sire had significant impacts on heifer age at first parturition for all sire groups and two dam groups. Dam had no significance in any dam groups nor in any sire groups.

Figures and Tables:

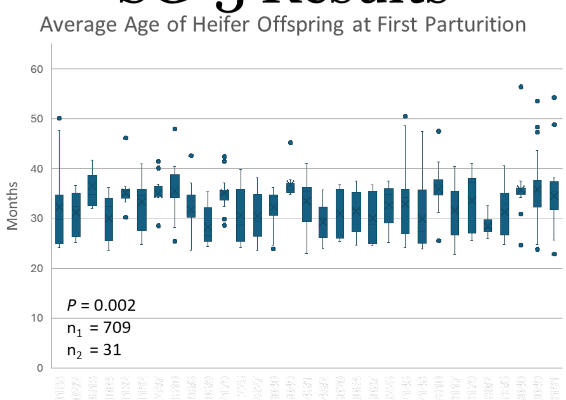
SG-1 Results



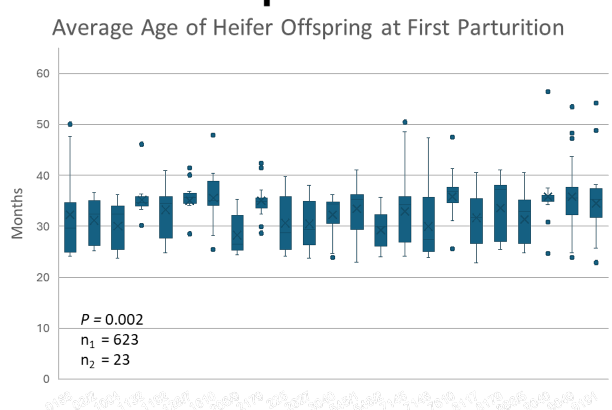
SG-2 Results



SG-3 Results



SG-4 Results



Ambient Temperature Impact on Cytokine, Chemokine, and Reproductive Cyclicity Response to Bovine Viral Diarrhea Virus and Infectious Bovine Rhinotracheitis

Sarah G. Blaske[1,2], Jaclyn N. Ketchum[1,2], Lacey K. Quail[1,2], Alexandria P. Snider[3], Chloey P. Carson[2], Charles R. Long[2], and George A. Perry[2]

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Application: The immune system utilizes cytokines and chemokines to regulate and guide immune responses, which can have subsequent effects on reproduction. This research was conducted to evaluate how seasonal ambient temperature impacted cytokine and chemokine production and estrous cyclicity following a pre-breeding vaccination.

Introduction: Vaccines are designed to help the immune system fight pathogens more effectively, but little is known on how ambient temperature impacts the immune response to vaccination. To avoid negative consequences on reproductive success, vaccines may need to be administered at a different time of year. Our objective was to evaluate the impact seasonal ambient temperature has on post-vaccination cytokine production and reproductive cyclicity.

Materials and Methods: Brahman and Brahman-influenced cows were immunized (2mL I.M.) with a combination Modified Live Vaccine (MLV) in either July (Summer; n=12) or November (Fall; n=6). Plasma samples collected on days 0, 2, 4, 6, 8, 10, and 14 were evaluated for concentrations of IFN-γ, IL-1α, IL-1β, IL-4, IL-6, IL-8, IL-10, IL-17A, MIP-1α, MIP-1β, IL-36RA, IP-10, MCP-1, TNFα, and VEGFA by a MagPix multiplex machine using a MILLIPLEX Bovine Cytokine/Chemokine Magnetic Bead Panel. Progesterone concentrations were determined by radioimmunoassay (RIA) on days 0, 2, 4, 6, 8, 10, and 14 and estradiol on day 0 using plasma. Differences in cytokine concentrations were analyzed as repeated measures using PROC MIXED (SASv9.4).

Results: There was significant treatment by day interactions on cytokine and chemokine concentrations of IL-4 ($P = 0.02$; Figure 1), IL-36RA ($P = 0.002$), IL-6 ($P = 0.002$), IL-8 ($P = 0.003$), IL-1α ($P = 0.001$), VEGF-A ($P < 0.0001$). The effect of season significantly impacted MCP-1 ($P = 0.01$), IL-4 ($P = 0.0002$), and IL-1β ($P = 0.03$; Figure 2), while time alone influenced IL-17A ($P = 0.0006$), IL-6 ($P = 0.0005$), IP-10 ($P = 0.0007$), IFNγ ($P = 0.01$), IL-36RA ($P < 0.0001$), IL-4 ($P = 0.003$). Concentrations of MIP-1β, MIP-1α, TNFα, and IL-10 were not impacted by treatment, time, or the interaction of treatment and time ($P \geq 0.06$). In the summer vaccinated females, IL-1β increased from day 0 to 4 ($P = 0.04$) and remained increased compared to fall vaccinated cattle until day 10 ($P \leq 0.05$). Fall vaccinated animals had increased concentrations of MCP-1 from day 2 to day 14; however, in the summer vaccinated animals MCP-1 concentrations decreased from day 0 to day 2 and remained decreased until day 14. There was a seasonal effect on IL-4 concentrations as this cytokine was increased in fall vaccinated cattle on all sample days compared to the summer treatment group. One out of the 9 animals (11%) vaccinated in the summer and one out of 6 animals (16%) vaccinated in the fall experienced an abnormal estrous cycle.

Conclusion: Animals vaccinated in both the summer and fall experienced an abnormal estrous cycle. Select cytokines responded or were influenced differently by ambient temperature. The inflammatory response indicated by the presence of IL-1β in the animals vaccinated in the summer could be responsible for the abnormal estrous cycle detected. The increased concentrations of IL-4 could have been trying to regulate the continued pro-inflammatory expression of the chemokine, MCP-1 in the fall vaccinated animals. Overall, these data suggest that cytokines could be influenced by ambient temperature that subsequently affects reproductive cyclicity when vaccinated at the time of breeding.

Acknowledgements: USDA-NIFA 2022-68008-36355 and Multistate Hatch project 9835.

Figures and Tables:

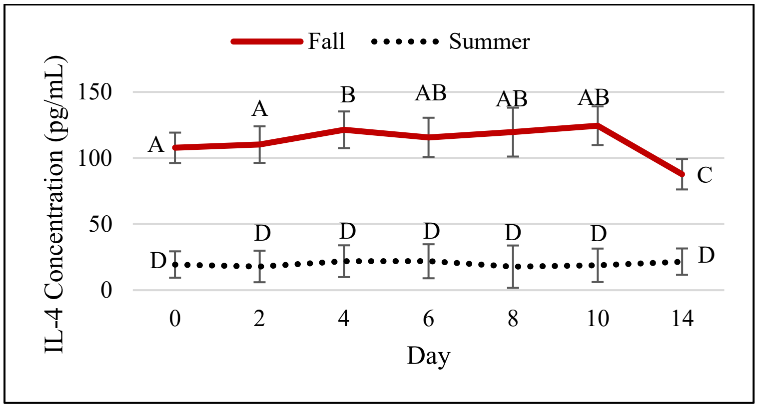

Figure 1: Plasma concentrations of IL-4 over time ($P = 0.003$) within animals that were vaccinated with a combination modified-live virus vaccine for bovine viral diarrhea virus (BVDV) and infectious bovine rhinotracheitis (IBR) on day 0 either in the fall (n = 6) or summer (n = 8; $P = 0.0002$).

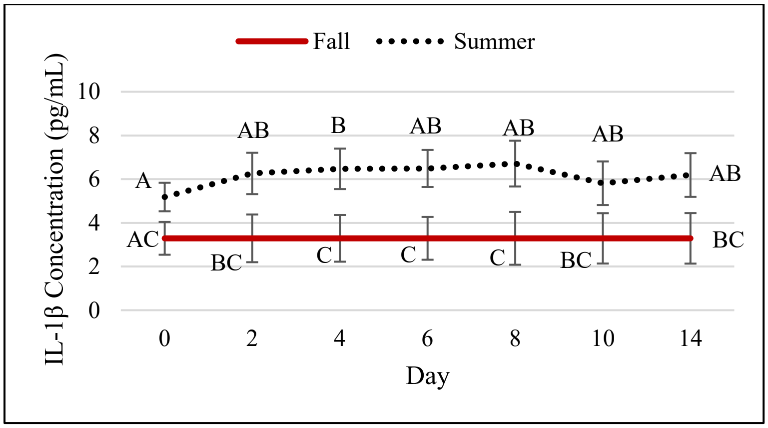

Figure 2: Plasma concentrations of IL-1β over time ($P = 0.2$) within animals that were vaccinated with a combination modified-live virus vaccine for bovine viral diarrhea virus (BVDV) and infectious bovine rhinotracheitis (IBR) on day 0 either in the fall (n = 6) or summer (n = 8; $P = 0.03$).

Ruminal microbiome responses of Angus, Brahman, and F1 cross steers supplemented with monensin

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Application: This research illustrated the potential of dietary supplementation with an ionophore (monensin) to influence the rumen's metabolome and microbiome of Angus, Brahman, and F1 cross steers, which could improve feed efficiency and productivity.

Introduction: Cattle genetics and rumen microbiome structure and their interaction (G×M) influence feed efficiency and animal productivity. Understanding breed-specific responses to dietary strategies could improve animal productivity and better utilize land resources. This study aimed to analyze the metabolic and microbial responses of the rumen in Angus, Brahman, and F1 cross steers fed a monensin supplement.

Materials and Methods: This study utilized 30 steers (582±13.22 lb BW) representing three breeds of cattle: Angus, Brahman, and F1 (Angus×Brahman). Steers were fed Tifton bermudagrass hay *(Cynodon dactylon) ad libitum*. Two phases were implemented where steers were fed within breed type a diet consisting of Tifton bermudagrass hay fed free choice for 21-d (Phase 1). After this phase, steers were transitioned to pens equipped with Calan gates in groups of five within breed type and given free choice bermudagrass hay along with a 1.2 lb supplement consisting of ground corn, soybean meal, and dried molasses with or without monensin (Rumensin 90; Elanco Animal Health, Greenfield, IN, USA) at a rate of 200 $mg \cdot steer^{-1} \cdot d^{-1}$. After 21-d, ruminal fluid was collected, homogenized, and subsampled for ruminal short-chain fatty acid and qPCR analysis and stored at -80ºC until analysis. Two additional 21-d time periods were repeated and collectively analyzed as Phase 2.

Results: Ruminal acetate:propionate ratio (A/P) differed between treatments where steers supplemented with monensin had a decreased A/P ratio compared to steers consuming the non-monensin supplemented diet ($P=0.04$; Figure 1). Ruminal methanogen abundance was also different between treatments where steers supplemented with monensin had lower abundance compared to steers supplemented with the control supplement ($P<0.01$; Figure 2).

Conclusion: This study illustrates the potential for dietary supplementation of monensin to alter the metabolic profiles and reduce the methanogen population in the rumen in Angus, Brahman, and F1 cross steers, which could ultimately lead to improvements in cattle efficiency and productivity.

Acknowledgements: We appreciate the assistance of Don Neuendorff, Dustin Law, Nevada King, Cara Case, Javid Mclawrence and Catherine Wellman at the Texas A&M AgriLife Research Center, Overton. We acknowledge the technical assistance for VFA analysis at the TAMU Integrated Metabolomics Core by Dr. Smriti Shankar and Dr. Cory Klemashevich.

Figures and Tables:

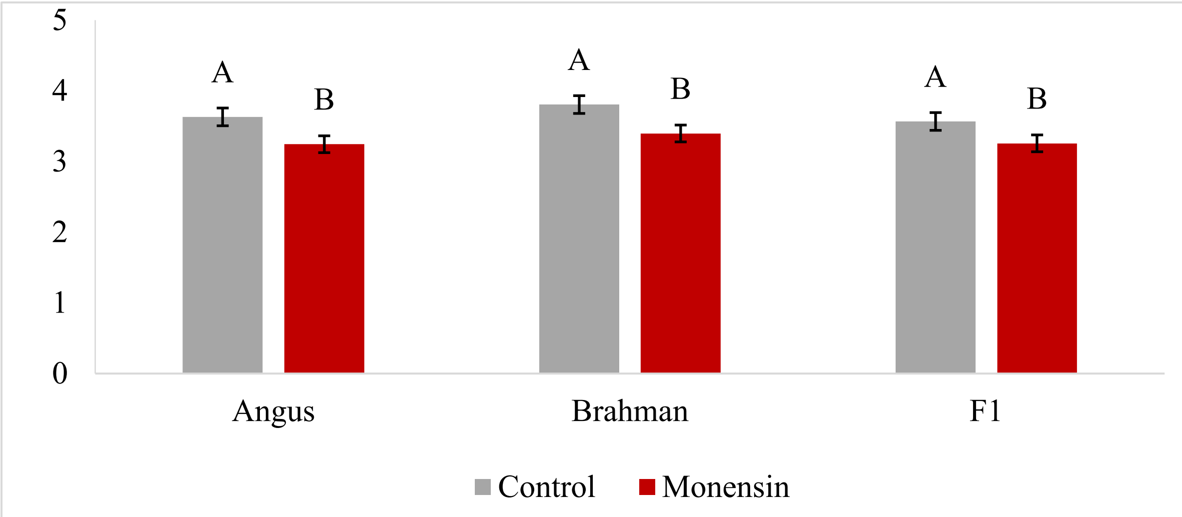

Figure 1. Ruminal acetate to propionate ratio. Values are least-square means (LSM) ± standard error of the means (SEM). Main effects of treatments on ruminal acetate:propionate ratio was different (P=0.001). A treatment-by-breed interaction was not observed (P=0.912). Letters A and B indicate significance between treatments (P<0.05).

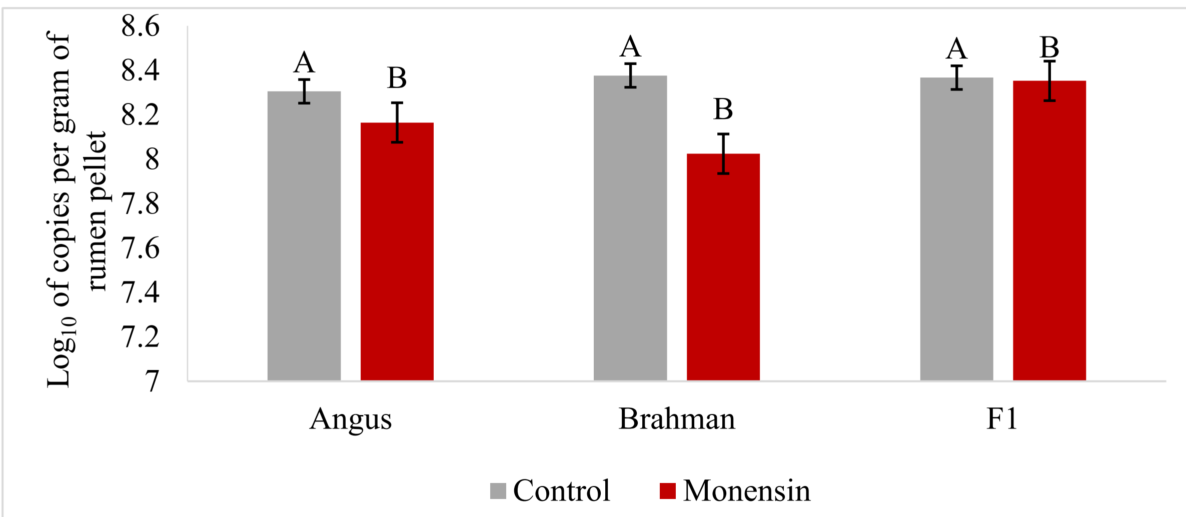

Figure 2. Ruminal methanogen abundance. Values are least-square means (LSM) ± standard error of the means (SEM). Main effects of treatments on ruminal methanogen content were different (P=0.005). No treatment-by-breed interaction was observed (P=0.069). Letters A, and B indicates significance (P<0.05). Letters A and B indicate significance between treatments (P<0.05).

Building high quality soil organic carbon stocks in East Texas grazing pastures

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Application: Increasing the quantity and quality of soil organic carbon (SOC) stocks is crucial for enhancing soil health and reducing the need for inputs such as fertilizers and lime. Estimating soil aggregation properties and SOC accumulation trends within soil aggregates can provide valuable insights on the effects of various grazing, forage, and fertilization practices, ultimately helping to identify the most effective combination of practices to increase SOC.

Introduction: East Texas has a humid-tropical and subtropical climate and is dominated by low-fertility, sandy-textured, acidic soils. These soils rapidly lose carbon and soil health under poor and intensive cultivation practices. In particular, overgrazing and a lack of forage diversity are major drivers of soil carbon decline in East Texas pastures. However, optimal grazing combined with legume integration has shown potential to enhance SOC sequestration. Understanding which practices increase soil aggregation and mineral occluded carbon (MOC) is essential. Soil aggregates are crucial for storing and increasing soil carbon, as they provide physical and chemical protection from microbial degradation and retain nutrients and water, which helps to reduce rapid leaching losses. While MOC represents the stable form of SOC and serves as a reliable indicator of SOC sequestration. However, it remains unclear whether both grazing and legume integration are equally effective conservation practices in East Texas pastures for increasing SOC, soil aggregation, and MOC due to a lack of data.

The objective of this study was to analyze soil aggregation properties, SOC content in soil aggregates, and their quality parameters in long-term (>50 years) grazing pastures under different grazing pressures, with and without nitrogen fertilization or cool-season clover-legume integration. A pine forestry site (FS) from this region was also used as positive control for our study.

Materials and Methods: Study pastures were (1) high grazing pressure with-iN fertilization (HG-iN), (2) high grazing pressure with oN fertilization (HG-oN), (3) low grazing pressure with-iN fertilization (LG-iN) and (4) low grazing pressure with oN fertilization (LG-oN) and a forest site (FS). Soil cores representing 0–60 cm soil profile was collected using hydraulic core sampling method. Collected soil cores separated into four soil depths of 0–5, 5–15, 15–40 and 40–60cm were used for aggregates separation: i) >0.25 mm (macro-aggregates), ii) 0.053-0.25 mm (micro-aggregates) and iii) < 0.053 mm (silt+clay fraction). Aggregate stability was expressed as Mean Weight Diameter (MWD). Aggregate associated SOC, C:N ratio (CNR), the SOC to mineral occluded carbo (rMOC), the ratio between macro+micro-aggregate SOC (aggSOC) and SOC in silt+clay fraction (indMOC) and sub-soil (40-60cm); fungal to bacterial ratio (FBR) were analyzed for comparing stocks and quality of SOC stocks.

Results: The highest MWD was observed under HGiN (1.04 mm $50g^{-1}$), while lowest was under LGiN (0.65 mm $50g^{-1}$) confirming the positive impact of high grazing pressure on soil aggregation (Fig. 1a). The highest average SOC stock was recorded in the FS system at 44.2 Mg ha^{-1} but was not significantly different from LGiN (40.3 Mg ha^{-1}) and LGoN (39.3^{A}Mg ha^{-1}) (Fig. 1b). The average SOC stocks under HGiN (26.7 Mg ha^{-1}) and HGoN (20.8 Mg ha^{-1}) systems, however, were significantly lower (Fig. 1b). The relative ranking of SOC quality parameters placed the systems in the order of FS > LGoN > LGiN > HGoN > HGiN. These results confirm that SOC stocks in FS were more stable and were created at higher efficiency, followed by LGoN and LGiN (Fig. 2).

Conclusion: Maintaining low grazing pressure with N-fertilization resulted in the highest SOC stocks; however, when compared across multiple quality indicators, the legume-integrated systems ranked similar. Our results emphasize the importance of incorporating SOC quality assessments with soil aggregation properties when evaluating grazing pastures to more effectively determine their potential for sequestering high-quality SOC stocks.

Figures and Tables:

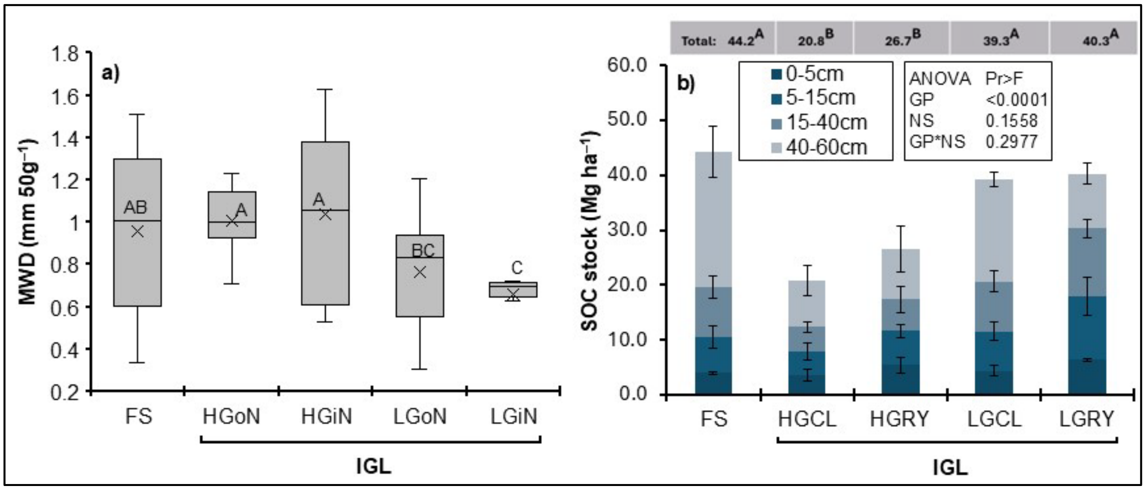

Fig. 1. Soil aggregate stability (MWD) and aggregate SOC stocks Different uppercase letters denote significant difference among systems at 0.05 level according to the Duncan Multiple Range Test.

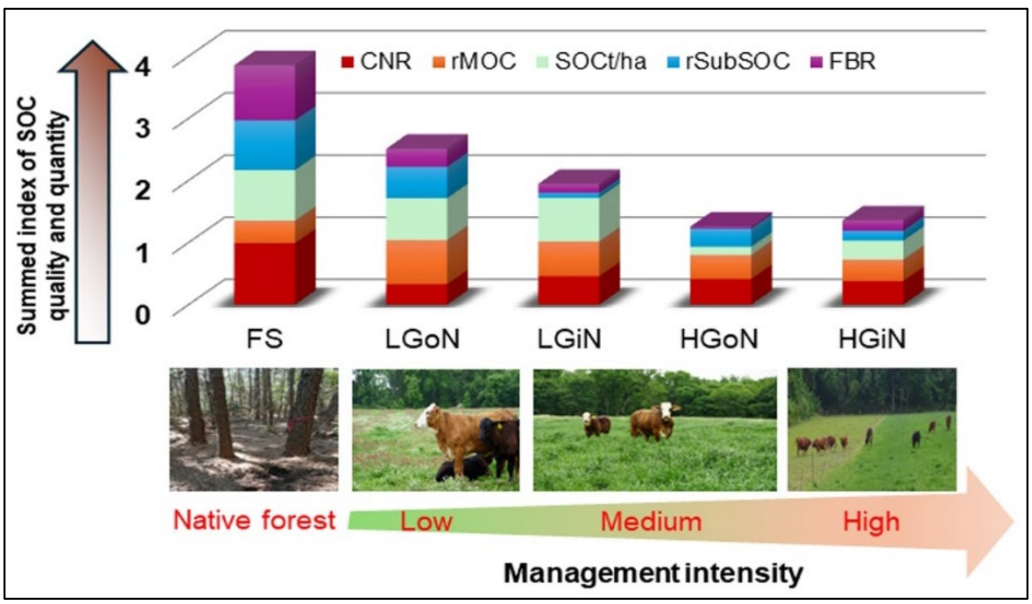

Fig. 2. Summed-index (nVar) of SOC quality indicators and SOC stocks (Mg ha^{-1}) expressed within 0 to 1

Full paper access link: [Assessing organic carbon sequestration in soil aggregates for building high quality carbon stocks in improved grazing lands - ScienceDirect].

Winter Pasture Establishment in Warm-Season Perennial Grass Pastures

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[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Warm-season perennial grasses (WSPG) are the primary forages grown for both pasture and hay in the subtropical climate of east Texas and the US southern region. Forty million acres of WSPG in this region currently support about 5.5 million cattle or 13% of total US cattle. Soils are generally sandy, acidic and infertile, and average annual rainfall ranges from 45 to 55 inches. Rainfall is generally evenly distributed throughout the year, but with reduced amounts in late summer and early fall. The introduced, tropical perennial grasses, bermudagrass (*Cynodon dactylon* [L.] Pers.) and bahia grass (*Paspalum notatum* Flugge), are dormant at least five months of the year from about mid-November to late-March. Clovers (*Trifolium* spp.), annual ryegrass (*Lolium multiflorium* Lam.) and small grains are often overseeded into these WSPG sods to extend the grazing period. Winter pasture establishment is a critical phase of this forage system and must occur during the early fall months (Sept-Oct) when rainfall is variable and temperatures are shifting from hot to cool.

Planning. Consider your options and make decisions as early as possible on the following: forage species and cultivars to plant; how many acres and where; soil amendments needed (lime and/or fertilizer); and planting methods.

Soil Testing. If you have had a soil test in the past 12 months, then additional testing may not be required. A soil test taken in the early spring will provide information on pH and available plant nutrients for both the WSPG and fall planted annual forages. On sandy, acid soils pay special attention to soil pH and liming requirements. Warm season perennial grasses are generally less sensitive to acid soil pH than ryegrass or clovers. For best results with overseeded ryegrass and annual clovers, the soil pH should be no lower than 6.0. Acid soils in combination with high soil aluminum can cause seedling death, stunting, and poor root growth for many winter annual clovers and ryegrass. Additional information on soil testing is available from Texas A&M AgriLife Extension Service Soil, Water and Forage Testing Laboratory (http://soiltesting.tamu.edu).

Timing, Timing, Timing and Luck. In theory, the perfect overseeded winter pasture species or mix would germinate and start rapid growth exactly when we had squeezed the very last grazing day or hay harvest out of our WSPG. And, they would continue to provide winter forage until the exact moment in March or early April when the WSPG started rapid growth. This 'perfect' species or mix in combination with WSPG would then provide year round grazing and of course produce excess forage to be harvested for hay. While the plant breeders are working overtime to develop this 'perfect' winter pasture species, we must depend on our best judgements and hope for 'good luck' with the weather and our timing choices.

Wishful thinking aside, we have to balance the management of WSPG with the timing of planting and winter pasture species choices to optimize livestock production from the pasture and forage system.

Basic Principles for Overseeded Winter Pasture Establishment

- Use soil testing to determine fertilizer and lime requirements.
- Plant winter pasture species and cultivars that are best adapted to your region, soil type and production system objectives. See 'Forage Legumes for Texas' in this publication. For ryegrass and small grain information see the following web sites. (http://Overton.tamu.edu) and (http://varietytesting.tamu.edu). Take note of seed tags for information on species, cultivar, germination and weed seed contamination.
- Reduce competition from existing warm season perennial grasses. Planting into a grass stubble taller than 2 inches will reduce establishment success. Reduce stubble height by hay harvest, grazing, and timing of planting. Early to mid-October is usually a good fall planting date target in northeast Texas.
- Ensure good seed to soil contact. Heavy thatch (dead grass and stems) buildup on the soil surface will cause problems with forage legume and ryegrass establishment. Light disking before planting will encourage decomposition of thatch and expose soil.
- Use appropriate seeding rates for the forage species. See Table below and following website for more seeding rates: http://aggieclover.tamu.edu.
- Match planting methods to forage species. Both clover and ryegrass can be planted with success by broadcasting over the sod with careful attention for seed to have soil contact. A no-till pasture drill will allow more precise seed placement and improve establishment relative to broadcasting over the sod. Small grain establishment will require deeper seed placement (1 to 1.5 inches) than needed for clovers or ryegrass and will need either a drill or moderate disking to ensure seed placement.
- Seed costs for winter pasture (current as of August 2024)

Forage Crop	**Planting Rate**	**Seed Cost**	**Total Seed Cost**
	Pounds/Acre	**$/Pound**	**$/Acre**
Ryegrass	40	$0.90	$36.00
Forage Rye	100	$0.50	$50.00
Crimson Clover	20	$1.20	$24.00
Arrowleaf Clover	10	$2.60	$26.00
White Clover	5	$4.60	$23.00

Improvement of Forage Cowpea for Texas

G.R. Smith[1] and F.M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: Cowpea (*Vigna unguiculata* Walp) is a productive warm-season legume that is well-adapted to upland soils in multiple regions of Texas. Cowpea produces high nutritive value forage and hay and has potential as a summer cover crop. Forage cowpea is also often planted to provide supplemental browse for white-tailed deer. Research is in progress to improve drought tolerance and root development in cowpea.

Introduction: Broad goals in our summer legume breeding program are to continue improvement of forage yield, seed yield, drought tolerance and pest resistance and to concurrently develop lines with different dates of maturity. Variable maturities are necessary for successful seed production in different Texas ecoregions and climatic conditions. Making wide crosses between standard breeding lines and wild perennial types has potential to improve root development and drought tolerance.

Specific objectives for this segment of our research are: improve cowpea drought tolerance; combine perennial traits with root-knot nematode resistance and large seed traits; increase root biomass, rooting depth and rooting spread; and determine utility of perennial trait.

Materials and Methods: Hand crosses were made in 2022 between TX-DEK-99 (*Vigna unguiculata* subsp. *dekindtiana*) and TX-840. TX-DEK-99 is a very small seeded (3g/100 seed) perennial selected from a plant introduction line from East Africa. TX-840 is breeding line with cream color seed, medium seed size (27g/100 seed) and high root-knot nematode resistance. The F1 and F2 generations were grown in the greenhouse at Overton in 2023. Limited field observations were made using F3 families in 2024.

Forty-five F2 seed from the cross TX-DEK-99 x TX-840 were planted in the greenhouse on Sept. 5, 2023. Seed were harvested from these F2 plants November 2023 through Jan. 2024. Data were collected on date of flowering, seed production per plant, seed color, pod size and shape, seed size and length of seed production period.

One F3 family (Vdek 3-3) was planted in field observation plots at Overton on June 17, 2024. The field site was a Darco, loamy fine sand. Each plot was 1.5 m long with 1.5 m spacing between plots. Ace cowpea, two cowpea breeding lines and Rio Verde lablab were included as check entries, and all entries were arranged in a randomized complete block design with three replications. Three grams of seed were planted per plot. Notes on ground cover and white-tailed deer utilization were made at 60, 90 and 120 days post-planting. On Oct. 16, 2024, one plant of Vdek 3-3 and one plant of Ace were excavated and root measurements made.

Results: On Oct. 5, 2023, all F2 plants were in full bloom or bud except for 5 plants that were still vegetative, and one plant that had died. By Nov. 9, 2023 only 3 plants were vegetative, and mature peas were harvested from 5 plants. All plants flowered by Dec. 1, 2023. Four seed color groups were identified and used to group the F2 lines (Table 1). Eleven plants produced cream color seed with seed size ranging from 11.1 to 7.4 g/100 seed. Five plants produced red mottle seed with seed size ranging from 17.2 to 8.9 g/100 seed. The remaining 23 plants produced mottled seed with various color combinations of black, tan, cream and silver markings and seed sizes ranging from 18.5 to 7.5 g/100 seed. All seed produced by the F2 plants was smaller than the TX-840 parent but much larger than the wild parent, TX-DEK-99.

Table 1. Phenotyping of F2 cowpea plants from the cross TX-DEK-99 x TX-840 as grouped according to seed color (parents included for comparison).

Seed Color Group and Parents	Number of Plants	Seed Size (g/100 seed)	Length of Production (days)	Seed Produced per Plant (g)
Cream	11	11.1 – 7.4	43 -7	12.3 - 4.2
Red Mottle	5	17.2 – 8.9	43 - 5	11.9 – 9.5
Black/Tan/Silver Mottle	13	12.6 – 7.5	48 - 6	17.1 – 0.7
Cream/Tan Black Mottle	10	18.5 -7.6	34 - 5	14.9 – 0.3
TX-840 parent	2	32.0 – 23.2	18 - 20	9.5 – 8.0
TX-DEK-99 parent	2	3.0 – 3.2	35 - 41	10.0 – 6.5

Percent ground cover and white-tailed deer utilization of the field study entries will be analyzed in a separate report. The excavated plant of Ace forage cowpea had a stem height of 140 cm and a root spread of 17 cm (diameter). The excavated plant of Vdek 3-3 had a stem spread of 240 cm (prostrate) and a root spread of 160 cm (diameter). The extreme difference in root system size between Ace and Vdek 3-3 calls for more research on the rooting habit of these hybrid F3 lines and shows the potential for improvement of root traits in cowpea. Future research will include root phenotyping of all available F3 families.

Improvement of Forage Lablab Bean for Texas

G.R. Smith[1] and F.M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: Cowpea (*Vigna unguiculata* Walp) and forage lablab bean (*Lablab purpureus* [L.] Sweet) are productive warm-season legumes and well-adapted to upland soils in East Texas. Both of these legumes produce high nutritive value forage and are also useful as summer cover crops. Cattle graze lablab more readily than cowpea but both cowpea and lablab are useful as supplemental plantings for white-tailed deer.

Introduction: Objectives in our summer legume breeding program are to continue improvement of forage yield, seed yield and pest resistance and to concurrently develop lines with different dates of maturity. Variable maturities are necessary for successful seed production in different Texas ecoregions and climatic conditions.

'Rio Verde' lablab bean was developed by Texas A&M AgriLife Research, Overton and released in 2006. Rio Verde produces high forage yields and will produce seed by late Oct. in NE Texas. Rio Verde was noted to be susceptible to anthracnose disease in seed fields near Midland, TX in 2010. Therefore, commercial seed of Rio Verde is unavailable. Our plant breeding program to develop improved, disease resistant cultivars of forage lablab bean will be outlined.

Materials and Methods: In 2008 and 2009, the Texas Plant Disease Diagnostic Laboratory identified fungal anthracnose (*Colletotrichum* spp.) as the causal organism in the loss of stands of irrigated Rio Verde seed fields near Mason and Andrews, TX. In mid-July 2010, 45 lablab breeding lines were planted at the Andrews location as an initial disease screening nursery. In Oct. 2010 about 80 acres of Rio Verde seed production at Andrews were a total loss due to an epiphytotic of anthracnose. On Oct. 13, 2010 49 breeding lines were rated for anthracnose disease reaction on a scale of 0 to 9, where 0 = no disease detected and 9 = dead or dying plants. Rio Verde and three breeding lines were scored as most susceptible (disease score = 9) and 17 breeding lines were scored as resistant or highly tolerant (disease score = 0 or 1). Breeding and evaluation has continued to combine anthracnose resistance with small seed size, high forage and seed yield and desirable pod traits.

Results: One anthracnose resistant line originated from a hand cross between two experimental lines that differed in pod type and leaf/stem coloration. Initial field evaluations of individual plants revealed segregation for leaf vein, pod, and stem color with both maroon (M) and green (G) variants noted (2:1, M:G). Progeny tests were conducted in 2023 and 2024 to identify pure lines with no segregation for coloration and pod type. Two generations of greenhouse progeny tests were conducted in 2023 with no success in identification of pure lines.

A third set of individual plants was evaluated in the greenhouse in 2023 using a quantitative rating system that scored the level of maroon color. The color scale used for expression of maroon color was zero, light, medium and strong. The zero rating for maroon color is equal to green (G). The observed ratio of light, medium and strong maroon color expression was 1:2.5:2.5, respectively. Seed was harvested from all plants and designated as B2xx-23.

On May 31, 2024, twenty plants each of four B2xx-23 lines were planted in the greenhouse for evaluation as individual plants. Three elite lines were identified with no segregation for the color expression trait (Table 1. And Fig. 1). Field seed increases for the elite lines are planned for summer 2025. The opportunity to develop a new forage lablab bean cultivar with high seed and forage yield, improved pod traits, and maroon color expression is promising.

Table 1. 2024 Lablab Line Evaluation (May 31, 2024 – Sept. 15, 2024)

LINE	**Color Expression 2023 Rating**	**Color Expression 2024 Rating**	**Segregation**	**Seed Per Plant, g**	**Note**
B263-23	Strong M	Strong M	None	23.7	
B284-23	Strong M	Mixed	7:5, SM:LM		Discard
B287-23	Strong M	Strong M	None	21.2	
B262-23	Light M/G	Light M/G	None	21.6	

Abbreviations: M = maroon color expression; G = none or very little color expression; SM = strong maroon; LM = light maroon.

Figure 1. Maroon color expression in forage lablab bean, line B263-23. Rating = Strong Maroon.

Evaluation of Forage Legumes as Browse for White-tailed Deer

G.R. Smith[1] and F.M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: Forage cowpea (*Vigna unguiculata* [L.] Walp) and forage lablab bean (*Lablab purpureus* [L.] Sweet). are often planted as supplemental browse for white-tailed deer. Research is in progress to develop new cultivars of warm season legumes with rapid ground cover and high acceptance as high protein browse.

Introduction: The interaction of wildlife management and agricultural practices is very important to the Texas economy and landowners. The inclusion of forage legumes in Texas cropping systems will provide high protein supplemental forages for white-tailed deer in seasonal times when native browse is often unavailable or greatly reduced in quantity and/or quality. More information is needed on response of specific warm-season legume cultivars and breeding lines to defoliation by white-tailed deer. The objectives of this study were to determine the rate of ground cover development and the intensity of utilization for cowpea, lablab and mung bean (*Vigna radiata* [L.] R. Wilczek) cultivars and breeding lines when exposed to unrestricted white-tailed deer browse.

Materials and Methods: Six warm-season forage legume entries were planted at the Overton South Farm on June 13, 2024. Entries were as follows: 'Ace', Turbo exp., TX-Xdek exp. and Bobcat exp. forage cowpeas; 'Rio Verde' forage lablab bean; and TX-24 exp. forage mung bean. The entries were planted in 5 ft rows with 10 ft spacing between rows. Entries were arranged in a randomized complete block design with three replications. The soil type at the planting site was a Darco loamy fine sand. Each plot was evaluated at 60, 90 and 120 days post-planting for ground cover and utilization by white-tailed deer. White-tailed deer utilization was confirmed by game camera monitoring. The percentage cover and utilization data were transformed using the inverse sine function, and an ANOVA was performed using the GLM procedure in SAS.

Results: No significant differences among entries were noted for ground cover or white-tailed deer utilization at any evaluation date, but trends were noted (Table 1). Rio Verde lablab never established full ground cover and had only minor utilization at 120 days. Both Ace and Bobcat forage cowpeas established good ground cover early, and both had greater than 70% cover at 120 days. Turbo is an early maturing experimental forage cowpea, and the ground cover of Turbo declined from 66 to 43% over the evaluation period. TX-24 mung bean had 81% ground cover at 60 days and maintained 60% cover at 120 days. TX-Xdek is an experimental forage cowpea derived from a cross using wild type perennial germplasm and has a vining, prostrate growth habit. TX-Xdek had 48% ground cover at 60 days with a consistent increase to 80% at 120 days.

Most white-tailed deer utilization in this experiment occurred between the 90-day and 120-day evaluations. The forage cowpea entries, Ace, Bobcat and TX-Xdek, were all rated at 25% or greater utilization at 120 days. Turbo forage cowpea, Rio Verde lablab and TX-24 mung bean were numerically lower at the 120-day utilization rating. In past experiments, mung bean was utilized less and later in the summer compared to forage cowpea. More studies are needed to determine if these cultivars and breeding lines are different in rate of ground cover establishment or deer preference as supplemental browse.

Table 1. Percent ground cover and white-tailed deer utilization (Util) of six warm-season legumes in 2024 at Overton, TX.

	60 Day Post Planting		**90 Day Post Planting**		**120 Day Post Planting**	
Entry	**Cover**	**Util**	**Cover**	**Util**	**Cover**	**Util**
Ace	66 a[2]	0	76 a	4 a	71 a	25 a
Turbo	66 a	0	48 a	2 a	43 a	16 a
Bobcat	63 a	0	55 a	5 a	85 a	34 a
TX-24 Mung	81 a	0	88 a	0 a	60 a	16 a
TX-Xdek	48 a	0	70 a	0 a	80 a	27 a
Rio Verde	41 a	0	43 a	0 a	40 a	14 a

[2] Numbers followed by the same letter within a column are not different according to Fishers Protected LSD (0.05).

Status of soil pH, nitrate-nitrogen, phosphorus, and potassium in overseeded ryegrass or clover bermudagrass pastures after 33 years of stocking

F.M. Rouquette, Jr.[1], K.L. Turner[1], K.D. Norman[1], M.L. Silveira[2], and G.R. Smith[1]
[1] Texas A&M AgriLife Research, Texas A&M Agricultural Research and Extension Center, Overton, TX.
[2] University of Florida, Range Cattle Research and Education Center, Ona, FL.

Application: Fertilization of bermudagrass in the Pineywoods vegetation region of Texas has been used to increase dry matter production in hay meadows and pastures.

Introduction: The primary objectives of this project were to document the changes in soil fertility nutrients in overseeded bermudagrass pastures during 33 years under grazing conditions.

Materials and Methods: 'Coastal' and common bermudagrass (BG) were established in different sized pastures at the Overton Center in 1968. Three different stocking rates of each BG were initiated in 1969 using cow-calf pairs. From 1969 through 1984, annual fertilization was 200-44-83 (N-P-K) with split applications of N. The BG pastures were grazed as pure stands through 1974. In fall 1974, all pastures were overseeded with mixtures of annual ryegrass plus clover and stocked starting in Feb-Mar to Oct each year through 1984. In fall 1984, all pastures were subdivided with one half overseeded with ryegrass + N fertilizer (RYG + N) and the other half overseeded with clover without N fertilizer (CLV + No N). From spring 1985 to 2018, these overseeding and stocking rate regimens have been in place. Fertilization with N has been split-applied with a single application of P and K (Table 1).

Table 1. Annual fertilizer[1,2] applications on bermudagrass pastures during various periods.

		Ryegrass + N			Clover + No N		
Period	**No Years**	**N**	**P**	**K**	**N**	**P**	**K**
			lb/ac			lb/ac	
1985-1989	5	410	0	0	0	0	85
1990-1997	8	250	0	0	0	0	85
1998-2004[3]	7	303	46	85	0	46	85
2005-2018[4]	14	278	30	54	0	30	54

[1] Fertilizer P_2O_5 x 0.46 = P; K_2O x 0.83=K.
[2] Limestone was applied to all pastures at 6 t/ac from 1968-1984; 8 t/ac from 1985-2005; 3.5 t/ac from 2006-2013.
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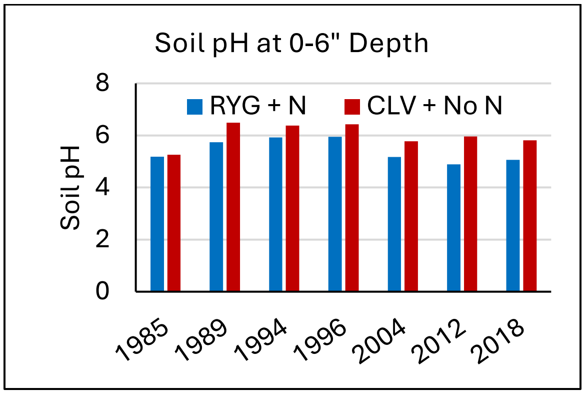

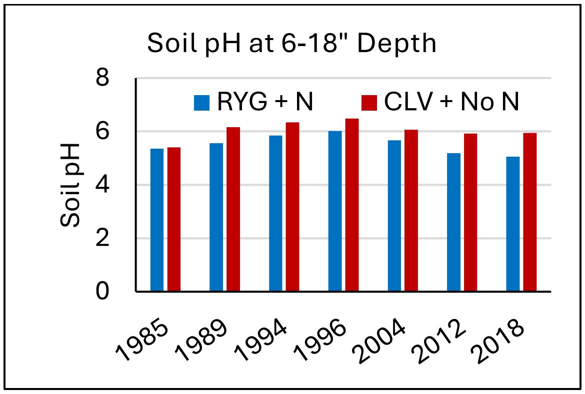

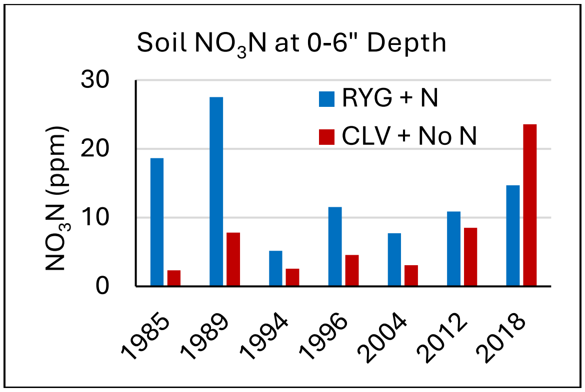

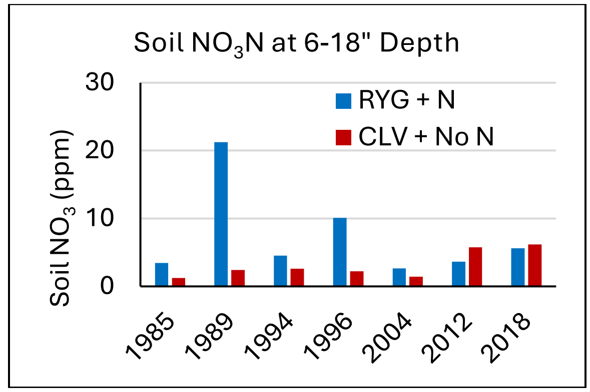

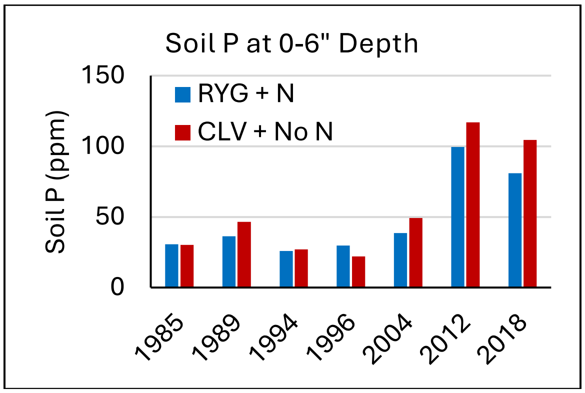

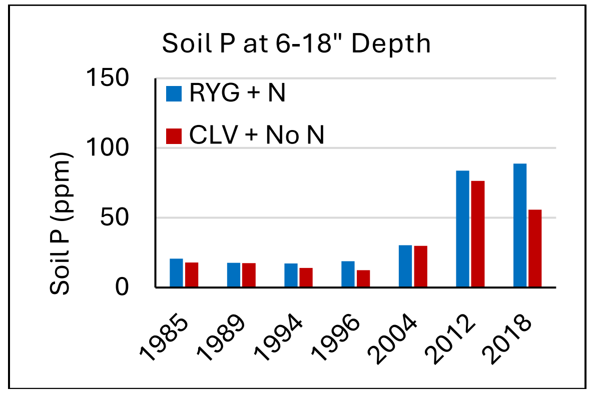

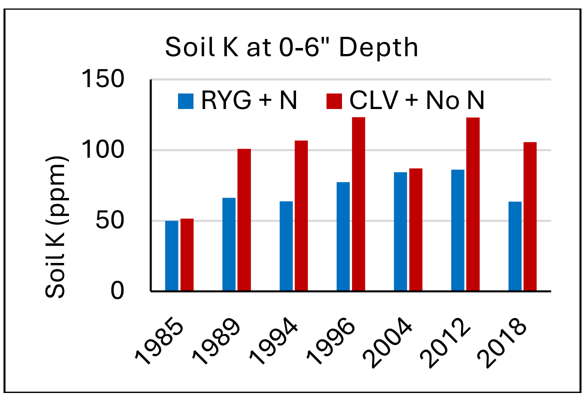

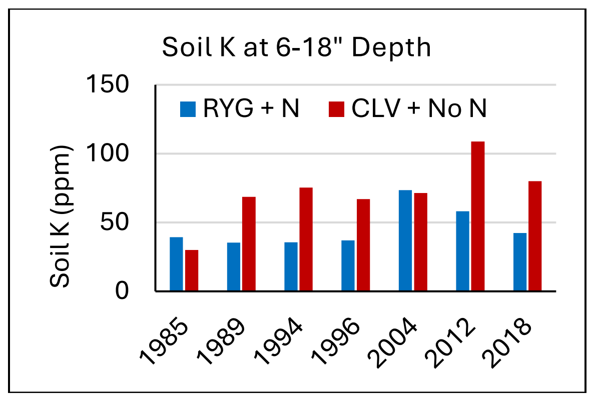

***Results*:**
Soil pH at 0-6" and 6-18" depths documented the effects of N fertilization, with lower soil pH occurring on these pastures with added N compared to those overseeded with clover and without added N. At the 0-6" and 6-18" depths, levels of soil nitrate-N were greater on the ryegrass + N pastures. Soil P increased from 2012 to 2018 at both 0-6" and 6-18" depths, which may be attributed to limestone additions in 2007 and 2013. With continued annual applications of K fertilizer from 1968, soil K was greater on non-N fertilized pastures at both 0-6" and 6-18" depths.

***Conclusions and Implications*:**
Nitrogen fertilization on sandy, low fertility soils is required for increased production of hay and for stocking rates. Since N fertilization increases soil acidity, routine soil sampling is recommended for appropriate limestone applications. Soil data in pastures receiving no N fertilizer provided positive documentation of effective nutrient cycling under stocking.

Soil pH, nitrate-nitrogen, phosphorus, and potassium in Coastal and common bermudagrass pastures after 48 years of stocking

F.M. Rouquette, Jr.[1], K.L. Turner[1], K.D. Norman[1], M.L. Silveira[2], and G.R. Smith[1]
[1] Texas A&M AgriLife Research, Texas A&M Agricultural Research and Extension Center, Overton, TX.
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Table 1. Annual fertilizer[1,2] applications on bermudagrass pastures during various periods.

Period	No Years	Ryegrass + N N	P	K	Clover + No N N	P	K
			lb/ac			lb/ac	
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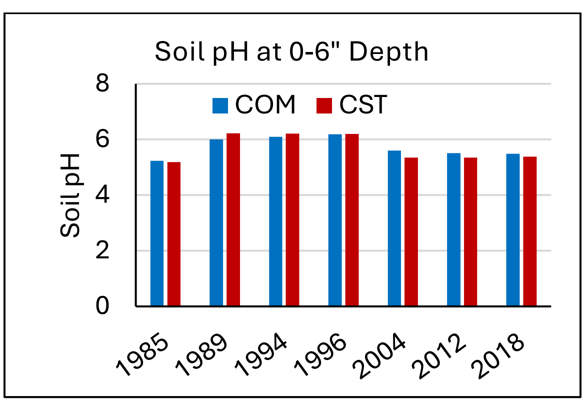

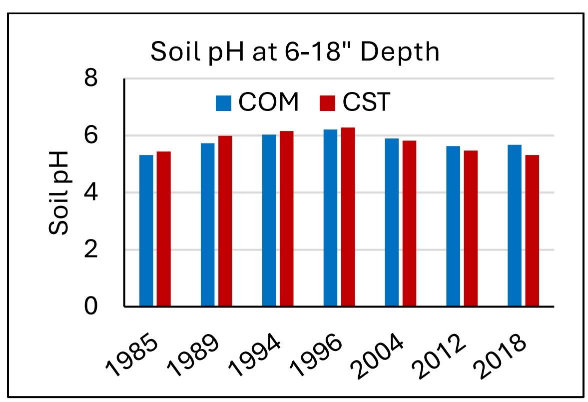

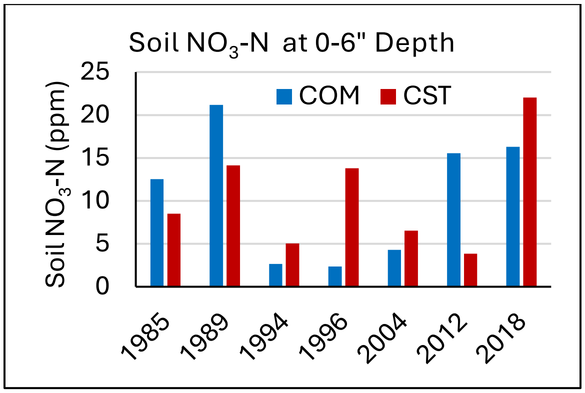

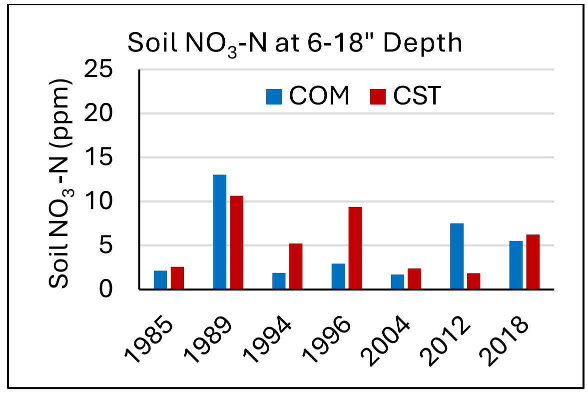

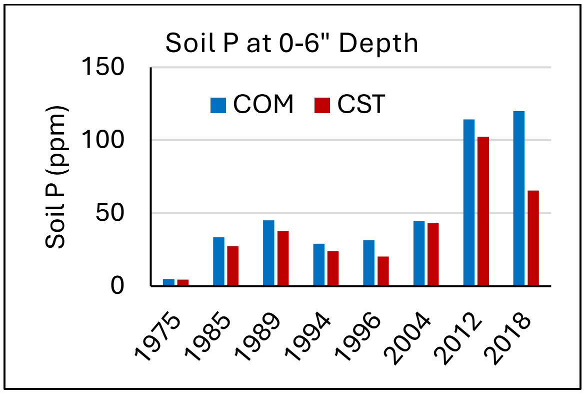

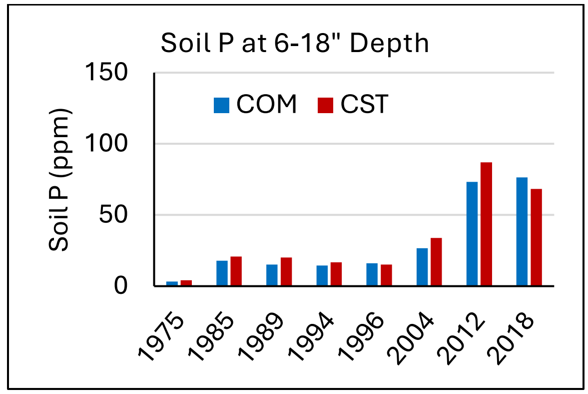

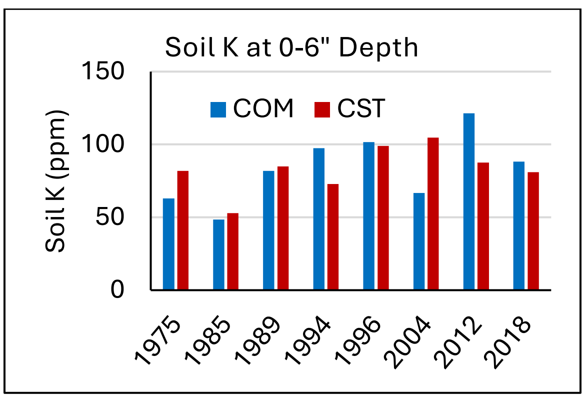

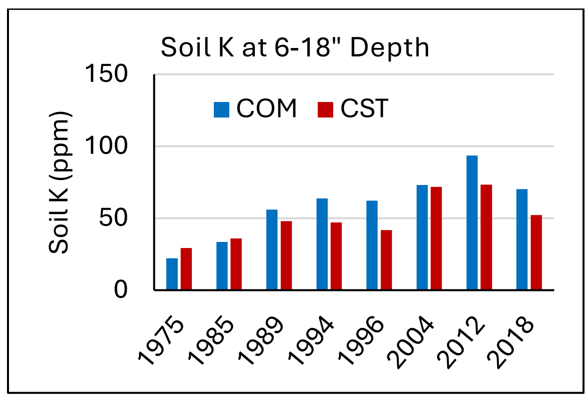

***Results*:**

Soil pH at 0-6” and 6-18” was similar for Coastal and common BG pastures throughout the stocking period. Soil nitrate-N levels at 0-6” and 6-18” depths showed no distinct patterns between bermudagrasses from 1985 – 2018. With a decrease in N rates from 1990 – 1997, there was a decline in soil nitrate-N levels. Although soil nitrate-N levels increased in 2018, the amount available in pastures was very low at approximately 30-40 lb/ac at 0-6” and less than 20 lb/ac at 6-18” soil depths. Soil P and K were greater at the 0-6” depth in common vs Coastal pastures, which may have been a result of reduced dry matter production of common BG.

***Conclusions and Implications*:**

Levels of soil nutrients in common and Coastal BG pastures did not show a build up after 48 years of fertilization and stocking.

Stocking rate effects on soil pH, nitrate-nitrogen, phosphorus, and potassium in bermudagrass pastures after 48 years of stocking

F.M. Rouquette, Jr.[1], K.L. Turner[1], K.D. Norman[1], M.L. Silveira[2], and G.R. Smith[1]
[1] Texas A&M AgriLife Research, Texas A&M Agricultural Research and Extension Center, Overton, TX.
[2] University of Florida, Range Cattle Research and Education Center, Ona, FL.

Application: Bermudagrass pastures are subjected to an array of stocking rates based on design or default by management.

Introduction: The objectives of this study were to examine long term changes in soil nutrient status of different stocking rates on bermudagrass pastures.

Materials and Methods: 'Coastal' and common bermudagrass (BG) were established in different sized pastures at the Overton Center in 1968. Three different stocking rates of each BG were initiated in 1969 using cow-calf pairs. From 1969 through 1984, annual fertilization was 200-44-83 (N-P-K) with split applications of N. The BG pastures were grazed as pure stands through 1974. In fall 1974, all pastures were overseeded with mixtures of annual ryegrass plus clover and stocked starting in Feb-Mar to Oct each year through 1984. In fall 1984, all pastures were subdivided with one half overseeded with ryegrass + N fertilizer and the other half overseeded with clover without N fertilizer (Table 1). From spring 1985 to 2018, stocking rates from mid-February to late September averaged 0.95, 1.5, and 2.2 cow-calf pair/ac (1 pair = 1500 lb) for common BG, and 1.1, 1.7, and 2.8 cow-calf pair/ac for Coastal BG, respectively for low, medium, and high stocked pastures.

Table 1. Annual fertilizer[1,2] applications on bermudagrass pastures during various periods.

		Ryegrass + N			Clover + No N		
Period	**No Years**	**N**	**P**	**K**	**N**	**P**	**K**
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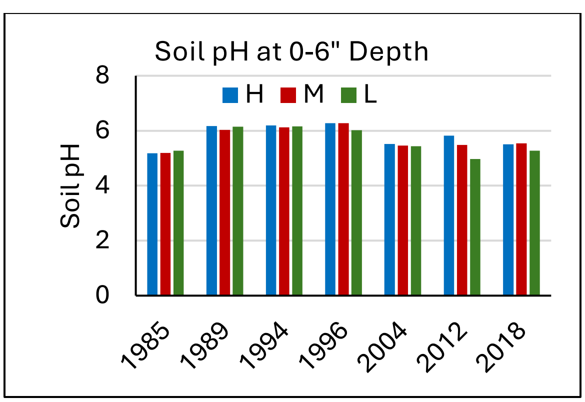

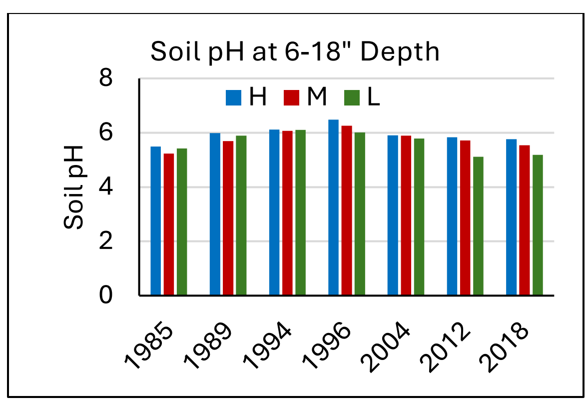

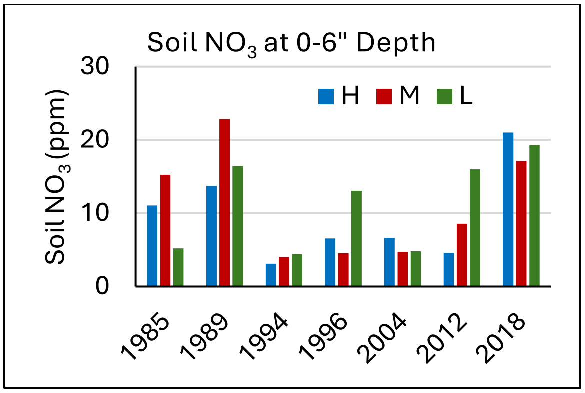

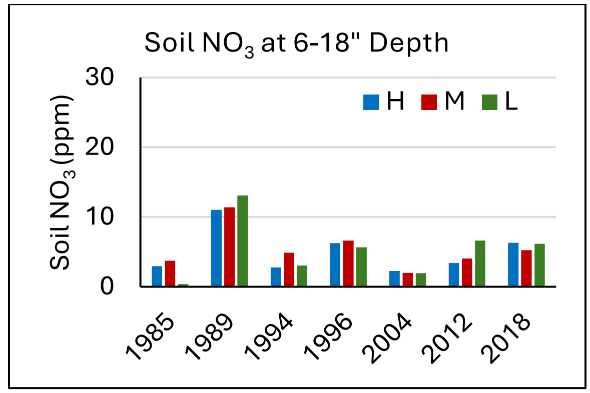

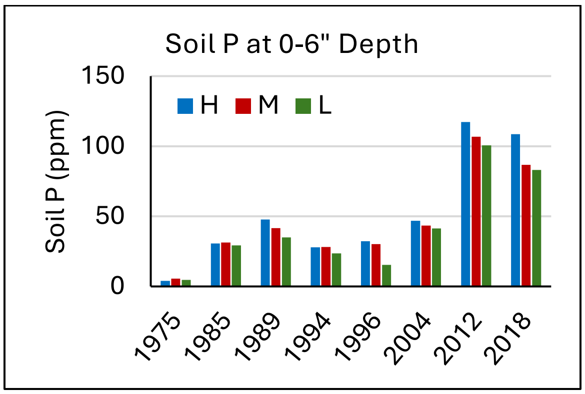

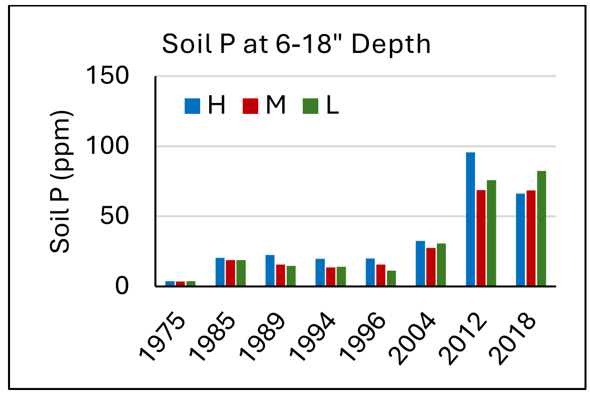

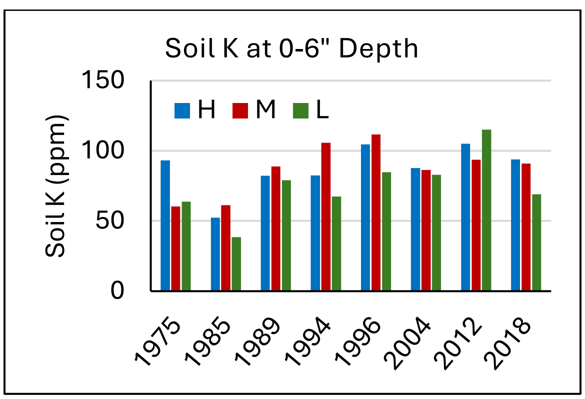

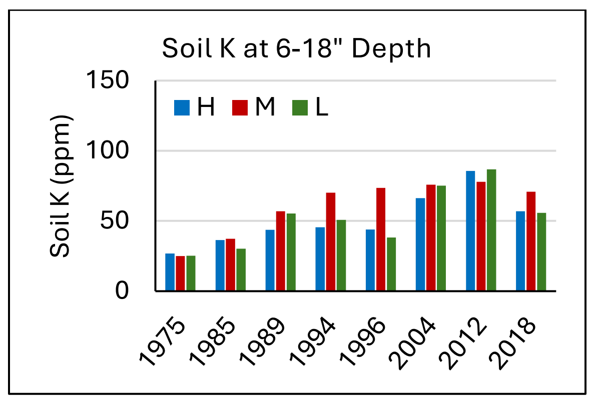

***Results*:**
Soil pH was not affected by stocking rates of about 1 cow-calf pair/ac to more than 2.5 cow-calf pair/ac. At the 0-6" depth, there were no definitive effects of stocking rate on soil nitrate-N, P, or K levels; however, all soil nutrient levels were greater at 0-6" compared to 6-18" depth.

***Conclusions and Implications*:**
Soil analysis of stocking rates on BG pastures indicated effective and efficient nutrient cycling under grazing conditions.

Soil carbon, nitrogen, organic matter, and related nutrients in overseeded ryegrass or clover on bermudagrass pastures after 33 years of stocking

F.M. Rouquette, Jr.[1], K.L. Turner[1], K.D. Norman[1], M.L. Silveira[2], and G.R. Smith[1]
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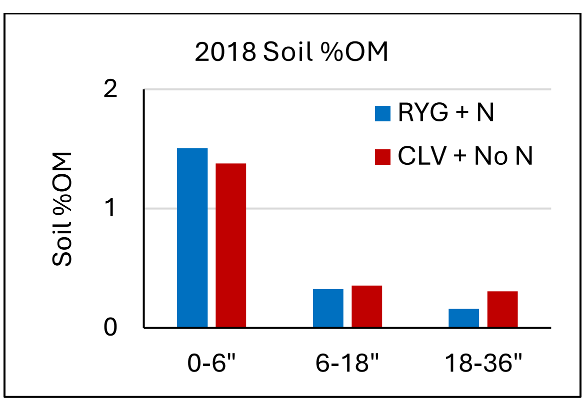

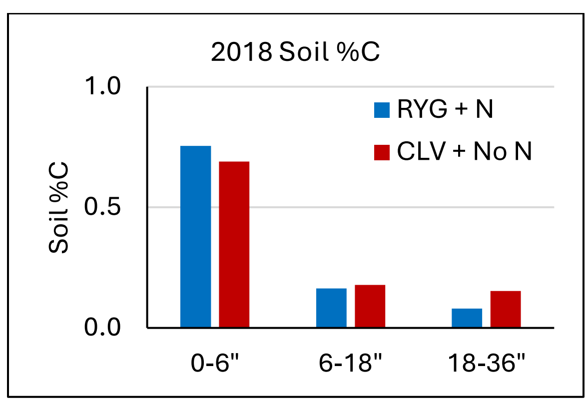

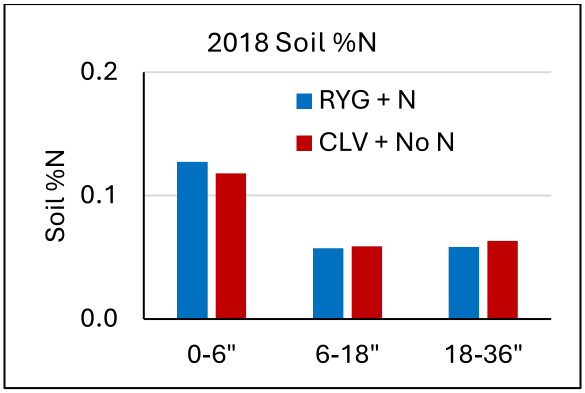

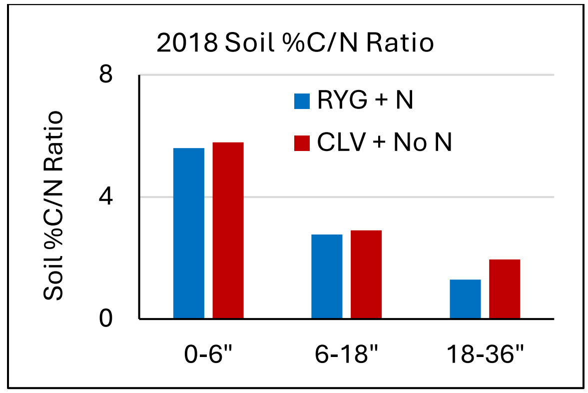

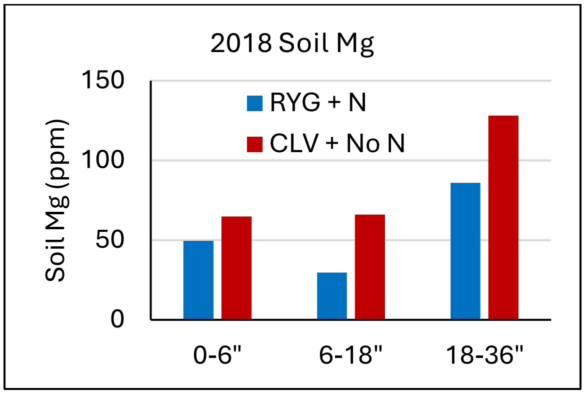

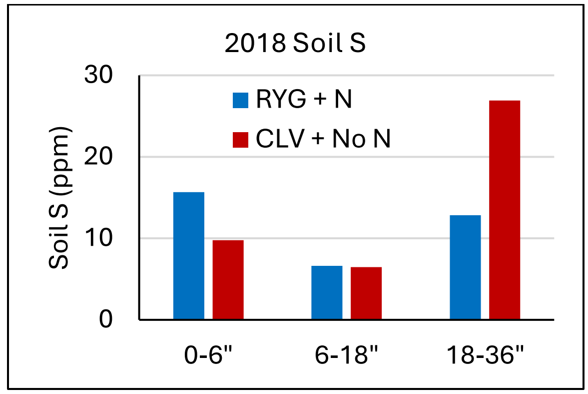

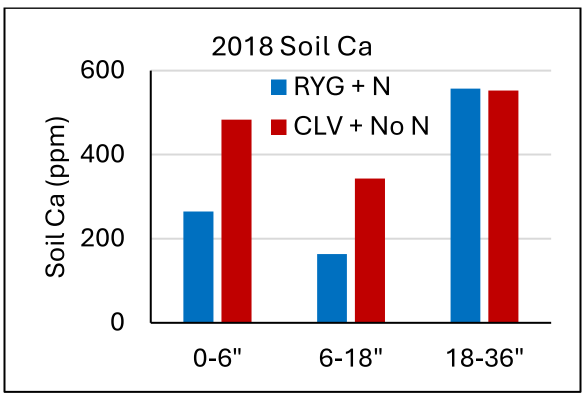

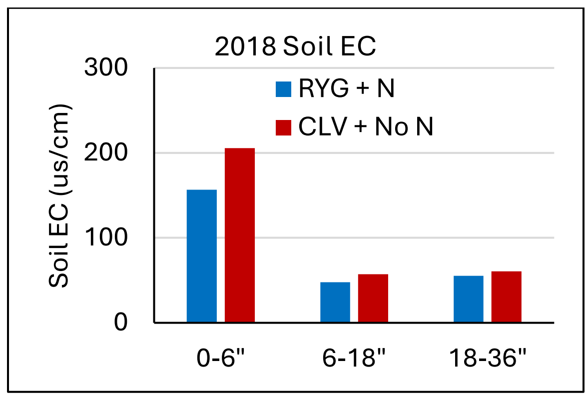

***Results*:**
Soil percent organic matter (OM), carbon (C), and nitrogen (N) were greater in N-fertilized pastures at 0-6” depth. The soil %C:N ratio in N-fertilized vs non-N-fertilized pastures was similar. Soil magnesium (Mg), sulfur (S), and calcium (Ca) showed accumulation at the 18-36” depth with higher levels of Mg and S in the non-N-fertilized pastures. Soil electrical conductivity (EC), a measure of soil water-salt content, is an indicator of soil health and exhibited higher status in non-N-fertilized pastures at 0-6” depth.

***Conclusions and Implications*:**
After 33 years of pastures receiving N vs no N fertilizer, soil percent organic matter remained low in these sandy, acid soils. The levels of percent soil C and N are indicative of stabilized C and N sequestration.

Status of soil carbon, nitrogen, organic matter and related nutrients in Coastal and common bermudagrass pastures after 48 years of stocking

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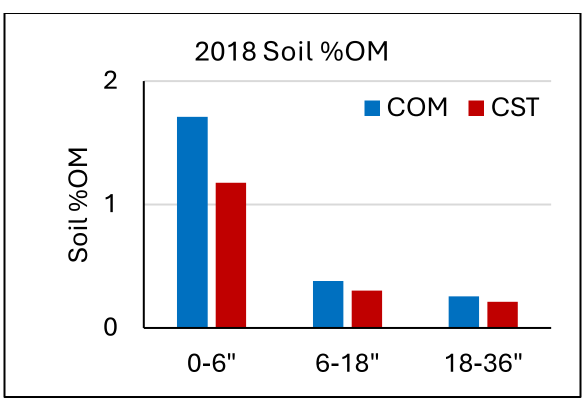
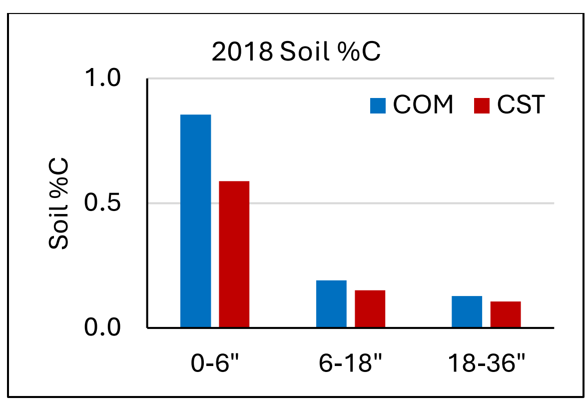
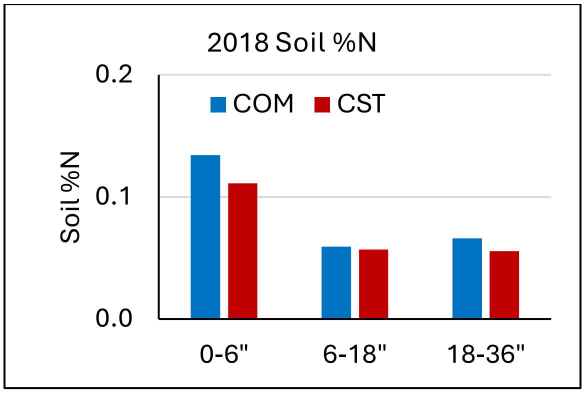
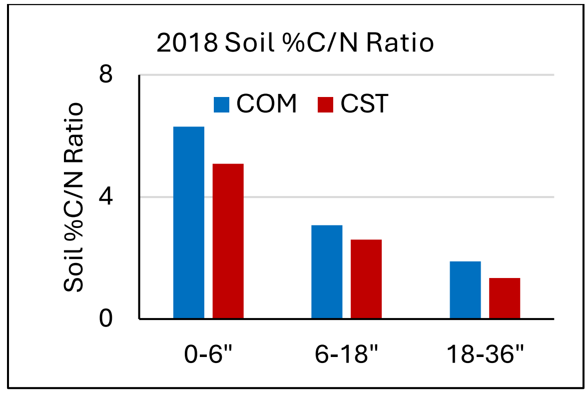
1990-1997	8	250	0	0	0	0	85
1998-2004[3]	7	303	46	85	0	46	85
2005-2018[4]	14	278	30	54	0	30	54

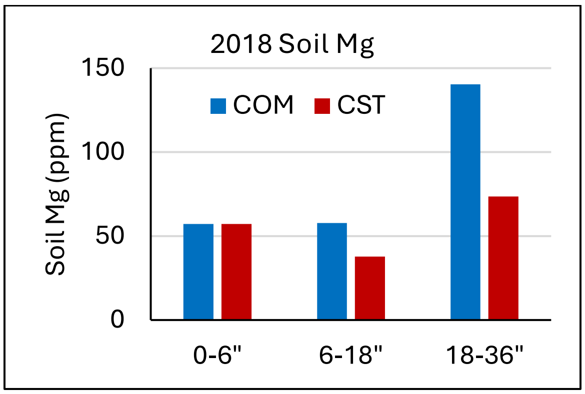
[1] Fertilizer P_2O_5 x 0.46 = P; K_2O x 0.83=K.
[2] Limestone was applied to all pastures at 6 t/ac from 1968-1984; 8 t/ac from 1985-2005; 3.5 t/ac from 2006-2013.
[3] From 1998-2004, all pastures received S, Mg, and B at 50, 27, and 1.0 lb/ac, respectively.
[4] From 2005-2018, all pastures received S, Mg, and B at 28, 15, and 0.7 lb/ac, respectively.

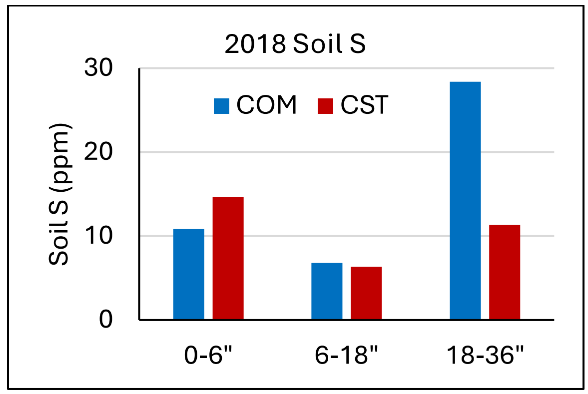


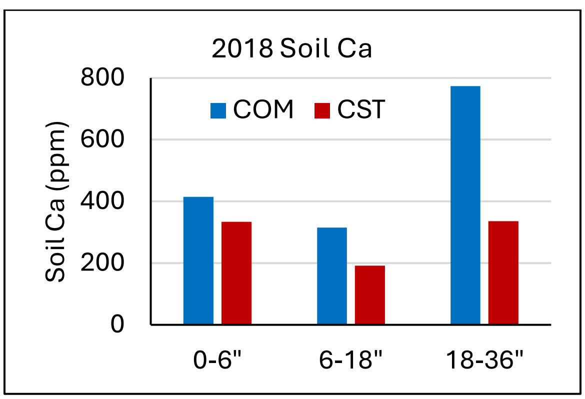


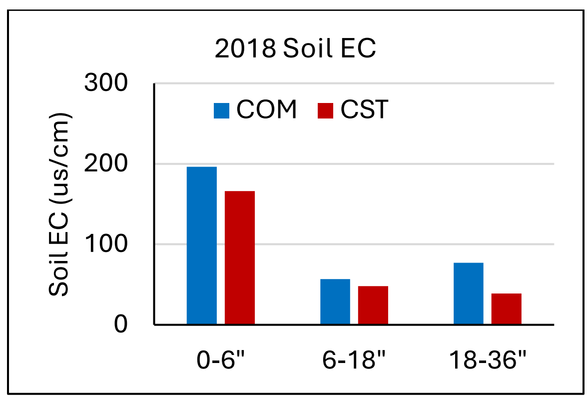












***Results*:**
At the 0-6" depth, percent soil organic matter (OM) carbon (C), and nitrogen (N) were greater in common compared to Coastal BG. These analyses showed a greater C:N ratio for common BG pastures. Common BG pastures had greater soil magnesium (Mg), sulfur (S), and calcium (Ca) at the 18-36" depths. This may be indicative of the greater soil depth of Coastal BG rooting dynamics. There was slightly higher soil electrical conductivity (EC) in common BG with higher levels in both bermudagrasses at 0-6" depth.

***Conclusions and Implications*:**
The slightly greater % soil organic matter, %C, %N, and %C:N ratio for common BG pastures at 0-6" depth, but much less for both bermudagrasses at > 6" depth, indicates the need for fertilization for enhanced productivity.

Effects of stocking rate on soil carbon, nitrogen, organic matter and related nutrients on bermudagrass pastures after 48 years of stocking

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Application: Bermudagrass pastures are subjected to an array of stocking rates based on design or default by management.

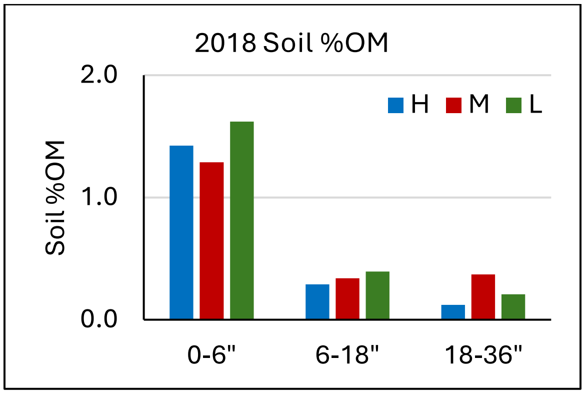
Introduction: The objectives of this study were to examine long term changes in soil nutrient status of different stocking rates on bermudagrass pastures.

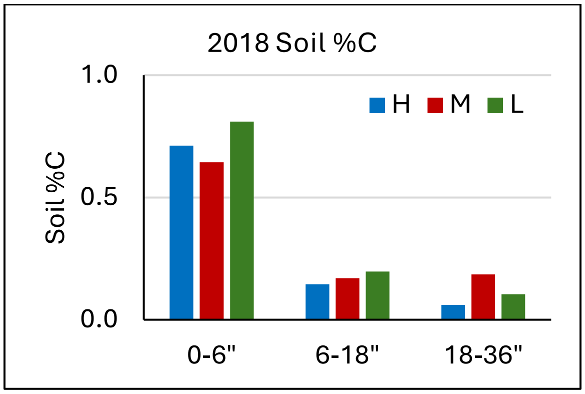
Materials and Methods: 'Coastal' and common bermudagrass (BG) were established in different sized pastures at the Overton Center in 1968. Three different stocking rates of each BG were initiated in 1969 using cow-calf pairs. From 1969 through 1984, annual fertilization was 200-44-83 (N-P-K) with split applications of N. The BG pastures were grazed as pure stands through 1974. In fall 1974, all pastures were overseeded with mixtures of annual ryegrass plus clover and stocked starting in Feb-Mar to Oct each year through 1984. In fall 1984, all pastures were subdivided with one half overseeded with ryegrass + N fertilizer and the other half overseeded with clover without N fertilizer (Table 1). From spring 1985 to 2018, stocking rates from mid-February to late September averaged 0.95, 1.5, and 2.2 cow-calf pair/ac (1 pair = 1500 lb) for common BG, and 1.1, 1.7, and 2.8 cow-calf pair/ac for Coastal BG, respectively for low, medium, and high stocked pastures.

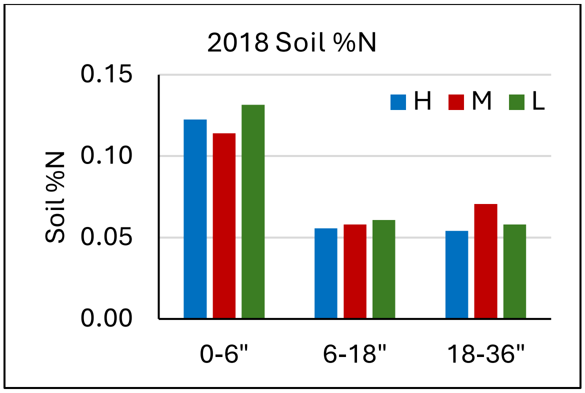
Table 1. Annual fertilizer[1,2] applications on bermudagrass pastures during various periods.

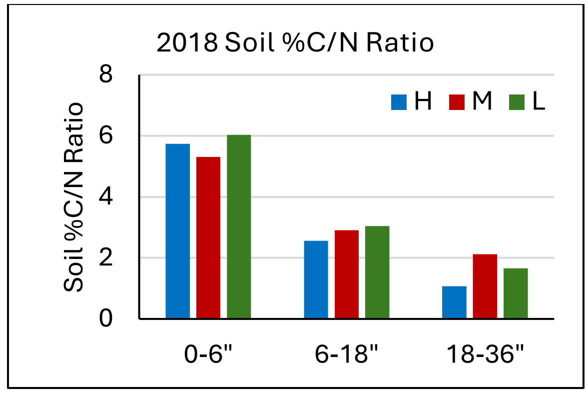
		Ryegrass + N			Clover + No N		
Period	**No Years**	**N**	**P**	**K**	**N**	**P**	**K**
			lb/ac			lb/ac	
1985-1989	5	410	0	0	0	0	85
1990-1997	8	250	0	0	0	0	85
1998-2004[3]	7	303	46	85	0	46	85
2005-2018[4]	14	278	30	54	0	30	54

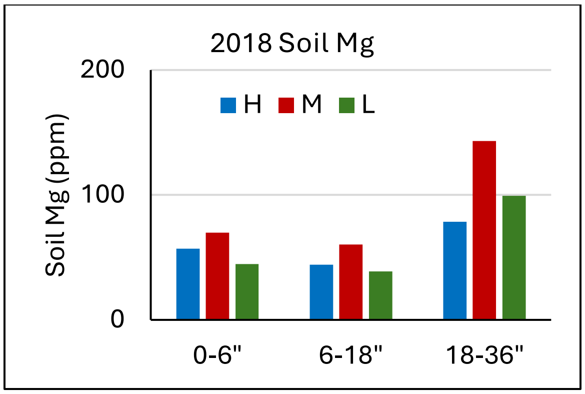
[1] Fertilizer P_2O_5 x 0.46 = P; K_2O x 0.83=K.
[2] Limestone was applied to all pastures at 6 t/ac from 1968-1984; 8 t/ac from 1985-2005; 3.5 t/ac from 2006-2013.
[3] From 1998-2004, all pastures received S, Mg, and B at 50, 27, and 1.0 lb/ac, respectively.
[4] From 2005-2018, all pastures received S, Mg, and B at 28, 15, and 0.7 lb/ac, respectively.

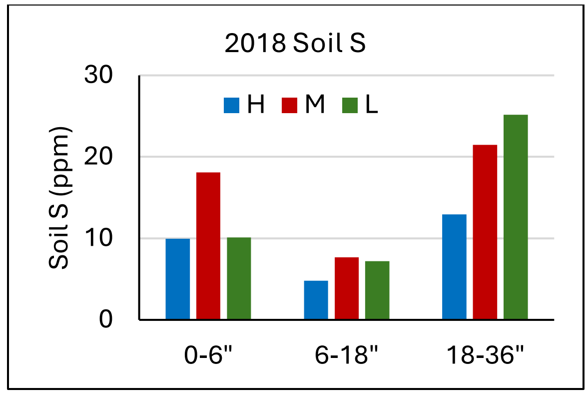


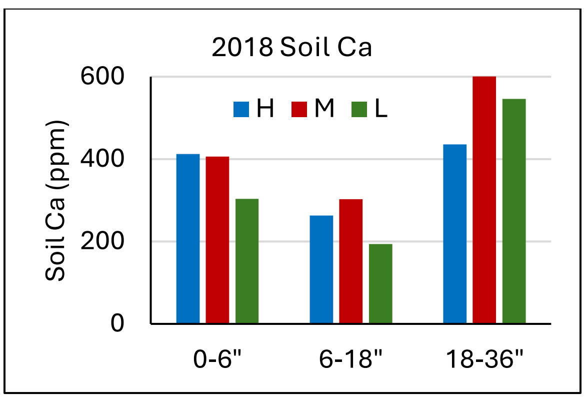


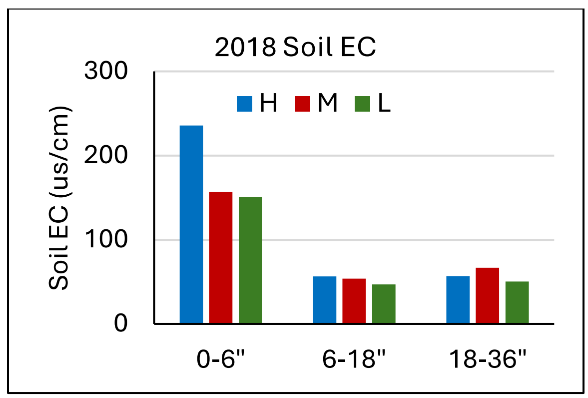












***Results*:**
There were no substantial differences in soil %OM, %C, %N, or %C:N ratio due to stocking rate of pastures; however, much greater concentrations of all these nutrients were at the 0-6” depth. Soil electrical conductivity (EC) was greater on high stocked pastures at the 0-6” depth. Soil Mg, S, and Ca were greater in concentration at the 18-36” depth.

***Conclusions and Implications*:**
Stocking rates ranging from about 1 cow-calf pair/ac to more than 2.5 pair/ac on sandy acid soils had limited to no effect on soil nutrient status at depths greater than 6”. This provided documentation for no hazardous buildup of nutrients after 48 years of stocking.

Level of whole corn or corn gluten on performance of F-1 (HxB) steers stocked on Tifton 85 bermudagrass and subsequent feedlot and carcass traits

F.M. Rouquette, Jr. [1], K.L. Turner[1], K.D. Norman[1], and C.R. Long[1]
[1]Texas A&M AgriLife Research, Overton, TX, USA

Application: Supplementation on Tifton 85 bermudagrass of F-1 (Hereford x Brahman) steers and subsequent feedlot-carcass traits offers management strategy options for continuous ownership through the stocker or feeder stage.

Introduction: The objectives of this 2-year study were to document the effects of the level of whole corn (Year 1) and corn gluten (Year 2) on performance of F-1 (HxB) steers on Tifton 85 bermudagrass, and subsequent performance in feedlot and carcass traits.

Materials and Methods: In each of 2 consecutive years, 2020 and 2021, F-1 (HxB) steers (1-steer = 600 lb BW) were stocked at 4.3 hd/ac on Tifton 85 bermudagrass from June 2 to Oct 7 (2020) and from July 21 to Oct 20 (2021). Pastures received 300 lb/ac 21-8-17 (63-24-51; N-P_2O_5-K_2O) for hay harvest followed by 3 applications of 68-0-0 for a total pasture-grazing allotment of 219-0-0 in 2020. In 2021, 2 applications of 68-0-0 were applied for a total pasture-grazing allotment of 136-0-0.

In Year 1, steers received daily levels of group-fed 0, 0.3%, and 0.6% BW whole corn. In Year 2, steers received daily levels of group-fed 0, 0.4%, and 0.8% BW corn gluten. Steers were weighed at initiation of stocking, at 28-day intervals, and at termination. Body condition scores (BCS) were taken at initiation and termination. At termination of stocking in Year 1 steers were transported to a Central Texas feedlot and to an abattoir in South Texas at finish. In Year 2, feedlot and abattoir changes were required, and steers were shipped to a West Texas feedyard and nearby abattoir. Carcass traits were taken by skilled, trained meat scientists.

Results: In Year 1, F-1 steers showed an increase in ADG and body weight with daily supplementation of 0.6% whole corn (Table 1). In Year 2, steers had greater ADG, BCS, and gain per acre from daily supplement of 0.8% corn gluten pellets (Table 2). With feedlots located about 400 miles apart in Year 1 and Year 2, days on feed were different to reach the desired backfat end point of at least 0.5” (Table 3). Although ADG was much greater at Feedlot 2, carcass traits did not differ between feedlots/years or supplement treatments, except for marbling and quality grade.

Conclusions and Implications: Supplementation of whole corn and corn gluten promoted ADG of F-1 steers stocked at more than 4 hd/ac on Tifton 85 bermudagrass pastures. Level of either energy-or protein-based supplementation on pasture had small to no effects on feedlot performance or carcass traits. The Quality Grades of 700 indicated USDA Choice. With 2025 cost of N at approximately $.70 per lb, 150 lb N/ac fertilizer cost is about $100 to $120/ac. With about 1000 lb steer gain per acre, the N fertilizer cost per lb gain ranged from $0.10 to $0.15/lb gain.

Table 1. Level of whole corn on performance of F-1 (HxB) steers stocked on Tifton 85 bermudagrass (Year 1).

Pasture Performance	Whole Corn[1] (% BW) 0	0.3	0.6
ADG (lb/d)	2.18 b[2]	2.42 ab	2.57 a
Off Pasture Wt (lb)	874 a	893 a	906 a
Off Pasture BCS	5.5 a	5.6 a	5.8 a
Gain / Ac[3] (lb)	997 a	1049 a	1155 a

[1] Daily level of whole corn group-fed as % BW (body weight) of the group.
[2] Numbers in a row followed by a different letter differ at $P < 0.05$.
[3] Body weight of 1 stocker = 600 lb.

Table 2. Level of whole corn on performance of F-1 (HxB) steers stocked on Tifton 85 bermudagrass (Year 2).

Pasture Performance	Corn Gluten[1] (% BW) 0	0.4	0.8
ADG (lb/d)	1.93 b[2]	2.24 b	3.21 a
Off Pasture Wt (lb)	842 b	869 ab	942 a
Off Pasture BCS	5.0 b	5.3 b	6.0 a
Gain / Ac[3] (lb)	925 b	1005 b	1348 a

[1] Daily level of corn gluten pellets group-fed as % BW (body weight) of the group.
[2] Numbers in a row followed by a different letter differ at $P < 0.001$.
[3] Body weight of 1 stocker = 600 lb.

Table 3. Feedlot performance and carcass traits for F-1 (HxB) steers receiving supplement on pasture and finished at two different feedlots.

	Feedlot-Year 1[1] Whole Corn (%BW)			Feedlot-Year 2[2] Corn Gluten (%BW)		
Carcass Trait	0	.3	.6	0	.4	.8
Days on Feed	241	241	241	181	181	181
Off-Feedlot Wt (lb)	1549 a	1612 a	1597 a	1503 a	1544 a	1583 a
Feedlot ADG (lb/d)	2.83 a	3.10 a	2.81 a	3.93 a	4.02 a	3.85 a
Hot Carcass Wt (lb)	928 a	966 a	957 a	899 a	924 a	947 a
Backfat (in)	0.67 a	0.75 a	0.65 a	0.60 a	0.67 a	0.68 a
Rib Eye Area, (in^2)	13.73 a	13.79 a	13.49 a	13.83 a	13.94 a	14.00 a
Predicted Yield Grade	3.91 a	4.12 a	3.67 a	3.40 a	3.63 a	3.69 a
Marbling Score	458 a[3]	511 a	429 a	416 b	489 a	423 b
Quality Grade	717 a	737 a	710 a	707 b	731 a	709 b

[1] Feedlot and Abattoir located in South Texas
[2] Feedlot and Abattoir located in West Texas
[3] Numbers in a row within a Feedlot-Year followed by a different letter differ at $P < 0.01$.

Level of corn-ration supplement and stocking rate on stocker performance from rye-ryegrass pasture and subsequent feedlot and carcass traits

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Application: Gain per animal and gain per acre of stockers on winter annual grass pastures provides information on management strategies for continuous ownership to harvest.

Introduction: Our objectives were to determine the effects of three levels of supplement and three stocking rates on gain per animal, gain per acre, and feedlot-carcass attributes.

Materials & Methods: 'Maton' rye at 100 lb/ac and 'TAM-90' annual ryegrass at 25 lb/ac were sod-seeded into bermudagrass in early October. Replicate pastures (n=18) were stocked from December 20 to May 17 at fixed stocking rates of 1.5, 2.1, and 3.0 hd/acre of 550-lb steers and heifers on the 3x3 experiment. The stockers were Simmental-sired from Angus x Brahman (F-1) dams. Corn-ration supplement was group-fed daily at 0, 0.4% BW, and 0.8% BW.
The corn-based ration consisted of 95.6% cracked corn, 2.5% dried molasses, 1.25% salt, 0.65% dicalcium phosphate, and Rumensin 80 at 0.0625% for 0.4% BW and 0.031% for the 0.8% BW to supply 150 mg/hd/da. At termination of stocking, cattle were shipped 425 miles to a commercial feedlot in South Texas. When feedlot cattle reached visual assessment of 0.5 inches backfat, they were transported 40 miles to an abattoir for harvest and carcass traits.

Results: On non-supplemented pastures, stocker ADG was affected ($P < 0.05$) by each stocking rate of low (1.5 hd/ac) at 2.80 lb/da, medium (2.1 hd/ac) at 2.21 lb/da, and high (3.0 hd/ac) at 1.12 lb/da (Table1). For both supplementation levels of 0.4% BW and 0.8% BW daily, ADG was similar at about 3 lb/da from cattle on low and medium stocked pastures. As stocking rate increased from 1.5 to 3.0 hd/da, ADG decreased ($P < 0.05$) by nearly 1 lb/hd/da. The efficiency of supplementation increased with increasing stocking rate, with cattle receiving 0.4% BW and on high stocking rate having the most efficient supplement:extra gain ratio of 3.9:1, and cattle receiving 0.8% BW and on low stocking rate having the least efficient ratio of 17:1.
High stocked cattle had higher feedlot ADG, greater dressing percent, and were on feed for a longer period of time (Table 3). All carcass traits were similar across stocking rates except Yield Grade, where low stocked cattle were graded lower (2.32) than high stocked (2.85). Steers were heavier off feed, had greater ADG, less days on feed, greater hot carcass weight, and larger ribeye area than heifers.

Conclusions and Implications: Low to moderate stocked rye + ryegrass pastures can result in daily gains of 2.2 to 2.8 lb. With daily supplement of an energy-based ration, ADG may range from 3.0 to 3.25 lb/day. Gain per acre can range from 650 to 700 lb/ac with non-supplement to 900 to 1000 lb/ac with 0.4% to 0.8% BW supplement. The supplement:extra gain efficiency was best on high stocked pastures.

Table 1. Effect of a corn ration supplement on stocker gains on rye + ryegrass pastures at three stocking rates.

	Daily Supplement[2] (%BW)		
Stocking Rate[1]	**0%**	**0.4%**	**0.8%**
		ADG (lb/da)	
Low	2.80 a[3]	3.11 a	3.24 a
Medium	2.21 b	2.86 a	3.11 a
High	1.12 c	1.93 b	2.10 b

[1] Stocking rates based on 550 lb BW = 1 stocker at initiation of grazing, with Low = 1.5 hd/ac, Medium = 2.1 hd/ac, High = 3.0 hd/ac.
[2] Supplement group fed at % body weight (BW) daily was a cracked corn ration containing Rumensin 80.
[3] Daily gains followed by a different letter in a supplement column are different at $P < 0.05$.

Table 2. Impact of stocking rate and sex of stockers on rye + ryegrass pastures with three daily levels of a corn ration supplement.

	Stocking Rate[1]		
	Low	**Medium**	**High**
Supplement[2]		ADG (lb/da)	
Pasture Only	2.80 b	2.21 b	1.12 b
0.4% BW CCR	3.13 a	2.86 a	1.93 a
0.8% BW CCR	3.24 a[3]	3.11 a	2.10 a
Sex of Stockers			
Steers	3.26 a	2.94 a	1.88 a
Heifers	2.86 b	2.51 b	1.56 b

[1] Stocking rates based on 550 lb BW = 1 stocker at initiation of grazing, with Low = 1.5 hd/ac, Medium = 2.1 hd/ac, High = 3.0 hd/ac.
[2] Supplement group fed at % body weight (BW) daily was a cracked corn ration (CCR) containing Rumensin 80.
[3] Daily gains followed by a different letter in a supplement column are different at $P < 0.05$.

Table 3. Feedlot and carcass traits of feeder calves previously stocked on rye-ryegrass pastures at three stocking rates with three levels of corn ration supplement

Carcass Trait	Stocking Rate[1]			Feeder Sex	
	Low	**Med**	**High**	**Steer**	**Heifer**
Final Feedlot wt (lb)	1400 a[2]	1390 a	1413 a	1442 a[3]	1360 b
Feedlot ADG, lb/d	3.51 b	3.56 b	3.96 a	3.88 a	3.47 b
Days on Feed	119 c	129 b	157 a	130 b	140 a
HCW, lb	882 a	881 a	912 a	915 a	869 b
Dressing %	63.0 b	63.4 b	64.5 a	63.5 a	63.9 a
Backfat, in	0.43 a	0.47 a	0.52 a	0.44 a	0.51 a
Rib Eye Area, in^2	15.5 a	15.4 a	15.0 a	15.6 a	14.95 b
KPH, %	1.81 b	1.81 b	1.97 a	1.84 a	1.88 a
Marbling	379 a	390 a	393 a	390 a	385 a
Quality Grade	679 a	690 a	693 a	690 a	685 a
Yield Grade	2.32 b	2.48 ab	2.85 a	2.44 a	2.66 a

[1] Stocking rates based on 550 lb BW = 1 stocker at initiation of grazing, with Low = 1.5 hd/ac, Medium = 2.1 hd/ac, High = 3.0 hd/ac.
[2] Numbers followed by a different letter in a row for Stocking Rate are different at $P < 0.05$.
[3] Numbers followed by a different letter in a row for Feeder Sex are different at $P < 0.05$.

Supplemental energy or protein level on stocker gain on rye + ryegrass pasture and effect on feedlot and carcass traits during two years

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[1] Texas A&M AgriLife Research, Overton, Texas, USA

Application: Supplementation of stocker calves on winter annual grass pastures may be used to buffer stocking rate and/or enhance gain per animal for niche marketing or feedlot tenure.

Introduction: The primary objectives of this 2-year study were to document effects of level of an energy or protein-based supplement on pasture and subsequent effects in feedlot and carcass trials.

Materials & Methods: Bermudagrass was sod-seeded each year in mid-October with 100 lb/ac 'Maton Rye' and 30 lb/ac 'TAM-90' ryegrass. Pastures were fertilized in late November, late January, early March and mid-April for a total annual rate of 254-20-43-455 in Year 1 and 205-0-0 in Year 2. Simmental-sired calves with Angus x Brahman (F-1) dams were born in Jan-Feb and weaned in late-September to mid-October. These steers and heifers grazed rye + ryegrass from mid-January to late May each year. Stockers were assigned to replicate pastures of pasture only and daily group fed cracked corn (CRN) at 0.4%, 0.8%, and 1.2% BW per hd/da; and 0.4% and 0.8% BW corn gluten (GLU) pellets. Rye + ryegrass pastures were stocked at 2.5 to 2.8 550-lb stockers per acre which could be classified as a medium stocking rate for these pastures with fertilizer applications. At termination of stocking pastures, cattle were transported 425 miles to a commercial feedlot in South Texas. When feeders reached a visual backfat of 0.5 inches, they were shipped 40 miles to an abattoir for carcass trait evaluations.

Results: The two-year average ADG was slightly higher than previous rye-ryegrass pasture experiments and ranged from 3.19 lb/da for cattle on pasture only to 3.82 lb/da for stockers receiving 1.2% BW CRN daily (Table 1). Stocker ADG was greater from 1.2% BW CRN, 0.8% CRN, and 0.8% BW GLU than the 0.4% BW level of CRN or GLU and pasture only (Table1). Gain per acre followed a similar trend of treatment differences as that of ADG, and ranged from 1160 lb/ac to 1247 lb/ac for 0.8% BW and 1.2% BW supplement, and 921 to 927 lb/ac for pasture only and 0.4% BW supplement. Feedlot ADG was greater for pasture only and lesser for 1.2% BW CRN (Table 2). Carcass traits were similar for all treatments.

Conclusions and Implications: With current demand and prices of stocker cattle, management strategies should consider value of calf at weaning, cost of winter pasture, cost of supplement, and anticipated value at the termination of stocking and at initiation of feeding.

Table 1. Effect of level of daily cracked corn or corn gluten supplement on gain per animal and gain per acre of stockers grazed on rye + ryegrass pasture during a two-year study.

Supplement[1]	**ADG (lb/d)**	**Final BCS**	**Final BW (lb)**	**Gain / Ac[2] (lb/ac)**
1.2% BW CRN	3.82 a[3]	6.2 a	1037 a	1247 a
0.8% BW CRN	3.63 a	6.1 a	1016 a	1135 a
0.8% BW GLU	3.67 a	5.8 ab	1014 ab	1160 a
0.4% BW CRN	3.21 b	5.5 bc	982 ab	927 b
0.4% BW GLU	3.35 b	5.8 ab	982 ab	919 b
Pasture Only	3.19 b	5.3 c	956 b	921 b

[1] Daily supplement group-fed at % bodyweight (BW) included cracked corn (CRN) or corn gluten (GLU).

[2] Body weight of 1 stocker = 550 lb.

[3] Numbers in a column followed by a different letter differ at $P < 0.05$.

Table 2. Two-year feedlot and carcass traits of feeder cattle stocked on rye-ryegrass pastures and receiving daily levels of cracked corn or corn gluten supplement[1].

	Cracked Corn (CRN)[1] %BW			**Corn Gluten (GLU) %BW**		**PAS**
	1.2	**0.8**	**0.4**	**0.8**	**0.4**	
Feedlot Final Wt (lb)	1453 a[2]	1492 a	1505 a	1513 a	1473 a	1466 a
Feedlot ADG (lb/d)	2.82 b	3.16 ab	3.18 ab	3.26 a	3.13 ab	3.37 a
HCW (lb)	913 a	928 a	953 a	939 a	918 a	929 a
Backfat (in)	0.55 a	0.39 a	0.44 a	0.48 a	0.45 a	0.45 a
Rib Eye Area (in^2)	16.41 a	16.96 a	17.02 a	16.15 a	16.30 a	16.93 a
KPH (%)	2.62 a	2.56 a	2.54 a	2.63 a	2.66 a	2.72 a
Marbling	426 a	425 a	455 a	447 a	419 a	432 a
Quality Grade	697 a	693 a	708 a	708 a	698 a	696 a
Yield Grade	2.62 a	2.09 a	2.29 a	2.62 a	2.41 a	2.27 a

[1] Daily supplement group fed at % body weight (BW) included cracked corn (CRN) or corn gluten (GLU)

[2] Different superscripts in a row of treatments following a number are different at $P < 0.05$.

Predicting the daily herbage intake of stockers grazing bermudagrass as influenced by herbage mass and nutritive value

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Application: By incorporating an improved function that accounts for the effects of herbage mass and nutritive value into an herbage intake prediction system, the scientific community and stakeholders can estimate the daily herbage intake of bermudagrass and the resulting daily gain of stockers more accurately.

Introduction: The critical herbage allowance (CHA), defined as the herbage allowance below which herbage intake becomes limiting, is a key variable defining the daily herbage intake of stockers grazing bermudagrass as constrained by herbage mass and nutritive value. This study evaluated a stocker daily gain model containing the CHA function using comprehensive data.

Materials and Methods: The stocker daily gain model with its CHA function (Equation 1) was evaluated, using the observed and model-predicted daily gain values involving 1032 stocker calves in 33 grazing trials conducted at Overton, TX.

$$CHA_d = 11.375 - 0.22TDN_d + 0.001TDN_d{}^2 \quad (1)$$

where the subscript **d** stands for the d-th day of year, and TDN is the bermudagrass total digestible nutrients.

Based on the evaluation results, the CHA function was then improved by incorporating an enhancement factor ***f*** (Equation 2) into the original CHA function.

$$CHA_d = f \times \left(11.375 - 0.22TDN_d + 0.001TDN_d{}^2\right) \quad (2)$$

The f value was derived by running the model with a potential f value and evaluating it using the daily gain data several times iteratively.

Results: Results showed that the daily gain model containing the original CHA function underpredicted ADG considerably (Figure 1), as the function was too restrictive to herbage intake. This issue indicated that the CHA function needed to be less restrictive. After several iterations of model running and testing, we derived 0.75 for f. With the modification of the CHA function, the model performance improved significantly (Figure 2). The modeling efficiency increased by about 31%, the modeling error decreased by about 16%, and the estimated herbage intake increased by about 11% for stockers grazing bermudagrass.

Conclusion: The improved CHA function can be a valuable tool in pasture-animal nutrition modeling for more accurately evaluating the impacts of various management and environmental factors on daily herbage mass, herbage intake, and stocker performance by providing the knowledge of day-to-day fluctuations in bermudagrass herbage mass and nutritive value.

Acknowledgements: Funding for this study was provided by Texas A&M AgriLife Research at Overton, TX.

Figures and Tables:

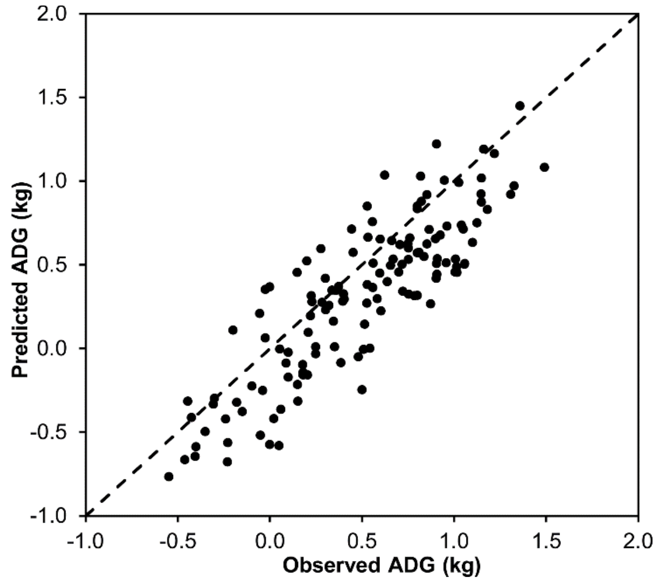

Figure 1. The observed vs. model-predicted values of daily gain (ADG) for stockers grazing bermudagrass pasture at Overton, TX during 1987-2020 using the daily gain model with the original CHA function (Equation 1).

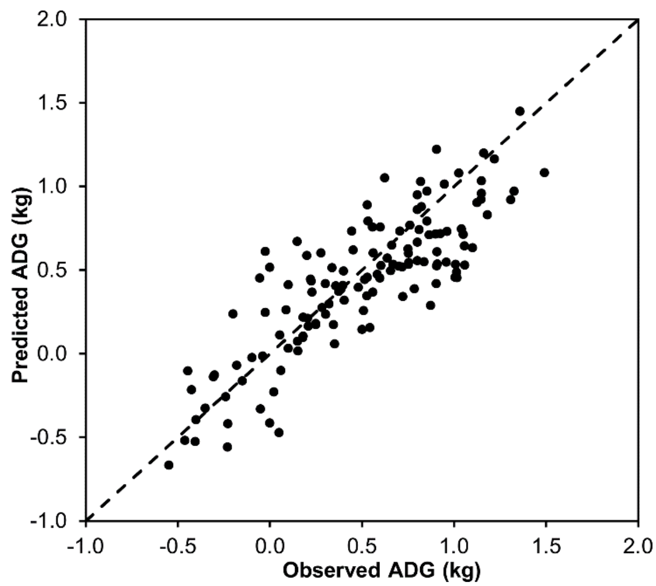

Figure 2. The observed vs. model-predicted values of daily gain (ADG) for stockers grazing bermudagrass pasture at Overton, TX during 1987-2020 using the daily gain model with the improved CHA function (Equation 2).

Predicting drought-induced yield loss of winter wheat in the Southern Great Plains region

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Application: The yield model we developed can predict the drought-induced yield loss of winter wheat in the Southern Great Plains region by taking into account the differential sensitivity of various phenological phases to drought. This model can be useful for minimizing the effects of drought on wheat yields through the adoption of necessary mitigation measures and scheduling irrigation allocation based on the phenological phases that are more sensitive to drought.

Introduction: The semi-arid region of Southern Great Plains is prone to drought and is projected to experience a drier climate. Although drought cannot be prevented, its losses can be minimized through mitigation measures if it is predicted in advance. Predicting yield loss from an imminent drought is an important need of stakeholders. This study developed a drought index (DI)-based yield model for predicting the drought-induced yield loss for winter wheat in this region by accounting for the phenological phase-specific sensitivity of this crop to water stress.

Materials and Methods: The dryland and irrigated yields of a general winter wheat cultivar spanning 96 seasons and the corresponding daily weather data were obtained for two locations in the region - Bushland, TX and Clovis, NM. From these yield data, the relative yield of winter wheat for a given season was calculated as the ratio of the dryland yield to the irrigated yield. From literature, the duration of each of the five phases considered in this study were estimated: planting-emergence, emergence-tillering, tillering-booting, booting-anthesis, and anthesis-maturity. For each location, the daily values of DI for each wheat growing season that had yield data were computed from the corresponding daily weather data. The daily values of DI, then, were averaged by phase to obtain 480 phasic values of DI for the two locations combined. By regressing the relative yield data against the phasic values of DI using Equation (1), the phase-specific drought sensitive coefficients (λ_p) for the wheat model were estimated.

$$\ln(Y_{l,s}) = \sum_{p=1}^{5} \{\lambda_p \times \ln(1 - DI_{l,s,p})\} \tag{1}$$

where Y is the relative yield; and the subscripts l, s, and p stand for the l-th location, the s-th season, and the p-th phenological phase, respectively.

Results: Once the sensitivity coefficients were estimated (the exponents in Equation 2), Equation (2) was derived as the relative yield model for winter wheat. The fraction of yield loss due to drought then could be estimated as 'one minus Y' (1 – Y).

$$Y = 0.97 \times (1 - DI)_{PE}^{0.068} \times (1 - DI)_{ET}^{0.086} \times (1 - DI)_{TB}^{0.279} \times (1 - DI)_{BA}^{0.07} \times (1 - DI)_{AM}^{0.042}, \tag{2}$$

where Y is the relative yield; and the subscript PE stands for the planting-emergence phase, ET the emergence-tillering phase, TB the tillering-booting phase, BA the booting-anthesis phase, and AM the anthesis-maturity phase. The evaluation results showed that the model was able to express the relationship between the drought index and the winter wheat yields accurately (Table 1; Figure 1).

Conclusion: This study developed a drought index-based yield model for predicting the drought-induced yield loss for winter wheat in the Southern Great Plains region. The model reflected the phenomenon of water stress decreasing winter wheat yields in this region and estimated the drought-induced yield losses reasonably well.

Acknowledgements: Funding for this work was provided by Texas A&M AgriLife Research at Overton, TX.

Figures and Tables:

Table 1. Values of the various measures used to evaluate the performance of the winter wheat yield model developed for the Southern Great Plains region of the United States

Measure	Value
Mean observed relative yield	0.40
Mean model-predicted relative yield	0.41
Willmott Index of agreement	0.86
Nash-Sutcliffe Index of modeling efficiency	0.61
Mean absolute error	0.09
Root mean square error	0.11
Percentage error	26.15

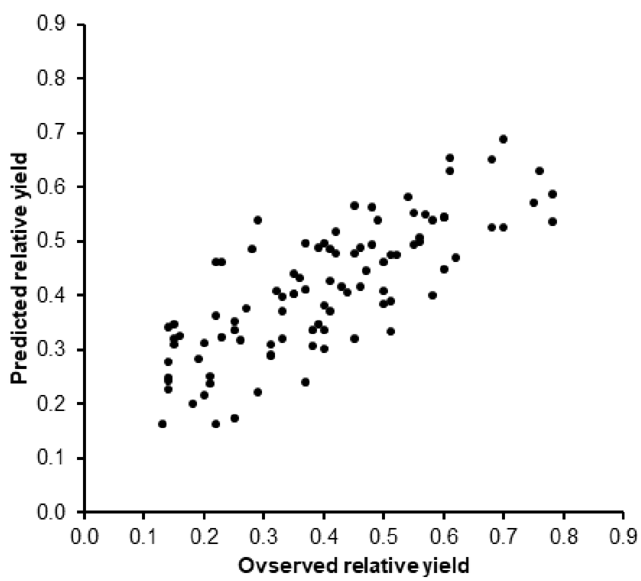

Figure 1. The model-predicted vs. observed values of the relative yield (dryland yield per unit of irrigated yield) of winter wheat in the Southern Great Plains region of the United States during 1947 through 2021.

Predicting the yield loss of winter wheat due to drought in the United States Southern Plains region as influenced by climate variability

Prem Woli, Gerald R. Smith, Charles R. Long, Francis M. Rouquette, Jr.
Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: By using the phenological phase by El Niño-Southern Oscillation (ENSO) phase-specific drought index (DI) values obtained from long-term historical weather data in the ENSO phase-specific yield models that this study developed, winter wheat growers in the Southern Plains region can estimate the yield loss of winter wheat from drought in an expected ENSO phase-year in advance. These models can also be useful to schedule irrigation allocation tailored to a given ENSO year based on the phenological phases that are more sensitive to drought.

Introduction: Wheat production is a major economic activity in the Southern Plains, a semi-arid region of the United States. This region is vulnerable to drought and is projected to experience a drier climate in the future. Since the interannual variability in climate in this region is linked to an ocean-atmospheric phenomenon, called ENSO, droughts in this region may be associated with ENSO. The losses due to an impending drought can be minimized through mitigation measures if it is predicted in advance. Predicting the yield loss from an imminent drought is crucial for stakeholders. This study developed ENSO phase-specific, DI-based models for predicting the drought-induced yield loss for winter wheat in this region by accounting for its phenological phase-specific sensitivity to drought.

Materials and Methods: The dryland and irrigated yields of a general winter wheat cultivar spanning 96 seasons and the corresponding daily weather data were obtained for two locations in the region - Bushland, TX and Clovis, NM. From these yield data, the relative yield of winter wheat for a given season was calculated as the ratio of the dryland yield to the irrigated yield. From literature, the duration of each of the five phases considered in this study were estimated: planting-emergence, emergence-tillering, tillering-booting, booting-anthesis, and anthesis-maturity. For each location, the daily values of DI for each wheat growing season that had yield data were computed from the corresponding daily weather data. The daily values of DI, then, were averaged by phase to obtain the phenological phasic values of DI for the two locations combined. To develop the ENSO phase-specific yield models, the years for which yield data were available were assigned to a specific ENSO phase. By regressing the relative yield data under a given ENSO phase against the related phonological phasic values of DI using Equation (1), the phenological phase-specific drought sensitive coefficients (λ_p) for the ENSO phase-specific wheat model were estimated.

$$\ln\left(\mathrm{Y}_{e,l,\mathrm{s}}\right) = \sum_{\mathrm{p}=1}^{5}\left\{\lambda_{\mathrm{e,p}} \times \ln\left(1 - \mathrm{DI}_{e,l,\mathrm{s,p}}\right)\right\} \tag{1}$$

where Y is the relative yield; and the subscripts e, l, s, and p stand for the e-th ENSO phase, the l-th location, the s-th season, and the p-th phenological phase, respectively.

Results: Once the drought sensitivity coefficients (the exponents in Equations 2 to 4) were estimated, these equations were used as the ENSO phase-specific relative yield models for winter wheat. The fraction of yield loss due to drought during a given ENSO phase then could be estimated as 'one minus Y_e' ($1 - Y_e$).

$$\mathrm{Y}_E = 1.21 \times (1-\mathrm{DI})_{E,\mathrm{PE}}^{0.03} \times (1-\mathrm{DI})_{E,\mathrm{ET}}^{0.082} \times (1-\mathrm{DI})_{E,\mathrm{TB}}^{0.443} \times (1-\mathrm{DI})_{E,\mathrm{BA}}^{0.043} \times (1-\mathrm{DI})_{E,\mathrm{AM}}^{0.039} \tag{2}$$

$$Y_L = 0.67 \times (1 - \mathrm{DI})_{L,\mathrm{PE}}^{0.037} \times (1 - \mathrm{DI})_{L,\mathrm{ET}}^{0.066} \times (1 - \mathrm{DI})_{L,\mathrm{TB}}^{0.165} \times (1 - \mathrm{DI})_{L,\mathrm{BA}}^{0.075} \times (1 - \mathrm{DI})_{L,\mathrm{AM}}^{0.023} \quad (3)$$

$$Y_N = 0.99 \times (1 - \mathrm{DI})_{N,\mathrm{PE}}^{0.03} \times (1 - \mathrm{DI})_{N,\mathrm{ET}}^{0.167} \times (1 - \mathrm{DI})_{N,\mathrm{TB}}^{0.263} \times (1 - \mathrm{DI})_{N,\mathrm{BA}}^{0.154} \times (1 - \mathrm{DI})_{N,\mathrm{AM}}^{0.019} \quad (4)$$

where Y_E, Y_L, and Y_N are the relative yields of winter wheat for the El Niño (E), La Niña (L), and Neutral (N) phases of ENSO, respectively; and the subscript PE stands for the planting-emergence phase, ET the emergence-tillering phase, TB the tillering-booting phase, BA the booting-anthesis phase, and AM the anthesis-maturity phase.

The evaluation results showed that the yield models were able to accurately express the relationship between DI and winter wheat yields in this region as impacted by ENSO (Table 1).

Conclusion: This study developed ENSO phase-specific, DI-based yield models for predicting the drought-induced yield loss for Southern Great Plains, a semi-arid region in the southern United States. The yield models accounted for the sensitivity of this crop during various phenological phases to drought reasonably well.

Acknowledgements: Funding for this work was provided by Texas A&M AgriLife Research at Overton, TX.

Figures and Tables:

Table 1. The values of the various measures used to evaluate the performance of the ENSO phase-specific winter wheat yield models in the Southern Plains region of the United States

	ENSO phase		
Measures	**El Niño**	**La Niña**	**Neutral**
Mean observed relative yield	0.52	0.32	0.37
Mean predicted relative yield	0.52	0.32	0.37
Mean absolute error	0.09	0.06	0.08
Root mean square error	0.10	0.07	0.10
Willmott Index of agreement	0.82	0.89	0.87
Nash-Sutcliffe Index of modeling efficiency	0.54	0.67	0.62
Percentage error	20	23	26

Predicting the yield loss of winter wheat from drought in the United States Southern Plains region based on the cultivar-specific sensitivity to water stress

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Application: By using phenological phase-specific drought index (DI) values obtained from the long-term historical weather data in the winter wheat cultivar drought sensitivity (CDS) group-specific yield models, various stakeholders in the United States Southern Plains region can estimate the yield loss from an anticipated drought for a wheat cultivar belonging to a particular CDS group in advance. The CDS group-specific yield models may also be useful for scheduling irrigation allocation tailored to a wheat cultivar belonging to a particular CDS group to ensure water access to the phenological phases that are more sensitive to drought.

Introduction: In most agricultural areas in the semi-arid region of the Southern Plains, wheat production is a primary economic activity. This region is drought-prone and projected to have a drier climate in the future. Predicting the yield loss due to an anticipated drought is crucial for wheat growers. Since different wheat cultivars exhibit varying levels of sensitivity to water stress, the impact of drought could be different on the cultivars belonging to different drought sensitivity groups. This study developed the CDS group-specific, DI-based models for predicting the drought-induced yield loss of winter wheat in this region by accounting for the phenological phase-specific sensitivity to drought.

Materials and Methods: The dryland and irrigated yields of a general winter wheat cultivar spanning 96 seasons and the corresponding daily weather data were obtained for two locations in the region - Bushland, TX and Clovis, NM. From these yield data, the relative yield of winter wheat for a given season was calculated as the ratio of the dryland yield to the irrigated yield. From literature, the duration of each of the five phases considered in this study were estimated: planting-emergence, emergence-tillering, tillering-booting, booting-anthesis, and anthesis-maturity. For each location, the daily values of DI for each wheat growing season that had yield data were computed from the corresponding daily weather data. The daily values of DI, then, were averaged by phase to obtain the phenological phasic values of DI for the two locations combined. To develop the CDS group-specific yield models, the wheat cultivars used in the trials in each season (year) were categorized into three groups in terms of drought sensitivity: non-sensitive, moderately sensitive, and highly-sensitive. By regressing the relative yield data for a given CDS group against the related phonological phasic values of DI using Equation (1), the phenological phase-specific drought sensitive coefficients (λ_p) for the CDS group-specific wheat model were estimated.

$$\ln\left(\mathrm{Y}_{g,l,s}\right) = \sum_{\mathrm{p}=1}^{5}\left\{\lambda_{\mathrm{g,p}} \times \ln\left(1 - \mathrm{DI}_{g,l,s,\mathrm{p}}\right)\right\} \tag{1}$$

where Y is the relative yield; and the subscripts g, l, s, and p stand for the g-th CDS group, the l-th location, the s-th season, and the p-th phenological phase, respectively.

Results: Once the drought sensitivity coefficients (the exponents in Equations 2 to 4) were estimated, these equations were used as the CDS group-specific relative yield models for winter wheat. The fraction of yield loss due to drought for a given CDS group phase then could be estimated as 'one minus Y_g' ($1 - Y_g$).

$$Y_N = 0.30 \times (1-\mathrm{DI})_{N,\mathrm{PE}}^{0.02} \times (1-\mathrm{DI})_{N,\mathrm{ET}}^{0.03} \times (1-\mathrm{DI})_{N,\mathrm{TB}}^{0.04} \times (1-\mathrm{DI})_{N,\mathrm{BA}}^{0.01} \times (1-\mathrm{DI})_{N,\mathrm{AM}}^{0.00}, \tag{2}$$

$$Y_M = 0.58 \times (1-\mathrm{DI})^{0.09}_{M,\mathrm{PE}} \times (1-\mathrm{DI})^{0.15}_{M,\mathrm{ET}} \times (1-\mathrm{DI})^{0.11}_{M,\mathrm{TB}} \times (1-\mathrm{DI})^{0.07}_{M,\mathrm{BA}} \times (1-\mathrm{DI})^{0.05}_{M,\mathrm{AM}}, \quad (3)$$

$$Y_H = 0.50 \times (1-\mathrm{DI})^{0.15}_{H,\mathrm{PE}} \times (1-\mathrm{DI})^{0.18}_{H,\mathrm{ET}} \times (1-\mathrm{DI})^{0.19}_{H,\mathrm{TB}} \times (1-\mathrm{DI})^{0.07}_{H,\mathrm{BA}} \times (1-\mathrm{DI})^{0.00}_{H,\mathrm{AM}}, \quad (4)$$

where Y_N, Y_M, and Y_H are the relative yields of wheat for the non-sensitive (N), moderately-sensitive (M) and highly-sensitive (H) group of cultivars, respectively; and the subscripts PE stands for the phenological phase planting-emergence, ET for emergence-tillering, TB for tillering-booting, BA for booting-anthesis, and AM for anthesis-maturity.

The evaluation results indicated that the relative yield models were able to accurately express the relationship between DI and winter wheat yields in this region as impacted by the genotypic difference in wheat cultivars (Table 1).

Conclusion: This study developed cultivar drought sensitivity group-specific, drought index-based yield models for predicting the drought-induced yield loss of winter wheat for Southern Plains, a semi-arid region in the southern United States. The yield models were able to predict the drought-induced yield loss of winter wheat satisfactorily by reflecting the CDS group-specific phenomenon of water stress decreasing the wheat yields in this region.

Acknowledgements: Funding for this work was provided by Texas A&M AgriLife Research at Overton, TX.

Figures and Tables:

Table 1. Values of various measures used to evaluate the performance of the yield models for three drought sensitivity groups of winter wheat cultivars in the United States Southern Plains region: non-sensitive (NS), moderately-sensitive (MS), and highly-sensitive (HS).

	Drought sensitivity group		
Measures	**NS**	**MS**	**HS**
Mean observed relative yield	0.253	0.270	0.201
Mean predicted relative yield	0.250	0.272	0.204
Mean absolute error	0.07	0.05	0.04
Root mean square error (RMSE)	0.08	0.06	0.04
Willmott Index of agreement	0.24	0.88	0.92
Nash-Sutcliffe Index of modeling efficiency	0.01	0.65	0.72
Percentage error	32	23	22

Understanding the Host and Varietal Preference of European Pepper Moth

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European pepper moth (EPM)

***Introduction*:** The European pepper moth (EPM) (*Duponchelia fovealis*), an invasive species in the U.S., has a broad host range and poses a significant threat to greenhouse and nursery production. First identified in California in 2004, EPM has since established populations in several states, including Texas. Its life cycle consists of four stages: egg, larva, pupa, and adult. The larval stage is particularly damaging, as larvae feed on various plant parts, including roots, stems, leaves, flowers, and buds. Infested plants often exhibit webbing, frass deposits, leaf damage, and girdled stems. Given the rapid growth of Texas' green industry, EPM has the potential to become a serious economic pest in the state.

In this study, we conducted a survey in a commercial greenhouse with an active EPM infestation to assess the varietal preference of EPM on potted Loropetalum plants. Additionally, we performed a controlled greenhouse experiment to evaluate EPM's host preference across different plant species.

Materials and methods:

Time and location of studies:
Between May and November 2024, we conducted a varietal performance study in a commercial nursery in Van Zandt County to evaluate the susceptibility of different *Loropetalum* varieties to European pepper moth (EPM) infestations. The study was carried out in a greenhouse with an existing EPM infestation, where three *Loropetalum* varieties—*Jazz Hands Bold*, *Cerise Charm*, and *Jazz Hands Variegated*—were being grown. Our objective was to assess EPM population levels, feeding behavior, and the extent of plant damage among these varieties under typical nursery conditions.

In addition to the field study, we conducted a controlled host-choice experiment in a greenhouse using a BugDorm to evaluate EPM host preference. Adult moths were introduced into the enclosure and provided with three plant species: Chrysanthemum, Loropetalum, and Dianthus. This experimental setup enabled us to closely observe the moths' behavior, including feeding activity, oviposition patterns, and overall plant selection. The controlled environment allowed for a more precise assessment of EPM host preference, offering valuable insights into its feeding and reproductive tendencies.

Results:

Varietal Preference of EPM:
Our study revealed that among the three Loropetalum varieties evaluated, Jazz Hands Bold exhibited the highest level of EPM infestation. This variety consistently showed greater pest pressure compared to Cerise Charm and Jazz Hands Variegated, suggesting that Jazz Hands Bold may be more susceptible to EPM infestations under greenhouse conditions.

Host Preference of EPM:
In our controlled greenhouse host preference study, we observed that Chrysanthemum and Loropetalum plants experienced 100% infestation by EPM, indicating that these plants are highly preferred hosts. In contrast, Dianthus remained completely uninfested throughout the study, suggesting that it may be a non-preferred or unsuitable host for EPM development.

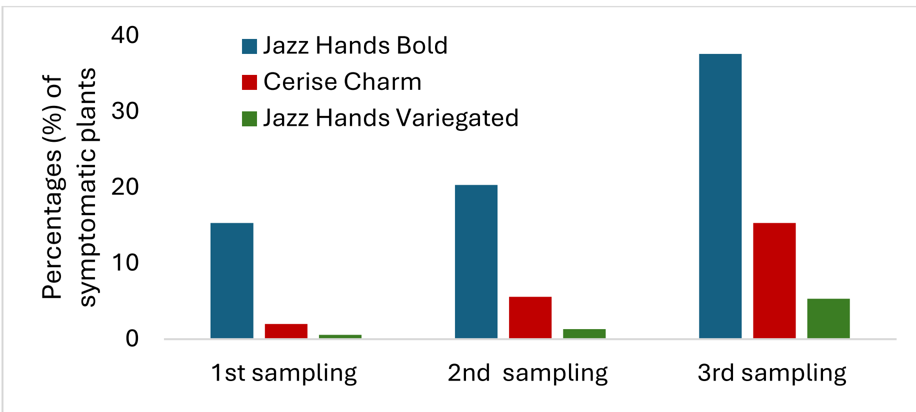

Figure 1. Percentages of symptomatic plants (feeding damage on leaves, girdle on stem, etc.)

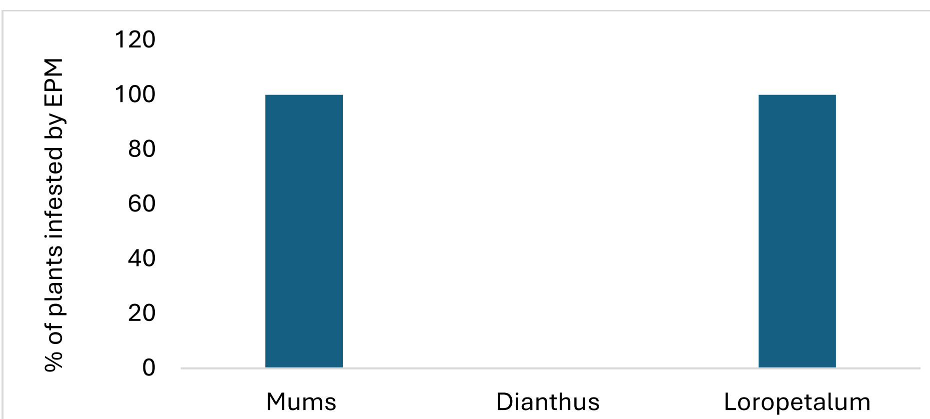

Figure 2. The percentages of infested plants by EPM in a host preference study

Managing Thrips Using Grower's Choice Chemicals

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***Introduction*:**

Thrips are a common pest in ornamental and nursery crops, known for their small size and piercing-sucking mouthparts. Their life cycle consists of five stages: egg, larva, prepupa, pupa, and adult. Both larvae and adults feed on plant sap from various plant parts, including leaves, stems, flowers, and buds. Their feeding damage leads to symptoms such as chlorosis, necrosis, and overall plant weakening, which can significantly impact plant health, reduce productivity, and diminish aesthetic value. Additionally, female thrips lay eggs inside plant tissues, causing stippling and further damage.

Thrips have a broad host range, feeding on numerous cultivated and wild plant species. To develop an effective management strategy, we conducted a greenhouse study evaluating the efficacy of a grower-selected chemical treatment. This study aimed to assess the treatment's impact on thrips populations and provide growers with data-driven recommendations for thrips control.

***Materials and Methods*:**

Time and location of the study, plant hosts:

At the Overton Research and Extension Center in Texas, we conducted a greenhouse study to assess the effectiveness of a chemical treatment chosen by growers for managing thrips populations. The study aimed to evaluate the impact of the selected treatment on thrips control, observing its ability to reduce thrips numbers and minimize plant damage. By testing the grower's preferred chemical approach, the goal was to provide practical insights into effective pest management strategies for thrips in nursery and ornamental crops. We selected potted petunia plants as we found they are preferred ornamental flowering plants in our previous study.

Sampling for thrips

The experiment was conducted by following a randomized complete block design and was replicated four times. There were five 4-inch potted plants in each experimental plot. Five flowers were collected randomly from each experimental plot and placed separately in the collection cups. The collection cups were brought back to the laboratory and washed with 70% ethanol to dislodge thrips. Thrips were then counted under a microscope.

Results:

Thrips in flower sample:

Both adult and larval thrips were observed in flowers. The highest number of adult and larval thrips were observed in Petunia compared to the other plants. Thrips populations were significantly lower in treated plants compared to the untreated check (Figure 1, 2, 3)

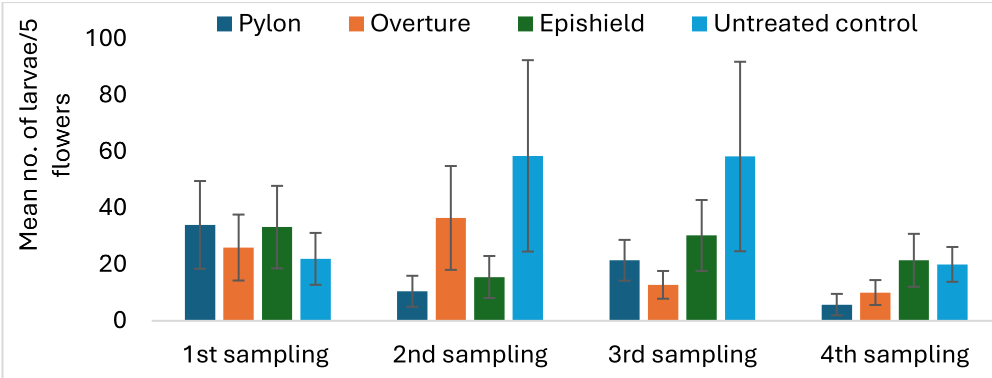


Figure 1. Mean ± SE number of larval thrips in petunia sample (5 leaves) treated with different chemicals on different sampling dates

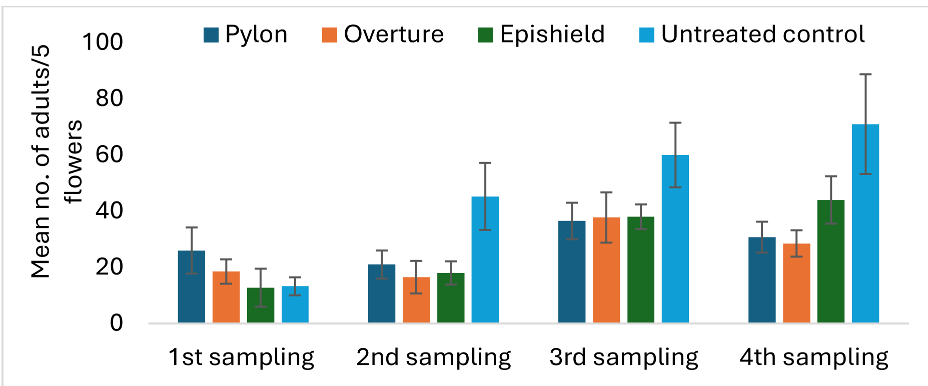


Figure 2. Mean ± SE number of adult thrips in petunia sample (5 flowers) treated with different chemicals on different sampling dates

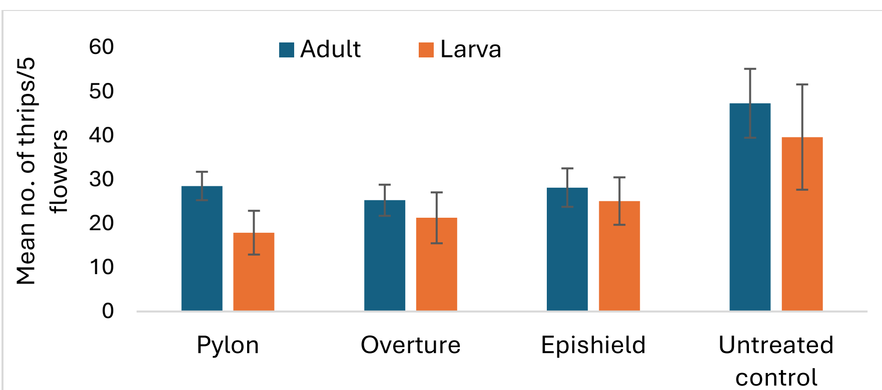


Figure 3. Mean ± SE number of thrips in petunia sample (5 flowers) treated with different chemicals

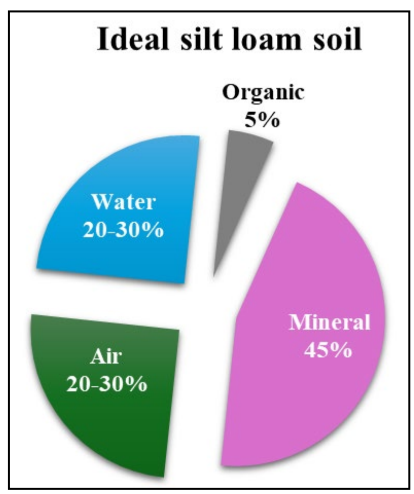
An overview of
Soil Fertility, Management, and Plant Nutrition for Forage Production

Vincent Haby, Ph.D., Texas A&M University System Regents Fellow and Professor Emeritus; Former Texas A&M AgriLife Research Soil Scientist; Texas A&M AgriLife Research and Extension Center-Overton

Introduction

Soil is basic to plant production and, thereby, to all of life. Agriculturally, soil is the layer of the earth's crust from which plants obtain their mechanical support, water, and many of their nutrients. Soils have many other uses such as for building sites, roads, biodegradation of wastes, waste disposal, ponds, etc., but this discussion will consider soils as a resource for plant growth. The term ***soil*** refers to the unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for growth of land plants. A soil is defined as a natural body consisting of organic matter and horizons (layers) of mineral constituents varying in thickness, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics.

Successful grassland farming requires recognition of the importance of a healthy soil-plant-animal biological system. Through a process called photosynthesis, plants convert radiant solar energy, carbon dioxide, and water to form carbohydrates, and then blend nitrogen (N) with carbohydrates to produce the amino acids found in protein. Most mineral elements required by animals and humans are transferred from the soil through water to the plant by diffusion and mass flow. The primary products produced by forage plants mainly move to the food chain through consumption and utilization by animals.



Economic success with producing healthy, productive livestock is dependent on growing ample quantities of good-quality forage for pasture and hay. To produce good-quality forage that allows livestock to achieve their productive potential necessitates diligent attention to the nutrient status of the soil on which the forage is produced.

Forages are produced on soils that are three-dimensional, dynamic natural bodies occurring on the surface of the earth, that are a medium for plant growth, and whose characteristics have resulted from the environmental factors of ***climate*** and ***living organisms*** acting upon ***parent material***, as modified by ***relief***, over ***time***. The ideal silt loam has been described as consisting of 20-30% air, 20-30% water, 45% mineral matter, and 5% organic matter. The organic (contains carbon) portion is considered the life of the soil as it consists of plant residues, earthworms, and microorganisms that convert organic and inorganic compounds into nutrients that are useable by living plants. Plant nutrients also are supplied from inorganic soil constituents such as the clay fraction that is considered the storehouse for these nutrients.

Physical Properties of Soils and the Plant Environment

For a soil to be in good physical condition for plant growth, the air, water, and solid particles must be in the proper proportions at all times. Soil that is expected to support life must be (a) sufficiently open to permit water to enter, but not so open as to allow excessive loss of water and plant nutrients by deep percolation; (b) sufficiently retentive of moisture to supply roots with water, but not so retentive as to create undesirable water tables; and (c) well aerated to permit all plant root cells to obtain oxygen at all times, but not excessively aerated that plant roots do not have continuous contact with moist soil particles.

Soil Bulk Density

Density of soil is referred to as bulk density (BD) because soils consist of air, water, mineral, and organic matter that make it lighter or less dense than solid substances such as rock. Because of variations in these constituents, soil BD can range from 1.0 to 2.0. Density is calculated by dividing the weight, or mass, of a material by its volume and is related to water that has a mass of 1.0 gram per 1.0 cubic centimeter, or a density of 1.0. It is important to know the BD of soils to determine the weight of an acre of soil 6-inches deep, to determine the amount of fertilizer to apply, or to determine volume of pore space. Bulk density of soil also may be used to evaluate soil compaction that inhibits root penetration and water flow in affected soils.

Bulk density can be estimated by collecting a core of soil using a sampling tube with an open side above the known diameter cutting tip to allow easy removal of the core. The core can be carefully cut to a specific length to allow calculation of the volume as length multiplied by 3.1416 (referred to as pi and represented by the symbol π) times the square of the radius of the core. The weight of the core after drying divided by its volume equals the soil BD. For example, a soil sampling probe has an inside diameter of the cutting tip that measures 5 cm. A sample of soil is collected using this probe; the core of soil is cut to a 15-cm length, placed onto a pre-weighed paper plate, and dried to remove all water. The weight of the plate is subtracted from the weight of the plate + dry soil to arrive at the dry weight of the soil. After drying, the soil core weighs 383 grams. Soil BD is estimated as 1.3 grams per cubic centimeter, i.e., BD = wt. of soil ÷ (length of core x π x radius^2).

$$\text{Bulk density} = 383 \text{ grams} \div [15 \text{ cm} \times (3.1416 \times 2.5 \text{ cm} \times 2.5 \text{ cm})]$$

Soil Color

Color is the most obvious feature of the soil. An experienced observer can often relate soil color to specific chemical, physical, and biological properties of soils. Color in soils is due primarily to the amount organic matter and the chemical state of iron and other compounds in the mineral fraction of the soil. Some broad generalizations are possible. For example, black soil color usually indicates the presence of greater amounts of organic matter. Red colors indicate the presence of free iron oxides common in well-oxidized soil. Other minerals such as quartz, granite, and heavy black minerals also influence soil color. Unweathered parent materials tend to be gray in color or else will have the color of the natural minerals from which they are derived.

The color of subsoils indicates a great deal about the age and drainage conditions in the soil. Iron compounds can exist as oxidized forms that are red, as hydrated oxides that are yellow, and as reduced forms which are gray in low oxygen environments. Here is the usual relationship between the subsoil color and drainage:

Subsoil color	Drainage condition
Red	Excellent
Reddish brown or brown	Good
Bright yellow	Moderately good
Pale yellow	Imperfect to fair
Gray	Poor
Dark (Black)	Variable

Surface soil color, as it relates to surface and subsurface drainage of water, can be used as an indicator of the types of forage crops capable of sustainable growth on meadow sites in the southern US. Well aerated light brown- to red-colored, upland surface soils will support growth of most forages commonly produced on the Coastal Plain as long as other conditions such as soil pH in the surface and subsoil, and nutrient and water availability are favorable. This includes most clovers, bermudagrasses, bahiagrasses, small grains, annual ryegrasses, and, if subsoils are well aerated and not strongly acidic, alfalfa. Soils that are poorly drained and that remain wet for prolonged periods will develop a gray to dark color indicating reducing conditions, or lack of oxygen. These soils, depending on the extent of wetness, may support dallisgrass, switchgrass, vaseygrass, eastern gamagrass, hardinggrass, bahiagrass, ryegrass, and tall fescue. The clovers berseem, ball, Persian, and white or Ladino clover, and singletary pea (also called caleypea or roughpea) may survive on wet soils. Alfalfa definitely will not survive on wet soils.

Soil Organisms

The mineral soil harbors a varied population of living organisms that play a prominent and indispensable role in the changes constantly occurring within the soil. Many groups of organisms live in the soil and range in size from microscopic to those that are clearly visible to the unaided eye.

Some of the microscopic-sized organisms are the bacteria, fungi, actinomycetes, algae, and protozoa. Most soil organisms depend on organic matter for food and energy, including the same nutrients used by plants. Consequently, they are mainly found in the top 12 inches, or less, of soil. One of the most important functions of these microorganisms is the decomposition of organic matter to produce carbon dioxide and mineralize nitrogen and other nutrients such as sulfur, making them available to growing plants.

Rhizobium is a genus of soil bacteria that is responsible for symbiotic nitrogen fixation in legume plants. These organisms penetrate plant roots causing the formation of small nodules on the roots. They then live in a symbiotic relationship, taking sustenance from the host plant, and fixing atmospheric nitrogen into forms usable by the legume plants. Decomposition of legume plant material by other soil organisms mineralizes this fixed nitrogen into forms useable by other plants.

Some soil microorganisms are harmful to soils and growing plants, either directly or indirectly. When the supply of air in a soil is limited, certain aerobic soil organisms take their supply of oxygen from compounds such as nitrates (NO_3^-). This reducing action may continue until nitrogen gas (N_2) is produced and is lost to the atmosphere. Other organisms in soils can cause plant diseases such as damping-off and potato scab. Bacteria are responsible for a host of diseases affecting crops, such as bacterial wilt. Nematodes, eel or worm shaped microscopic organisms, cause root knots, galls, lesions, or excessive root branching and injured root tips. This root damage causes reduced growth, appearances of nutrient deficiencies, and wilting in hot weather due to inadequate ability to uptake water.

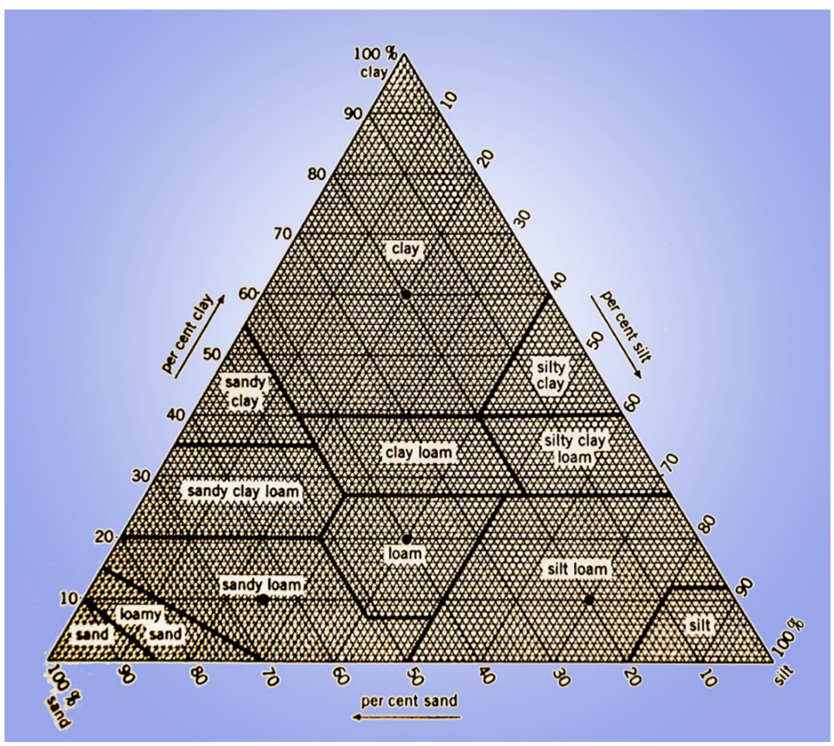
Organic Matter

Soil organic matter represents an accumulation of partially depleted and partially resynthesized plant and animal residues. Such material is in an active state of decay, being subject to attack by soil microorganisms. Consequently, organic matter is a mandatory soil constituent and must be renewed constantly by addition of plant residues. The organic matter content of the soil is small, ranging from less than 0.5% to greater than 5% by weight in most surface soils. Organic matter serves as a "granulator" of the mineral particles and largely is responsible for the loose, friable condition of productive soils. Mineralization of organic matter in soil provides nitrogen, phosphorus, sulfur and other nutrients to plants.

By affecting the physical condition of soils, organic matter also tends to increase the amount of water a soil can hold and the proportion of this water that is available for plant growth. The capacity of decomposed organic matter (humus) to hold water and nutrients greatly exceeds that of clay, its inorganic counterpart. Small amounts of humus tremendously augment the soil's capacity to promote plant production.

Soil Texture

The mineral portion of soil consists of sand, silt, and clay-sized particles in varying percentages. The relative proportion of sand, silt, and clay in a given soil is referred to as soil texture. A soil that contains 40% or greater clay-size particles may be classified as a clay, sandy clay, or silty clay, depending on its concentration of sand or silt in addition to the clay. Below 40% clay, a soil may be classified texturally as a sandy clay, sandy clay loam, sandy loam, loamy sand, sand, loam, or silt loam as the concentration of sand increases from 45% to 100%. With less than 40% clay and less than 45% sand, the textural classification may be loam, clay loam, silt loam, silty clay loam, or silt as the amount of sand is decreased.



Soil texture is most often analyzed in the laboratory by suspending 50 grams of soil in a dilute calgon solution in a settling cylinder and taking readings on a hydrometer at specific times to determine the percent silt and clay after the sand has settled to the bottom. With experience, the major mineral categories can be estimated by feel. Sand is gritty to the touch and the individual grains or particles that range in size from 0.05 - 2.0 millimeters (mm) can be seen with the unaided eye. It is the largest of the three size classes of soil particles. A soil in which sand predominates is classified as a sand-textured soil or simply a sandy soil. Soils that are classified as sandy loam, loamy sand, and sand are course in texture. The surface horizon of most East Texas soil is predominantly course textured while Blackland soil is fine textured.

Silt is smooth and slippery to the touch when wet. Individual particle size is 0.002 - 0.05 mm, is smaller than those of sand, is larger than clay, and can only be seen with the aid of a microscope. Silt-textured or silty soils contain more than 40% silt and are silty clay, silty clay loam, silt loam, and silt.

Clay particles are sticky and plastic-like to the touch when wet. Individual cl0ay particles are smaller than 0.002 mm and can only be seen with the aid of an electron microscope. Clay-textured, or clay soils, are rich in clay and fine in texture. Soils containing a large percentage of clay particles will form a ribbon when a properly moistened sample is repeatedly pressed forward between a person's thumb and forefinger. Soils that are high in clay content hold larger amounts of plant-available water than do soils that are high in sand. Soils that contain more than 40% clay are texturally classified as sandy clay, clay, or silty clay. Sandy clay loam, clay loam, and silty clay loam textural categories contain less than 40% clay.

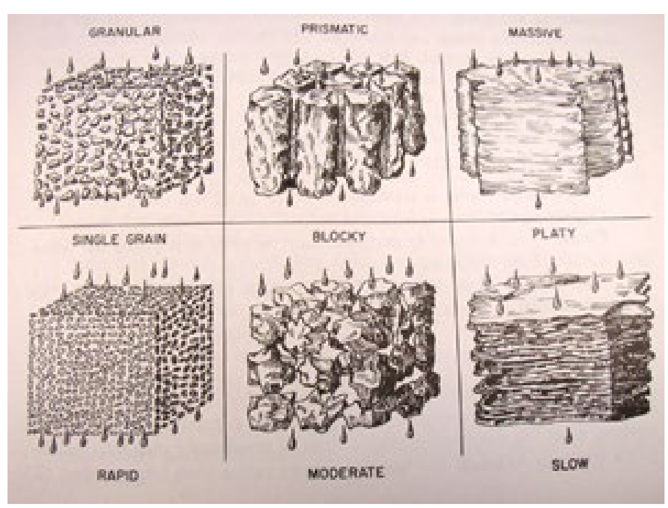
Soil texture is important for water holding capacity. Also, the texture of soils has a strong influence on soil productivity. Generally, soils with large amounts of clay and organic matter have a greater ability to store and release plant nutrients and will be more fertile than sandy soils that are low in clay and organic matter. Examples of plant nutrient holding capacity (also called cation exchange capacity) are:

	meq/100 g[†]		**meq/100 g**[†]
Sands (light colored)	3- 5	Silt loams	15- 25
Sands (dark colored)	10- 20	Clay and clay loams	20- 50
Loams	10- 15	Organic soils	50- 100

[†]meq/100 g (milliequivalents/100 grams of soil) is a chemical term used to designate the concentration of an element. The higher the number, the greater the concentration of nutrients.

Soil Structure

The arrangement of soil particles into groups or aggregates determines the "structure." Natural aggregates are called *peds* and are fairly water stable. A single mass or cluster of soil consisting of many soil particles held together in a particular way imparts physical characteristics to the soil, such as *platy*, *prismlike*, *blocklike*, or *spheroidal*.



Platy structure refers to soil peds arranged in a matted, flattened, or compressed appearance. Prismlike structure has peds arranged in a long vertical axis bounded by flattened sides. In the blocklike structure, peds resemble imperfect cubes like baby blocks, but usually much smaller. Spheroidal structure includes peds arranged in imperfect spheres like marbles, but usually smaller.

Other terms used to describe soil structure include *single grained* like sand particles, *granular* like single grained but of larger size, and *massive* that appears to be almost structure less.

Soil structure is often more important than the texture to the farmer. Single grain structure such as sand (a) allows rapid infiltration of water; (b) allows a high rate of leaching of water-soluble nutrients such as nitrate-nitrogen, sulfate-sulfur, and chloride; (c) has low water-holding capacity so these soils will be droughty; (d) allows rapid root penetration; and (e) has low clay content, therefore will have lower nutrient holding capacity and lower concentrations of acidity requiring less limestone for acid neutralization.

Platy and massive structures (a) usually occur in higher clay content soils; (b) inhibit water and root penetration; (c) have slower leaching loss of water-soluble nutrients; and (d) have lower potential for good crop yields.

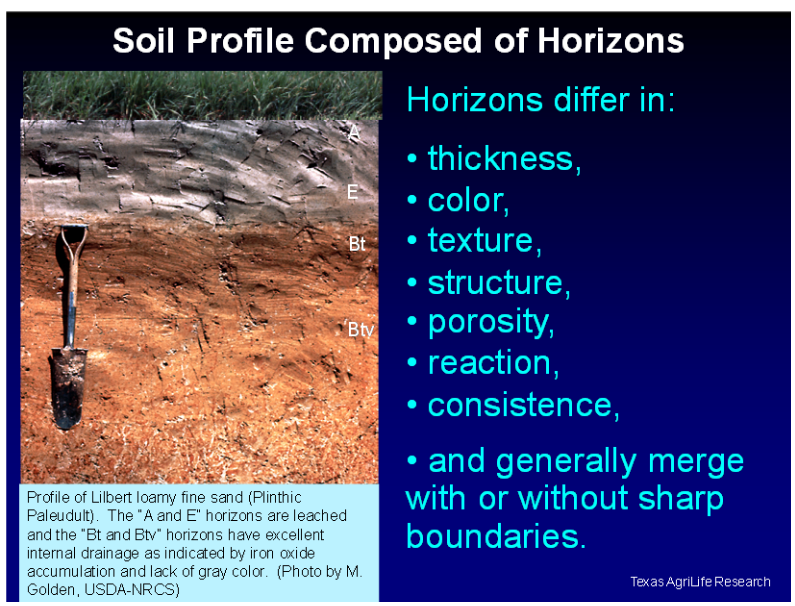
Blocky and prismatic structures (a) occur in higher clay content soils that have more organic matter, so will have elevated nutrient exchange capacity, (b) allow moderate rates of water and root penetration, (c) have moderate leaching loss rates, and (d) have higher yield potential.

Soil structure can be modified. Addition of organic matter through plant growth, application of manure or other organic materials, and proper tillage can be used to improve soil structure.

The Soil Profile

The profile in developed soils is comprised of two or more identifiable layers called horizons, one below the other, each lying parallel to the surface of the land. These horizons above the parent material are referred to as the solum (Latin for soil). Important characteristics of the various horizons are:

- Soil horizons differ in color, texture, structure, consistence, porosity, organic matter content, and soil reaction.
- Soil horizons may be several feet thick or as thin as a fraction of an inch.
- Soil horizons generally merge with one another and may or may not show sharp boundaries.



Profile of Lilbert loamy fine sand (Plinthic Paleudult). The "A and E" horizons are leached and the "Bt and Btv" horizons have excellent internal drainage as indicated by iron oxide accumulation and lack of gray color. (Photo by M. Golden, USDA-NRCS)

Soils in climates where microbial decomposition of plant residue is inhibited by excess moisture, and temperatures sufficiently cold to inhibit activity of microorganisms through the greater part of the year may have an "O" horizon defined as a surface accumulation of organic material varying from 20 to 30% organic matter overlying a mineral soil.

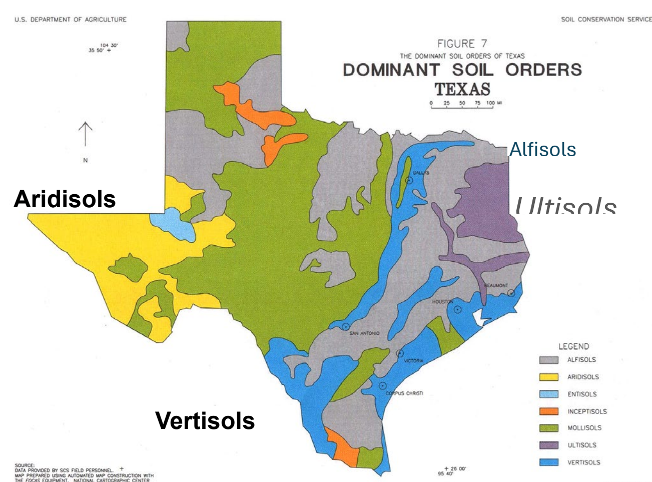
In mineral soils, plant residues, originally deposited on the surface, have become incorporated by earthworms and other organisms into the soil and have been disintegrated and partially decomposed by microorganisms. This surface, biochemically-weathered portion of the soil profile is called the “A” horizon and is distinguished from the material below (subsoil) by a higher organic matter content and an abundance of plant roots and soil organisms, giving this zone a darker color. The A-horizon is the major zone of root development and contains a large share of the water and nutrients used by the plants. It can be manipulated and managed by proper cultivation and incorporation of organic residues, plant nutrients, and limestone where needed to adjust pH. The fertility and productivity of the A-horizon may be managed and stabilized at levels consistent with economic crop production.

The subsoils underlying the A-horizon, especially in mature humid-region soils, present two general belts: (a) an upper zone of transition called the “E” horizon and (b) a lower zone or “Bt” horizon. The E-horizon, just below the A, is a leached area called the zone of eluviation. Dissolved and suspended materials are moved out of the E horizon by water when rainfall exceeds evaporation. The E-horizon contains less organic matter and has a lighter color than the A, and less clay than the underlying Bt horizon. The Bt horizon, or zone of accumulation, may contain an aggregation of compounds such as iron and aluminum oxides, clays, gypsum [calcium sulfate, ($CaSO_4 \cdot 2H_2O$)], and $CaCO_3$ depending on the soil order. Living organisms are fewer in number in the Bt horizon than in the A horizon, but more abundant than in the underlying Btv horizon. Color is transitional between A and Btv horizons as well.

The parent material or “Btv” horizon underlies the Bt and is the deepest of the three major horizons. The Btv horizon contains the material from which the mineral part of the soil forms. The subsoil below the A horizon is important as a source of slowly available nutrients and water for penetrating plant roots. Nutrients such as nitrate, chloride, and sulfates are easily leached, or moved, through the upper soil horizons by water and tend to concentrate in the Bt horizon. Shallow rooted plants such as ryegrass may not have access to nutrient accumulations in the Bt horizon, depending on the depth of the A and E horizons.

Soil Orders

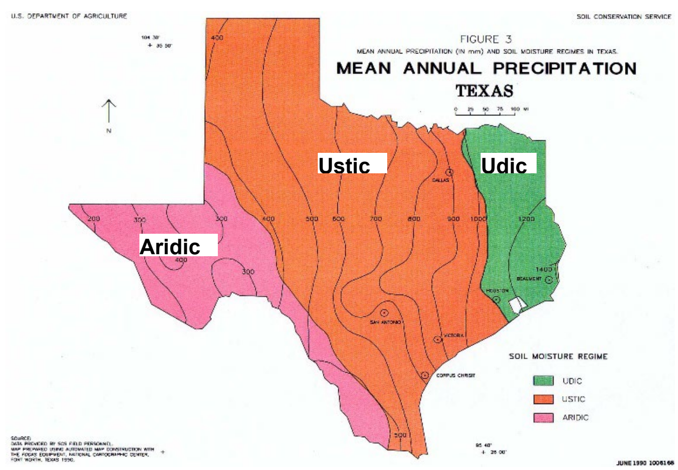
Soil scientists have classified soils into twelve orders. Each order has distinctive characteristics such as color, clay type, reaction, base saturation, etc. At least seven of these orders are found in Texas. Soils of the East Texas Timberlands are dominated by Ultisols and Alfisols. Ultisols are leached acid soils with some shade of brown color in the surface and a distinctive B-horizon of clay accumulation and low base supply [calcium (Ca), magnesium (Mg), sodium (Na), and potassium, (K)]. Ultisols have low organic-matter content and are temperate or warm and moist. These Coastal Plain soils occur on gently to moderately sloping terrain in woodlands and pasture and extend across the southern states in the high rainfall, warm, and humid regions of the US. Alfisols that occur in similar climatic zones may be acidic, but are distinguished from Ultisols by a higher content of soil basic nutrients in the Bt horizon. Alfisols have a gray to reddish brown surface horizon with sub-surface horizons of clay accumulation, and are usually moist but may be dry during the warm season.



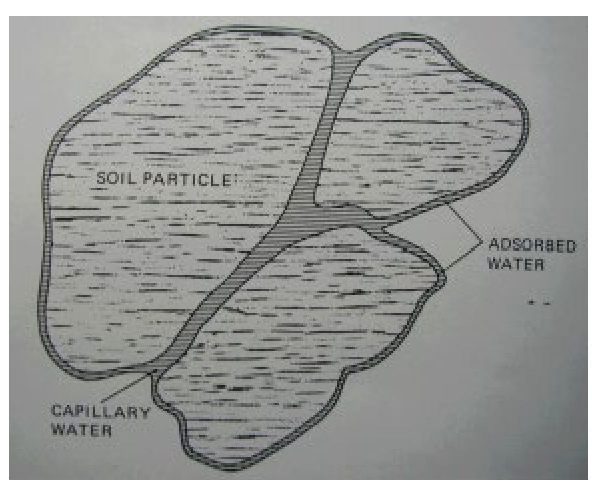
Farther to the West are the Vertisols and Mollisols, with some Alfisols and Inceptisols. Vertisols are high clay-content soils that have a high shrink-swell capacity as they dry and are rewetted. Vertisols are usually, but not always, alkaline in reaction. Mollisols are high organic matter soils that also may have high clay content and are less weathered than Ultisols. Inceptisols have less developed diagnostic features, highly resistant parent material, and an abundance of volcanic ash. Aridisols and some Entisols are found in West Texas. Aridisols are associated with arid and semiarid climates and with desert vegetation, while Entisols are the more recent soils that are sufficiently young to have developed no diagnostic horizons. Soil orders are further delineated into suborders, great groups, subgroups, family, series, and phases of series or soil types. Soil series names are most commonly used to distinguish soils on the local level. Examples of soil series include Bowie fine sandy loam, Darco loamy fine sand, and Lilbert fine sandy loam.

The USDA Natural Resources Conservation Service classifies soils in each county to the series and type and provides a map of soils in the county along with a description of each soil on that map. This information is located in a book referred to as the Soil Survey and is available for most counties in Texas. Soil Survey data are on the Internet by county at http://websoilsurvey.nrcs.usda.gov/. This is the best source available for information on farm and ranch soils. Each landowner can obtain a copy of their county soil survey or access the Web soil survey and familiarize themselves with the soils and the land capability descriptions on their farm or ranch.

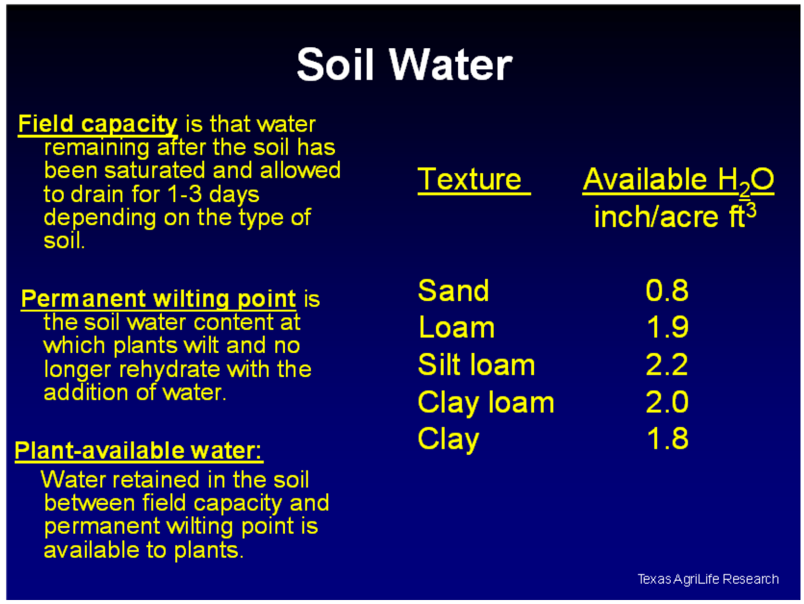
Soil Water



Mean annual precipitation in Texas is categorized as Udic, Ustic, and Aridic going from east to west. Eastern Texas is characterized as Udic, or humid, with rainfall averaging from 39 to 47 inches annually. The majority of north, central, and south Texas is characterized as Ustic, or burnt, with rainfall amounts ranging from 12 to 39 inches annually going from west to east across this region. In the extreme southern and western areas of Texas, the mean annual rainfall pattern is considered Aridic, with amounts of less than 4 to possibly 12 inches annually. In areas of low mean annual rainfall, forage production is quite low, resulting in much lower stocking rates and/or a change in type of livestock produced.



Water in soils occupies capillary pore spaces and exists as adsorbed (tightly-held thin layers of molecules) water around soil particles. Generally, the smaller the capillary pore spaces, the more water a soil will hold. Clay has much smaller pore spaces than sand. Thus, clay soils will hold a greater volume of plant-available water than will sands. In inches of plant-available water per acre-foot of soil (one acre, 12-inches deep), sands hold 0.8 in., loam holds 1.9 in., silt loam holds 2.2 in., clay loam holds 2.0 in., and clay holds 1.8 in. of plant-available water. Therefore, sandy soils need rainfall or irrigation more frequently with lower amounts of water, while clay type soils need less frequent rainfall or irritation with greater amounts of water depending on how long it has been since the last significant precipitation event or irrigation.



Soil is a storage reservoir for accumulated rainfall, slowly releasing this stored water to plants. When a soil is full to the point that it cannot hold more water, it is considered saturated. Most forage plants cannot exist in soils that remain saturated for extended periods. Field capacity water is that water remaining after the soil has been saturated and allowed to drain for 1 to 3 days depending on the type of soil; clay soils require longer drainage time; sands require less drainage time. Plants can easily take up water stored at field capacity. Much of the water in soil at field capacity is stored in intermediate-sized pore spaces between soil particles.

Water and its dissolved nutrients stored in soil may be more or less difficult for plants to take into their roots. As plant transpiration and evaporation continue to dry the soil, water is held in progressively smaller pore spaces between clay particles at increasingly stronger tensions on the soil clay until plant roots can no longer pull it away form the clay. When plants can no longer absorb water from the soil and wilt to the point that they cannot rehydrate when water becomes available, the soil water availability is described as being at the permanent wilting point. Water retained in the soil between field capacity and the permanent wilting point is considered available for uptake by plants. A drought may be described as the combination of lack of rainfall and the inability of soil to provide sufficient plant-available water to maintain plant growth.

Soils have other physical properties that will not be discussed here such as pore space or the voids that hold air and water between the soil particles, soil temperature that influences seed germination and plant growth, and soil consistence that refers to the attribute of cohesion and adhesion or resistance of soil material to rupture or deformation.

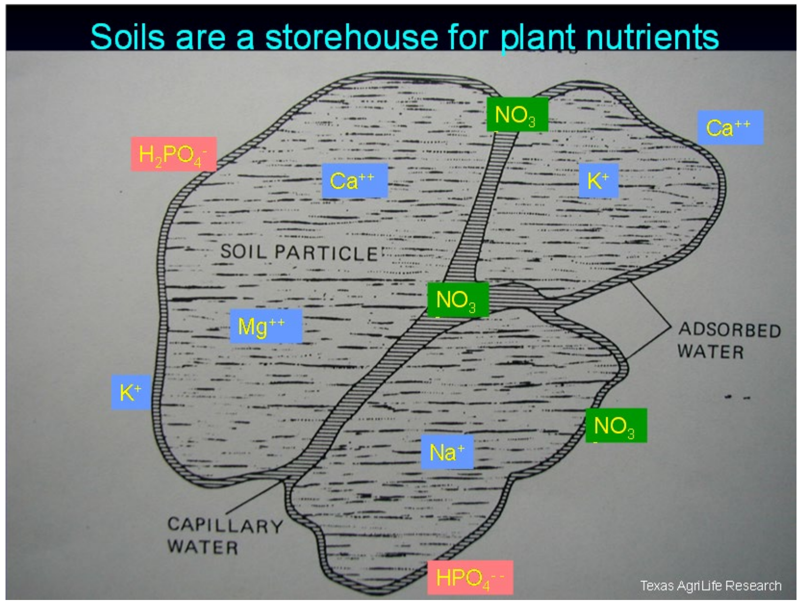
Chemical Properties of Soils and the Plant Environment

Chemistry of Soils

In addition to providing mechanical support and water to plants, soils serve as a storehouse for plant nutrients. Plant nutrients are those chemical elements that plants need in order to grow and produce seed to complete their life cycle. These are described as plant-essential elements. Except for the plant essential elements carbon and oxygen obtained from carbon dioxide (CO_2) and oxygen and hydrogen obtained from water (H_2O), plants obtain the majority of their essential elements from the soil. Plant-essential elements that are deficient in the soil for plant growth must be provided as fertilizer, manure, or other soil amendments.

Cation Exchange Capacity

The clay fraction of soil is chemically active. The chemical structure of clay consists of layers of aluminum and hydroxyl (OH^-) groups and silica atoms that are associated with layers of oxygen atoms. Some of the negative charge on these oxygen (O^{2-}) and hydroxyl groups is neutralized by K^+ and Mg^{++} that, when lost from the clay creates an excess of negative charges on the clay. Loss of cations from within the clay crystalline structure contributes negative charge to clays. This negative charge is neutralized by adsorption of positive charged elements to the edges of the clay. These positive charged elements are called cations. Examples of cations that are plant nutrients are Ca^{2+}, Mg^{2+}, and K^+. These plant nutrients are referred to as basic cations. In alkaline soils the negative charge of the clay may be saturated on exposed edges with basic cations. These cations can be released into soil solution for uptake by plants through a series of exchanges with other ions that have a positive charge. The ability of clay to hold and release cations is referred to as "cation exchange capacity" or CEC. Aluminum (Al^{3+}) in acid soils, and zinc (Zn^{2+}), copper (Cu^{2+}), manganese (Mn^{2+}), and iron (Fe^{3+}) are also cations.



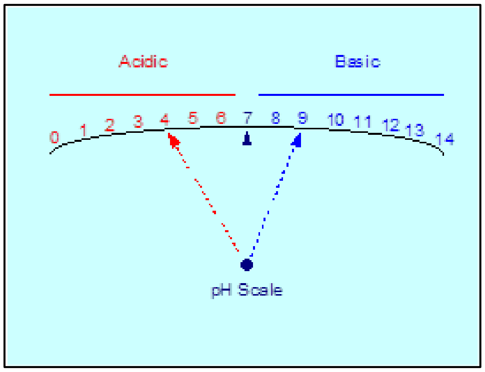
Soils containing a high percentage of organic matter have a high CEC. Sandy soils containing a low percentage of clay and organic matter have a low CEC. This helps explain why sandy soils require more frequent applications of lime and fertilizer than soils containing more clay. Soils such as the Houston Black clay predominantly are montmorillonitic and have a much higher CEC than the kaolinitic clay minerals in the highly leached soils of the southern US.

Cations can also exist in soils and water along with negative charged elements (anions) as compounds. Examples of anions include nitrate (NO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}). These negative-charged elements also are plant nutrients. In addition to being dissolved in soil water, these anions are adsorbed by electrostatic attachment to positive charges on clay due to broken chemical bonds between aluminum and hydroxyls and silica and oxygen atoms.

Soil pH

Soils may be acid, neutral, or alkaline in reaction depending on the amount of weathering that has occurred. Soils in warm, high-rainfall regions will be highly weathered and acidic. Weathering refers to dissolving and removal of basic cations by leaching them downward through the soil. Highly weathered soils have low base status and will be acidic. Soils of the ustic and aridic regions of Texas usually contain a greater concentration of basic cations due to lower amounts of rainfall that results in less weathering and leaching of basic nutrients.

The strength of the acidity or alkalinity is indicated by pH (a measure of the concentration of hydrogen ion, H^+ - acid; or hydroxyl ion, OH^- - basic) that is represented on a scale from 0 to 14. The normal range of soil pH is between 4.0 and about 9.0. A soil with a pH above seven is referred to as alkaline or basic. A soil with a pH above 7.0 that contains unreacted calcium carbonate is considered calcareous. Soils with pH above 8.5 usually contain an accumulation of sodium and are considered sodic.



A pH of 7.0 is considered neutral. A soil with a pH below seven is acidic. The stronger the acidity, the lower the pH of the soil will be. The pH scale is logarithmic. Therefore, a soil with a pH of 5.0 is ten times more acidic than a similar soil with a pH of 6.0, and soil with a pH of 4.0 is 100 times more acidic that a soil with a pH of 6.0.

Soil Acidity

Soil acids are weak acids in pure chemistry terms even though soil acidity is referred to as strongly acidic at the lower end of the soil pH scale. Soil acidity is caused by several factors including leaching of cations, plant uptake of cations with exchange of hydrogen from the plant to the soil, mineralization (decomposition) of organic matter with the formation of organic acids such as very dilute hydrochloric, nitric, and sulfuric acids, oxidation of iron sulfides to form sulfuric acids, acid rain, and by conversion of ammonium nitrogen compounds to nitrates (nitrification). Nitrification of ammonium nitrogen is the greatest cause of increasing acidity in low buffer capacity agricultural soils. The accepted value for acid inputs to soils from the ammonium nitrogen sources urea, ammonium nitrate, and anhydrous ammonia is 1.8 lb of $CaCO_3$ neutalizable acidity per pound of actual ammonium nitrogen applied and converted to nitrate, or 1.8 pounds of $CaCO_3$ is needed to neutralize the acidity created by one pound of ammonium nitrogen that is converted to nitrate (Table 1). Ammonium sulfate and diammonium phosphate require 5.4 pounds of $CaCO_3$ to neutralize acidity created per pound of ammonium nitrogen converted to nitrate.

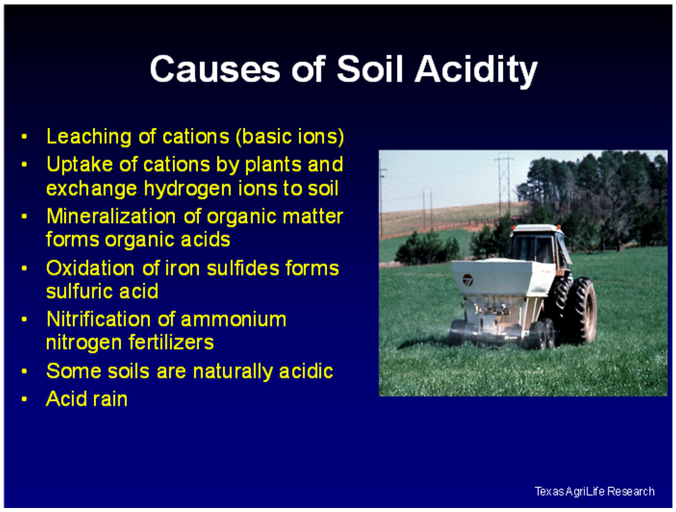


Table 1. Estimated soil acidity caused by soil biological nitrification of ammonium fertilizers.

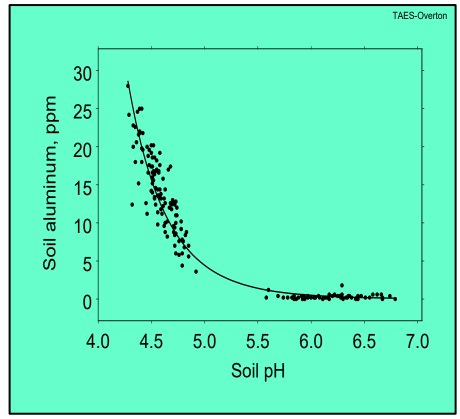
Source	Formula	Nitrogen	-----------Residual acidity-------- Maximum value	Accepted value
		%	lb $CaCO_3$/ lb N applied	lb $CaCO_3$/ lb N applied
Anhydrous ammonia	NH_3 (gas)	82	3.6	1.8
Urea	$(NH_2)_2CO$	46	3.6	1.8
Ammonium nitrate	NH_4NO_3	34	3.6	1.8
Urea-ammonium nitrate	$(NH_2)_2CO$-NH_4NO_3	32	3.6	1.8
Ammonium sulfate	$(NH_4)_2SO_4$	21	7.2	5.4
Monoammonium phosphate	$NH_4H_2PO_4$	10	7.2	5.4
Diammonium phosphate	$(NH_4)_2HPO_4$	18	5.4	3.6

As soil acidity increases, hydroxyl (OH^-) ions are neutralized in the soil solution, and the measured pH value declines. Increasing acidity of the solution in contact with soils hastens breakdown of soil compounds such as aluminum hydroxides [$Al(OH)_3$] that release aluminum (Al^{3+}) into solution and onto the clay edges. Aluminum in sufficiently high concentrations is toxic to plants. It disrupts the growing points of roots and root hairs of susceptible plants, preventing root extension and interfering with water and nutrient uptake. Plants such as clovers, alfalfa, some of the cereals, and annual ryegrass are very sensitive to soil acidity. Rye, millet, bahiagrass and bermudagrasses are less sensitive to soil acidity.

As acidity increases, soils also become less productive due to declining availability of some plant nutrients. Nitrogen, phosphorus (P), Ca, Mg, and molybdenum (Mo) become less available to plants in acid soils. Aluminum that becomes increasingly soluble as pH declines below 5.5 complexes with P making the P less available for plant uptake. Micronutrients, except for molybdenum, become more available to plants as soil pH declines.

The majority of soils in Texas are alkaline rather than acidic. Alkaline soils have a pH above 7.0 and are considered calcareous if they contain undissolved calcium carbonate. Alkaline soils predominantly occur in the ustic or aridic zones that receive lower rainfall, and leaching of the basic cations is much less than in udic regions. Soils in the ustic regions may be acid in the surface depth, but usually will have an accumulation of basic cations in the subsoil depths. It is not uncommon for some sandy, ustic-region surface soils to need limestone to neutralize acidity for improved production of forages and other crops. Examples of ustic-region acid soils occur in the Texas Central Basin. This landscape is dominated by hills of granite, gneiss, and schist that are incised by southeastward-flowing rivers such as the Llano and Colorado.

Limestone Application on Acid Soils



Soil acidity increases in strength as the pH declines below 7.0. As soil pH decreases below 5.5, aluminum becomes increasingly soluble and the increase becomes exponential (rapidly increases) below pH 5.0 (see figure at right. Aluminum in sufficient concentrations is toxic to growth of acid sensitive plants and is a major factor in decreased production of crops on strongly acid soils.

Ryegrass

Application of limestone to acid soils decreases acidity with a corresponding increase in soil pH and a decrease in exchangeable aluminum. Excellent ryegrass yields were obtained by liming strongly acid soils at TAMU-Overton. Ryegrass dry matter (DM) yield increased by 0.87 tons/acre from application of only 600 lb of limestone per acre in the first year (Table 2). Yield was increased by 1.3 tons of dry forage per acre due to application of 1.7 tons of limestone per acre. By the fall following this summer application, surface soil pH 0- to 6-inches deep increased from 4.7 to 5.7. In the third and fourth years after liming, this 1.7 ton per acre limestone rate increased ryegrass dry matter yields by 2.0 or more tons of dry forage per acre compared to unlimed plots. The three-year average ryegrass yield increased due to 1.7 tons of limestone per acre was 1.89 tons of dry matter per acre greater than the dry matter production in the unlimed check plots. This increased yield was well worth the investment in applied limestone.

Table 2. Response of soil pH and annual ryegrass to limestone application.

	-----Year 1-----		**-----Year 3-----**		**-----Year 4-----**	
Lime rate	**Soil pH**	**DM yield**	**Soil pH**	**DM yield**	**Soil pH**	**DM yield**
tons/ac		tons/ac		tons/ac		tons/ac
0.0	4.7	1.39	4.5	1.72	4.5	0.32
0.3	4.8	2.26	4.7	2.29	4.5	0.49
1.7	5.7	2.69	6.2	3.71	4.6	2.71

By summer of the fourth year, ammonium nitrogen applied for double-cropped bermudagrass and ryegrass over four years theoretically required 2 tons of 100% effective limestone per acre to neutralize the acidity produced if all the applied ammonium-N were nitrified. Soil in plots treated with 1.7 tons of limestone per acre to raise pH to 6.2, experienced a decline in pH to 4.6 after four years, but yield remained 2.4 tons per acre higher than in unlimed plots where DM production had decreased to 0.32 tons per acre. Although soil pH four years after treatment had dropped to 4.6 in the plots treated with the high lime rate, extractable soil Ca remained at a level of 300 ppm. This level of Ca and only 13-ppm exchangeable aluminum allowed reasonable ryegrass growth. Yield improvement due to liming resulted from elimination of a phytotoxic (phyto meaning plant) level of exchangeable aluminum with a simultaneous increase in phosphorus efficiency. At pH 4.6, this soil needed another limestone treatment. Literature on liming of acid soils indicates that continued application of limestone and fertilization with nitrogen for several years slowly neutralizes acidity in the subsoil.

Coastal bermudagrass

Response of Coastal bermudagrass to limestone applied to acid soils has been difficult to predict based on soil pH. This grass was selected from hybrid bermudagrass cultivars growing in acid soil, so it possibly was selected to be tolerant to moderate levels of soil acidity. However, it has responded to increased pH due to liming (Table 3). Research in the early 1960s found the critical pH at which to lime soils was 5.1 in two Tifton soils and 5.6 in a Rains soil. Studies on a Cecil soil showed the critical pH was 4.8 and 5.4. Data from more recent research in Texas indicate the critical pH at which to lime soils established to Coastal bermudagrass varies from 5.5 to 5.9. From data in Table 2, it appears that response of Coastal bermudagrass to limestone applied to acid soils is difficult to predict based on soil pH alone.

Table 3. Coastal bermudagrass response to increasing soil pH due to liming acid soils.

Scientist	Year	State	Soil	Low pH	Critical pH	Response
Jackson	1961	Georgia	Tifton	4.3	5.1	+ 23
Jackson	1961	Georgia	Tifton	4.0	5.1	+ 50
Jackson	1961	Georgia	Rains	4.3	5.6	+ 11
Adams	1967	Georgia	Cecil	4.4	4.8	+ 9
Adams	1967	Georgia	Cecil	4.0	5.4	+ 300
Haby	1969	Texas	Boy	5.2	---	0
Eichhorn	1981	Louisiana	Ruston	4.9	---	- 7
Young	1984	Texas	Darco	4.7	5.9	+ 25
Young	1984	Texas	Nacogdoches	4.8	5.5	+ 11
Haby	1992	Texas	Darco	5.2	5.6	+ 27

Coastal bermudagrass grown on low-calcium soils, those below pH of about 5.6, may contain insufficient calcium for beef cattle. Stocker steers need 0.79% calcium for a high rate of gain according to NRC (1984). When grazing Coastal bermudagrass, high rate-of-gain stocker steers will need calcium supplement because this bermudagrass growing on inadequately limed acid soils contains insufficient calcium to meet their requirement. Average production lactating cows with a 3½ month old calf need 0.29% calcium as a percent of the minimum daily dry matter requirement. Calcium concentrations in bermudagrass grown on well-limed soil exceeded 0.29% in the first two harvests but not in the late summer harvest. Coastal bermudagrass grown on unlimed acid soil contained sufficient calcium only for the maintenance of stocker steers and for dry cows in the middle trimester of pregnancy. Maintaining soil pH above 5.6 by application of high-quality lime is important even for acid tolerant grasses such as many of the hybrid bermudagrasses to help provide adequate calcium to grazing animals and to maintain efficiency of plant nutrients in the soil and those applied as fertilizer.

Tifton 85 bermudagrass

Unlike Coastal bermudagrass, Tifton 85 bermudagrass responds to limestone as indicated by soil pH in Table 4. At a pH range approximating 5.0, Tifton 85 bermudagrass dry matter yield was about 9,800 lb/acre compared to about 12,400 lb/acre at a considerably higher pH of about 6.5 to 7.0. Therefore, to maximize yields of Tifton 85 bermudagrass, acid soils need to be treated with sufficient limestone to raise pH above about 6.5. Ideally, this limestone should be incorporated into the surface soil before sprigging the Tifton 85 bermudagrass.

Table 4. Tifton 85 bermudagrass yield response to pH range (limestone) and poultry litter (PL).

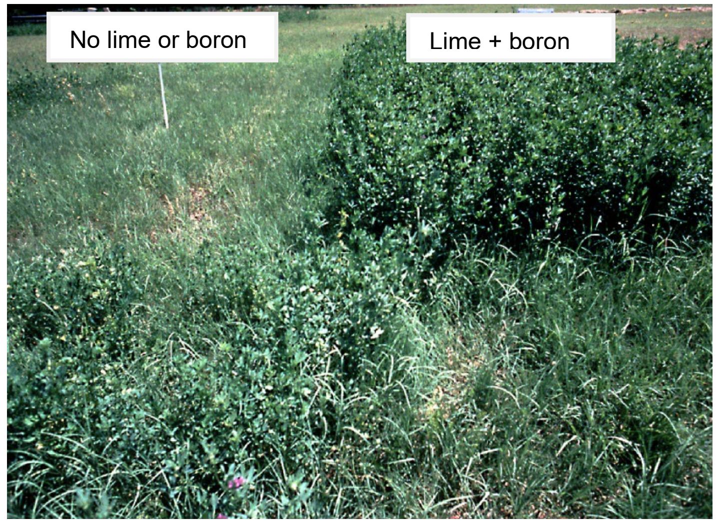
	Dry matter yield by harvest date and total† (2004)					
pH range	**June 7**	**June 25**	**July 16**	**Aug. 30**	**Oct. 12**	**Total**
	----------lb/acre----------					
Low	779 b	924	2,324 c	3,443 c	2,325 b	9,795 c
Medium	948 a	999	2,823 b	3,974 b	2,519 b	11,263 b
High	1,021 a	1,007	3,145 a	4,332 a	2,872 a	12,376 a

Clovers

In general, forage legume crops require a higher soil pH than do grasses. In research at SFASU-Nacogdoches, arrowleaf clover yield was maximized at pH 6.6, but in a drought year, maximum yield occurred at pH 5.3 while crimson clover yielded best at pH 5.7. In greenhouse pot culture studies at LSU-Baton Rouge, crimson clover (var. 'Dixie') produced highest yields at pH 6.2 and 1 ppm aluminum, but yield produced at pH 5.2 was 95% of maximum. None of these cool-season clovers produced acceptable yields without lime application when soil pH was 4.6 and the aluminum level was 111 ppm. Yields were also lower at pH values above 7.0.

In general, soil pH in the range of 6.0 to 6.2 is needed for optimum production of clovers. A soil test is necessary to verify pH and to rate the availability of other plant nutrients for bermudagrass growth. Scientists at TAMU-Overton emphasized the importance of maintaining the pH of acid soils above 6.0 for optimum clover growth. Soils limed to pH above 6.0 are best for arrowleaf, subterranean, crimson, Persian, rose, and white clovers. Berseem and red clovers grow best at pH greater than 6.5 and will grow at lower soil pH levels, but yields will be reduced. Birdsfoot trefoil, large hop, and vetch are considered tolerant to acid soil, while black medic, button bur, and spotted or southern bur do well above pH 6.0. Winter pea is intolerant to strongly acid soils, while sweet clovers and lappa clover do well in neutral to calcareous soils.

Many clovers are intolerant of high-pH soils. Rose clovers tolerate pH above 7.0, while other clovers such as subterranean vary in susceptibility to micronutrient deficiencies that occur in calcareous soils. 'Karridale', 'Nangeela', 'Tallarook', and 'Mississippi Ecotype' subclovers have severe iron deficiency chlorosis when subjected to low soil oxygen (reducing conditions, excessively wet) according to scientists at TAMU-Beeville. Under similar conditions, 'Clare', and 'Koala' showed no chlorosis in a calcareous Parrita sandy clay loam. In the same study, 'Yarloop', 'Larisa', 'Meteora', and 'Trikkala' exhibited only slight chlorosis. Scientists at TAMU-Beeville ranked the adaptability of clovers to calcareous Parrita soils as (most well adapted listed first): 'Bigbee' berseem = 'Kenstar' red = 'Kondinin' rose = Clare subterranean > Dixie crimson >> 'Mt. Barker' subterranean > 'Yuchi' and 'Meechee' arrowleaf.



Alfalfa is sensitive to soil acidity. Maximum alfalfa yields have been attained in the soil pH range from 6.5 to 7.7. Regression analysis of research data from Texas A&M- Overton projected highest alfalfa DM yield occurred at pH 7.7 on Darco loamy fine sand (Table 5). At this pH and with only 0.3 ppm B in the 2- to 6-inch soil depth, DM production was 4.2 tons per acre per year for alfalfa planted in rows 21-inches apart. With soil pH at 7.7 and B at 0.7 ppm in the 2- to 6-inch depth, the predicted alfalfa yield was 8.1 tons per acre. These are excellent yields for alfalfa planted at the 27-inch row spacing in a limed, rain-fed acid soil.

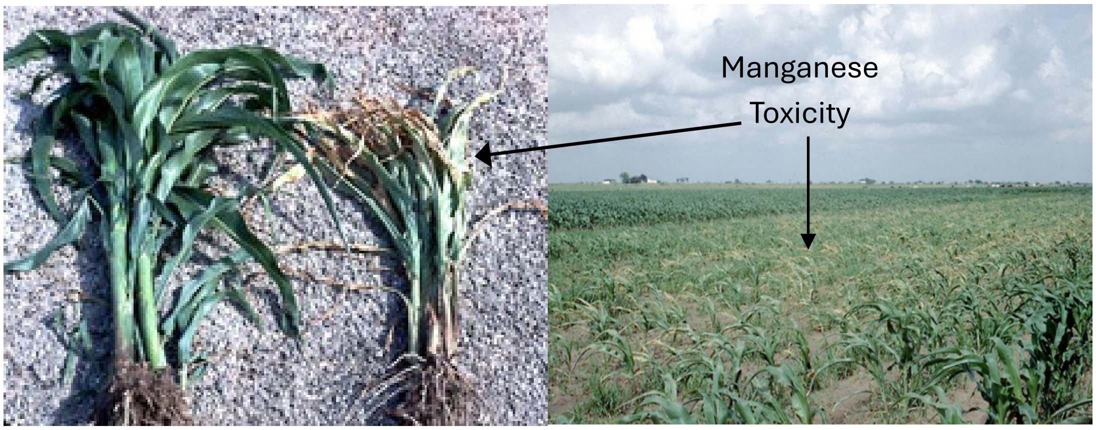
Table 5. Predicted response of alfalfa to soil pH and hot water-soluble boron (B) in the 2- to 6-inch depth of Darco loamy fine sand.

	------------------------Soil boron, ppm----------------------				
Soil pH	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**
	------------------------DM, tons/acre----------------------				
5.7	0.97	1.17	1.90	3.15	4.94
6.2	2.05	2.24	2.98	4.23	6.01
6.7	2.93	3.14	3.86	5.16	6.91
7.2	3.64	3.84	4.57	5.82	7.60
7.7	4.16	4.36	5.08	6.34	8.13

Row spacing 21 in., Mn 7.4 ppm, and applied B at 2 lb/acre in 1994.

This underscores the importance of maintaining good fertility levels for alfalfa production on highly limed Coastal Plain soils. Field-scale alfalfa production on five livestock producers' ranches indicates yields have ranged from 4 to 5.5 tons of hay per acre under rain-fed conditions on Coastal Plain soils in eastern Texas.

Excess manganese is another factor that can cause decreased plant growth in strongly acid soils. As soil pH decreases below the range of 5.2 to 5.5, manganese becomes increasingly available for plant uptake. Manganese toxicity was observed in corn growing on an unlimed Katy fine sandy loam soil in the Gulf Coastal Plain (see two images on next page). Soil pH was 5.2 and the soil was saturated by recurrent rainfall for at least one month before the corn leaves exhibited the manganese toxicity. At a similar soil pH and with much dryer conditions the previous year, the manganese toxicity failed to occur in the unlimed soil.



Liming Acid Soils Increases Forage Production

When limestone is applied to a very strongly acid soil that has a high aluminum saturation percentage, the limestone begins to dissolve, forming calcium, bicarbonate, and hydroxyl ions. As the neutralization reaction continues the calcium exchanges with aluminum on the clay, the hydroxyl ions precipitate the aluminum, and carbon dioxide is liberated to the atmosphere. The overall result is an elevated soil pH, decreased aluminum toxicity, increased plant nutrient availability, and increased plant growth and production.

Limestone Quality and Efficiency

Limestone is calcium carbonate or calcium-magnesium carbonate that is mined from open pits, crushed, and screened to fineness suitable to react with and neutralize soil acidity. Limestone varies in quality and efficiency. Limestone quality is determined by chemical tests to evaluate the neutralizing value and calcium and magnesium content, and by physical tests of particle fineness to determine the neutralization efficiency.

Limestone quality begins at the quarry. The calcium carbonate is blasted from the quarry wall and hauled to crushers where it is crushed and screened to produce coarse grades of aglime. Further processing is required to produce the more-efficient fine limestone.

Limestone may be calcitic, dolomitic, or a combination of these two major types. The differences are based on the calcium carbonate and magnesium carbonate content. Pure calcite, or calcium carbonate, contains 40% calcium. Pure dolomite, or calcium-magnesium carbonate, contains 21.7% calcium and 13.1% magnesium. In the agricultural liming trade, the dividing point between dolomitic limestone and calcitic limestone is not clearly defined. Generally, calcitic limestone contains very little magnesium. No definite requirements for the magnesium content of dolomitic limestone exist. In Texas, limestone containing in the range of 4 to 5% magnesium has been referred to as high-magnesium limestone.

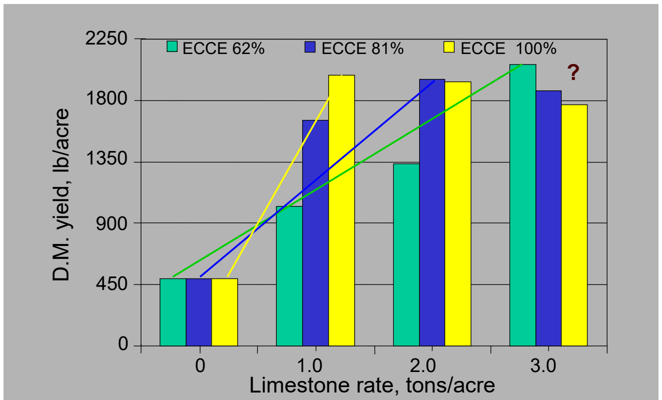
Table 6. Comparison of coarse and fine limestone samples for screen-size fractions and calculation of CCE, ECCE, and effective liming material (ELM) in each example.

Limestone sample	Sieve size	Limestone fraction	Efficiency factor	Efficiency rating	CCE	ECCE†	ELM‡
	mesh	%		%	%	%	lb/ton
Coarse,	>8	5.6	0	0			
High CCE	9-20	28.1	.2	5.62			
	20-60	26.2	.6	15.72			
	<60	40.1	1.0	40.10			
				61.44	101§	62.05	1240
Fine,	>8	0.1	0	0			
High CCE	8-20	0.2	.2	.04			
	20-60	0.5	.6	.30			
	<60	99.2	1.0	99.20			
				99.54	101§	100.54	2000

† (Sum of efficiency ratings ÷ 100) x CCE = ECCE
‡(ECCE ÷ 100) x 2000 = ELM;
§ CCE above 100 due to magnesium carbonate in the limestone.

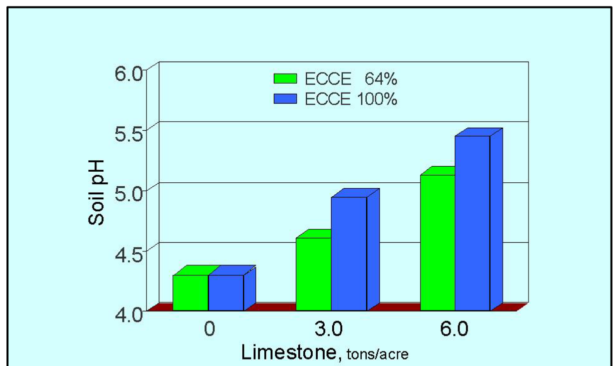
The efficiency rating multiplied by the CCE yields the effective calcium carbonate equivalence (ECCE). The ECCE is the percentage of the limestone that will effectively neutralize soil acidity. The ECCE percentage multiplied by 20 determines the pounds of effective liming material (ELM) in a short ton of limestone. Values in Table 5 represent results from testing two grades of limestone having equal CCE. The coarse limestone had particles remaining on all screens. The overall efficiency factor for this material was 61%. Nearly all the fine limestone passed the 60-mesh screen and had an efficiency rating of 99.5%. The coarse limestone had an ECCE of 62% compared to 100% for the fine limestone.

The ELM of the fine limestone indicates that it contained the equivalent of 2000 lb of effective limestone compared to 1240 lb of effective material in the coarse limestone sample. An ELM of 1240 indicates that 760 lb (2000 – 1240) of the coarse limestone are relatively ineffective for neutralizing soil acidity. In that 760 lb, the particle size is excessively large to effectively neutralize soil acidity in three years.



Crimson clover response to limestone rate and ECCE on Darco loamy fine sand 2.5 yr. after surface treatment of field plots.

The increased effectiveness of finer limestones was evaluated in field research on crimson clover and results are shown in the chart at left. Data show that 2.5 years after application, clover dry matter yield was optimized by three tons of ECCE 62% limestone (green bars). Clover dry matter yield was optimized by two tons of ECCE 81% limestone (blue bars). And most efficient of all, clover dry matter was optimized by application of only one ton of ECCE 100% limestone (yellow bars). These data indicate the increased effectiveness of the finer limestone (higher ECCE) for forage production, and this increased effectiveness is shown to endure for a number of years.



Effect of ECCE on soil pH seven years after the last treatment of a Darco lfs with rates of 0, 1, and 2 tons/acre in '88, '91, and '92.

Historically, statements indicating that limestone must contain a certain percentage of coarse particles in order to be effective at maintaining the desired soil pH level have been erroneously repeated through generations of scientists. The chart to the right represents soil pH resulting from 0, 3, and 6 tons of ECCE 62% and 100% limestone materials applied at rates of 0, 1, and 2 tons/acre in 1988, 1991, and 1992. Soil pH was measured in 1999, seven years after the last application. The ECCE 100% limestone treatment consistently maintained pH at least 0.3 units above pH due to ECCE 62% limestone. Closer examination reveals that the ECCE 100% limestone applied at the total rate of 3 tons/acre maintained soil pH nearly equal to the pH due to 6 tons of ECCE 62% material. The historical wisdom was inaccurate because, as shown in Table 5, much of the coarse limestone is ineffective for neutralizing soil acidity. The finer limestone is essentially all reactive, raising soil pH to a higher level that resists re-acidification over a longer time.

"When is the best time to lime?" is an often-heard question. Limestone can be applied anytime that a spreader truck is available and crop growth permits. Limestone is usually spread using fertilizer trucks. Since it is more profitable to spread fertilizer at lower rates on more acres, limestone is usually spread in the slow fertilizer application seasons in early winter and mid summer in Texas. When to spread limestone is based on the crop to be grown and the initial pH of the soil on which that crop is to be grown. It is always best to apply and incorporate limestone well in advance of the time that the crop that needs a higher pH is to be planted. For fall-seeded ryegrass and leguminous crops such as clovers, limestone will be effective if applied and incorporated by light disking in early to mid-summer. Limestone should be applied in the winter and disk-incorporated in early spring when alfalfa is the intended crop for planting the following fall.

In Conclusion

Now that you are more aware of soils terminology presented in this paper, here are a few "words of wisdom" for your consideration.

- Next to water, the soil is your ranch or farm's most important natural resource.
- Livestock production is dependent on forage yield and nutritive value.

  Forage yield and nutritive value are dependent on soil management.

  Therefore, since livestock production is dependent on forage yield and nutritive value, and since forage yield and quality are dependent on soil management, it naturally follows that livestock production is dependent on soil management.
- I often wonder why some livestock growers who are undaunted by manure, sometimes being in it up to their shoulders, are so negligent about sampling soils.
- Take proper care of your soils and your soils will support you.
- Realize that you are growing forages - animals are your harvesters.
- Attend to your soils and forages as closely as you look after, and tend to, your livestock, and your chances for successful livestock production will improve.
- Finally, soil is not synonymous with dirt. Dirt is soil out of place.

Although I had to search far and wide, I finally located a "cowboy" that agrees with my concept regarding the importance of soils. The plaque heading reads,

"FROM THIS SOIL COME THE RICHES OF THE WORLD." By Carl Jensen, 1999.

"THE HISTORY OF THERMOPOLIS, WY IS CLOSELY TIED TO THE SOIL OF THE AREA."

Ironically, the plaque also states, "The statue depicts a cowboy sifting ***dirt*** through his hands in 1897 when Thermopolis, Wyoming was founded."

Since it's in his hands and probably blowing in the wind, its soil out of place and can rightfully be called dirt.

Frequently asked questions about Soils, Soil Fertility, Fertilizer Use and Plant Nutrition

Vincent Haby, Ph.D., Texas A&M University System Regents Fellow and Professor Emeritus; Former Texas A&M AgriLife Research Soil Scientist; Texas A&M AgriLife Research and Extension Center-Overton.

Questions Asked:

1. What is the greatest soil fertility problem for bermudagrass hay production in Texas?
2. The potassium fertilizer rate suggested on my soil test report appears to be too low. How can I be certain that my bermudagrass is getting sufficient potassium?
3. I want to make hay out of my first growth of bermudagrass and then graze it for the remainder of the year. How should I fertilize the bermudagrass with potassium in this situation?
4. I have heard that Coastal bermudagrass grows well on acid soils, so it doesn't need much lime. Is that true?
5. How much nitrogen do I really need to produce Coastal bermudagrass and when should this nitrogen be applied for best results?
6. I want to sprig Tifton 85 bermudagrass. How should I prepare my soil for sprigging this grass?
7. Regulations for growing "organically produced" beef don't allow use of commercial nitrogen fertilizer on forages. Why? How is nitrogen fertilizer made?
8. How can I ensure that my hybrid bermudagrass is getting sufficient phosphorus?
9. How does a drought or adequate rainfall affect soil fertility for grass production?
10. What nutrients are most crucial for producing high nutritive value bermudagrass?
11. What is the most limiting factor in producing high nutritive value bermudagrass?
12. What is the most common mistake made in bermudagrass production? What do you recommend to producers as a solution?
13. What is K-Mag® and how is it used?
14. I found an opened bag of fertilizer that I didn't finish using last year and some of the material in it was quite powdery. Is this still good?
15. I've heard that nitrogen applied to my pastures is all gone in 60 days. How often should nitrogen be applied to a bermudagrass meadow for grazing?
16. When is the best time to lime my soil?
17. How long does it take for my fertilizer recommendations to arrive after sending my soil sample to the laboratory for analysis?
18. I received my soil test report in the mail and I can't understand parts of it. Can you help me interpret what some of the statements mean?

19. Recently, I read that there are differences in types of limestone used to neutralize soil acidity. This confused me. Isn't all limestone the same?
20. I would like to plant alfalfa on my farm. My neighbor says alfalfa cannot be grown in East Texas. How should I begin to determine if I have the right soil for producing alfalfa in East Texas?
21. One of my fields has Bowie soil that I think may be suitable for alfalfa. How do I determine for sure that alfalfa will do well on this soil?
22. Whenever alfalfa production is mentioned, a question that is sure to be brought up is "What about the blister beetle?"
23. How should I sample my soil to determine if it is suitable for alfalfa?
24. I am researching the possibility of growing alfalfa as a forage crop for deer. Have you conducted research in this area?
25. What is the proper soil pH for blueberry plants?
26. What about land application of oil well drilling mud on my pasture soils?
27. What effect is all this fall and winter rain going to have on my soil's pH?
28. Are there any problems with using broiler litter as a plant nutrient source?

Questions answered:

1. What is the greatest soil fertility problem for bermudagrass hay production in Texas?

Next to inadequate rainfall (hydrogen and oxygen as H_2O) thinning of hybrid bermudagrasses stands due to inadequate levels of plant-available potassium is one of the biggest soil fertility issues facing growers in the Pineywoods and Post Oak Savannah regions and other regions such as the Central Basin of Texas. Potassium in these mostly sandy acid soils usually is low and must be applied as one of the plant nutrients for bermudagrass production in these regions. Research by Texas AgriLife Research scientists with the Texas A&M System and by scientists at other universities has shown improved persistence and yield of Coastal bermudagrass stands that are adequately fertilized with potassium applied as muriate of potash or potassium chloride (0-0-60). The majority of research studies on Coastal bermudagrass response to muriate of potash evaluated only potassium levels in soils and plant tissue. More recent research evaluating Tifton 85 response to muriate of potash determined this bermudagrass also responded with increased yields to chloride, the accompanying anion applied with potassium. Blackland soils and other alkaline, higher clay-content soils of Texas usually contain more plant-available potassium for crop production, but even these soils sometimes show increased bermudagrass yield when fertilized with potassium. Potassium deficiencies in soils also have been associated with increased incidence of *Helminthosporium* leaf spot, a plant disease that has been related to bermudagrass stand decline. Fertilization of bermudagrass according to soil test recommendations overcomes potassium deficiency problems.

2. The potassium fertilizer rate suggested on my soil test report appears to be too low. How can I be certain that my bermudagrass is getting sufficient potassium?

Fertilizer rates suggested on a soil test report take into consideration the amount of potassium analyzed to be plant available in the sample of soil that was tested. The fertilizer rate is adjusted to account for this plant available soil potassium. Additional potassium is usually applied throughout the season with nitrogen for bermudagrass production, especially where mechanically harvested forage is removed from the field. If the soil test level of potassium is very low or even low, research data have indicated that the rate of applied potash (K_2O) should approximately equal the rate of nitrogen for bermudagrass hay production; other reports indicate that a 3:2 ratio of N:K_2O is adequate to maintain bermudagrass stands on soils testing low in potassium. (The term, K_2O, is the symbol used to express the potash content in fertilizer.) However, plants take up potassium as K^+, not K_2O. Two pounds of K_2O in the 3:2 ratio corresponds to only 1.7 pounds of K, therefore, a 3:2 ratio of N: K2O corresponds to only a 3:1.7 N:K ratio and this is insufficient potassium for bermudagrass grown on low-potassium soils. Bermudagrass takes up approximately 85% as much potassium (K^+) as it does nitrogen. In soils that contain very low levels of potassium, fertilization of hybrid bermudagrasses such as Tifton 85 and Coastal with potassium rates nearly equal to applied nitrogen rates, or a 1:1 ratio of N: K_2O is recommended for optimum production and stand persistence.

3. I want to make hay out of my first growth of bermudagrass, and then graze it for the remainder of the year. How should I fertilize the bermudagrass with potassium in this situation?

Compared with potassium removal from soil in hay, silage, or green chop, total potassium removal by grazing is minimal, with most of the potassium being recycled to the soil as animal wastes. Scientists have reported that less than 2% of the potassium in forages consumed by cattle in a continuous grazing system is removed from pasture as animal tissue potassium. As a result, lower potassium application rates are needed for grazed pastures compared with hay meadows unless the soil test potassium level is low. Potassium application will help overcome unequal distribution of potassium that is recycled in animal wastes, replenish potassium lost by leaching below the root zone, and may increase soil test potassium levels.

Where the first growth is to be harvested for hay, the majority of the recommended potash fertilizer (up to 100 lb per acre) should be applied with nitrogen, phosphorus, and other soil-test recommended fertilizer materials at initial green up of the bermudagrass in early spring. Bermudagrass usually contains about 42 lb of potassium (50 lb of K_2O) in each ton of dry hay produced. Apply the additional recommended amounts of potash once or twice with nitrogen during the remainder of the growing season.

4. I have heard that Coastal bermudagrass grows well on acid soils so it doesn't need much lime. Is that true?

Coastal bermudagrass is relatively tolerant to acid soils. However, bermudagrass grown on low-calcium soils, those below pH of about 5.6, may contain insufficient calcium for beef cattle. Stocker steers need 0.79% calcium for a high rate of gain according to the National Research Council (1984). When grazing Coastal bermudagrass growing on inadequately limed acid soils, high rate-of-gain stocker steers will need calcium supplement because this bermudagrass will contain insufficient calcium to meet their requirement. An average production lactating cow with a 3½-month-old calf needs 0.29% calcium as a percent of the minimum daily dry matter requirement. Calcium concentrations in bermudagrass grown on well-limed soil exceeded 0.29% calcium in the first two harvests but not in the late summer harvest, probably because the lime-treated surface soil was dry and plants could only obtain water from the unlimed, low-calcium acid subsoil.

Coastal bermudagrass grown on unlimed acid soil contained sufficient calcium *only* for the maintenance of stocker steers and for dry cows in the middle trimester of pregnancy. Maintaining acid soil pH above 5.6 by application of high-quality lime is important even for acid tolerant grasses such as hybrid bermudagrasses in order to help provide adequate calcium to grazing animals and to maintain efficiency of plant nutrients in the soil and applied as fertilizer. The pH range of 6.0 to 6.2 is needed for optimum production of clovers. A soil test is necessary to verify pH and to estimate the availability of other plant nutrients for bermudagrass growth. Suggested recommendations for application of deficient plant nutrients and limestone will be made based on test results.

Increasing acidity (decreasing pH) in low buffer capacity sandy soils, with the related nutrient inefficiencies and deficiencies associated with strongly acid soils, is another problem with hybrid bermudagrass production in Texas. Nitrogen fertilizers applied to improve grass production increase soil acidity as the ammonium (NH_4^+) in these fertilizers is converted to nitrite (NO_2^-) by Nitrosomonas bacteria, with the release of two hydrogen ions (H^+) for each ammonium ion converted. The released hydrogen increases soil acidity. Other soil bacteria called Nitrobacter rapidly convert the nitrite to nitrate (NO_3^-), the form of nitrogen most readily taken up by the plant. Soils are also acidified due to loss of basic nutrients such as calcium, magnesium, and potassium that are depleted by leaching below the plant root zone in the soil and by plant uptake and removal in mechanically harvested forage. As soils become increasingly stronger in acidity, aluminum is more readily soluble. Solubilized aluminum forms complexes with phosphorus making phosphorus less available for plant uptake with a resulting decrease in forage yields on soils already near marginal levels of plant-available phosphorus.

Excess manganese also is a potential problem in strongly acid soils. As soil pH declines, manganese oxides increase in solubility. As pH nears 5.2 and lower, manganese can be toxic to susceptible plants growing in strongly acid soils. The potential for manganese toxicity in strongly acid soils is increased when soils are water logged for an extended time.

5. How much nitrogen do I really need to produce Coastal bermudagrass and when should the nitrogen be applied for best results?

Inadequate nitrogen fertilization of bermudagrass is a common problem in Texas. Some bermudagrass growers delay timely fertilization of their bermudagrass meadows in spring because nitrogen applied for the bermudagrass also increases weed growth. Increased rainfall occurring during late fall, winter, and early spring leaches the majority of plant available nitrogen below the root zone leaving the soil deficient in this nutrient for grass production in spring. An adequate supply of available nitrogen is critical for production of bermudagrass that contains a high level of crude protein. Weeds in first-growth bermudagrass can be controlled so they will benefit less from fertilization. Timing of nitrogen application to coincide with spring growth of bermudagrass varies across Texas. Guidelines suggested for determining the proper timing of nitrogen fertilization for first growth bermudagrass are when nighttime temperatures remain above 60° and mean daily temperatures are approaching 75° F.

Nitrogen fertilizer normally should be applied according to suggestions based on a test of a properly collected and handled soil sample. Suggested rates of nitrogen for bermudagrass when the soil test indicates that available nitrogen is low follow:

Improved Bermudagrass:

Hay- 100 lb of N/acre for each cutting†.

Grazing- 60 lb of N/acre up to three times during the growing season.

Establishment - 40 lb of N/acre after sprigs are established and growing followed by an additional 50 lb of N/acre to enhance establishment for one cutting the establishment year.

† For Tifton 85, the nitrogen rate for hay may need to be raised 20 to 30 lb/acre per cutting and possibly an additional 20 lb/acre for each grazing, or 60 lb/acre four or five times per season.

Common Bermudagrasses:

Hay- 70 lb of N/acre for each cutting

Grazing- 60 lb of N/acre up to three times during the growing season

Establishment - 30 lb of N/acre after the seedlings are established and growing followed by an additional 50 lb of N/acre to enhance establishment for one cutting the establishment year.

6. I want to sprig Tifton 85 bermudagrass. How should I prepare my soil for sprigging this grass?

There are several steps needed for preparing a soil area for sprigging Tifton 85 bermudagrass. The initial steps are the same as for getting ready to sprig any hybrid bermudagrass, such as soil sampling and having the soil tested in fall, well before time to sprig, applying the recommended phosphorus and limestone in late fall or early winter, thoroughly removing all other vegetation, particularly any other bermudagrasses or other perennial grasses by using a combination of herbicides and disking followed by roller packing the soil to conserve moisture. What is different about Tifton 85 bermudagrass compared to most other hybrid bermudagrasses is that it responds to limestone applied to raise soil pH (Figure 1). This 3-dimensional surface plane graph shows that Tifton 85 bermudagrass yielded about 4 t hay/acre at pH 4.5 (strongly acid) when the soil was fertilized with adequate nitrogen and potassium. When the soil pH was raised by limestone application, the yield response to pH 7.5 was a straight line (linear; highest pH was 7.4 in these plots.) In practical terms, each 0.5 unit pH change increased Tifton 85 hay production by about 0.4 tons per acre. When this Darco loamy fine sand was limed with two tons of effective calcium carbonate equivalence (ECCE) 100% limestone to increase pH from 4.5 to 6.5 at a cost of $50.00/ton per acre (spread), or $100.00 worth of limestone,, the total increased hay production was about 1.6 tons/acre. This increased production, in a normal rainfall year, should offset the cost of limestone the first season. If limestone spread on your soil costs less than $50.00/acre, you are even further ahead financially. Of course, if your soil has a pH above 7, limestone is not needed for Tifton 85 bermudagrass production.

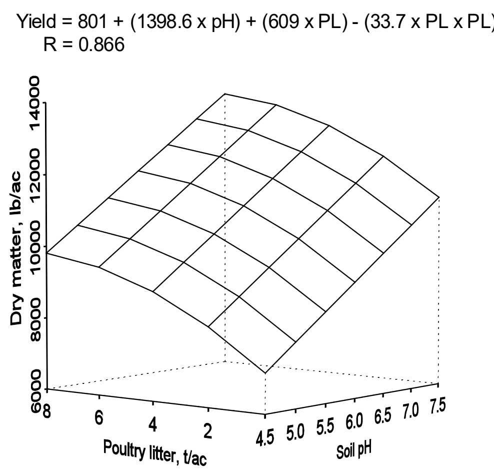


Fig 1. Tifton 85 bermudagrass response to soil pH and poultry litter rate on Darco soil in 2004.

Texas Agricultural Experiment Station

The graph also indicates that if your soil has a higher fertility level, in this case from application of broiler litter, the response to limestone is even greater. For example, with the soil pH at 4.5 with nitrogen and potash applied but with no broiler litter applied, hay production was 4.0 tons/acre, but at a pH of 6.5 with 4 tons of broiler litter applied, hay production was 6.6 tons/acre.

Hay yield would have been considerably less than 4 tons per acre at pH 4.5 without broiler litter if the additional nitrogen and potassium had not been applied.

7. Regulations for growing organically produced beef don't allow use of commercial nitrogen fertilizer. Why? How is nitrogen fertilizer made?

There are misconceptions in this world. The regulation against use of non-organic (contains no carbon) nitrogen fertilizers in production of foods for the organic market is one of these misconceptions. Plants take up nitrogen as ammonium (NH_4^+) and nitrate (NO_3^-) from the soil into their roots, and also take up some nitrogen through their leaves. Plants do not discriminate between ammonium and nitrate that was put into the soil as organic sources such as manures or inorganic sources such as commercial fertilizers. Even if plants could distinguish the difference, they would not discriminate between organic and inorganic sources of nitrogen because ammonium and nitrate are chemically the same no matter where they came from to get into the soil for plants to use.

Nitrogen fertilizers are made by combining nitrogen from the air (N_2) with natural gas (CH_4) under high temperature with steam and pressure to produce ammonia (NH_3) with carbon dioxide (CO_2) as a co-product. The overall approximate chemical reaction may be written:

$$\underset{\text{Methane}}{7CH_4} + \underset{\text{Water}}{10H_2O} + \underset{\text{Nitrogen}}{8N_2} + \underset{\text{Oxygen}}{2O_2} \rightarrow \underset{\text{Ammonia}}{16NH_3} + \underset{\text{Carbon Dioxide}}{7CO_2}$$

The NH_3 can be reacted with CO_2 to form urea or with nitric acid (HNO_3) to form ammonium nitrate. Ammonium sulfate is a co-product of nylon carpet manufacturing processes, but it could be manufactured by combining NH_3 with sulfuric acid (H_2SO_4).

8. How can I ensure that my hybrid bermudagrass is getting sufficient phosphorus?

It has become a common practice to include phosphorus, potassium, and sometimes sulfur with nitrogen applied for each re-growth of bermudagrass. Normally, the total phosphorus needs of hybrid bermudagrass for the season can be supplied with the first application of nitrogen in the spring. When the soil tests low in phosphorus, bermudagrass needs the higher rate of applied phosphorus at the beginning of the season because phosphorus applied as commercial fertilizer is only about 25% efficient the first year. Applying one-third or less of the total phosphorus needed for bermudagrass production for each re-growth on soils that test low in phosphorus limits forage production because of phosphorus deficiency. On those soils that test in the moderate soil test phosphorus range, applying a low rate of phosphate with nitrogen and potassium in a 5-1-5 ratio (N - P_2O_5 - K_2O) applied for each re-growth of bermudagrass may be acceptable for maintenance of the soil phosphorus level, but even with a moderate soil test phosphorus level, all the fertilizer phosphorus is best applied with the first nitrogen treatment in spring.

9. How does a drought or adequate rainfall affect soil fertility for grass production?

Increased rainfall leaches plant available nitrogen below the rooting depth leaving the soil deficient in this nutrient for grass production. It is common knowledge that bermudagrass is highly responsive to fertilizer application during periods of adequate rainfall.

In contrast, soil drying that characteristically occurs in late summer, limits water uptake from the surface soil. The first few inches of the surface soil depth usually contain the largest quantities of plant available nutrients that are applied, such as phosphorus, potassium, calcium, magnesium, and many of the micronutrients that are mineralized from decaying plant residues. When the surface soil becomes devoid of plant available water, roots can no longer obtain these nutrients from this more readily available supply.

During a drought, properly fertilized bermudagrass out-yields non-fertilized or inadequately fertilized bermudagrass. It is especially important to fertilize bermudagrass during a drought when grass production is at critically low levels. When a rain shower does occur during a dry period, grass that is fertilized can readily benefit from the fertilizer. The advantage of plant nutrient availability for the grass is greatly reduced when fertilizer is applied after a rain shower.

10. What nutrients are most crucial for producing high nutritive-value bermudagrass?

Nitrogen, phosphorus, potassium, sulfur, and chloride, particularly in acid, low organic matter, deep, sandy soils, are the most crucial nutrients for producing high-quality bermudagrass because they are usually the most limiting of fertilizer-applied plant nutrients in these soils. On deep, sandy soils in high rainfall regions, these five plant nutrients are usually deficient and need to be applied when establishing a new planting of hybrid bermudagrass. Once established and with the root system extending down into the B-Horizon or zone of accumulation of clay-sized particles and mobile plant nutrients, hybrid bermudagrasses may obtain sulfur from accumulations that exist in this horizon from previous applications of sulfur. Sulfur is a mobile nutrient, one that readily leaches from the surface soil and accumulates in the B-Horizon.

In the higher organic matter and higher clay-content, more alkaline soils (those with pH above the 7.0 to 7.5 range), nitrogen and phosphorus are usually the most limiting. Greater amounts of phosphorus are needed when bermudagrass growers push for increased production using higher rates of nitrogen and irrigation compared to rain-fed production and lower rates of nitrogen. On these soils, bermudagrass also may respond to fertilization with sulfur and to the potassium and chloride in applied potash.

Any of the 16 or 17 chemical elements normally considered essential for plant growth and reproduction can become crucial for production of high-quality bermudagrass if they become deficient in the soil. Calcium and magnesium are plant nutrients that potentially can become limiting, but deficiencies of these two elements for plant growth have rarely been documented in research studies. Hydrogen (H) and oxygen (O), although not applied as fertilizers are, by far, the most crucial plant nutrients for high-quality bermudagrass production. Obviously, without water (H_2O) there is no plant growth.

11. What is the most limiting factor in producing high-quality bermudagrass?

Nitrogen becomes the most limiting factor in producing high nutritive value bermudagrass when:

- All other plant-essential nutrients are available in adequate supply,
- Soil pH is adequate,
- Soil water and all other plant nutrients are available in adequate supply,
- And timely harvest management practices are applied.

12. What is the most common mistake made in bermudagrass production? What do you recommend to producers as a solution?

The most common mistake made in bermudagrass production, other than not fertilizing, is failure to harvest at the time the bermudagrass contains its optimal nutritive value for the targeted animal. Timely harvest is important, whether the bermudagrass is being produced for hay, silage, green chop, or for grazing. Delaying harvest of bermudagrass beyond four to six weeks following initiation of re-growth in spring or after the previous cutting during periods of high production causes rapid deterioration in nutritive value.

To maintain the highest nutritive value in properly fertilized bermudagrass cut for hay, producers would do well to harvest bermudagrass at timely intervals of no longer than four to six weeks following initiation of re-growth. When continuously stocked with animals, recommendations indicate that bermudagrass should be grazed moderately short to maximize carrying capacity, yet grazing should be sufficiently light to allow some grass to accumulate for best average daily gain. When grazing in a rotationally stocked system, stocking with a sufficient number of animals to remove bermudagrass forage to 2 to 4-inch stubble from each pasture in 3 to 7 days and allowing 20 to 28 days for re-growth is one recommendation to maintain high nutrititive value bermudagrass.

A word of caution is advised when growing Tifton 85 bermudagrass for hay production. Tifton 85 stems are larger in diameter than stems of other bermudagrasses. If highly-fertilized Tifton 85 is allowed to grow much longer than four weeks during a period when available water is adequate, cutting, drying, and baling this grass can become quite difficult because of the longer time needed to dry the stems and because of the volume of forage produced.

13. What is K-Mag® and how is it used?

K-Mag® is mined as langbeinite, a water soluble mineral that contains potassium, magnesium, and sulfur. K-Mag® is primarily used in blended (mixed) fertilizers to supply magnesium and sulfur when these nutrients are deficient in soils and to supplement potassium that is most often provided in the blend by use of muriate of potash (K_2O , 0-0-60).

14. I found an opened bag of fertilizer that I didn't finish using last year and some of the material in it was quite powdery. Is this still good?

Generally, the chemical content of nitrogen, and the phosphorus and potassium in plastic fertilizer bags will not decrease. Only the physical characteristics will be affected by heat (formation of powder-like particles of ammonium nitrate) and moisture (caking) over time. It is best to purchase only what is needed for one application so that it does not deteriorate in the bag.

Sometimes, if you can't get to a fertilizer/feed store on a regular basis, you need to purchase fertilizer ahead of when you plan to use it, so it sits in the bag for an extended period and solidifies. Simply lift the bag and drop it on a cement drive from about 4 feet up (if the bag hasn't deteriorated due to moisture reacting with the contents), or pound on the bag with your hand and it may break up. For more hardened caked fertilizer that won't break up by these methods, your only options are to rub loose the individual grains from the caked fertilizer, or try to dissolve the chunks in water in a plastic bucket, but be careful not to apply too much to your garden when dissolved in water.

15. I've heard that nitrogen applied to my pastures is all gone in 60 days. How often should nitrogen be applied to a bermudagrass meadow for grazing?

Nitrogen applied to actively growing grass pastures can be lost from the soil when: (1) the plants take it into their roots; (2) excess rainfall leaches (washes) the nitrate (NO_3) form of N down into the soil; (3) some that is in the ammonium form may be converted to ammonia gas (NH_3) and will volatilize if left on the soil surface and unincorporated; and (4) when the soil remains wet for prolonged periods depriving the aerobic bacteria of their normal oxygen source so they begin using oxygen from the NO_3 forms of N. When they have taken most of the oxygen, the N reverts to the atmospheric nitrogen gas and it will leave the soil as the gas form.

How long N remains in the soil depends on all of these factors. If N is applied to a dry soil surface and if no rain or dew is received for 60 days under very low humidity conditions, the N will remain on the soil surface to be dissolved and moved into the soil when rains finally do arrive. Dew will dissolve fertilizer leaving it at the soil surface. In pasture situations, once you have your suggested N fertilizer rate based on analysis of your soil sample and it calls for split application of the N during the season, let your knowledge, experience, and observation be your guide as to when you need to refertilize. When you begin to see pale, yellowish-green forage between the darker green forage in bovine defecation spots, it is probably a good time to add more N. Remember that each one pound of actual N applied (3 lb of ammonium nitrate or 2.2 lb of urea) creates, on average, 1.8 pounds of acidity that eventually will have to be neutralized by applying limestone to maintain a favorable pH for forage growth. Ammonium sulfate is a stronger acidifier. For each pound of N applied as ammonium sulfate, an average of 5.4 lb of ECCE 100% limestone is needed to correct the acidity formed.

16. When is the best time to lime my soil?

At least two possible answers are heard, "anytime" or "it depends". Limestone can be applied anytime that a spreader truck is available. Limestone is usually spread using fertilizer trucks. Since it is more profitable to spread fertilizer at lower rates of application on more acres during the busy fertilizing seasons, limestone is usually spread in the slower fertilizer application seasons in early winter and late summer in Texas. The "it depends" answer to the when to apply limestone question is based on the crop to be grown, and the initial pH of the soil on which that crop is to be grown. It is always best to apply and incorporate limestone well in advance of the time that the crop that needs a higher pH is to be planted or sprigged. The best time to adjust the soil pH by liming for fall-seeded forage crops would be to apply the limestone in late winter-early spring and disk incorporate the limestone at the transition time between the decline of the cool-season forage and regrowth of warm-season forages. Since this most likely will not be done, the next best option for liming soils for ryegrass and leguminous crops such as clovers that grow during the higher-rainfall winter months, limestone (ECCE 100%) will be effective if applied in late-summer and lightly disked into the soil when preparing the seedbed a couple of weeks before seeding these cool-season crops. When alfalfa is the intended crop for planting the following fall, limestone should be applied in the winter and disk-incorporated in early spring.

17. How long does it take for fertilizer recommendations to arrive after sending my soil sample to the laboratory for analysis?

When a soil testing laboratory is operating at its maximum efficiency, it should not take more than two weeks for your test results to be returned to you with suggested fertilizer rates. At times, lab equipment can malfunction or the lab is extremely busy and it can take longer.

18. I received my soil test report in the mail and I don't understand parts of it. Can you help interpret what some of the statements mean?

- The pH on this report is 5.3 and indicates that your soil is acidic. It is not strongly acidic, but does need the lime for Tifton 85 bermudagrass, ryegrass, and for clover production. In addition to testing pH in water, the Buffer pH test is used to determine the amount of limestone to apply. In this instance, the laboratory recommended application of 1.0 ton of limestone per acre. The recommendation is for application of ECCE 100% limestone. If the only source of limestone available is ECCE 62%, the rate of application would need to be increased to 1.6 tons/acre [(100 ÷ 62) x 1.0] to compensate for the inefficiency of the coarser limestone. Disk the limestone into the soil, even if only a couple of inches deep just before the bermudagrass begins to grow in spring. Pack the freshly disked soil with a weighted roller to conserve moisture.

- The test for nitrogen indicates that the surface 6-inch depth that you sampled contains 20 parts per million (ppm) nitrogen in the nitrate form. This represents 40 lbs of nitrate nitrogen in the 6-inch depth. Therefore, the lab recommended that only 60 lbs of nitrogen be applied per cutting of bermudagrass for three cuttings. Actually, the first cutting of bermudagrass will use the residual soil nitrogen, so the fertilizer rate should be increased to 80 to100 lb of N/acre for the second and third bermudagrass regrowth if the grass is to be cut for hay.

- The remainder of the tests show a number and are given a "level" rating that may be Very Low, Low, Medium, High, or Very High. The amount of phosphorus is indicated as 8 ppm and the rating is low. The resulting recommendation is to apply 80 lbs of phosphorus as P_2O_5 per acre for 6 tons of hay. Because phosphorus tested low, all of this fertilizer phosphorus should be applied with the first application of nitrogen in spring.

- Potassium is indicated as 50 ppm and is categorized as low. The recommendation is for application of 220 lbs of potash as K_2O for bermudagrass that should be split into three applications. The largest application should be 100 lbs per acre applied with the first treatment of nitrogen and phosphorus. This represents about a 3-4-5 ratio of N- P_2O_5- K_2O. The following split applications of 60 lbs per acre should be made with the second and third applications of N following the first and second cuttings of bermudagrass using a 4-0-3 ratio of N- P_2O_5- K_2O using ammonium nitrate as the nitrogen source in the warm season.

- Magnesium and sulfur tested low in this soil. The laboratory recommended application of KMag® at 30 lbs of magnesium and 60 lbs of sulfur per acre. But, 1.0 ton of ECCE 100% limestone that contains 4% magnesium is available, and when mixed with the acid soil, will supply the magnesium. The sulfur in the recommendation can be supplied as ammonium sulfate in the early spring fertilizer treatment. Your fertilizer dealer will likely blend 912 lb of ammonium sulfate (21-0-0 + 23 sulfur); 555 lb of diammonium phosphate (18-46-0); and 533 lb of Muriate of Potash (0-0-60) to make a blend of 14% N, 12% P_2O_5, and 16% K_2O, with 11% sulfur. The application rate will be 626 lb of the blend per acre on your 10 acres.

- Notice that the recommendations for a clover/ryegrass mixture do not call for application of nitrogen. Clover gets its nitrogen from symbiotic *Rhizobia* in nodules on roots. These bacteria convert N in the air into a form that the clover can use. The soil level of N is adequate for germination and initial ryegrass seedling growth, but additional N at a rate approximating 30 to 50 lb/acre should be applied to the clover/ryegrass mixture after seedling emergence for increased ryegrass growth when winter grazing is needed. Apply additional N at the rate of 60 to 75 lb/acre in late January and again in mid-March for increased ryegrass production. Nitrogen applied in fall for a clover/ryegrass mixture will increase growth of ryegrass but not help growth of the clover. For a clover/ryegrass mixture, the clover yield will diminish when N is applied, but total season forage production can be optimized when N is applied at 60 lb/acre one month after seeding, followed by additional N at 60 lb/acre in late January. Grazing animals will return most of the nitrogen and other nutrients in the clover to the soil for use by succeeding forages.

For the clover/ryegrass mixture where increased clover production is desired, application of 30 lb of nitrogen per acre may be applied several weeks after seedling emergence, and delay additional nitrogen application until late February when 60 lb of nitrogen per acre may be applied for the ryegrass. Limiting nitrogen application to a ryegrass and clover mixture will give the clover a better chance to become established.

19. Recently, I read that there are differences in types of limestone used to neutralize soil acidity. That confuses me. Isn't all limestone the same?

The term "limestone" refers to a crushed calcium carbonate ($CaCO_3$) rock. The calcium carbonate content determined by chemical analysis and the fineness of grind evaluated by sieving determine the quality of a limestone. Chemical analysis determines the calcium carbonate equivalence (CCE), also referred to as neutralizing value (NV), and calcium and magnesium content. The total capacity of a limestone to react is related to its CCE. Physical analysis determines particle size ranges in the limestone. The rate at which limestone reacts in a strongly acid soil is related to particle size, chemical composition, and the physical nature of the limestone particle.

Limestone is mined in open-pit quarries, crushed, and passed through a 3/32 x ½ inch (2.4 x 12.7 mm) screen to produce the coarser limestone material usually referred to as aglime. In the crushing process, some fine particles are produced that increase the overall effectiveness of the aglime. The size of the holes in the screens used in this process limits the fineness of limestone produced by crushing. The moist finer particles readily plug a screen with smaller holes.

Highly reactive limestone can be produced by washing fine particles from the sand-size aglime and from concrete-aggregate rock, then settling these fine particles in ponds. When a settling pond is full and the water drained from the pond, the fine calcium carbonate is removed, dried to about 7 to 9% moisture, and shipped for spreading on acid soils.

A. Neutralizing value or calcium carbonate equivalence.

Liming materials differ in their ability to neutralize acid soils (Table 1). Pure $CaCO_3$ (calcite) is the standard against which other liming materials are measured and its neutralizing value or CCE is considered 100%. Neutralizing value or CCE is defined as the acid-neutralizing capacity of an agricultural liming material expressed as a weight percentage of calcium carbonate.

Table 1. Neutralizing value (or calcium carbonate equivalence, CCE) of common liming materials and some alternative materials.

Liming material	NV or CCE, %	Liming material	NV or CCE, %
CaO	179	Marl	70-90
$Ca(OH)_2$	136	Blast furnace slag	75-90
$CaMg(CO_3)_2$	109	Basic slag	60-70
$CaCO_3$	100	Electric furnace slag	65-80
$CaSiO_3$	86		

1a. Limestone sources. The carbonates of calcium (Ca) and magnesium (Mg) are the most common liming materials used for field treatment of acid soils (Table 1). A limestone that is pure $CaCO_3$ will contain 40% Ca and have a CCE of 100%. Calcium oxide (CaO) is a white powder formed by heating finely ground $CaCO_3$ to drive off CO_2. It is commonly termed unslacked lime, burned lime, or quicklime, and is quite disagreeable to handle. Calcium oxide is the most effective of all the liming materials. Pure CaO has a CCE of 179% compared with pure $CaCO_3$ that has a CCE of 100%.

Calcium hydroxide [$Ca(OH)_2$], a white powdery lime formed by adding water to CaO is difficult and unpleasant to handle. It is frequently referred to as slacked lime, hydrated lime, or builders' lime. Pure $Ca(OH)_2$ has a CCE of 136%. Both CaO and $Ca(OH)_2$ are very fine lime materials. They usually are not economical to apply on a large acreage unless obtained as by-product materials sold at a reasonable price mainly to remove them from the manufacturing site. Because of their extreme fineness, both materials are difficult to apply using spreader trucks. Dust from these materials spread dry will stop up air filters on spreader trucks.

Marls and various types of slags also are used as liming materials. The CCE of these materials varies from 60 to 90% depending on purity. Other materials that have acid neutralizing value include fly ash from coal-burning electricity generating plants, lime-treated sludge from municipal and industrial water treatment plants, and flue dust from cement manufacturing. Sugar mill lime, pulp mill lime, carbide lime, acetylene lime, and packinghouse lime contain varying amounts of acid neutralizing Ca and/or Mg compounds. Use of these materials to neutralize acid soils should be based on their CCE, Effective Calcium Carbonate Equivalence (ECCE), and cost per pound of Effective Liming Material (ELM) on a dry-weight basis. Field proximity to the source, cost of transportation, and handling and spreading characteristics dictate their use as liming materials.

2a. Calculating neutralizing value. To determine the neutralizing value (NV) or CCE, a sample of lime, accurately weighed to the milligram, is reacted with an acid, usually hydrochloric (HCl), using a prescribed standardized procedure. The CCE can be calculated based on the amount and strength of the acid not consumed in the reaction. For example, a 1-gram sample of limestone is reacted with 50 mL of 0.5 molar HCl (concentrated HCl diluted with ion-free water or 25 milliequivalents of HCl). The excess acid is titrated with 0.25 molar sodium hydroxide (NaOH, a dilute solution of a strong base in water). If the titration required 36 mL of 0.25 molar NaOH, the calculations are:

$$\begin{aligned}\%\ CaCO_3 \text{ Equivalence} &= 2.5 \times [\text{mL HCl} - (\text{mL NaOH} \div 2)] \\ &= 2.5 \times [50 - (36 \div 2)] \\ &= 80\end{aligned}$$

3a. Magnesium content. A liming material that contains a high percentage of Mg is called dolomitic limestone. Some states require that limestone containing a minimum of 6% Mg (20% $MgCO_3$) be classified as dolomitic. Limestone containing less than 6% Mg is referred to as high-Mg limestone.

Dolomite is a mineral composed of Ca and Mg carbonates ($CaCO_3$-$MgCO_3$). Pure dolomite contains 40 to 45% $MgCO_3$ and 54 to 58% $CaCO_3$. Liming material described as dolomitic limestone can have 15 to 20% or higher $MgCO_3$ not to exceed 45% with compensating percentages of $CaCO_3$ plus impurities and a maximum NV of 109%. Dolomitic limestone is preferred for neutralization of low-Mg content acid soils, but its reaction rate is slower than that of calcitic limestones. Comparisons between dolomitic and calcitic limestones of similar particle size ranges showed that the calcitic reacted at a rate approximately twice that of dolomitic. Other research showed that calcitic limestone with an ECCE of 102% increased soil pH more rapidly than did dolomitic limestone with an ECCE of 110% during the first year following incorporation by disking into a Katy fine sandy loam. At 18 months, pH was equal for both sources at the 2, 4, and 6-ton/acre rates. When the same sources and rates were surface applied on a Boy loamy fine sand, the calcitic source consistently maintained pH approximately 0.3 units above that produced by the dolomitic limestone.

4a. Impurities. One of the quality factors of agricultural limestone is the NV, or CCE. The NV of agricultural limestone is compared to pure calcite that has a NV of 100%. Some limestones have neutralizing values near 100%, while others may have NVs of 80 or less. If limestone has a NV less than 100, the difference between 100 and the actual NV is the percentage of impurities it contains. These impurities are non-reactive in acid and usually are sand to clay size materials.

5a. Moisture content. Since limestone is sold by weight, the percent moisture it contains is an important consideration. Agricultural limestone sold at the quarry or stockpiled at retail sales locations usually contains moisture. Very fine limestone washed from aggregate rock and deposited in settling ponds can be reclaimed and spread in the field at a moisture content near 8 to 9% to minimize formation of lumps and dust. If applied too dry, much of the fine limestone will be blown from its target site when applied on a windy day. Fine limestone is usually hauled to the field site in covered trucks. If there is a short delay between hauling and spreading, fine limestone should be stored under cover to prevent dehydration in the sun or excessive re-hydration by rain. Excess moisture in very fine limestones will cause it to lump and prevent uniform spreading. Moisture also adds weight as water and decreases the amount of effective liming material (ELM) on a ton basis. Ten-percent water in limestone is 200 lb of water in each ton. The application rate should be increased at the time of sale to account for this water.

B. Particle size.

Crushed limestone is screened through a series of sieves to determine the particle size ranges. Research showed that the highest pH occurred six months after liming for materials 60 mesh (0.25 mm) or finer. The 50 (0.338 mm) to 60 mesh fraction maximized reaction in 12 months. Particles coarser than 50 mesh took 18 months, and those coarser than 10 mesh (2 mm) had little value for correcting soil acidity. Other studies showed that particles in the 10- to 20-mesh (0.85-mm) fraction were 14% as effective as those in the 100-mesh fraction. These studies also showed that particles larger than 10 mesh essentially were of no value for neutralizing acid soils.

As fineness increases, the amount of reactive surface area in a given quantity of aglime increases. Assume that a piece of limestone with a volume of one cubic centimeter has a flat surface area of approximately six square centimeters. That same piece of limestone ground so that each particle is the exact size to pass a 100-mesh screen, and assuming that these particles remain perfect cubes, would have an increased flat surface area approximating 400 square centimeters. Actual surface area likely will be greater because the limestone rock breaks in irregular planes. Increased surface area allows aglime to be distributed more evenly on the soil, to dissolve more rapidly in acid soils, and raises pH in a shorter time. Finer particle-size limestone will neutralize a greater concentration of soil acidity, raise pH to a higher level, and maintain that higher pH change against re-acidification longer than the same weight of a coarser-ground material from the same limestone source.

1b. Effect on rate of reaction. The efficiency or rate at which lime reacts with soil is largely determined by soil pH, limestone particle size, the extent of lime-soil intermixing, and by the neutralizing value, application rate, and solubility of the limestone. The reaction rate between lime and soil is greater at lower pH because of the acid strength-dependent solubility of liming materials. On incorporation into a moist acid soil, limestone particles begin to dissolve by reacting with soil acids. As the reaction progresses, H^+ and Al^{3+} on clay surfaces are replaced by Ca or Mg. The neutralization reaction will continue as plant roots take up Ca and Mg, and as these cations diffuse away from soil clay surfaces. Calcium diffusion and uptake leaves excess negative charge on the clay that is neutralized by H^+ and Al^{3+} to maintain the balance of charges and this increases soil acidity. Applied limestone dissolves and neutralizes this increased acidity. Finely ground limestone mixed with the soil provides more surface area and particles per volume of soil, less distance between particles, and more rapid neutralization of soil acidity than coarse limestone. However, as pH increases toward neutrality regardless of the fineness of limestone, the rate of reaction decreases because less acid is available to dissolve the lime.

Some scientists state that if the recommended amount of very fine limestone is properly mixed with moist soil, planting can follow immediately. However, although sufficient fine lime is present to raise pH above the level where Al and Mn are toxic and to correct any Ca deficiency, this is an agronomically unsound practice. Incorporation of calcitic limestone just before planting saturates the soil solution of low-buffer-capacity, acid soils with Ca. High levels of Ca compete with K and Mg for uptake by plant roots. Excess Ca created K deficiency symptoms in alfalfa seedlings in low-K soils fertilized with potash in greenhouse, field, and in garden conditions. Seedlings rapidly grew out of the deficiency, but growth was temporarily slowed.

2b. Efficiency rating. In Texas, particle size of ground limestone is estimated by washing a sample through 8-, 20-, and 60-mesh, dried and pre-weighed sieves. Particles larger than 8-mesh are considered to have no neutralizing value. Those that pass an 8-mesh sieve but are retained on a 20-mesh sieve are considered 20% effective. Particles finer than 20-mesh but that remain on a 60-mesh sieve are rated as 60% effective. Those finer than 60-mesh are considered 100% effective for neutralizing soil acidity. The percentage limestone in each size range multiplied by its effectiveness factor generates an efficiency rating (Table 2).

C. Product comparisons.

Whenever possible, some measure of the reactivity of the limestone should be obtained. When this is not available, the purchaser should be guided by the fineness of the material, the neutralizing value, the Mg content, and the cost per ton applied to the soil.

1c. Calculating ECCE and ELM. Examples of coarse, fine, and very fine dry limestones are shown in Table 2. The NV of 101% in samples 1 and 3 is due to a small amount of $MgCO_3$ in the sample. The percentage of limestone in each particle-size range multiplied by its respective efficiency factor generates the efficiency rating. The sum of efficiency ratings multiplied by the NV or CCE of the limestone produces the effective neutralizing value (ENV) or ECCE.

The ECCE is an estimate of the percentage of effective limestone in the product. The ECCE percentage divided by 100 and multiplied by 2000 lb/ton (or ECCE % x 20) equals the pounds of effective liming material (ELM) in each ton of limestone. The coarse limestone (sample 1) contains only 1241 lb of ELM in each ton. Compare this to the fine, high-CCE limestone (sample 3) where 99.5% of the particles pass the 60-mesh sieve. This limestone has the equivalent of 2011 lb of ELM/ton, or 770 lb more ELM per ton than does the coarse limestone. Therefore, the finer limestone would neutralize more soil acidity than the coarser limestone.

Table 2. Calculation of limestone quality as effective calcium carbonate equivalence (ECCE) and effective liming material (ELM) per ton in limestone samples.

Limestone sample	Sieve Size	Limestone Fraction	Efficiency Factor	Efficiency Rating	NV or CCE	ENV or ECCE†	ELM‡
	mesh	%		%	%	%	lb/ton
1. Coarse	>8	5.6	0	0			
(high CCE)	8-20	28.1	0.20	5.62			
	20-60	26.2	0.60	15.72			
	<60	40.1	1.00	40.10			
				61.44	101§	62.05	1241
2. Fine	>8	0.2	0	0			
(medium CCE)	8-20	0.8	0.20	.16			
	20-60	5.0	0.60	3.00			
	<60	94.0	1.00	94.00			
				97.16	83	80.64	1613
3. Fine	>8	0.1	0	0			
(high CCE)	8-20	0.2	0.20	0.04			
	20-60	0.5	0.60	0.30			
	<60	99.2	1.00	99.20			
				99.54	101§	100.53	2011

† (Sum of efficiency ratings ÷ 100) x CCE = ECCE; ‡ECCE x 20 = ELM. §NV or CCE above 100 due to Mg carbonate in the limestone.

2c. Limestone economics. The amount of limestone recommended to neutralize an acid soil is based on applying ECCE 100% limestone. If one ton of ECCE 100% limestone selling at $50/ton spread in the field is recommended per acre, and the cost of the ECCE 62% coarse limestone is $48/ton applied in the field, the actual cost of one ton of ELM in the coarse limestone is $77.36.

(2000 lb ELM/ton ÷ 1241 lb ELM/ton) x $48/ton = $77.36/ton

Compare this to the cost of a ton of the fine limestone (ECCE 100%) selling for $50.

(2000 lbs ELM/ton ÷ 2011 lb ELM/ton) x $50/ton = $49.73/ton†

†Usually considered as having only 2,000 lb ELM/ton, costing $50.00

When comparing these two materials, the cost is $27.63 more per acre to adjust soil acidity to a similar pH using the ECCE 62% coarse limestone.

3c. Effect of limestone ECCE and ELM on yield and soil pH. In a greenhouse study, increasing the limestone ECCE from 59% to 100% continued to increase yield response of subterranean clover at the two lowest rates. Clover yield at the low rate of ECCE 100 limestone equaled yield at double that rate using ECCE 59%. At the high application rate, clover yield increased as limestone ECCE increased to 78%. As the limestone increased in fineness to 90 and 100% at this high rate, yields declined, possibly due to decreased availability of boron or other micronutrients.

Yield of crimson clover increased progressively as ECCE was increased from 62 to 100% at the 1.0 ton per acre rate in a field study on a Darco soil. At the 2-ton per acre limestone rate, the ECCE 81 and 100% treatments maximized yield 600 lb/acre above yield of clover limed with ECCE 62%. Clover yields continued to climb with increasing rate of ECCE 62% limestone to the 3 ton per acre rate. Yield due to the 81 and 100% ECCE limestone applied at one ton per acre was higher than yield at double that rate for ECCE 62%. Clover yields peaked at the 1 ton per acre rate of ECCE 100%, at 2 tons of ECCE 81% per acre, and at 3 tons of ECCE 62% per acre. These increased yields from lower rates of finer limestone compared to higher rates of coarse limestone demonstrate the greater efficiency of fine limestone for neutralizing soil acidity for crop production.

Several experiments have shown that ECCE 100% limestone increases soil pH faster and to a higher level than limestone with an ECCE of 62%. In fact, the pH change induced by the 2000-lb ELM limestone (ECCE 100%) compared to the 1241-lb ELM material (ECCE 62%) is more valuable than calculations reveal. Research in Texas shows that one-half the amount of ECCE 100% limestone per acre increases soil pH to a level equal to, and sometimes higher than the increase due to double that rate using ECCE 62% limestone. When equal rates of ECCE 62% and 100% materials were compared over time, the pH change effected by finer limestone remained 0.32 pH unit higher than the pH affected by coarse limestone seven years after the last application (Figure 2).

The 3 ton per acre rate of ECCE 100% limestone maintained soil pH at nearly the same level as did the 6 ton per acre rate of ECCE 62% seven years after the last lime treatment. These results discredit the long-held belief that agricultural limestone must contain coarse material to provide lasting change in pH and resist the acidifying effect of N fertilizers.

Fine limestone neutralizes much more acidity than coarser material. Because pH is a logarithmic function ($pH = -\log [H^+]$, read as the negative logarithm of the hydrogen ion activity), an increase of 0.32 pH unit is actually a 2.1-fold, or a 210% decrease in soil acidity. A pH change from 5 to 6 is a 10-fold, or 1000% decrease in acidity. Evaluation of research data reveals that the 6 ton/acre rate of ECCE 62% limestone maintains soil pH only 0.18 pH unit above the pH due to the 3 ton/acre rate of ECCE 100% seven years after the last application.

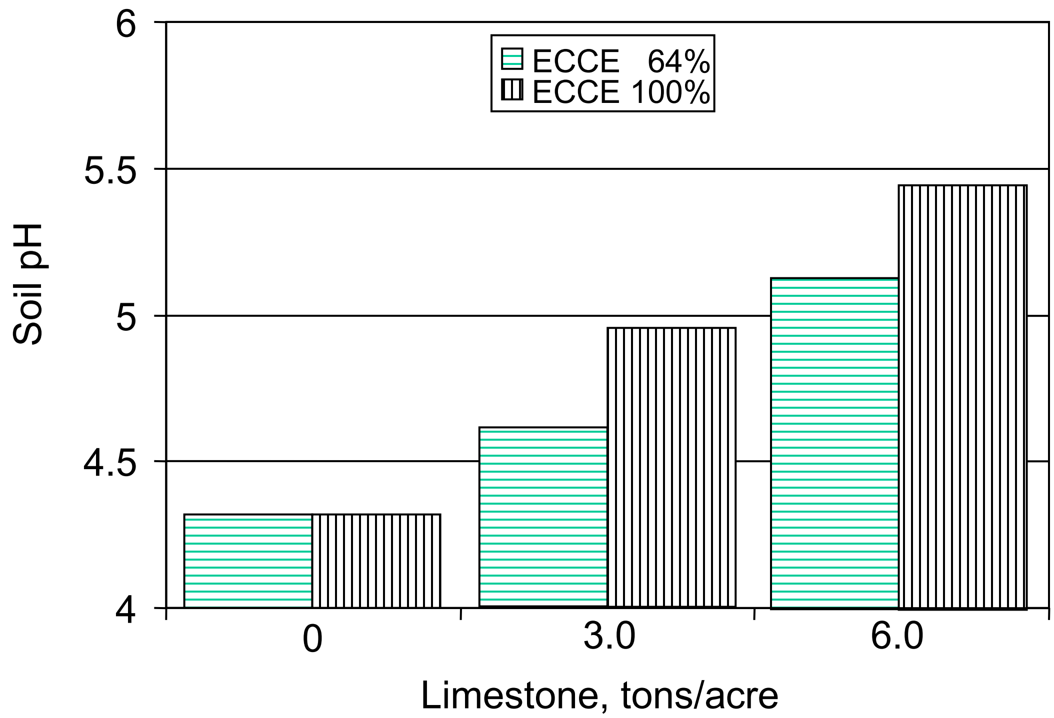


Fig. 2. Effect of ECCE on soil pH seven years after the last treatment of a Darco lfs with rates of 0, 1.0, and 2.0 tons/acre in '88, '91, and '92.

The importance of liming moderately acid and more strongly acid soils for clover production cannot be over emphasized. There was negligible crimson clover production where no limestone was applied to a Darco soil at pH 5.7. Use of the best quality limestone is important for crop production as well as increased pH. Calcitic limestone applied as ECCE 100% at the rate of 1 ton/acre increased ryegrass and crimson clover production compared to the same rate of ECCE 62% limestone.

Table 3. Crimson clover response to limestone with increasing ECCE percentage averaged over rates.

ECCE	1991	1992	1993	3-yr. total	Difference†	Added beef value‡
%	-----------------Dry matter, kg ha^{-1}	--------------------				$/acre
62	1458 b	2550 b	1682 b	5690 b	0	
81	1746 ab	2712 ab	2027 ab	6485 a	795	71.55
100	1880 a	2854 a	2236 a	6970 a	1282	115.38

† Compared to ECCE 62%
‡ Based on a value of $0.60 per pound of beef gain
§ Values in a column followed by the same letter are significantly different at p = 0.05

Over three years, ECCE 81% limestone increased crimson clover yield 795 lb per acre and ECCE 100% increased yield 1282 lb per acre compared to yields from ECCE 62% (Table 3). If the ECCE 100% limestone is spread in the field at a cost of $50.00/ton, the cost of an average rate of 1.5 tons of ECCE 100 limestone is $75.00. The predicted increased value of beef gain due to ECCE 100% limestone over the three years is $115.38 per acre. To obtain a similar response using ECCE 62% limestone would have cost $116.12 for the required higher rate of this coarser limestone [(100 ÷ 62) x 1.5 x $48.00 = $116.12]. In addition, the predicted increased value of beef gain (1282 lb clover x 2.25 lb beef gain/15 lb clover x $0.60 value of beef gain = $115/acre) from the extra clover produced over the three years by use of ECCE 100% limestone paid for the cost of the finer limestone but only broke even with the cost of the higher rate needed when using ECCE 62% limestone.

D. Calculating application rates.

Rates of limestone recommended to neutralize soil acidity to a desired pH are based on 100% effective limestone on a dry weight basis. Limestone vendors can provide the ECCE of limestone materials available for field application. Given the ECCE, the rate of ELM to apply per acre can be calculated by dividing the recommended limestone rate by the ELM and adjusting this value for moisture content, the correct limestone application rate can be determined. For example, with a soil pH of 5.2 the limestone recommendation for cool-season grass production on a sandy loam is 1.5 tons ELM/acre. If the ELM of the limestone is 1200 lb/ton and the limestone contains 10% moisture, the calculation becomes:

(ELM in lb/acre required x ELM equivalent conversion) x moisture adjustment = tons of material/acre.

(3000 lb ELM/acre x 1 ton/1200 lb ELM) x 1.1 = 2.75 tons/acre

20. I would like to plant alfalfa on my farm. My neighbor says alfalfa cannot be grown on the acid soils in East Texas. How should I begin to determine if I have the right soil for producing alfalfa?

You are right. Alfalfa can be grown in your area, but your success with growing alfalfa will depend largely on the type of soil that is in the field where you plan to grow it.

Before we go any further to discuss how to grow alfalfa, I need to tell you that alfalfa planted in the spring has not been successful due to weed competition and insufficient rooting depth by the time our normal summer dry season arrives. In addition, alfalfa needs a soil pH very near 7.0 for optimum production. If the soil is not at pH 7.0, it must be limed and the limestone needs time to change pH. Alfalfa does best when planted in fall as soon as adequate rainfall has been received to allow germination and continued growth of alfalfa seedlings. For fall-seeded alfalfa, limestone should be applied the previous winter and disked into the soil in early April.

The first step in your plan to grow alfalfa is to locate a favorable soil on your ranch or farm. You can find the names of your soils in the Natural Resources Conservation Service soil survey of your county. In each county, the Natural Resources Conservation Service office should be located in the Department of Agriculture USDA Service Center. The NRCS office staff should be able to help you locate your farm site in that soil survey manual and determine the soil series on the site where you would like to grow alfalfa. The soil must be well drained internally and externally. This means that creek bottom soils usually are not good candidates for alfalfa production in East Texas. Upland soils that have two to four feet of sand in the surface above a yellow to reddish orange clay B-horizon with little or no gray color are good candidates for alfalfa soils. If it looks good on paper, your next step will be to collect soil samples by one-foot depths to four feet for analysis of pH to determine the strength of subsoil acidity.

We no longer recommend overseeding bermudagrass pastures with alfalfa. Alfalfa is much too valuable as a hay crop and the stand is easily killed by continuous grazing.

21. One of my fields has Bowie soil that I think may be suitable for alfalfa. How do I determine for sure that alfalfa will do well on this soil?

Bowie is one of the better soils on which we have evaluated alfalfa growth. If you have a soil survey manual for your County, you can locate the soil description in it. If not, use the link below:

http://soils.usda.gov/technical/classification/scfile/index.html

Under "Introduction" click on "Soil Series Name Search," then type "Bowie" into the rectangle, and then click on "Process." The name "Bowie" will show as a link. Click on "Bowie "and the entire soil series description will show.

Many of the horizons in the Bowie soil indicate that the soil is very strongly acid. As you are aware, we can adjust the surface soil pH using a high quality limestone. However, it is difficult to make rapid changes in subsoil pH. Subsoil pH can be adjusted toward neutral by maintenance of an adequate liming program on the surface over a number of years, but there is no really quick fix. That is why we are recommending that potential sites for alfalfa be tested for pH by one foot depths to four feet.

A pH of 5.5 or higher is desired in these depths, otherwise, soluble aluminum that can become toxic to alfalfa root growth may be a problem that limits alfalfa from growing its roots sufficiently deep to continue extracting water and producing during periods of drought. Soil samples by one foot depths can be taken by use of a hydraulic probe, a bucket auger, or even a post-hole digger. No less than five random locations within each field should be sampled, with samples from all one-foot depths going into a common bucket, samples from all second foot depths going into another bucket, etc. On completion of sampling, mix the soil in the individual buckets, label a soil sample bag for each depth and place about a half pound of thoroughly mixed soil into the bag, then send these samples to a laboratory for pH analysis. This test, along with knowledge of the soil drainage that you already know, may tell you if the Bowie or any other soil will be suitable for alfalfa. If the pH in these subsoil depths is much below 5.5, it is best to reconsider that site for some other forage that is more acid tolerant. However, if you can irrigate alfalfa and keep the upper depths moist, subsoil pH is not as much of a problem.

22. Whenever alfalfa production is mentioned, a question that is sure to be brought up is "What about the blister beetle?"

If you will go to a search engine on the Internet and type in "blister beetle," you can find pictures of this insect. The blister beetle may be from ¾ inch to 1¼ inch long. The most common color types are gray or striped. They are gregarious and don't stay long in one place as they feed on alfalfa.

Blister beetle is harmful to horses if they consume dead beetles in hay. If your market for the alfalfa is for horse hay, the first two cuttings of alfalfa in northeastern and eastern Texas should be free of this insect because it does not become active until sometime in late spring or early summer. Alfalfa in its second year of growth will produce two cuttings by the time bermudagrass is ready for its first cutting. In all of the 25 experiments that we have done with alfalfa in and around the Overton, Texas vicinity, we have not seen a blister beetle. This is not to say that it will not show up some day in the future. If you market your alfalfa for horse hay, you would be wise to walk through your field carefully looking for blister beetle before cutting the alfalfa. Additionally, do not use a hay conditioner to crimp the alfalfa stems during cutting. Live blister beetles will leave drying hay.

23. How should I sample my soil to determine if it is suitable for alfalfa?

Before proceeding to collect soil samples, it is most important to determine the name or names of the soils on the field where you want to plant alfalfa. Once we have determined that the soil series is one on which alfalfa may do well, proceed to sample as follows:

For the most accurate representation of your potential alfalfa field, collect at least fifteen samples of the surface soil at zero to six-inches deep from randomly selected locations throughout the field. All these 0 to 6-inch depth samples should be placed in the same bucket. At the same time that you are collecting the 0 to 6-inch deep sample, you also can select five of those locations at random and, using four additional buckets, sample the following depths: 6 - 12 inches, 12 to 24 inches, 24 to 36 inches, and 36 to 48 inches. Each similar depth is placed into the bucket marked for that depth. You do need to sample to 48-inches deep as described, but you may want to collect these deeper samples in a second trip over the field.

When sampling is completed, mix the soil in each individual bucket. Mark soil sample bags that can be obtained from your County Agent's office, with your name, your sample number, and the depth at which that sample was collected. Place about one pound of soil into the bag from the depth represented on the bag.

On completion of your sampling, you will have individual bags of soil that represent the 0 - 6, 6 - 12, 12 - 24, 24 - 36, and 36 - 48-inch depths of that field. Complete a soil sample information form that will accompany the samples to the laboratory. On that form, request the standard analysis battery of tests **plus boron** on the 0 - 6-inch depth. On the deeper depths, tell the lab to analyze these samples for pH only, but ask the lab not to discard your soil samples until we know that the pH of the deeper samples is 5.5 or higher. If pH on these deeper samples is slightly below 5.5, you will need to have the lab analyze the samples for exchangeable aluminum. Ask the lab to extract exchangeable aluminum using 0.01 molar calcium chloride solution. If pH is below 5.5 and aluminum is above 1.0 ppm in any of the subsoil samples below 6-inches deep, avoid this site for alfalfa, because the aluminum may be toxic to root growth on sensitive plants such as alfalfa.

The best way to sample these deeper depths is by use of a pickup-mounted hydraulic probe. This is not a common piece of equipment that anyone has available, so the next best tool is a soil auger that has cutting bits on the bottom designed for sand. These can be obtained from Forestry Supplies, Ben Meadows, Nasco, or possibly other companies that handle soil augers. Each company has an Internet Web Site that you can find by typing the company name into a search engine. Once on that company’s web site, locate the search box, type soil auger, then press the enter key or point the mouse to and click on go. Some producers also have successfully collected these deeper samples using a post-hole digger and a carpenter’s tape measure.

24. I am researching the possibility of growing alfalfa as a forage crop for deer. Have you conducted research in this area?

We have supervised alfalfa production in a Sustainable Agriculture Research and Education Funded Project in NE Anderson County. Prior to this, we have done extensive studies to learn how to grow alfalfa in NE Texas acid soils, primarily in the five counties adjacent to Overton where the Texas A&M AgriLife Research and Extension Center is located. What we have learned is applicable to acid and alkaline soils. And yes, alfalfa is excellent forage for deer.

The first question someone wanting to grow alfalfa must ask is, do I have the right soil and soil conditions for alfalfa. First, alfalfa needs a well-drained and aerated soil and if it is a high fertility soil that is even better. If the soil is acid, an additional selection criterion must be applied. We can correct the pH for alfalfa by mixing lime into the surface depth to change the pH to 6.8 or higher, but if the subsoil is strongly acidic, alfalfa will not be able to extend its root system sufficiently deep to give it a chance to obtain water and produce during a drought.

Therefore, if the surface soil is acidic, a test for subsoil pH is needed. This is accomplished by collecting samples of subsoil by one-foot depths to four feet from at least five random locations in a field (less from a half-acre food plot). Each one-foot depth goes into a bucket labeled for that depth sample. When sampling is complete, mix the samples in each individual bucket, and then place a sample of the mixed soil into a lined soil sample bag that can be obtained from your county agent. You will have a bagged sample from each bucket (depth). Send these samples to the laboratory of your choice and have them analyzed for pH only. For successful alfalfa production, the pH of these samples to four feet must be 5.5 or above. Alfalfa will grow is the pH of these samples is below 5.5, but it will not produce as well.

Another sample of the 0-6-inch depth collected from at least 15 locations in the proposed alfalfa field should be mixed in a bucket and a composite sample of about one pound of soil should be bagged and sent to the laboratory for what commonly is referred to as the standard tests, but for alfalfa, a test for plant available boron is also needed and you must request this test. Liming an acid soil will tie up much of the plant-available boron, so if the test comes back indicating low boron, this plant nutrient must be applied along with other nutrients needed based on the soil test.

Of special importance, if your soil has a pH that indicates limestone application is needed for alfalfa and you want to plant alfalfa this fall but it already is September, please save your money this year and begin planning now to plant next fall. (In Texas, alfalfa must be planted in fall to have the best chance to succeed.) The reason, several months are required for the limestone to react to change pH into the range favorable for alfalfa.

25. What is the proper soil pH for blueberry plants?

A soil pH of 5.2 is ideal for growing blueberries. Rabbiteye blueberries grow and produce well in soils with pH values ranging from 4.0 - 5.5. However, the ideal pH range is more like 4.5 - 5.5. Rarely, is limestone recommended for blueberry plants, and when it is recommended at a pH below 4.5, the amount applied should be low, even less than 1 ton per acre.

We adjusted pH 0.1 units upward by applying and incorporating 600 lb of ECCE 64% limestone to the total area of a pH 4.5 Lilbert loamy fine sand. I would hesitate to adjust pH upward more rapidly than this because blueberry plants are calcifuge plants i.e. plants that do not grow well in calcareous soils. It is easy to put blueberry plants into an iron deficiency situation by application of too much limestone.

Also, blueberry plants grow best in loam or sandy loam soils. The fine, fibrous root system of the blueberry plant requires open, porous soils. These roots cannot penetrate compact, heavy clay soils. A mixture of acid peat with the sandy loam in the planting hole is usually recommended.

26. What about land application of oil well drilling mud on my pasture soils?

A permit for land treatment of drilling mud is needed only if the drilling mud is moved from the site (farm) where the drilling occurred. If the drilling mud is land treated on the site where it is produced, no permit is required. Obtaining the permit is the responsibility of the drilling company. However, the drilling company must have the permission from the land owner to land treat the drilling mud.

A much abbreviated chemical analysis is required. The chloride content of the drilling mud must be less than 3,000 ppm. A normal range of chloride in drilling mud is 300 to 900 ppm with 1,500 ppm sometimes occurring. Chloride is highly leachable, so will not remain on the soil after extensive rainfall has occurred following land treatment. However, the sodium that accompanies the chloride will remain for some time after treatment, particularly on low cation exchange capacity sandy acid soils.

The drilling mud must be oil free as determined by visual inspection- no oil film visible. This is very subjective. Apparently, heavy metals are not considered a problem in drilling mud.

Other requirements for land treatment are that the material applied must be contained on site, out of water ways and ponds. The ideal would be to have the company pay for the cost of disk incorporation of the drilling mud to enhance soil microbial decomposition of any volatiles contained in the applied material. Also, the application rate must be less than or equal to 1,000 barrels per acre and the application is not to be repeated on the same land.

Drilling mud which is normally alkaline in reaction is composed of sodium bentonite. A normal pH range may be 7.5 to 8.5. This indicates that some pH benefit may come from application of drilling mud to acid, sandy soils, but the drilling mud likely will not supply much calcium to these acid soils.

Sodium bentonite is very fine clay. As such, the drilling mud should provide some increase in the cation exchange capacity, and even some small increase in water holding capacity of these sandy soils.

27. What effect is all this fall and winter rain going to have on my soil's pH?

Whether the excess rainfall will change soil pH depends on when you normally sample your soils. If you always take samples in the late winter or early spring, you may not notice any change in pH, except that due to small variation in your sampling technique or in lab analytical technique.

However, if you normally sample in fall, especially on sandy, low organic matter, low clay soils, and then you want to compare pH in spring sampled soils, you should notice an increased pH in your spring-collected samples compared to your fall-collected samples. The pH increase in the spring collected samples may be as much as 0.5 pH unit. Why?

Coastal Plain soils, the type mentioned above, normally go toward a more dry condition through summer and into fall. During the same time, fertilizer nutrients (salts) are applied to enhance crop growth. The result of this drying and the slightly increasing salt content causes a salt-effected pH, or a pH that is lower. In a laboratory that tests pH, the procedure normally is done in a 1:1 or 1:2 soil: water suspension in the USA. If a small amount of salt, for example- a few drops of a potassium chloride solution is added to the water suspension, the pH will go lower. The potassium added exchanges additional hydrogen from the clay. Soil pH measures potential hydrogen (pH) in the soil suspension, so if additional hydrogen is removed from the clay into solution, the pH will register this additional hydrogen and the pH value will go down.

For this reason, soil testing labs should analyze pH in a dilute salt suspension such as a 0.01 molar potassium chloride solution (molar is a concentration term- in this case, a very dilute solution of potassium chloride in distilled water). Soil pH measured in this dilute salt solution changes very little from fall to spring, but the measured pH will be lower than that measured in a soil: distilled water suspension. Couldn't we get used to our pH being 0.5 units lower when it gives us a more consistent and accurate measurement that does not change from fall to winter??? This measure of soil pH normally is not used to determine the limestone needed to raise an acid soil pH to a more desirable level for cool-season annuals- limestone needed normally is determined by a lime requirement test.

28. Are there any problems with using broiler litter as a plant nutrient source?

The odor of freshly applied broiler litter is horrible. Once I visited a friend's place and on exiting the car, I had to ask what died on the place. Oh! I had broiler litter applied to fertilize my grass a couple of days ago, he responded. The only animal manure that may be worse smelling, in my opinion, would be hog manure that passed through slatted floors and was caught in containment areas beneath.

Here is a table that shows the average nutrient contents of broiler litter (BL) and the range of values for these major plant nutrients that samples of broiler litter were found to contain.

Nutrient content of broiler litter.

Plant nutrient	Average	Range
	lb/ton	
Nitrogen (N)	62	34- 96
Phosphate (P_2O_5)	59	22-142
Potash (K_2O)	40	13- 99
Calcium (Ca)	35	13- 98
Magnesium (Mg)	8	3- 34
Sulfur (S)	6	0.2- 13

From the ranges shown, broiler litter varies tremendously in all nutrients. If you want to know what amounts of nutrients are applied, it is necessary to collect a representative sample of the batch of BL hauled to your place before it is spread in the field.

In broiler litter, phosphorus is nearly as high as is the N content. If broiler litter is applied at rates sufficient to satisfy the total N needs of grass forages, the soil phosphorus level will increase. In the past, broiler producers used to apply all their produced litter on their own few acres, and the soil phosphorus level went extremely high. When fertilizing with broiler litter, it is best to apply rates that will satisfy the phosphorus needs of the forage, and then supplement the grass with N and potassium, if economically priced, to obtain the recommended levels of these nutrients.

Excess phosphorus in runoff from fields can contribute to eutrophication in water and cause fish kills. Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die.

Advantages of broiler litter:
Contains other nutrients in addition to N, P, and K
Slow release of nitrogen
Contains calcium compounds that maintain soil pH
Organic matter increases water and nutrient holding capacity of soil
Disadvantages of broiler litter:
Variable nutrient content within and between batches
P level exceeds forage needs
Odor (temporarily makes unpleasant neighbors)
Not always available when needed or desired

Spreading poultry litter

Long-Term Cow-Calf Performance on Overseeded Bermudagrass Pastures at Different Stocking Rates and Fertility Regimens: 2022 Fertilizer Prices and Costs of Gain

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The "energy crisis" we thought we had encountered a few years ago was just an appetizer compared to the "servings" we experienced in forage-animal production in 2022. Regardless of current domestic oil and gas production policies, captive supplies, import quotas, future inventories, fuel substitutes, or greed, the costs of living and doing business in the US have experienced dramatic price increases. With increased and seemingly ever-increasing energy prices, the costs of "doing business" have caused many to re-think their operating strategies. For the agricultural producer, not only have they experienced increased prices in fuel, fertilizers, and feed ingredients, they also have had to deal with appraisal districts and increased taxes for all land uses. Management strategies and implementation options for pastures and beef production were drastically altered by the more than doubling of nitrogen fertilizer prices from 2003 to 2008. However, the 2008 prices for fuel and fertilizers were just the introduction to the policy decisions made in 2020 that caused some drastic increases in prices of fuel and fertilizers for 2021 and into 2022. With the current world-wide energy demands, escalating prices of feed grains, and uncertain supplies of oil and gas, beef producers have been forced into major reassessments of management input and cash-flow alternatives. The economic dilemma for producers is that there is no transition period to adapt to the new pasture-beef production cost paradigm. With no likely price reductions in fuel, fertilizer, and feed grains in either the short-term or long-term future, every cash input must be evaluated and scrutinized for potential returns.

Although there are no archived pasture-animal databases to answer all management concerns, there are some specific, long-term, fertilizer regimen x stocking rate experimental data for both common and Coastal bermudagrass from Texas A&M AgriLife Research at Overton (BeefSys, Rouquette et al, 2003). The text that follows will provide forage-animal experimentation information with discussions on general fertilizer x stocking rate management options and projected pasture production and forage persistence for cow-calf operations.

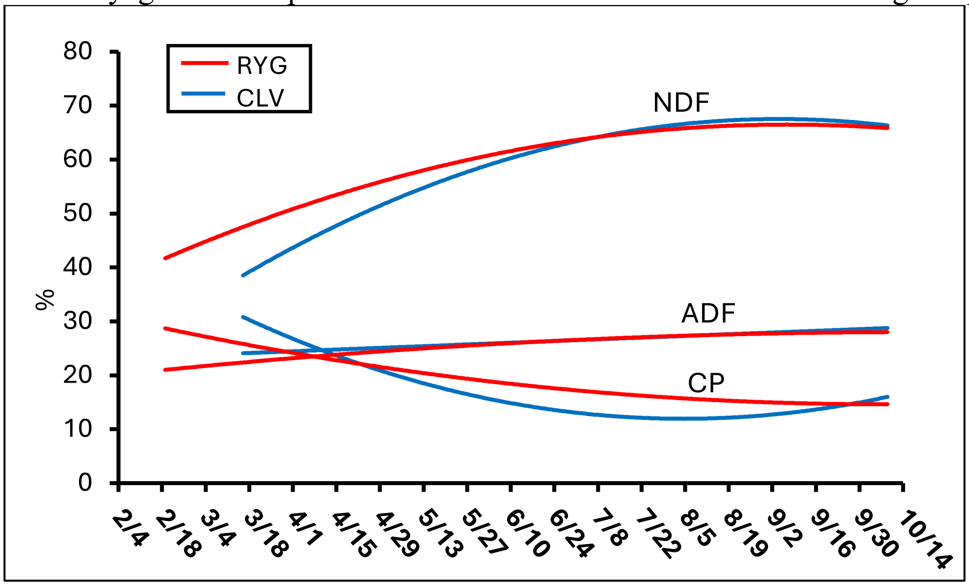
Recycled Nutrients and Cow-Calf Stocking Rates

Background. During the spring of 1968, common and Coastal bermudagrass pastures were established at the Texas A&M AgriLife Research and Extension Center at Overton. Initial pH ranged from 5.7 to 6.4 on these upland, sandy loam Coastal Plain soils. During the year of establishment, all pastures received 2 ton/ac lime (ECCE 65) and split-applications of fertilizer at a rate of 120-65-65 lb/ac N-P_2O_5-K_2O. Grazing was first initiated during the spring of 1969 with three stocking rates based on forage availability. Beginning in 1969, all pastures received a total fertilization rate during the growing period of 200-100-100 lb/ac N-P_2O_5-K_2O. Nitrogen was split applied at 50-65 lb/ac at each time of fertilization, whereas P_2O_5 and K_2O were applied once at the initial spring fertilization. During the 1969 and 1970 grazing seasons (April to October) of 180-days, pastures consisted of bermudagrass only and were not overseeded. Common bermudagrass pastures were overseeded in the fall of 1970 with a mixture of 'Gulf' ryegrass and 'Dixie' crimson clover. Coastal bermudagrass pastures were evaluated as pure stands until overseeding with Gulf ryegrass and 'Yuchi' arrowleaf clover in the fall of 1974. Since the initiation of grazing overseeded common bermudagrass in 1971 and overseeded Coastal bermudagrass in 1975, all pastures have been overseeded with ryegrass and/or clover. The original fertilization strategy was to apply N-P_2O_5-K_2O at an approximate ratio of 2:1:1. The average annual fertilizer applications were 200-100-100 lb/ac N-P_2O_5-K_2 from 1969 through 1984.

In the fall of 1984, a nutrient cycling experiment was initiated, and all stocking rate pastures for both common and Coastal bermudagrass were sub-divided equally into two fertility x winter annual forage treatments: 1) N + ryegrass, and 2) no N + K_2O + clover (Silveira et al. 2016). Phosphorus fertilizer was not included as a component of either N vs no N-fertility treatments because soil P concentrations were assessed to be adequate for grass or clover production. In addition, we wanted to eliminate long-term residual soil P buildup under stocking conditions. Fertilizer applications of either N-0-0 vs. 0-0-K_2O were used from 1985 through 1997. The N rates varied from an average of 408 lb/ac from 1985-1989, 238 lb/ac from 1990-1994, 290 lb/ac for 1995-1996, 221 lb/ac for 1997, and an average of 250 lb/ac from 1998 to today. The annual K_2O rates averaged about 112 lb/ac through 2004, and about 60 lb/ac from 2005 to present. From 1985-1997, no fertilizer P was applied. Beginning with the 1998 grazing season and continuing through today, all pastures received phosphorus, potassium, sulfur, magnesium, and boron. Phosphorus was applied at about 100 lb/ac P_2O_5 from 1998 through 2004, and then 60 lb/ac through present. However, only the N + ryegrass pastures received nitrogen fertilizer with 2022 rates of 250-60-60.

Stocking rates have varied by bermudagrass and fertility regimens according to forage mass available for meeting experimental protocol. Samples for forage mass (availability) were taken from each pasture by hand-clipping quadrats to ground level at initiation of stocking and again at approximate 28-d intervals. Three stocking rates were achieved using a variable stocking rate (put-and-take) to create three levels of forage mass. The targeted forage mass ranged from 500 to 1000 lb/ac for High stocking rates, 1250 to 2000 lb/ac for Medium stocking rates, and > 2500 lb/ac for Low stocking rates. At approximate 14-d intervals, forage samples from each pasture were collected to assess nutritive value. At several locations in each pasture, hand-plucked forage samples that visually represented animal selectivity were collected. The selected plant parts collected represented >80% leaf and <20% stems. After drying, samples were ground to pass a 1mm screen and a sequential analysis of neutral detergent fiber (NDF) and acid detergent fiber (ADF) was made (Goering and Van Soest, 1970). Forage nitrogen was determined using a block digester colorimetric method via Technicon Auto Analyzer. Figure 1 illustrates changes in nutritive value components during the seasons from cool-season annuals to exclusive bermudagrass (Rouquette et al. 2018).

Figure 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude protein (CP) of annual ryegrass and Apache arrowleaf clover overseeded on bermudagrass pastures.



Long term, 30-yr, averages for stocking rates from mid-February to late September have approximated 0.95, 1.5, and 2.2 cow-calf pair/ac (1500 lb BW= 1 cow and calf) for common bermudagrass, and about 1.1, 1.7, and 2.8 cow-calf pair/ac for Coastal bermudagrass (Rouquette 2017). To accommodate overall length of cool-season and warm-season stocking seasons, rebreeding and calving season, and pasture size, fall-calving pairs were stocked on overseeded bermudagrass pastures from February to mid-June; whereas, winter-calving pairs were stocked on exclusive bermudagrass pastures from late June to late September or early October. Cattle from both calving seasons were exposed to bulls for 75 days. Animal performance for both calving seasons has been used to provide forage-animal relationships from February to October without disruptions for calving or breeding on test pastures (Rouquette et al. 2018).

Cow-Calf Performance and Stocking Rates

The Average daily gain (ADG) responses to stocking rate for both fall-and winter-calving pairs shows season-long effects of stocking rate on both lactating cow and suckling calf for both Coastal (Fig. 2) and common bermudagrass (Fig. 3) overseeded with ryegrass + N or clover without N fertilizer. Both cow and calf ADG decreased with increasing stocking rates as anticipated. However, the impact of lactation showed a buffering effect on stocking rate impact on calf ADG. At low stocking rates with opportunities for selective grazing, calf ADG was more than 2.5 lb/day from either clover or ryegrass. With increased stocking rates, bermudagrass overseeded with ryegrass + N had greater calf ADG than clover without N. Cow ADG was positive at the low and medium stocked Coastal and low stocked common bermudagrass. At high stocking rates, cows lost 1 to 1.5 lb/day and had reduced body condition score (BCS). Additional data analyses showed that bred, lactating Brahman-influenced F-1 cows may be grazed at stocking rates that reduce BCS to 4 or less at weaning and recover BCS on bermudagrass pastures with ad libitum forage mass for 90% rebreeding (Rouquette et al., 2020).

Figure 2. 29-yr average relationship of cow and calf ADG to stocking rate on Coastal bermudagrass overseeded with ryegrass (RYG) or clover (CLV)

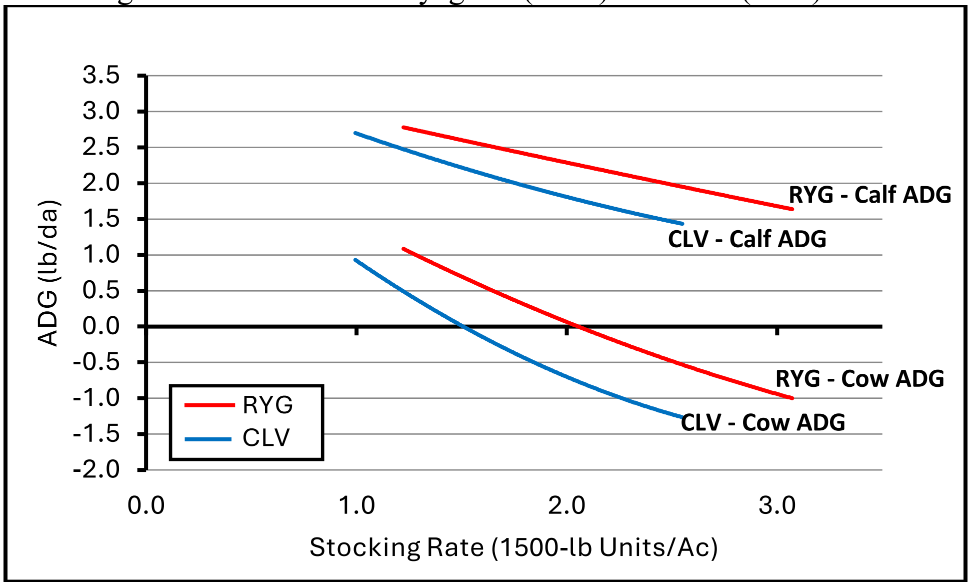


Figure 3. 29-yr average relationship of cow and calf ADG to stocking rate on common bermudagrass overseeded with ryegrass (RYG) or clover (CLV)

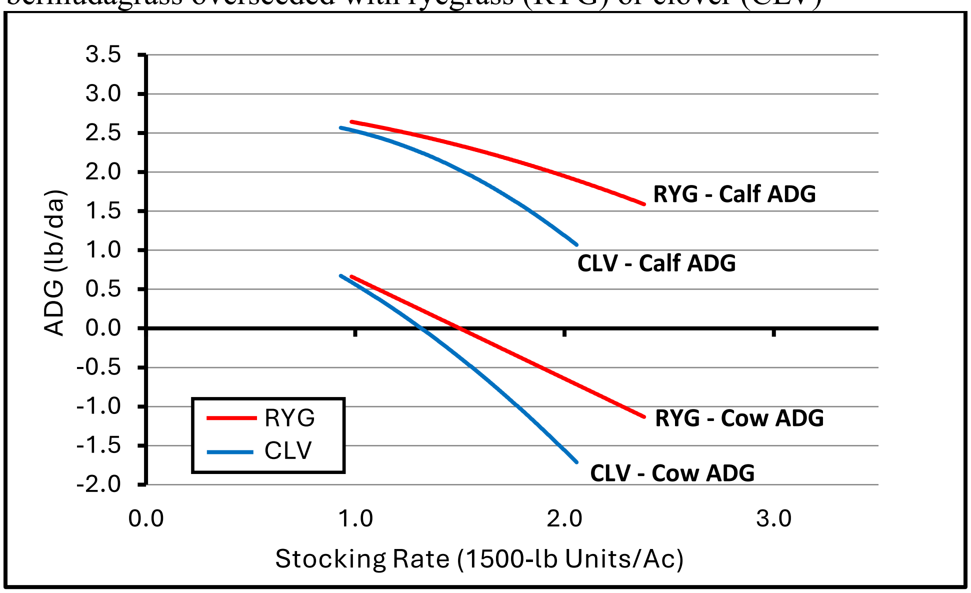
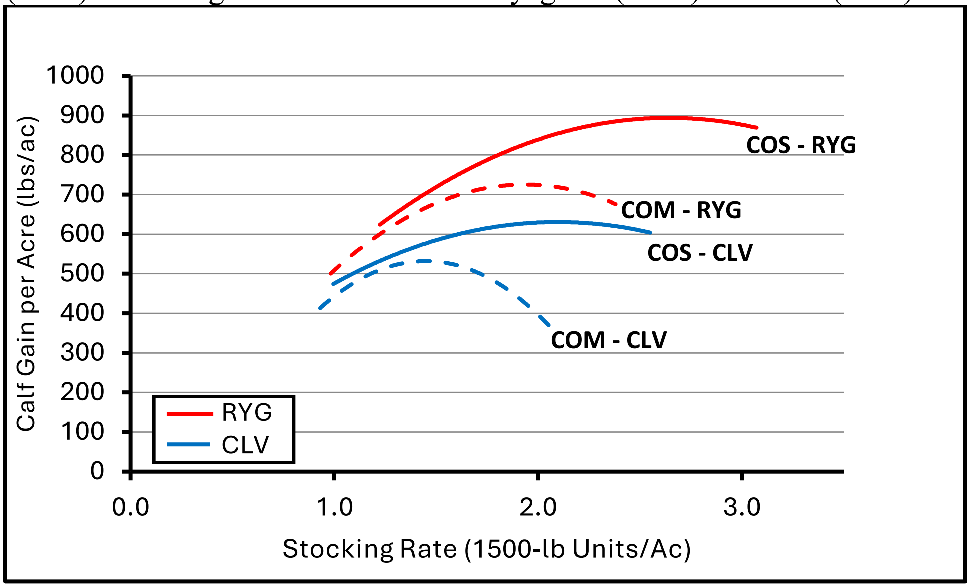


Figure 4 shows the 29-yr average suckling calf gain/ac was greater for Coastal overseeded with ryegrass due to more forage production from N-fertilized pastures. Common bermudagrass overseeded with clover and without N fertilization had the lowest calf gain per ac, and was most negatively affected by high stocking rate due to reduced forage mass.

Figure 4. 29-yr average relationship of cow gain to stocking rate on common (COM) and Coastal (COS) bermudagrass overseeded with ryegrass (RYG) or clover (CLV)



The relationship of cow and calf ADG with level of forage mass is shown in Figure 5. Lactating cows required approximately 1800 lb/ac forage mass to maintain body weight. For optimum calf ADG, about 2500 lb/ac bermudagrass mass was required. Figure 6 shows the relationship of ADG with cow and calf forage allowance. Forage allowance is the relationship of forage dry matter (DM) with animal body weight (BW). Thus, the optimum forage allowance for cow ADG showed to be about 1.0 (DM:BW) (Fig 6). The optimum forage allowance for the suckling calf was about 0.90 (DM:BW) with lactation providing a buffer to stocking rate.

Figure 5. 29-yr average relationship of cow and calf ADG to forage mass on common and Coastal bermudagrass overseeded with ryegrass or clover

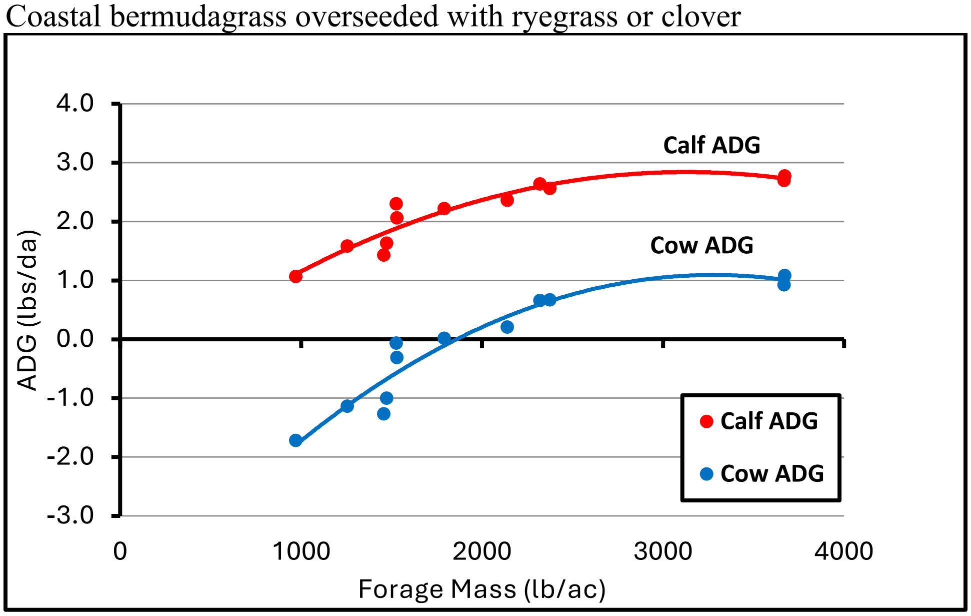
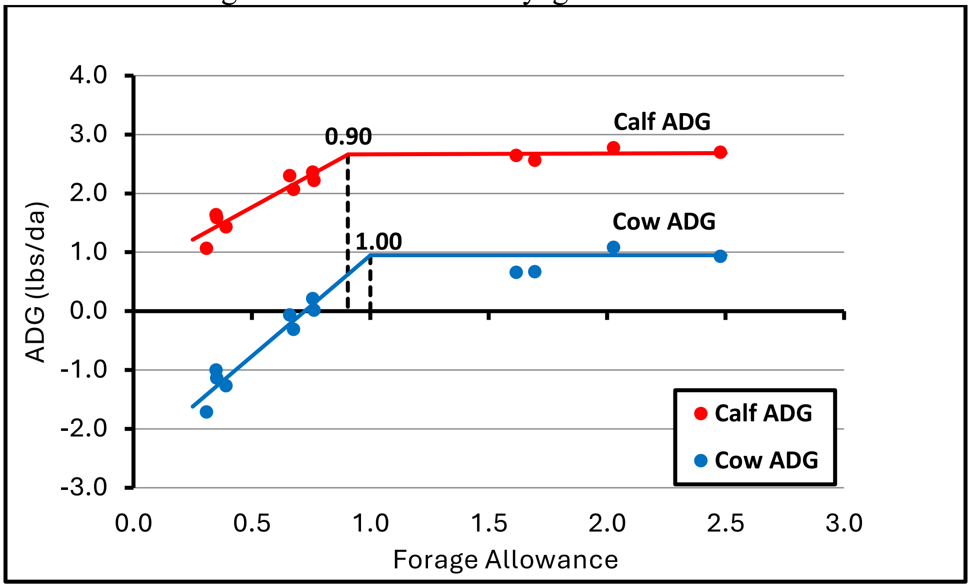


Figure 6. 29-yr average relationship of cow and calf ADG to forage allowance on common and Coastal bermudagrass overseeded with ryegrass or clover



Fertilizer Costs

The 29-year average stocking rates and resulting suckling calf gain per acre are shown in Table 1. Calf gain per acre ranged from a low of about 450 to 470 lb/ac for clover without N overseeded on Coastal bermudagrass at a low stocking rate and common bermudagrass at both a low and high stocking rate (Fig 4 and Table 1). Using ryegrass and nitrogen on Coastal bermudagrass, calf gains were about 900 lb/ac at high stocking rates. There are numerous expenditures that may be used for estimating a year-long cow budget. Although seed and fertilizer expenditures represent the major pasture costs for overseeded bermudagrass pastures, only fertilizer prices will be included to provide an estimate of fertilizer costs/lb calf gain. Other costs associated with wintering, land costs, labor, interest, etc. must be included for accurate year-long expenses. Evaluating only fertilizer costs, it becomes readily apparent that the clover overseeded pastures have the least fertilizer costs per lb gain (Table 1). Bermudagrass overseeded with annual ryegrass and fertilized with 250-60-60 had fertilizer costs of $365/ac, with N costs at $1.10/lb. Thus, fertilizer costs/lb gain ranged from $0.40 /lb gain to $0.68 /lb gain. With N fertilizer cost at $0.75/lb, the fertilizer costs for overseeded ryegrass on bermudagrass was $268.50/ac. This reduced cost of N resulted in fertilizer costs/lb calf gain from $0.30 to $0.51/lb (Table 1). With increased costs of N fertilizer, Coastal bermudagrass would be the preferred pasture to fertilize with nitrogen and with a medium to high stocking rate depending upon management strategies for calf sales and body condition of cows at weaning. From the perspective of reducing risk plus the opportunity to harvest hay off the pastures, a lower stocking rate of about 1 to 1.5 acres per cow-calf unit during the February to October period may be a best management strategy.

Table 1. 29-year average stocking rate, suckling calf gain per acre, and fertilizer costs per pound of gain on Coastal (COS) and common (COM) bermudagrass pastures using 2022 fertilizer prices.

	Clover			Ryegrass			
						Cost of N	
						$0.75/lb	$1.10/lb
Bermudagrass	Stocking rate, pair/ac[1]	Calf gain, lb/ac	Fertilizer costs, $/lb gain[2,4]	Stocking rate, pair/ac[1]	Calf gain, lb/ac	Fertilizer costs, $/lb gain[3,4]	Fertilizer costs, $/lb gain[3,4]
COS – Low	0.99	470	$0.17	1.22	612	$0.44	$0.58
COS – Med	1.50	560	$0.14	1.88	796	$0.34	$0.45
COS – High	2.55	610	$0.13	3.07	894	$0.30	$0.40
COM – Low	0.93	446	$0.18	0.98	522	$0.51	$0.68
COM – Med	1.47	537	$0.15	1.55	727	$0.37	$0.49
COM – High	2.06	454	$0.18	2.38	779	$0.35	$0.46

[1]One cow-calf pair = 1500 lb body weight

[2]Clover fertilizer: 0-60-60 = $81/ac

[3]Ryegrass fertilizer: 250-60-60; with N @ $1.10/lb = $356/ac; with N @ $0.75/lb = $269/ac

[4]Fertilizer component costs: P_2O_5 = $0.65/lb; K_2O = $0.70/lb; N varies between $0.75/lb to $1.10/lb

Pasture-Beef Cattle Fertilizer Management Options

The basic fact for all pasture-livestock producers to remember is that grass production is nitrogen dependent. The basic forages for pastures in Texas, as well as in most of the Southwest and Southeastern US, are warm-season perennial grasses. This category of forages includes bermudagrass, bahiagrass, dallisgrass, and numerous other introduced and native species. In many areas of Texas, nitrogen-containing fertilizers have been a regular part of hay and pasture production for livestock. The immediate and perhaps long-term extended changes in fertilization use on forages for pasture and/or hay will be dependent upon numerous factors including: 1) price of fertilizer; 2) price of cattle; 3) forage requirements for soil N-P-K and lime to meet pasture and/or hay needs; 4) economic stocking rate that is sustainable with moderate, minimum, or no fertilization; and 5) alternative land-use, leasing, and with or without livestock. Thus, some of the management questions may include…"How many cattle can my pastures accommodate with reduced or eliminated fertilizer input?" "How sustainable are my perennial grass pastures without nitrogen fertilizer?" "How long can I "mine" these pastures?" "Should I produce or purchase hay?" "Can I afford to use winter annual forages?" "If I make only one application of nitrogen, what is the best rate and when is the best time of the year to fertilize?" "Should I consider stocker cattle in my operation?" "Should I substitute supplementation for fertilizer?" "Should I lease more land…or lease my own land to someone else?" The primary management concerns remain focused on how to offset cow costs associated with fertilizer, hay, supplemental feed, fuel, etc. with projected percent calf crop weaned, sale weight of calves, retained ownership, and culling of cattle.

Cow-calf and/or stocker operations from pastures require on-going management decisions to adjust for seasonal and total forage production-availability, animal performance expectations, wintering costs, and other operating expenses. In general, rainfall and temperature fluctuations and soil nutrient status control forage production. Thus, stocking rate adjustments dictate requirements for fertilizer, hay, and/or supplemental feed to meet animal performance expectations. For cow-calf producers, wintering costs associated with hay and supplement to maintain cow condition for calving and rebreeding are responsible for a substantial part of the 12-month cow costs. Thus, decisions about fertilizer management during the summer months, hay production or purchase, and inclusion of winter annual pastures require primary consideration during escalating input prices. In response to increased fertilizer prices, management may choose an array of options; however, these strategies will likely include one of the following: 1) eliminate all fertilizer; 2) reduce fertilizer to minimum applications; or 3) continue with moderate fertilization applications. With any strategy, there is an action followed by reaction or adjustment due to those decisions. Some of the action-reaction scenarios for fertilizer management may include some of the checklist items that follow:

Eliminate All Fertilizer

1. Obtain a soil test analysis. If soil status of pH, P, etc are acceptable, then clovers may be overseeded for late winter-early spring grazing. These grazed clovers provide a source of nitrogen fixation via excreta, and these nutrients are available for use by bermudagrass or other warm-season forage. This recycling of nutrients stimulates forage production and reduces the “soil mining” effects.
2. Reduce stocking rate and/or lease additional pastureland to account for reduced forage production.
3. Hay requirements may be met by purchasing hay based on nutritive value and weight. However, if clovers are components of the pasture system, then allowing them to set seed with hay harvest after seed maturation will provide some of the hay requirements. In addition, these clover seed-abundant hay bales can act as a method of reseeding pasture areas, and this process is enhanced by “unrolling” the round bales onto new seeding areas during the autumn.
4. Supplementation may be required during the wintering period depending upon nutritive value of hay and/or deferred pasture for “standing hay.”
5. Time of calving may have to be adjusted to fit the seasonal availability of forage nutrients and dry matter from pasture and/or hay. In general, if winter annual forages are not components of this system, then a late spring calving may best fit pasture conditions without prolonged supplementation of the cow herd.
6. Herbicide applications and/or mowing of pastures will be required to control annual weeds and perennial woody species that will invade pastures.
7. Bahiagrass and common bermudagrass will initially dominate these pastures with an extended absence of N-fertilizer. Subsequent invasion by other annual and perennial grasses may become more predominant with time.

Reduce Fertilizer to a Minimum Amount

1. Obtain a soil test analysis.
2. Fertilizer strategies based on soil analysis may include non-Nitrogen fertilizer plus overseeded clovers with required lime and/or Phosphorus fertilizer.
3. Other fertilizer strategies may include overseeding with annual ryegrass with one or two winter N applications (50 lb/ac) to stimulate ryegrass and/or one or two spring-summer N applications (50 lb/ac) to stimulate bermudagrass, bahiagrass, etc.
4. Strategic, timely application of N is imperative to match climatic conditions and best utilize the optimum effectiveness of N rate and forage production.
5. Hay requirements may be met with harvest of clover and/or ryegrass at seed maturation, or by purchasing hay based on nutritive value and weight.

6. Evaluate forage conditions for proper stocking rate and incorporate a regimented cow culling procedure based on performance.
7. Herbicide applications and/or mowing may be required to control annual weeds and perennial woody species.
8. Some forage species composition changes will likely occur on non N-fertilized pastures with increases in bahiagrass and assorted ecotypes of common bermudagrass.

Continue With Moderate Fertilization

1. Obtain a soil test analysis for use with overseeded winter annual clovers, ryegrass, and/or small grains.
2. Apply lime (ECCE-100) as appropriate primarily for cool-season annual forages.
3. Consider rates of 50 to 60 lb N/ac for each application with the potential of 3± applications on small grain + ryegrass, 2± applications on ryegrass, and/or 2 to 3 applications during the exclusive bermudagrass phase.
4. Increase forage production-utilization efficiencies by harvesting hay and/or utilization of stocker calves (retained and/or purchased).
5. Consider selling excess hay.
6. Adjust calving and weaning dates for increased weaning percent and weaning weight.
7. Apply herbicides to eliminate competition for nutrients, water, and space.

Stocking Strategies and Nutrient Cycling

Stocking strategies and nutrient cycling have inseparable relationships, and in the course of stable or diminishing cattle prices and unstable and increasing costs of fertilizer, fuel, and feed grains, there is an increased dependency on recycled nutrients for forage production. Management strategies are personal and "zip code specific." Using the long-term fertility regimen x stocking rate nutrient cycling database from Texas A&M AgriLife Research-Overton as a model for management strategies, the following options should be considered for production and costs for specific sites:

- Pastures in the Pineywoods Vegetational region at Overton had a 15-year history of N-P-K applications from 1969 through 1984. Once fertilization strategies were changed and implemented, soil P was deemed to be at moderate to high levels. However, from 1998 to 2022, P_2O_5 had been applied. The soil nutrient "base" determines the fate of reduced fertilization of pastures. A soil test analysis provides this information on suggested rates of fertilizer and limestone.
- By eliminating all N fertilizer and overseeding bermudagrass with an adapted clover, pastures continued to be stocked from about March 1 through September. And, at low stocking rates of 1.5 to 2.0 acres per cow-calf pair, forage will likely be sufficiently abundant to minimize risks due to climate. However, at high stocking rates, bahiagrass and various bermudagrass ecotypes are likely to invade the pastures. Perhaps more important is that the absence of N fertilization on bermudagrass pastures allows for increased opportunities for weed invasion, which in turn, requires herbicide applications or mowing.

- When applying only N fertilizer and eliminating P_2O_5 and K_2O, overseeded ryegrass on bermudagrass has provided a more reliable winter-spring forage supply to initiate grazing by mid- to late February. Ryegrass is more tolerant of dry conditions and frequent defoliation compared to clovers. With the N + ryegrass strategy, nutrient cycling is active and suggested N fertilization may include one to two applications of 50 lb/ac N for ryegrass period and one to two applications of 50 lb/ac N for the bermudagrass growing phase. Annual ryegrass, however, is not tolerant to low soil pH of less than 5.0 to 5.5; thus, soil tests and limestone recommendations are required management strategies.

As forage-cattlemen move into the next paradigm of input costs, the "secrets for success" are closely tied to "using forages that produce and animals that perform." This mandates that every aspect for the forage-cattle operation must be critically evaluated. For many operators who choose to eliminate most if not all fertilizers, the long-term experimentation at Texas A&M AgriLife Research-Overton suggests nutrient cycling is a valuable asset for forage production. And, some species composition changes will occur once N fertilizer is removed for prolonged durations. Some of the checklist management strategies that may be implemented to counter increased fertilizer, fuel, and feed prices include the following:

1. Create a pasture management plan of action that is firm but flexible.
2. Implement a fertilization strategy via soils test and reason(s) for need.
3. In many situations, the most cost-effective fertilizer strategy is to apply one or two applications of only Nitrogen at 50 to 60 lb/ac per application.
4. Hybrid bermudagrasses such as Coastal or Tifton 85, for example, produce more forage per unit of N fertilizer compared to common bermudagrass.
5. Add legumes to the pasture system after assessing soil analysis and pH.
6. Use broiler litter as a nutrient source.
7. Increase efficiency of forage utilization for specific classes of cattle.
8. Make hay from pastures and eliminate exclusive hay meadows.
9. Purchase hay based on nutrient analysis and weight of package.
10. Make strategic, timely herbicide applications as warranted.
11. Maintain accurate, up-to-date cattle records for culling options.
12. Reduce stocking rate.
13. Enhance weaning percent, weaning weight, and/or weight at time of sales.
14. Alter weaning schedule and consider retained ownership options for stockers with or without supplementation.
15. Critically assess supplementation strategies, product cost, and supplement to extra gain conversion.
16. Market cattle proactively through special sales, etc.

The "rules" for management have changed with increasing fertilizer and fuel costs for operating pastures-livestock systems. Although the "game" does not "look like" the more familiar one of a few years ago, the "game plan" remains the same. And, that is to set production targets, manage to manipulate forage utilization systems to enhance economic returns, and sustain the soil – plant resources.

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Above-Yearling Brahman Bulls, March 2025. Below-Brahman Heifers in 2014.

The bull pictured on the right is MR. TAES 2627. He was born on September 11, 2012. He was 10 years old and in pasture condition when this picture was taken. This bull reached puberty at 10 months of age, and we had semen collected and frozen when he was 12 months old.

Young Brahman Bulls

Brahman Cow Herd

Brahman Steers on Pasture


ELBON
Rye
TX-RYE-12
Rye