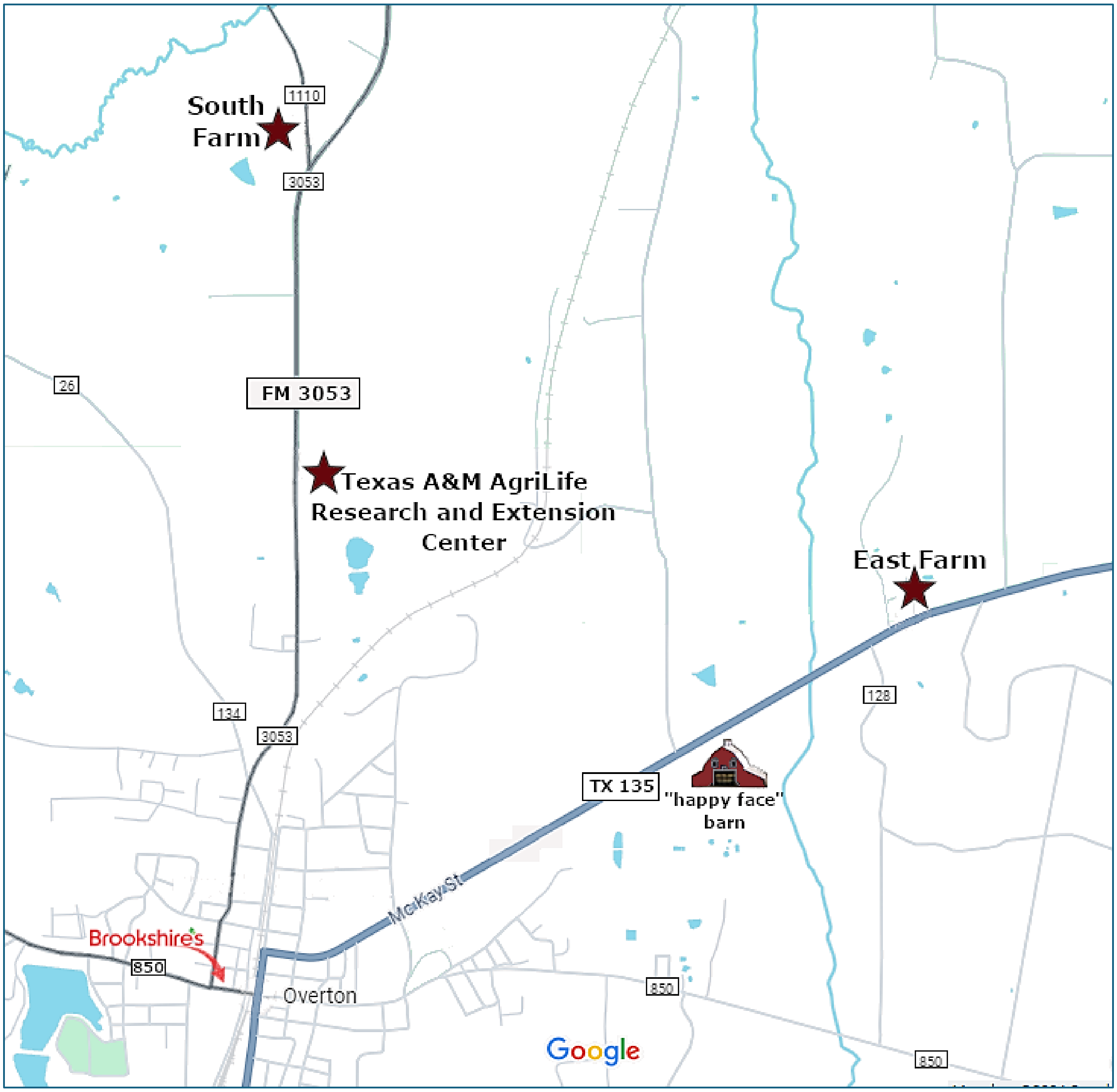
FORAGE & BEEF CATTLE FIELD DAY - 2024

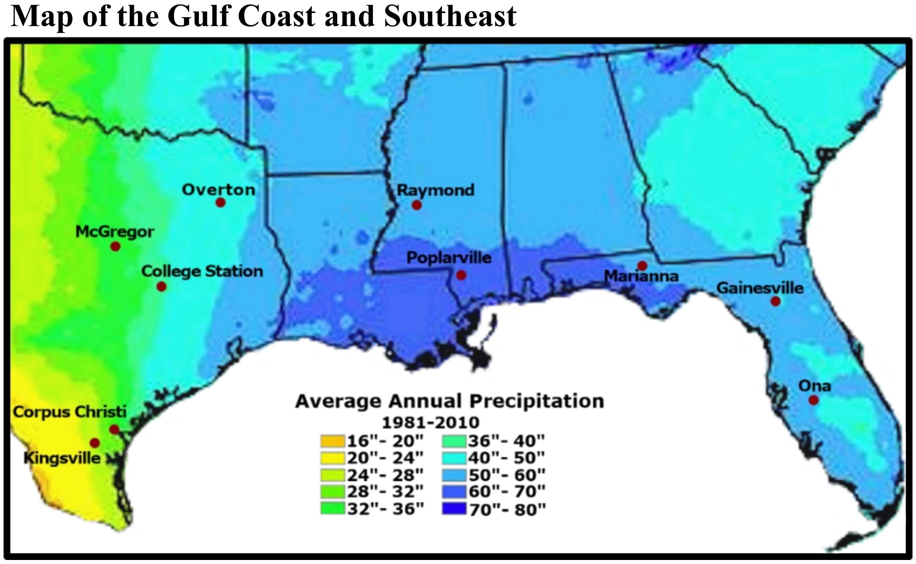
Texas A&M AgriLife Research and Extension Center at Overton

April 11, 2024 - Center Technical Report 24-1

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.

FORAGE & BEEF CATTLE FIELD DAY - 2024

1710 FM 3053N, Overton, TX 75684
Thursday, April 11, 2024

PROGRAM

8:00 AM - Registration

8:30 AM - Introductions - Current Soil, Forage and Beef Cattle Research
Texas A&M AgriLife Research Faculty - Research Leaders:

Dr. Anil Somenahally, Soil Microbiology

Dr. Gerald Smith, Plant Breeding

Dr. Monte Rouquette, Forage Physiology

Dr. George Perry, Reproductive Physiology

9:30 AM - Break

10:00 AM - Weed Control in Forages
Dr. Vanessa Corriher-Olson, Forage Extension Specialist

11:00 AM - Environmental Benefits of Grazing Management Strategies
Dr. Jacquelyn Prestegaard, Extension Livestock Sustainability Specialist

NOON - Lunch

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.

- **Beef Cattle Research - East Farm** (2211 State Hwy. 135)

Production Efficiencies in Cow-Calf Operations with current technologies: Pregnancy check methods and Testing for diseases and parasites.

- **Forage Research - South Farm** (401-499 County Road 1110)

Winter Pasture Options for East Texas

Forage Management Strategies for Year-Long Stocking Systems

FACULTY AND STAFF

Texas A&M AgriLife Research and Extension Center at Overton

Name	Position
Aguilar, Chastity	Research Assistant
Banta, Jason*	Associate Professor & Extension Beef Cattle Specialist
Blaske, Sarah	Graduate Student
Carson, Chloey	Research Assistant
Clary, Colby	Information Technology
Cole, Judy	Senior Administrative Coordinator I
Del Vecchio, Joe	Research Technician I
Goldman, Mary	Senior Custodial Worker
Graves, Kelsey	Student Worker
Harkless, Judson	Agricultural Research Worker
Harris, Shelia	District Extension Administrator
Jeffus, Jancy	Research Assistant
Keese, Tyson	Extension Program Specialist - Pond Management
Ketchum, Jaclyn	Graduate Student
Khan, Rafia *	Assistant Professor & Extension Specialist - Entomology
Knight, Baker	Research Assistant
Laird, Katie	TCSI Ambassador
Law, Dustin	Farm Research Service Manager
Long, Charles*	Resident Director of Research & Professor
McLendon, Marcellus	Research Technician I
McSwain, Jheri-Lynn *	4-H Specialist
Melton, Canen	East Regional Coordinator-FCH
Newburn, David	Technician I
Norman, Kelli	Systems Administrator 1
Oli, Prem*	Assistant Professor - Production Systems Modelling
Olson, Vanessa*	Professor & Extension Forage Specialist
Perry, George*	Professor - Reproductive Physiology
Pierce, Larry	Regional Prog Leader, AGNR & 4-H
Portley, Reggie	Senior Custodian
Putnam, Tammy	Regional Project Specialist, BLT
Quail, Lacey	Graduate Student
Receptionist Desk	Receptionist
Romero, Adrian	Research Assistant
Rouquette, Monte*	Professor & Regents Fellow - Forage Management
Sarker, Tushar*	Postdoctoral Research Associate
Schaefer, Zach	Disaster Assessment Recovery Spec.
Sensing, Michelle	Administrative Associate III
Smith, Gerald*	Professor & Regents Fellow - Legume Breeding
Snowden, Scott	Resesarch Technician II
Somenahally, Anil*	Associate Professor - Soil Microbiology & Health
Stover, Emily	Research Technician I
Taylor, Eric*	Assistant Professor & Forestry Specialist
Turner, Kyle	Senior Research Associate
Velvin, Jay	Maintenance Worker II
Walton, Carolyn	Administrative Associate II
Watson, Rhonda	Administrative Associate II
Welch, Sandra	Senior Administrative Coordinator I

* PhD

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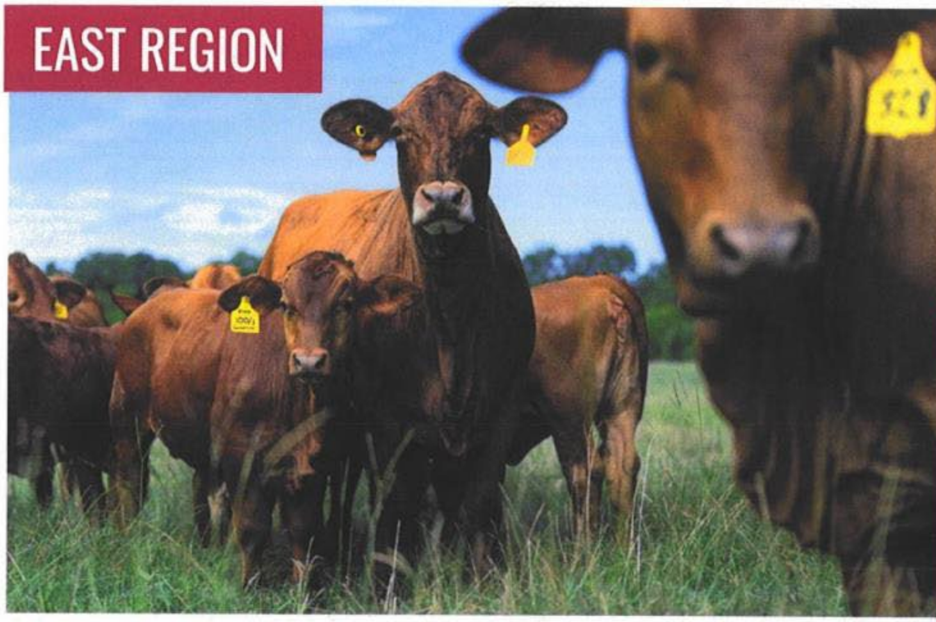
- Agriculture & Natural Resources

TEXAS A&M AGRILIFE EXTENSION

EAST REGION



44 Regional Counties | 52 ANR Agent Positions

ANR Program Summary

- **354,272 Total Participants**
- **298,419 Total Educational Hours**

TOP PROGRAM FOCUS AREAS

- Beef Cattle and Forages
- Home / Community Horticulture
- Green Industry Professionals
- Small Acreage Landowners
- Wildlife and Natural Resources

44

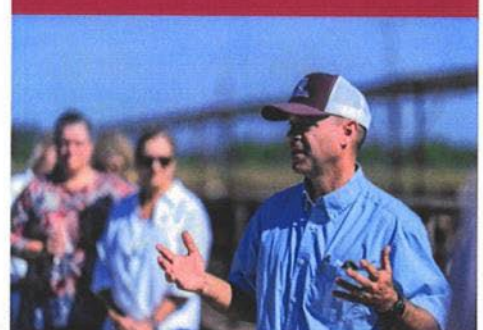
COUNTIES INVOLVED

including events, newsletters & media

665,540

PEOPLE REACHED

including events, newsletters & media



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.

2023 Regional Overview
- Agriculture & Natural Resources

TEXAS A&M AGRILIFE EXTENSION

PROGRAM HIGHLIGHTS

1256 Master Naturalist Volunteers provided 98,263 hours of education, outreach, and service to the management of natural resources in the East Region.

Their volunteer service is worth over $3M to the East Region.

"Thanks for spending time with us at our property. We gained alot of useful information and look forward to ongoing interaction as we have questions to better manage our land."

Small Acreage Landowner, Grayson County

Beef Cattle and Forages

- **38**- Counties Involved
- **36,800** - People Reached, Including Volunteers Engaged

806 of 1034 (78%) participants responded to surveys at beef and forage educational programs. **680 of 806 (84%)** respondents increased their understanding on one or more items at these programs. Survey respondents owned or managed **231,045 acres** and/or **45,955 head of livestock** and anticipated a **total economic benefit $2.8M** as a result of these educational programs.

Home and Community Horticulture

- **31** - Counties Involved
- **34,531** - People Reached, Including Volunteers Engaged

19 Master Gardener Associations have **1379** Master Gardener Volunteers. This year, **317** new Master Gardener Interns were trained and **153,582** volunteer hours of service were provided in the East Region. **1010 of 1721 (59%)** participants responded to surveys at **33** home horticulture programs. **911 of 1010 (90%)** respondents increased their understanding on one or more items at these programs.

Small Acreage and New Landowners

- **20** - Counties Involved
- **1,690** - People Reached, Including Volunteers Engaged

219 of 297 (74%) participants responded to surveys at small acreage and new landowner programs. **207 of 219 (95%)** respondents increased their understanding on one or more items at these programs. **193 of 219 (88%)** respondents plan to adopt at least one practice or technology learned at these educational programs.

Larry W. Pierce, Jr.
Regional Program Leader, ANR / 4-H
Texas A&M AgriLife Extension Service
903.834.6191 | larry.pierce@ag.tamu.edu

The Texas Climate-Smart Initiative

Vanessa Corriher-Olson, Ph.D., Professor & Forage Extension Specialist,
Texas A&M AgriLife Research and Extension at Overton Extension

Introduction:

The Texas Climate-Smart Initiative is a five-year pilot project led by Texas A&M AgriLife Research and funded by USDA's Natural Resource Conservation Service. This groundbreaking initiative aims to foster climate-smart agriculture for all major Texas agricultural commodities and create market opportunities across the commodities (forestry, orchards, vegetables, perennial forage, pastures and rangeland, annual crops, and concentrated animal feeding operations).

Focus and Goals:

Our focus on this project is to simultaneously improve resilience to climate change and mitigation of climate change through adoption of climate-smart practices. Texas' diversity in agriculture and natural resources—seen in our climates and soil—particularly, makes Texas a great place to create solutions that can be scaled to other areas of the nation and build upon existing infrastructure. The grant involves more than 65 researchers from across AgriLife Research, Texas A&M AgriLife Extension Service and Texas A&M Forest Service. Two other Texas A&M University System entities are also involved, Prairie View A&M University and Tarleton State University.

The Texas State Soil and Water Conservation Board, TSSWCB, leads the development of climate-smart management plans and manages participant incentives. BCarbon and Nori are carbon market aggregators that will assess select operations for potential carbon crediting.

Frequently Asked Questions:

Who may participate in the program?
Programs are designed specifically for Texas farmers, ranchers, and small forest owners.

What type of resources are available?
Texas Climate Smart Initiative individuals will work with participants through the entire process, from helping them understand climate-smart practices to loaning necessary equipment.

Are there incentives for participating?
An incentive structure has been created, considering the cost of operations.

Participation:

To participate in the Texas Climate-Smart Initiative, you will 1) apply at the website (https://climatesmart.tamu.edu), 2) go through a selection process, 3) meet with an implementation planner and Climate-Smart Ambassador, 4) complete a contract, 5) participate in an environmental assessment evaluation (for select practices), 6) implement the practices, and 7) meet with a Climate-Smart Ambassador for continued measurement and assessment. The lands of the producers selected must be in Texas and not currently enrolled in any existing program that pays federal funds for conservation practices.

Conclusion:

This is a unique effort where researchers and extension professionals collaborate with producers, ranchers, and forest landowners across the state in implementing climate smart practices and monitoring its progress. This is a great opportunity for producers to work with a wide variety of experts to improve the efficiency of their working land while receiving incentives to try agricultural practices that could make their operations more environmentally sustainable.

Texas Climate Smart Initiative Pastures and Grazinglands Team:

Dr. Vanessa Corriher-Olson, Professor Forage Extension Specialist, Texas A&M AgriLife Extension

Dr. Jason Banta, Associate Professor Beef Cattle Extension Specialist, Texas A&M AgriLife Extension

Dr. Monte Rouquette, Professor, Forage Physiology, Texas A&M AgriLife Research

Dr. Gerald Smith, Professor, Legume Breeding, Texas A&M AgriLife Research

Katie Laird, Climate Smart Ambassador, Texas A&M AgriLife Extension

History of the Overton Center

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

Introduction: The Texas A&M AgriLife Research and Extension Center at Overton (initially named East Texas Research and Extension Center at Overton) began operations in 1965 with the official opening and headquarters dedication in 1967, thanks to the initiative of East Texas agricultural and community leaders and the Bruce McMillan, Jr. Foundation. The McMillan Foundation donated $300,000, 150 head of Hereford cattle and 22 acres of land for the Center headquarters and provided seventy-five years of leases of two farms containing 1,221 acres to be used in the research activities. The J. T. Montgomery family donated 4.5 acres for the Center headquarters. The Bruce McMillan, Jr. Foundation has continued to support Center programs including providing, in 2016, the use of their 446-acre farm east of Overton.

Historical Events: Several early events led to the initial opening and operation of the Center.

- November 7, 1961-East Texas agricultural leaders met with Texas A&M officials at Blackstone Hotel in Tyler to explore developing a consolidated agricultural research station for East Texas.
- January 18, 1965-Plans announced jointly by the Bruce McMillan, Jr. Foundation and Texas A&M University, under the direction of President Earl Rudder, for the new East Texas Research & Extension Center at Overton. The Foundation grant and the Montgomery family donation, detailed in the introduction, were provided at this time..
- September 1, 1965-Al Lancaster, Research Technician, transferred from Mt. Pleasant Station to Overton to become first on-site personnel to initiate field research.
- February 1, 1966-First research scientist, Dr. Joseph Burns, Forage Physiologist, arrived to initiate basic and applied research on forages and pastures for East Texas.
- February 1, 1967-Dr. Bill Ott, first Resident Director of Research with the Texas Agricultural Experiment Station, arrived to facilitate building and research staffing.
- June l, 1967-Center officially opened with staff including Resident Director of Research Dr. Bill Ott, District Extension Directors-Agriculture R. S. Loftis & W. H. Lehmberg, & District Extension Directors-Home Economics Mary Cothran & Margaret Bracher for Districts 5 and 9.
- June 1, 1967-Dr. James Long, Farm Management Specialist in Mt. Pleasant, and Wayne Taylor, Farm Management Specialist in Nacogdoches, transferred to Overton as first Extension subject- matter specialists.
- September 20, 1967-Formal dedication of East Texas Research and Extension Center at Overton. Dr. H. 0. Kunkel, Acting Director of the Texas Agricultural Experiment Station, and Dr. John Hutchison, Director of Texas Agricultural Extension Service, were in attendance.
- August 1968-Name of East Texas Research and Extension Center officially changed to Texas A&M University Agricultural Research and Extension Center at Overton.
- February 23, 1971-Feed mill and cattle working pens constructed using Bruce McMillan, Jr. Foundation grant and Texas A&M University System funds.
- October 11, 1976-Center expansion plans initiated to include new auditorium, additional office and laboratory space. McMillan Foundation grant & A&M System funds were used.
- April 25, 1979-Dedication of new building addition to Overton Center.
- October 3, 1991-Grant from Bruce McMillan, Jr. Foundation and funds from Texas A&M University for new Horticultural Center, Reproduction Physiology Laboratory and Hazardous Chemical Storage at North Farm and Hazardous Chemical Storage at Headquarters.

Results: Overton Center facilities include the 28,186 square-foot headquarters building, about 2 miles north of downtown Overton, with an auditorium seating 275, a classroom, kitchen, videoconferencing, offices, and laboratories. The grounds contain a parking lot, 7 greenhouses, a head house, chemical storage, shop, equipment yard and shed. Programs are conducted on 1,666 leased acres of pasture, forest, and plot lands. Research resources include a herd of beef cattle and an inventory of vehicles, tractors and equipment (incl. computers and lab equipment).

Outcomes: Over the years, accomplishments by faculty and staff of the Overton Center have been numerous, diverse and very significant. Agricultural impacts of Texas A&M AgriLife at Overton have been numerous and include variety and cultivar releases, improved management technology and technology transfer to stakeholders in East Texas, Texas and the southeastern United States. Overton faculty conduct many outreach activities including presentations to clientele groups and addressing inquiries from individuals. Teaching has been an integral part of programs; Overton-based graduate students have earned 123 MS and 102 PhD degrees. The performance of faculty and support staff has been recognized by several entities. Since 1987, Texas A&M AgriLife personnel at Overton have received a total of 127 awards, of which 10 were team awards. Eight Overton faculty members have earned the designation of Texas A&M System Regents Fellow, awarded by the Texas A&M Board of Regents. Overton personnel have been active in regional, national and international organizations and symposia, holding offices and hosting activities. Overton programs are recognized locally, nationally and internationally.

Conclusion: Research and Extension faculty at the Overton Center target specific needs of East Texas that must be addressed in the East Texas ecosystem. Major contributors to East Texas' annual agricultural farm-gate income (about $6 billion) are livestock (primarily beef cattle), horticultural crops, poultry and timber; other agricultural income is from hay and other feed crops, recreation and dairy. Texas A&M AgriLife programs at Overton, in cooperation with County Extension programs, address the traditional and evolving needs of clientele.

Historical Research Focus and Activity at Overton

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

Introduction: Texas A&M AgriLife Research is an agency of the Texas A&M University System. Research at the Overton Center targets specific needs of East Texas that must be addressed in the East Texas ecosystem. Contributors to East Texas agricultural income include Livestock and meat, Horticultural crops, Poultry, Timber, Feed crops, including hay, Recreation and ag related activities, Miscellaneous crops/livestock and Dairy. Research programs at Overton address Livestock, Forages including hay and Horticultural crops with some attention to Forestry and Rural recreational aspects; this relates to about 80 to 90% of the agricultural income production of the region. Research conducted at Overton addresses current issues in agriculture and natural resources, including 1) Rising production costs (fuel, fertilizer, feed, labor, etc.); 2) Urban development and land fragmentation; 3) Texas' competitiveness, nationally and globally; 4) Water quality and availability; environmental quality, nutrient management; 5) Alternative fuel sources/biofuels; producing and utilizing plant biomass; and 6) Production management related to food quality, safety and consumer acceptance.

Research activities are conducted in two primary areas, 1) Forage-Based Beef Cattle Production Systems and 2) Horticultural Production. In both areas, research trials address simultaneously issues of both production parameters and environmental sustainability. The subject matter disciplines of soil science, plant physiology, plant breeding and genetics, animal physiology and production system science are focused on fundamental and applied research targeting highest priority issues.

Program Impact: Research at Overton has produced significant results over the past several years. From an academic viewpoint, these programs have added to fundamental and applied knowledge in the specific disciplines addressed as well as provided training for numerous graduate, undergraduate, and high school students. With regard to economic impact to the East Texas region, major accomplishments have been achieved. Research results from Texas A&M AgriLife Research coupled with educational efforts of Texas A&M AgriLife Extension Service specialists and agents, have yielded the impacts outlined.

***Forage-Based Beef Cattle Production Systems*:** Overton-based programming has a current annual economic impact of $150 million to the $1.5 billion forage, pasture and livestock industries of East Texas. These are the cumulative impacts of technologies which include new adapted productive varieties of ryegrass and clover, the practice of sod-seeding clovers, small grains and ryegrass for winter grazing, soil fertility management, warm season perennial grass evaluation, environmental conservation measures and reproductive and growth management of Zebu and other tropically adapted cattle. Emerging technologies from Overton include production of alfalfa on East Texas soils and new adapted legume varieties, and seeded bermudagrass for forage production. Sample research outputs that enhance forage plant production and management and beef cattle management are described here.

Ryegrass Forage Varieties. TAM 90 Ryegrass released from Overton is a very popular cool season annual forage, with approximately 100,000 acres planted each year across the southern United States. TAM TBO and Nelson are tetraploid ryegrass varieties released from Overton. The tetraploid ryegrass is more robust and productive than diploid types and will likely be utilized extensively by the industry.

Apache Arrowleaf Clover. Apache arrowleaf clover is a disease tolerant, cool-season annual legume developed by the Forage Legume Breeding Program at Overton and released by Texas A&M AgriLife Research. Annual seed sales of Apache average 130,000 lbs/yr. Total value of Apache seed sales total $1.1 M for the first five years of commercialization and nitrogen crop value totals $3.9 M. Apache is licensed to a Texas seed company and is sold all across the US southern region.

Rio Verde Lablab. Rio Verde lablab is a new warm season annual legume cultivar developed as a dual purpose forage crop for grazing by livestock and as browse for white-tailed deer. Rio Verde was developed by Forage Legume Breeding Program at Overton and released by the Texas A&M AgriLife Research. This new cultivar has the value-added attribute of Texas seed production and is licensed to three Texas seed companies. It is a cash seed crop for some producers and a forage or deer foodplot plant for others.

Forage Legumes. With large increases in fertilizer cost, using forage legumes is an option for livestock producers in East Texas. Forage researchers at Overton have bred more productive and persistent varieties; developed management practices to improve stand survival, forage production and nitrogen fixation; assessed the economic benefits through grazing studies; and demonstrated nutrient recycling in legume-grass pastures without nitrogen fertilizer.

Alfalfa in East Texas. Technology was developed to allow farmers and ranchers to grow economically sustainable alfalfa on East Texas soils. The net per-acre income averaged ~ $300 annually for four years on well-managed sites with alfalfa hay valued at $135 per ton. Site selection techniques were developed and validated for acid soils that support sustainable alfalfa. This technology is being used increasingly by farmers and ranchers across the Coastal Plain states.

Improved Limestone Efficiency. Fine limestone (ECCE 100%) increased cost efficiency, forage production efficiency, and duration of soil pH change compared to coarse limestone (ECCE 62%). One ton of fine limestone increases pH to the same extent as caused by 1.61 tons of coarse limestone. In the Tyler-Longview area, cost savings is ~$22.75 per acre using fine limestone for equivalent effectiveness.

Use of Poultry Litter. Eighty percent of the Texas Broiler Industry is in Northeast Texas. Broiler litter is an alternative to commercial fertilizer at half the cost. The main problem is the build-up of soil phosphorous which can cause water quality problems. Research at Overton has shown that the use of clover on pasture fertilized with broiler litter reduces soil phosphorous buildup and avoids potential environmental problems.

Plant-Animal Interface Using Cows and Calves.
Adapted cow breedtypes such as F-1 Brahman x English breeds and terminal sires can result in calf gains in excess of 1000 lbs per ac. Fall-born calves stocked on clover or ryegrass can exceed 850 pounds at weaning. Heavy-weight calves at weaning require reduced feedlot residence and demand premium prices. Efficiency of animal production using forage mass and nutritive value parameters has major implications for beef cattle industry sustainability

Nutrient Cycling Under Grazing. Long term stocking of bermudagrass pastures overseeded with ryegrass plus nitrogen or clover without nitrogen fertilizer has been studied. Stocking rate was not a contributing factor to soil nitrate-nitrogen levels. Soil analysis indicated no potential contamination due to stocking rate or phosphorus fertilization. The bermudagrass stand was sustainable at low stocking rates without nitrogen fertilization; at high stocking rates, a shift in plant species composition occurred.

Tifton 85 Bermudagrass for Stockers. Stocker average daily gain on Tifton 85 increased 25 to 50% compared to Coastal bermudagrass. Stocking rate of four 600-lb steers per acre allows for gain of 750-1000 lbs per ac. This offers renewed opportunities for retained ownership or commercial stocker operations. Stocker gains during the summer allow for reduced feedlot residence. Tifton 85 with supplementation provides an opportunity to produce heavy-weight cattle for direct harvest.

Rye and Ryegrass for Stocker Cattle. Low to moderate stocking rates allow for average daily gains of nearly 3 lbs per day. Stocking rates and stocking strategies can produce gains of 650 to 900 lbs per acre. Pasture with or without supplementation can result in steer body weights of more than 1000 lbs with reduced feedlot residence. Direct harvest of cattle off pasture has potential to produce acceptable beef for niche markets.

Tropically Adapted Cattle. Research targeting reproductive management of tropically adapted cattle has been underway at Overton for over 30 years. Systems developed for Brahman and Brahman- influenced cattle have resulted in improved reproductive efficiency of the Brahman and Brahman crosses used for beef production in Texas and other Gulf Coast states. Other tropically adapted types have been included in this research, conducted cooperatively with scientists at other sites in Texas and the U.S.

Beef Cattle Temperament. Beef cattle temperament (calm versus wild) has been determined to affect performance. Both exit velocity and pen scores are valid methods to evaluate temperament. Measures taken early in life (at or before weaning) are more predictive than those taken later. Calm cattle have higher average daily gains, better response to vaccination and improved carcass traits. Seedstock producers should consider culling the more fractious animals.

Early Puberty Brahman Line. Tropically adapted cattle play a very large role in global beef production. In the southern U. S. cattle with Zebu/*Bos indicus* breeding are used in many production operations. Around the world, beef production in many areas requires tropical adaptation and many production enterprises utilize Zebu cattle and/or crosses. The registered Brahman herd at the Overton Center was established in 1975 and bulls from Texas and Louisiana breeders were used in the herd. A genetic line of Brahman has been developed to reach puberty at an early age. Bulls of this line produce semen suitable for freezing by 15 months of age and heifers first calve at 24 to 27 months of age.

Horticultural Production: Overton-based programs have contributed to the expansion of the horticultural industries in East Texas. These expansions include a doubling of watermelon production in 10 years, increase in nursery and greenhouse production, creation of a blueberry industry, increased efficiencies and quality in ornamental plant production, and improvement in home landscape and gardening success. Annual economic impact of the horticultural industry in East Texas is estimated in excess of $1.2 billion.

Bedding Plant Greenhouse and Garden Performance Trials. Each year hundreds of newly introduced varieties from the major seed companies in the U.S. are evaluated for performance under local conditions. Information gathered and disseminated via field day and web site enables producers and consumers to select varieties that will perform well in this climate. An awards program entitled the "North Texas Winner's Circle" designates the top performers in these trials in order to facilitate industry and consumer awareness and marketing of these superior plants. The comprehensive benefit of the Bedding Plant Performance Trials is the link between the rural bedding plant producers and the urban consumers which serves as a basis for improving the quality of life for the citizens of Texas.

Plant Growth Regulator Research. Plant growth regulators are an integral part of ornamental plant production used for growth control and improving postharvest longevity. Work in cooperation with the federal IR4 program has resulted in improvements in the use of these compounds for improving branching in woody plants and lengthening postharvest longevity of floricultural crops.

Using PET to Develop Water Budgets for Residential and Commercial Landscapes. A model landscape has been installed with soil moisture sensors to be used for intensive monitoring of water use by plants typically used in this region. Water use will be compared to potential evapotranspiration (PET) to determine the appropriate water coefficient to use for irrigation scheduling in home and commercial landscapes. This method will lead to significant water savings when irrigating landscapes.

Turf Ryegrass Varieties. Three turf-type annual ryegrass varieties: Axella, Axcella 2 and Panterra: have been released from Texas A&M AgriLife Research at Overton. These varieties are overseeded for winter use on many sports fields, home lawns and golf courses in the southern United States. Characteristics such as rich green color, termination of growth at the proper time in the spring and tolerance to foot traffic are important in these varieties.

Improvement of handling and storage of field grown, bare-root rose plants. A large portion of the garden rose plants that are processed in Texas by either packaging or forcing for containerized bud and bloom sales are initially field grown in Arizona. Work at the Overton Center with a colleague at the University of Arizona has shown how maintenance of plant water content can improve the survivability of processed plants. In addition, this work has shown that 2 weeks of cold temperature storage is needed for plants that are dug for early finishing schedules to enable successful and timely regrowth after containerization of bare-root plants for bud and bloom sales.

Testing of rose progeny for disease and heat tolerance: The Overton Center continues to play an important role as a location for testing field resistance to black spot, one of the most important diseases of garden roses worldwide. Progeny from a breeding program in College Station have been tested as part of a goal of breeding varieties that are resistant to the disease. In addition, work at the Overton Center in cooperation with scientists in College Station and at the El Paso Center has addressed the definition of plant characteristics involved in heat tolerance in garden roses.

Scenes on Overton Center Research Farms in the Past:

Cattle grazing Blackhawk arrowleaf clover

Above: F1 Hereford X Brahman cows with calves. Below: Cattle grazing Neches white clover.

Research Cattle Herds at Overton

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

Introduction: From the beginning of research operations at the Overton Center, the plans included conducting projects to provide knowledge and technology to improve productivity of beef cattle production in East Texas, the State and the Nation. The vision was to conduct research and development activities to improve forage production and availability and beef cattle performance through all phases of production.

Acquisition & use: Texas A&M AgriLife Research at Overton purchased F1 Brahman-Hereford heifers in 1967 and registered Brahman cattle in 1974. These herds were established to provide cattle for conducting basic and applied research on productivity and management of tropically adapted cattle. The Brahman herd (*Bos indicus)* is used to conduct research to improve reproductive performance, nutritional management and health. The F1 (HerefordxBrahman) cows are mated to Simmental bulls and are used to conduct grazing management research with cow-calf pairs and stockers. Crossbred and purebred Brahman stockers are grazed and then fed in a commercial feed yard to yield carcass data. Recently, the Center has begun to build a herd of Simmental cattle. Addition of this breed will provide *Bos taurus* purebreds as well as F1 BrahmanxSimmental heifers, bulls and steers for inclusion in the research. This will expand the applicability of our beef cattle research results to more regions of the U. S. and internationally.

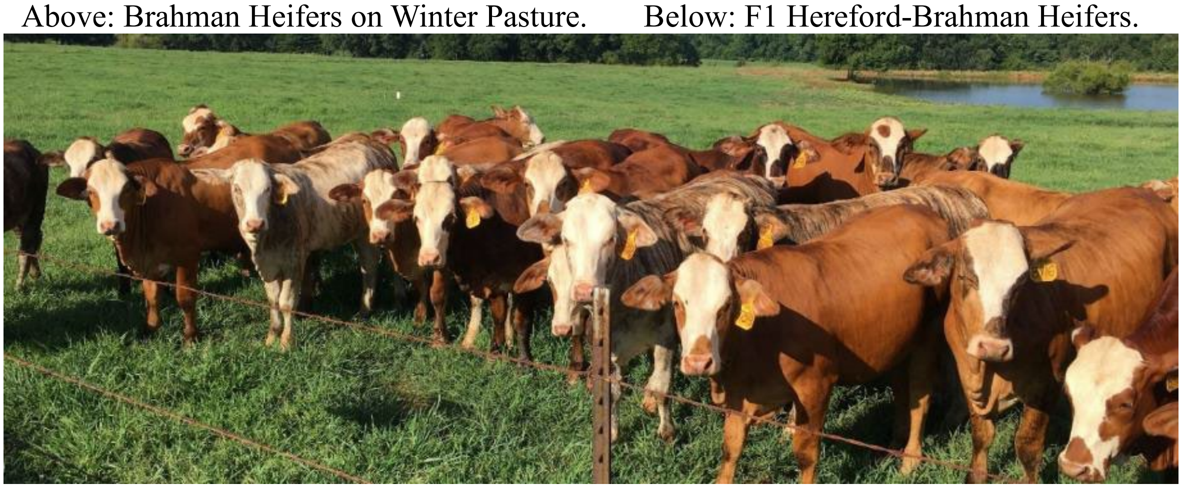
Outcomes: The Brahman herd at Overton is one of only four such research herds in the United States and is one of the largest. The F1 herd is also unique. In addition to the data, results and technology produced, undergraduate interns and graduate students are trained in this program. This research has been and continues to be a team effort. The plan is to continue research with Brahman and other breeds and crosses into the future to serve the needs of beef producers and consumers in Texas and beyond. Tropically adapted cattle will continue to be important to beef production in subtropical areas of this country and tropical regions of the world.
Research conducted at Overton will significantly impact future beef production.

Cattle currently on Center pastures:

Above: Brahman Cows with Young Calves.

Above: Brahman Bull with Cow-calf Pairs. Below: Weanlings in the Fall, 2023.

Above: Brahman Heifers on Winter Pasture. Below: F1 Hereford-Brahman Heifers.



Cattle Movement Through the Texas Beef System

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

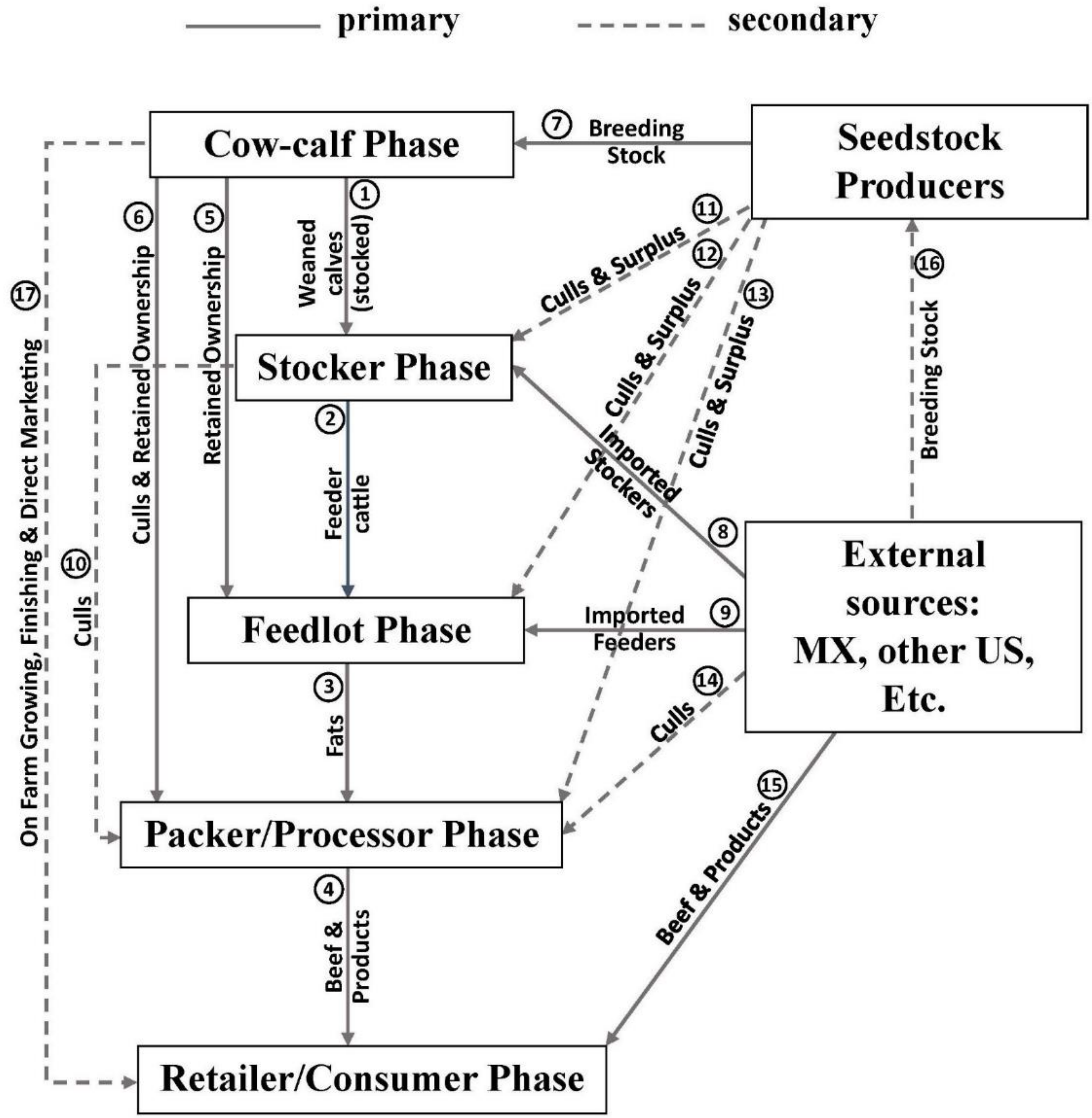
Application: The flow and ownership changes of cattle and beef products through the Texas Beef System are complex. This paper is intended to illustrate some aspects of the system and increase awareness and understanding of the system to aid producers in managing their operations.

Introduction: The Texas Beef Industry is a complex system composed of five primary phases: Cow-calf, Stocker, Feedlot, Packer/Processor and Retailer/Consumer: with high levels of capital investment and a myriad of business arrangements. One aspect of this system is the change of ownership of cattle and beef among the various phases of beef production. While many innovative ideas are currently being implemented in many areas of beef production, change in ownership between phases is likely to continue to be a major issue within the industry (perhaps to a lesser degree or with a different structure). Furthermore, cattle producers should be aware of these issues in order to make decisions relating to the production and marketing of their cattle.

Results: The diagram on the next page is a representation, not necessarily complete, of many of the ownership changes which can occur. Described here are the numbered pathways of exchange. Pathways 1, 2, 3 and 4 represent direct exchange in which ownership changes between all phases. Pathways 5 and 6 represent retained ownership by a cow-calf producer through the stocker or feedlot phase (also cull cows). Pathway 7 is the flow of breeding stock into the commercial cow herds. Pathways 8 and 9 represent importation of live cattle, from countries such as Mexico and Brazil and from other states. Pathways 10, 11, 12, 13 and 14 are movement of culls into production and/or slaughter. Pathways 15 and 16 represent imported beef and products as well as seedstock, respectively. Pathway 17 represents calf producers growing and finishing calves on farm to sell beef products directly to consumers.

Conclusion: While other exchanges may be visualized (for example, stocker-feeder operations are not shown), these seventeen pathways represent the majority of ownership changes and cattle flow in the Texas beef industry today. Some modification of these exchanges may come about through alliances or other arrangements. Also, some of the exchanges are being enhanced through innovations such as premium calf sales of commingled, backgrounded calves. One may expect new ideas and innovations in the future. Awareness of this aspect of the Texas Beef System will help producers adapt to future trends.

Texas Beef System
Cattle Flow Diagram



Each arrow represents change in ownership

Cattle Pen Design and Use

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

As one contemplates applying modern technology to a beef herd and makes plans on how to pen and work the cattle, a few considerations on pen design, construction and use are warranted. This activity, like many others, is subject to a wide variety of approaches, decisions and variations in final implementation.

Pen Design and Construction. The design of pen facilities for beef cattle varies across locations and reflects differences in many factors, including region, tradition, terrain, herd size, cattle type, managemental requirements, cost, frequency of use, available materials and personal preference of managers. There are a few general considerations that may be applied universally to the design of cattle pens and working facilities. A few of these are the following:

1) Maximize handler and cattle safety and comfort.
2) Locate gates properly to promote ease of cattle movement and convenience of operation. More gates are usually preferable to fewer gates, except for cost.
3) Build the working facility to optimize or balance access for loading cattle transport vehicles with distance and ease of bringing cattle from pastures into pens.
4) Pens should be of adequate size to contain the entire herd with plenty of room to sort, separate and hold groups such as cows, calves by sex, etc. Horseback sorting and working requires larger pen areas than does sorting on foot. Nervous cattle may handle more easily and safely by horseback.
5) Design alleys, chute and associated gates to facilitate your cattle working plan which contains order of activities, details of treatments, etc. Set up your squeeze chute to permit some sorting when cattle are released and do not locate the squeeze chute to release cattle back into a pasture. If possible, observe a squeeze chute in use before purchasing.
6) Build chutes, gates, alleys, etc. to proper dimensions for the cattle to be worked; a variable width chute may be warranted to accommodate cows and calves with minimal attempts to turn back. The height and design of fences, chute/alley sides and gates are important; higher fences discourage cattle from attempting to jump out. Catwalks along working chute/alley provide convenience, safety and reduce worker fatigue. A calf table is a good investment, particularly with larger herds. Roofs over the crowding pen, working chute/alley and squeeze chute are excellent protection for workers and cattle from rain and sun. Drainage of all areas is important. Windbreaks should be considered, particularly to the north.
7) The design of the means of getting cattle into the work alley/chute is very important. A tub, bud box or other design to fit working preferences should be built with consideration to how it will be used. Ease and efficiency of getting cattle into the tub or bud box are also important.
8) Wire traps and perhaps wings may be a good investment to facilitate penning and also holding groups of cattle for extended periods. Watering facilities in traps and one or two pens permit holding cattle for a few days.
9) Electricity at the working facility is often a good investment for operating various equipment such as branding irons, clippers, scales, etc. Also, occasionally a need to work on cattle at night arises and electric lighting is better than a flashlight or lantern.

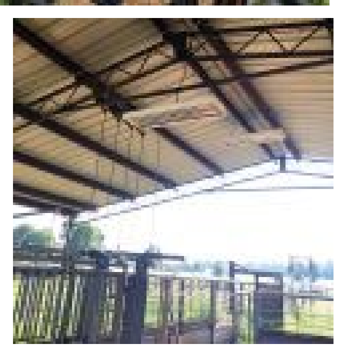
10) Commercially available plans and equipment should be considered. If the operation covers several locations, a set of portable working pens may be preferable to building working facilities on each place, particularly leased properties.

These are not the only important points. As in many endeavors, common sense and attention to detail will help to accomplish goals.

Using the Pens. As discussed elsewhere, there are a number of alternative methods one may use to get the cattle into the pen. The most important consideration is to pen all the cattle with minimum stress. This attention to low stress handling should continue throughout the working session and release back into the pasture. A few suggestions to help in this endeavor are listed below:

1) Do not release cattle from the pens through the same gate used to bring them into the pens. If practical, locate pens so that when moving cattle to a different pasture they travel through the pen area. If this is done, moving into the pen area becomes routine to the cattle and penning them for working becomes a matter of closing the right gates.
2) Move cattle through the pens, sorting, working through the chute and applying treatments at a moderate pace with as little noise as practicable.
3) Before releasing cattle from pens and/or traps, allow cattle to settle down, pair with their calves and otherwise calm down before opening a gate and allowing them to leave.
4) In the course of handling your herd when not penning to work the cattle, it may be possible to allow them to enter then leave the pen at a slow pace without any harassment; this may facilitate penning on the day you wish to work them.
5) Study cattle behavior and their reactions to various actions on your part. Anticipating reaction of cattle is key to effective, low-stress handling.

Some stress on cattle is unavoidable. However, if one emphasizes low stress handling, the goal can be achieved.



Penning Cattle

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

Introduction: In today's cattle business, management of beef herds to ensure the ability to take advantage of all appropriate profit enhancing technology depends on being able to pen all of one's cattle at will. Several methods of accomplishing this task of penning are available. These include 1) using feed to entice cattle into a pen; 2) driving cattle into the pen afoot or using horses, four-wheelers, pickups, helicopters or some combination; 3) trapping cattle at water or feed troughs with spring-loaded or one-way gates; 4) use of cattle dogs in one or more scenarios; or 5) some other approach not included above. Each method has advantages and disadvantages for the different classes or types of cattle, the various regions and pasture types and sizes, the seasons of the year, owners' and managers' preferences and other pertinent considerations including effectiveness, cost, availability and impact on cattle performance. Availability of knowledgeable hands, whether on the payroll or as day hands, is also important.

Application: Impact on cattle performance is a very important consideration. An appropriate goal in penning cattle is to accomplish the task with minimal stress on the cattle (and the owner) along with minimal cost. Each penning method has its pros and cons and is used by various cattle managers with appreciable levels of success in meeting the goal of low stress and low cost. Discussion of each method follows. Of course, once cattle are penned they should continue to be worked in a fashion to minimize stress.

Training Cattle. Cattle can be handled during daily activities to become accustomed to behaving in a desired fashion. For example, if a manager moves cattle from one pasture to another (with more grass), and does it in a similar manner every time, cattle will learn to change pastures easily. If in the course of changing pastures cattle can be taken through the working facility, then it is relatively easy to pen them by closing the appropriate gates. Further, cattle that are taught to follow a feed truck and are rewarded with a little feed, can be led into or through pens in that way. Cattle that are properly introduced to being worked with dogs (that work in the proper fashion) will learn to settle calmly and remain in the herd which can then be moved. In all these cases the training is through enticement and reward or applying and relieving pressure on the cattle. The goal is to have the cattle become trained so these activities become routine.

Penning with Feed. This method is used successfully by many owners/managers particularly with smaller herds. This method is generally inexpensive, does require some time and cost to familiarize cattle with cubes or other feed, and works well with herds that don't fear humans. The primary concern is that often one or more cows, especially in seasons of good forage availability, may not come into the pen.

Driving to Pen. Penning cattle afoot or with horses, four-wheelers, pickups, helicopters or a combination is used by many operations with good success. Using a helicopter incurs significant hourly charges but in areas of large pastures and less gentle cattle may actually save both time and cost compared to other methods. Horses and four-wheelers provide good mobility to move herds into pre-pen traps and then to strongly fenced working pens. Availability of experienced personnel in a timely fashion is important. Construction of properly designed wings, traps and pens can greatly enhance the efficiency and effectiveness of this approach. This approach costs more than using feed but is very effective with small and large herds.

Trapping, Roping or Darting. Using water traps or feed baited traps is sometimes effective, but while often good for cleaning wild cattle out of a pasture, it is not an approach that works well for application of technology in modern beef operations. Reasons include time required, variable success, distance from an effective trap location to a good working pen and other considerations. Roping or darting cattle with tranquilizers to capture or treat them is also used with success on individual cattle but is not usually practical for large numbers. The safety of workers and cattle is also a concern.

Cattle Dogs. The use of dogs for penning cattle in conjunction with one of the methods listed above may enhance the effectiveness of the method and /or may reduce the number of workers needed for penning a herd of a given size. For example, trained dogs may be used with the feed to encourage stragglers or runoffs to join the herd in the pen. Or cowdogs may be used to find cattle and/or to help keep together a herd being driven to the pen so as to reduce the number of riders needed. Costs and availability of personnel and dogs are a concern, as well as time to accustom cattle to being handled with dogs.

Benefits of Low Stress Cattle Penning. Consider an example comparing cattle penned easily at a walk to cattle penned with difficulty. A group of 100 seven-hundred-pound steers are to be penned, loaded on a truck to be weighed and sold using that weight to determine payment. If the cattle have been handled and trained so that penning is a routine task accomplished by walking the cattle into the pen in less than an hour, the cattle have been stressed minimally and weight shrink will be 2% or less. If the cattle have not been made accustomed to being penned routinely, the job could take significant time with the cattle running some and being stressed significantly. This could result in weight loss (shrinkage) of 7% or more, depending on the situation. The difference in shrinkage between the two groups in this example would be 5 percentage points, which would be 35 pounds per steer. For the herd this would be 3,500 pounds. At today's market prices these steers would likely bring $2 or more per pound. Two dollars times 3,500 pounds is $7,000. Low stress cattle penning reaps benefits.

Summary. Several methods of penning cattle are available with many variations to fit various situations. Minimizing stress on the cattle and cost are key considerations. The value of penning a herd of cattle in the first attempt at a walk to be worked calmly and with minimal stress should be clear to any cattle owner. Gentle well-behaved cattle are the result of good management.

Root-mycorrhizae interactions contributed to organic carbon density in the sandy soil profiles of adapted grazing lands

Anil Somenahally, Javid McLawrence, Jesse I. DuPont, Jeff Brady, Reshmi Sarkar, Monte Rouquette Jr.
Texas A&M AgriLife Research and Extension Center at Overton

Application: This study demonstrated the substantial impact of improved grazing and forage diversity management practices on soil organic carbon (SOC) accumulation potential in low-productive sandy soils. Additionally, the findings emphasized the role of key soil microbial interactions, particularly arbuscular mycorrhizae (AM), and potential application by optimizing grazing management strategies to enhance carbon sink capacity in grazing lands.

Introduction: Improved grazing lands (pastures) cover a significant portion of global land area. In warm-humid regions, like East Texas, pastures are often situated on marginal quality sandy soils with low fertility and organic matter content, posing challenges for SOC accumulation. The limitations to SOC sequestration in sandy soils include poor soil health properties such as soil aggregation, and subsoil acidity, and nutrient leaching, all of which hinder root proliferation and belowground productivity. Enhancing root-microbial interactions and subsequently the SOC sequestration through grazing and forage diversity management holds potential for transforming these low-fertile lands into carbon sinks. Root biomass, especially from deep-rooted perennial forages, plays a crucial role in SOC accumulation, while beneficial microbial interactions, particularly the arbuscular mycorrhizae (AMF), contribute to soil aggregation and nutrient retention. The study objectives of this study were to evaluate the impacts of long-term grazing management, including grazing pressure and nitrogen (N) fertilization, on root and microbial biomass, and SOC stocks in soil profiles.

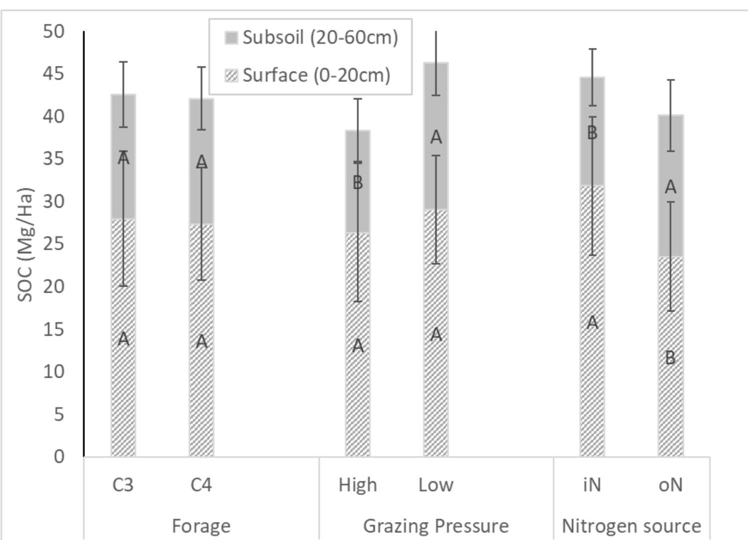
Materials and Methods: This study was conducted on long-term experimental grazing pastures near Overton, TX, under consistent management for more than 30 years. The experimental treatments evaluated different grazing pressure and nitrogen fertilization strategies using legume integration, to assess their impact on forage systems. The extended grazing season included both warm-season perennial grass (Bermudagrass), and cool-season C3 ryegrass (N-fertilized) or clover-legume (not N-fertilized). Deep soil sampling and analysis were conducted seasonally, aimed to assess soil organic carbon stocks, microbial biomass, and root biomass under different grazing pressures (high vs low) and forage systems (bermudagrass-ryegrass (iN) and bermudagrass-clover system (oN)). Statistical analysis was performed to compare the effects of grazing pressure, nitrogen sources, and grazing seasons on soil organic carbon and microbial biomass, providing insights into the impact of long-term grazing management practices on soil health and productivity.

Results: Long-term grazing and nitrogen management significantly influenced SOC stocks, with lower grazing pressure and legume organic nitrogen (oN) treatments leading to higher SOC accumulation in both surface and subsoil layers. Total nitrogen (TN) levels were significantly affected by grazing pressure, with lower levels observed under high grazing pressure treatments. Grazing pressure treatments significantly impacted aboveground and belowground biomass, with contrasting effects observed between aboveground forage biomass stand (FBS) and total forage biomass (TFB), while root biomass and microbial biomass carbon (MBC) were higher under high grazing pressure treatments. Distribution of belowground biomass carbon pools in surface and subsoil varied in response to grazing and nitrogen treatments, with higher surface SOC stocks under inorganic nitrogen (iN) fertilized treatments but higher subsoil SOC stocks under organic nitrogen (oN) legume systems and in low grazing pressure treatments. Microbial biomass, particularly bacterial biomass carbon (BBC) and arbuscular mycorrhizae biomass carbon (AmBC), played a significant role in SOC stocks accumulation, with higher levels observed under low grazing pressure and oN treatments, especially in the subsoil layers.

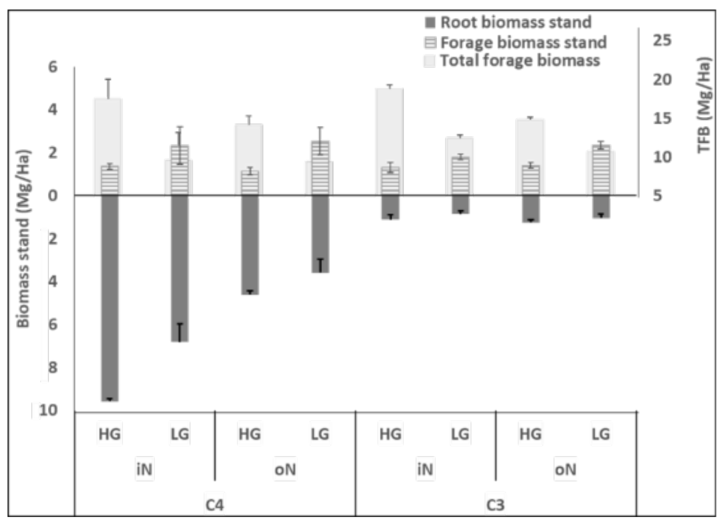
Conclusions: It was concluded from this study that several belowground biomass pools, particularly roots and AmBC contributed to SOC stocks in the soil profile and can be improved through strategic management of grazing pressure and N fertilization. The SOC density in surface soil was significantly increased under iN fertilized C4 and C3 grass rotation systems, whereas oN-legume systems promoted SOC stocks in the subsoil. A combination of oN and low grazing pressure was also effective in promoting AmBC in the soil profile. Results further confirmed that increasing beneficial root-AMF interactions had more effectively contributed to a higher rate of SOC accumulation in these soil profiles. Warm season perennial grasses (C4) were a major source of root and microbial biomass carbon, whereas cool season annual forages (C3) supported comparable microbial biomass. It was evident that several belowground attributes are critical for SOC sequestration and were responsive to grazing and N management and must be considered for choosing appropriate land stewardship practices to build SOC stocks.

Acknowledgements: Mrs. Cara Case. USDA project#1006103s, TEXO-1-9603 and TEXO-9754

Figures and Tables:



Soil organic carbon stocks in the soil profile as influenced by different experimental factors.



Estimates for above ground and belowground biomass as influenced by different experimental factors.

History of Crimson clover in the United States

Gerald R. Smith, Ph.D., Professor & Regents Fellow
Texas A&M AgriLife Research and Extension Center at Overton

Introduction: Crimson clover (*Trifolium incarnatum* L.) is the most important annual clover to US agriculture, with primary use as a winter annual forage legume overseeded on warm season perennial grass pastures in the southeast US. The history of use and improvement of crimson clover in the US stretches back to the mid 1800's with several changes in management and breeding objectives. Crimson clover was first used in the US as a non-reseeding pasture legume and as a green manure crop. The development of reseeding strains and more recently, improved cultivars with high hard seed levels was critical to modern crimson clover breeding programs and lead to increased use of this annual clover in US agriculture.

Crimson clover is an important component of forage production systems from Virginia to east Texas and the beautiful crimson flowers enhance the landscapes of both pastures and roadsides in this region. In 2019 through 2021 Oregon crimson clover seed production averaged 7.5 million lbs/yr with an estimated seed sales value of $6.6 million per year. Crimson clover is native to southern Europe and has been grown in the USA for more than 150 years but with increasing use in the last 60 years (Piper, 1935). As introduced from Europe, this forage legume did not have high hard seed levels and was not reliable in producing volunteer (reseeding) stands in the temperate, year around rainfall, climate of the eastern and southeast USA (Hollowell, 1947).

Early Use in the Southeast: Duggar (1898) noted the potential of crimson clover as a green manure crop for use in cotton cropping systems in Alabama. Interest in the use of crimson clover as a grazing crop in the southeast increased in the 1940's as reseeding strains became available (Donnelly and Cope, 1961). Crimson clover was grown as a seed crop and as a combination grazing and seed crop in the southeast US for 40 years beginning in the 1930's. Crimson clover seed production in the southeast US declined rapidly in the 1960's and early 1970's (personal communication, Dr. Jim Bostick, Alabama Crop Improvement Association). Some possible reasons for this decline are: loss of seed harvest and processing infrastructure; shift from clover and grass pastures to nitrogen fertilized grass pastures; and clover head weevil damage to the crimson clover seed crop.

Crimson in Texas: The exact beginning of crimson clover use in Texas is difficult to discern but for Rusk County, Texas the first crimson clover planting is well documented. Reseeding crimson clover was introduced to east Texas in 1949 from Alabama (Anon., 1951) and interest in this new clover increased rapidly as results from the first plantings were noted. The attributes that made crimson clover a success at this time in Texas were: three months of winter and spring grazing; reseeding stands; and cash income from seed crops. Texas Governor Allan Shivers proclaimed the week of April 30, 1951 as Crimson Clover Week. Dr. Bruce McMillan, a prominent Rusk

County agricultural leader, was instrumental in the introduction of this new clover from Alabama.

Crimson Clover Improvement: “Dixie” crimson clover was developed in Georgia in the early 1950’s in response to the need for a cultivar with improved reseeding traits that could also be produced as certified seed. Dixie is a composite of three crimson clover farm strains that exhibited excellent field reseeding, high forage yields and high hard seed test results in laboratory evaluations (Hollowell, 1953). As recent as 1959, common crimson clover had less than 5% hard seed at harvest (Bennett, 1959), but improvement in the hard seed level through recurrent selection could be demonstrated. “Chief” crimson clover was developed in Mississippi (Hollowell, 1960) through nine cycles of recurrent selection for hard seed with the final generation stabilized at 65% hard seed (as measured at harvest with hand-cleaned seed).

The hard seed trait in Dixie crimson clover was shown to be very stable over years and environments in a nine year study conducted in Alabama, Mississippi and Georgia in the 1950’s (Knight et al., 1963). The hard seed level of Dixie was consistently 60 to 80% at harvest with little effect from seed production location or year. In a three year experiment in Texas beginning in 1994, Dixie crimson clover averaged 33% hard seed at harvest (Evers and Smith, 2006) but did produce acceptable reseeding stands (>100 seedlings m^{-2}) in each year. This indicates a reduction in hard seed content for this cultivar from the levels reported by Knight (1963). Both “Flame” and “AU Robin” are crimson clover cultivars selected for early maturity out of Dixie (Baltensperger, et al., 1989; van Santen, et al., 1992). Parental lines of AU Robin were selected based on bloom date, dry matter yield and nitrogen yield. Flame was selected from a population of Dixie that had reseeded for seven years in warm-season perennial grass sod under winter grazing and summer hay management. “Tibbee” crimson clover (Knight, 1972) was developed as a reseeding variety through seven generations of natural selection for reseeding.

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Cool season forage legumes for East Texas

G.R. Smith and F.M. Rouquette, Jr.
Texas A&M AgriLife Research and Extension Center at Overton

Application: Forage legumes are useful components of Texas livestock production systems and as supplemental forages for wildlife. Several different species of true clovers (*Trifolium* spp.) are adapted to the sandy, acid soils of the Pineywoods and Post Oak Savannah ecoregions. These legumes are usually overseeded in the fall into warm-season perennial grass sods and provide grazing when the grass sods are dormant. Cool-season forage legumes provide forage with high nutritive value and add nitrogen to the pasture system through biological nitrogen 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.

Arrowleaf clover (*Trifolium vesiculosum* Savi) is one of the major annual clover species grown in the southeastern U.S. It has large white flowers that turn light pink when pollinated 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 6.0 to 6.5 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 low 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. Virus diseases are a major problem with older arrowleaf clover varieties like Yuchi. Leaves of affected plants will be crinkled, have a light and dark green mosaic pattern, and a chlorotic appearance. ‘Apache’ arrowleaf, developed at Overton and released by Texas A&M AgriLife Research in 2001, has high tolerance to bean yellow mosaic virus disease.

Ball clover (*Trifolium nigrescens* Viv.) has small ovate leaflets and small white to yellowish-white flowers 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 sandy soils near creek or river bottoms that maintain good soil moisture. Ball clover is shallow-rooted and does not tolerate dry upland soils well. It is medium maturity, flowering about a month later than crimson with yields usually slightly less than crimson clover. Ball clover is excellent at natural reseeding and will often reseed even under medium to light grazing pressure.

Crimson clover (*Trifolium incarnatum* L.) 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 pastures and roadside plantings 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 6.5. 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 of 15°F or lower have caused some leaf damage 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. Dixie crimson is the recommended variety.

White clover (*Trifolium repens* L.) is a perennial legume grown in the eastern half of the US. While perennial in nature, white clover in East Texas and the southeastern US generally persists as a weak perennial and re-seeding annual. There are small, medium, and large (ladino) white clover types. Small and medium white clover types are better seed producers than large leaf types, which is important for reseeding in the south. Recommended varieties are Louisiana S-1, Neches (developed at Overton) 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 warm season perennial grass stands. Best production will be obtained on fertile, loam and clay loam soils with good moisture. White clover will tolerate wet and poorly drained soil conditions better than most clover species. Because it is often found on wetter sites, white clover may survive a drought during the summer months better than other forage legumes. Forage production of white clover in East Texas is later than crimson and arrowleaf clover with peak production in May and early June.

Neches white clover with mature seed and in full bloom. June 4, Overton, Texas.

Improvement of warm-season forage legumes

G.R. Smith and F.M. Rouquette, Jr.
Texas A&M AgriLife Research and Extension Center at Overton

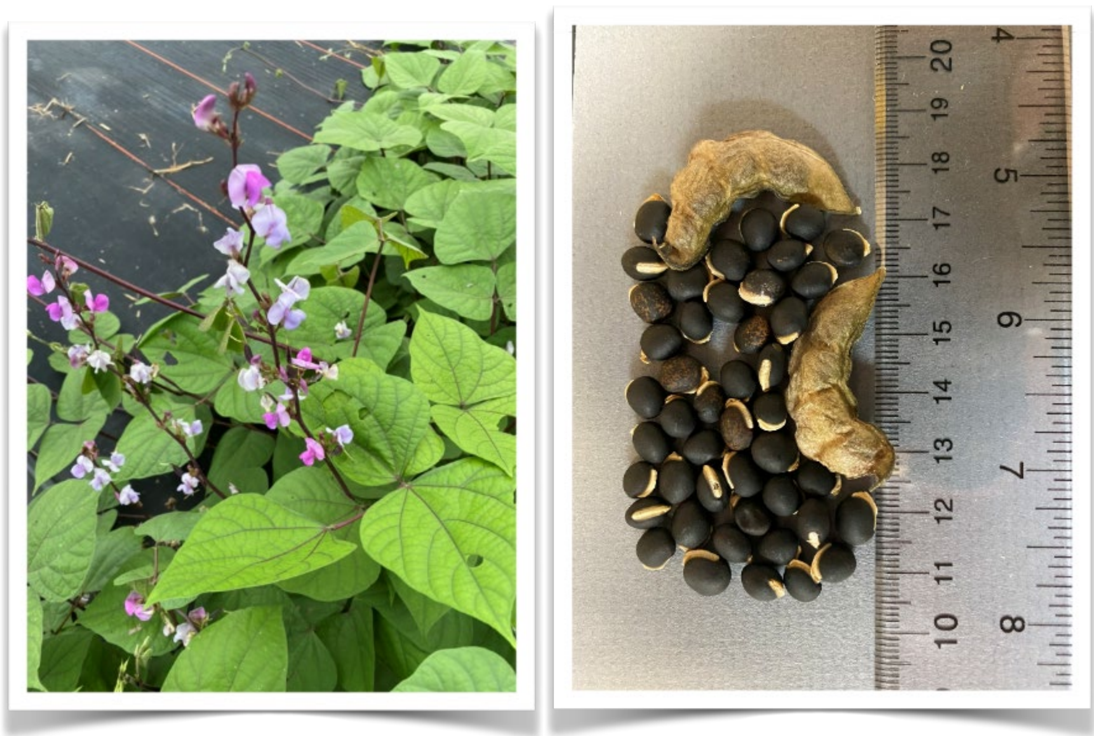
Application: Cowpea (*Vigna unguiculata* Walp) and lablab bean (*Lablab purpureus* [L.] Sweet) are productive warm-season legumes and well-adapted to upland soils in East Texas. Both of these legumes produce high nutritive value forage and are also useful as summer cover crops. Cattle graze lablab more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

Introduction: Two new cultivars of forage cowpea were recently developed at Texas A&M AgriLife Overton. 'Ace' forage cowpea (Smith et al., 2020) is small-seeded (9000 seed lb^{-1}) with high forage yields and good race 3 root-knot nematode resistance. 'Giant' forage cowpea (Smith et al., 2023) has medium size seed (3500 seed lb^{-1}), high forage yields and is resistant to both race 3 and race 4 root-knot nematodes. Both Ace and Giant produce mature seed in mid to late Oct. in northeast Texas. Commercial seed of Ace is available from Turner Seed, Breckenridge, TX (800 722-8616). We expect commercial seed of Giant to be available in 2025. 'Rio Verde' lablab bean was developed by Texas A&M AgriLife, 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. Commercial seed of Rio Verde is unavailable.
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 maturities. Variable maturities are necessary for successful seed production in different Texas ecoregions.

Materials and Methods: Numerous cowpea breeding lines were evaluated at Overton in 2015 and 16 for maturity, forage production, early seed yield and root-knot nematode resistance. In 2016 hand crosses were made between two lines identified with complementary traits (TX3-NR1 x PI 367863). Progeny of this cross was evaluated in the F2 and F3 generation for maturity and forage yield. Three F3 families were advanced from F4 to F6 using the bulk population method. In 2021 the three elite families were planted May 25 and evaluated as spaced plants. Multiple single plant selections were made based on maturity and seed yield. 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 the 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 have continued to combine anthracnose resistance with small seed size, high forage and seed yield and desirable pod traits. Pod shape, size, texture and tendency to shatter all vary widely in lablab germplasm.

Results: The forage cowpea breeding line TX-18-19-3 had 80% mature seed on Sept. 13, 2021 compared to no mature seed for Ace cowpea at this date. The line TX-18-19-3 was evaluated again in 2022 at Overton and no segregation for maturity or seed traits were noted. Evaluation of T-18-19-3 continues under the experimental cultivar name 'Turbo'.

Elite breeding forage lablab breeding lines have been identified with anthracnose resistance, high forage yield and good pod traits. Seed production evaluations of the elite forage lablab line TX-B2-8-7 is in progress. Leaf, flower, seed and pod traits of this line are shown in the photos below.



TX-B2-8-7 Forage Lablab Experimental Line

Winter forage establishment in warm-season perennial grass pastures

G.R. Smith and F.M. Rouquette, Jr.
Texas A&M AgriLife Research and Extension Center at Overton

Application: Planning and implementation of planting methods to ensure proper establishment of cool-season forages into warm-season perennial grass (WSPG) pastures are critical steps in providing winter forage for livestock in East Texas.

Introduction: Warm-season perennial grasses 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 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.

Materials and Methods:

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. 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. 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 'Cool season forage legumes for East 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 1. 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.

Table 1. Recommended planting rates and seed costs (2023) for cool-season forage legumes and grasses for East Texas.

Forage Crop	**Planting Rate**	**Seed Cost**	**Total Seed Cost**
	Pounds/Acre	**$/Pound**	**$/Acre**
Ryegrass	40	$0.80	$32.00
Forage Rye	100	$0.50	$50.00
Crimson Clover	20	$2.50	$50.00
Arrowleaf Clover	10	$2.60	$26.00
White Clover	5	$3.70	$18.50

Comparison of Apache arrowleaf, Blackhawk arrowleaf, and Red Hawk white clovers for growth traits and root nodulation

F.M. Rouquette, K.L. Turner, K.D. Norman and G.R. Smith
Texas A&M AgriLife Research and Extension Center at Overton

Application: Legume root mass and nodulation has direct impact on plant growth, accumulation, and nitrogen fixation.

Introduction: 'Apache' and 'Blackhawk" arrowleaf clovers (*Trifolium vesiculosum* Savi) were released by Dr. G.R.Smith at Overton. 'Red Hawk' white clover (*Trifolium repens* L.)was selected by Dr. Smith and is awaiting release as a cultivar. Our objectives were to compare accumulation growth, plant height, root length, and nodulation of these 3 clovers.

Materials and Methods: Apache, Blackhawk, and Red Hawk clovers were drilled on 7" centers on November 23, 2022, each in half acre prepared seedbed sites. Sites received ECCE-100 limestone during the previous year to provide a soil pH ~ 7.0. All planted areas received 300 lb/ac 0-20-20-8-4.25-0.2 (N-P2O5-K20-S-Mg-Bo). All clovers were harvested for accumulated dry matter (DM) on Apr 27, 2022, when all were in vegetative stage, and again on June 15, 2022, when all were setting seed. Several whole plants, 30 to 50 of each clover, with intact roots were dug up on May 5-9, 2022, to measure plant height, root length, and root nodulation. Nodules were counted and scored via the Nodule Rating System-Pulse for each clover root sample.

Results: At the first harvest on April 27, 2022, average plant height and DM were: 7.5 in and 2525 lb/ac- Red Hawk; 13 in and 3404 lb/ac- Blackhawk; and 19 in and 6457 lb/ac- Apache. Seven weeks later on June 15, 2022 at seed set, height and DM were: 6 in and 4282 lb/ac- Red Hawk; 14 in and 8896 lb/ac- Apache, and 17 in and 9523 lb/ac- Blackhawk. Plant height on May 5-9 was different ($P<.001$) between clovers and ranked Apache > Blackhawk > Red Hawk (Figure 1). Root length was different ($P<.001$) between clovers and ranked Blackhawk > Apache > Red Hawk (Figure 2). Root nodulation count and score were greater for Red Hawk than Apache and Blackhawk (Table 1).

Table 1. Legume root nodulation from Apache arrowleaf, Blackhawk arrowleaf, and Red Hawk white clovers.

Variety	Nodules/Root	SE	Nodule Score[1]	SE
Red Hawk	35.8 a[*]	2.61	5.8 a	0.28
Apache	23.0 b	2.21	5.0 b	0.24
Blackhawk	15.9 b	2.91	3.5 c	0.32

[*] Values within a column not followed by the same letter differ at $P < 0.001$.

[1] Nodule Scoring: 3: 0-15 nodules; 4: 15-20 nodules; 5: 20-25 nodules; 6: >25 nodules.

Figure 1. Plant height of Apache arrowleaf, Blackhawk arrowleaf, and Red Hawk white clovers.

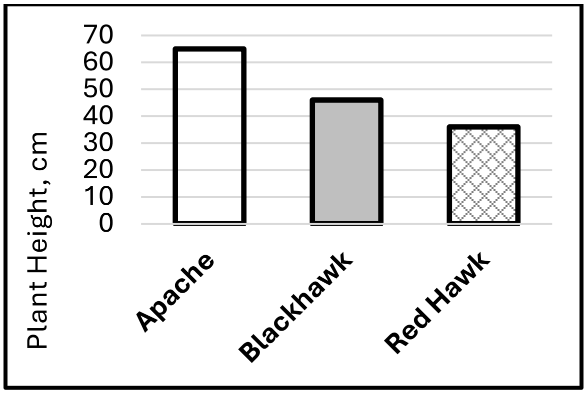
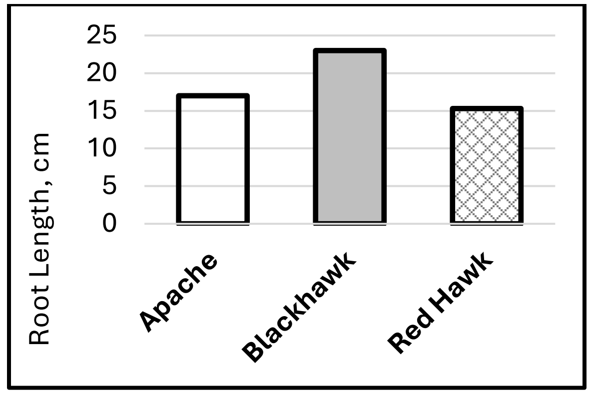


Figure 2. Root length of Apache arrowleaf, Blackhawk arrowleaf, and Red Hawk white clovers.



Nodule Score ≈ 5 - 6

Nodule Score ≈ 5 - 6

Nodule Score ≈ 3

Nodule Score ≈ 3

Conclusions and Implementation: Red Hawk white clover had the most abundant root nodules compared to Apache and Blackhawk arrowleaf clovers. Increased root nodulation indicates better soil-seed and moisture conditions for symbiotic relationship with Rhizobium spp. Also, increased nodulation provides more potential nitrogen fixation in leaves and stems for conversion to crude protein for livestock. The more upright and robust growth characteristics of arrowleaf provides more forage mass for potential increased stocking rates and/or baleage-hay production.

Relationship of forage allowance and daily gain on rye-ryegrass pastures at different stocking rates with continuous and rotational stocking

F. M. Rouquette, Jr.[1]; Norman, K. D.[1]; Long, C. R.[1]; and van Santen, E.[2]
[1] Texas A&M AgriLife Research and Extension Center at Overton
[2] Institute of Food and Agricultural Sciences, Univ. FL, Gainesville

Application: Forage mass and forage allowance (DM:BW) are the primary factors controlling gain per animal and gain per ha.

Introduction: Our objectives were to: 1) compare stocking methods for daily gain per animal (ADG) and gain/ha; and 2) quantify relationships of ADG with forage mass and forage allowance.

Materials and Methods: 'Maton' cereal rye and 'TAM-90' annual ryegrass (RRG) were sod-seeded into bermudagrass pastures in mid-Oct. Rye was drill-seeded at 110 kg/ha and ryegrass broadcast at 33 kg/ha. Four split applications of 226-22-48 kg/ha (N - P_2O_5- K_2O) were applied each year. Three stocking rates were used with 3 replicates each of continuous (CONT) and 8-paddock rotational (ROTN) stocking methods with 3 steers and 3 heifers, winter-born, per replicate (1 stocker = 250 kg). All ROTN pastures had a 2-d residence and a 14-d rest period. Forage mass was hand-clipped to ground level at time of pre- and post-stocking on ROTN paddocks and at 28-d intervals on CONT pastures. A linear plateau model was created of ADG = $\mathbf{b_0}$ + $\mathbf{b_1}$*X for X ≤ **a**, and ADG = $\mathbf{b_0}$ + **a***X for X > **a**, where ADG is average daily gain, $\mathbf{b_0}$ equals the intercept, $\mathbf{b_1}$ the slope, **x** the independent variable (forage mass or forage allowance) and **a** equals the join point where the slope response changes to a plateau.

Results: Each of 3 levels of stocking rate, 4.9, 6.4, and 8.6 hd/ha affected ADG at 1.24, 1.04, and 0.74 kg/d, and gain/ha at 821, 991, and 794 kg/ha, respectively (Table 1). There were no effects of stocking method on ADG at 1 kg/d or gain/ha at 870 kg/ha. There was a 2-stage linear relationship for ADG and forage mass with the join point for maximum gain at 1850 kg/ha forage mass (Fig 1). The 2-stage join point for forage allowance was 1.0 Forage DM : Animal BW (Fig 2).

Table 1. Average daily gain (ADG) and gain per ha (Gain/Ha) from rye + ryegrass pastures stocked at three rates with continuous vs rotational stocking methods during 7 years.

	ADG		**Gain/Ha**	
Management Strategy	**kg/d**	**SE**	**kg/ha**	**SE**
Stocking Rate (animal/ha)†				
Low (4.9)	1.24 a*	0.042	821 b*	50.32
Medium (6.4)	1.04 b	0.048	991 a	60.97
High (8.6)	0.74 c	0.042	794 b	50.32
Stocking Method				
Continuous	1.02	0.040	873	46.26
Rotational	1.00	0.040	865	45.79

† One stocker = 250 kg bodyweight; pastures stocked from late Dec to May.

* Different letters within columns indicate a difference (P <0.01) between stocking rates

2 – plane linear plateau and join point
For every unit increase in total forage mass, ADG increased by 0.64 kg/d up to the join point of 1850 kg/ha (Fig. 1). For every unit increase in total forage allowance, ADG increased by 1.34 kg/d up to the join point of 0.99 DM:BW and was rounded to 1.0 (Fig 2).

Figure 1. Forage mass and join point of rye + ryegrass for maximum daily gain (ADG) for 250kg stockers.

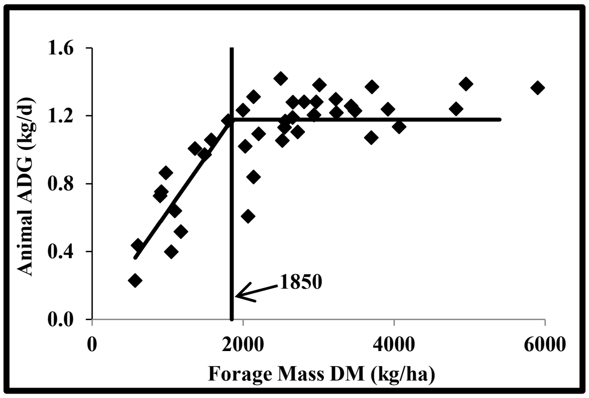
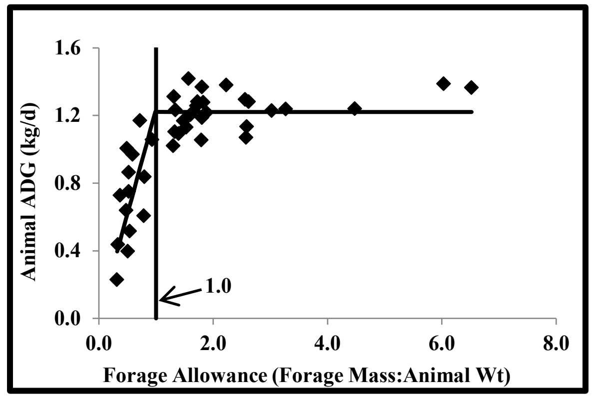


Figure 2. Forage allowance and join point of rye + ryegrass for maximum daily gain (ADG) for 250kg stockers.



Gain per animal vs gain per ha
The relationship of ADG and gain/ha with stocking rates showed a linear decrease in ADG and curvilinear response in gain/ha (Fig 3). Average body weight growth of stockers stocked at three rates on RRG showed differences in growth rate and final body weight (Fig 4).

Figure 3. Relationship of average daily gain (ADG) with gain per ha at different stocking rates of 250kg stockers.

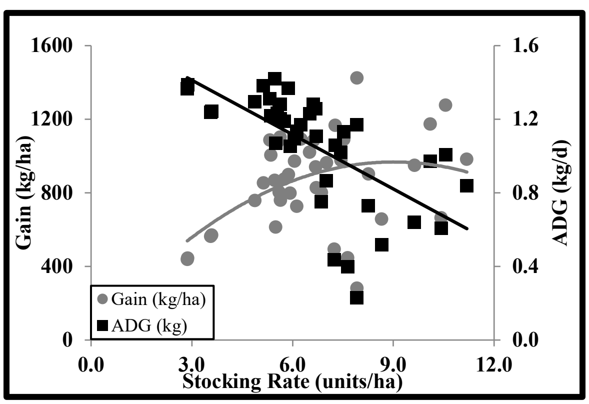
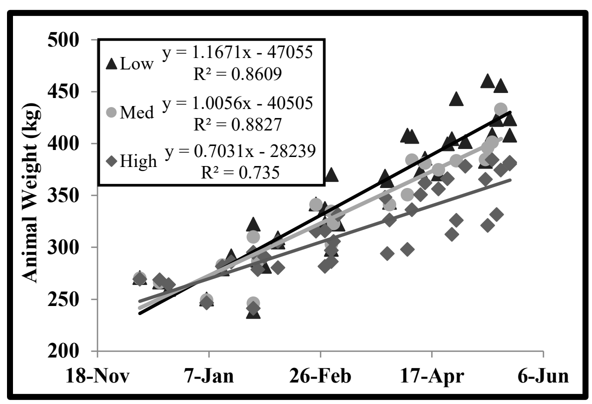


Figure 4. Average growth and body weight of steers and heifers stocked at three rates on rye + ryegrass.



Conclusions and Implications
Rotational stocking using any rest-defer system may allow for desired utilization strategies; however, increased performance per animal or per unit land area would not likely be different than CONT stocking.

Effects of level of dried distillers grain supplement on stocker performance stocked on Tifton 85 bermudagrass

W. B. Smith[1], J. P. Banta[2], J. L. Foster[3], L. A. Redmon[4], C. R. Long[6], L. O. Tedeschi[5], and F. M. Rouquette, Jr.[6]

[1]Department of Animal Science, Auburn University, Auburn, AL
[2]Department of Animal Science, Texas A&M AgriLife Extension, Overton, TX
[3]Texas A&M AgriLife Research, Beeville, TX
[4]Department of Soil and Crop Sciences, Texas A&M AgriLife Extension, College Station, TX
[5]Department of Animal Science, Texas A&M University, College Station, TX
[6] Texas A&M AgriLife Research, Overton, TX

Application: Supplementation of stocker cattle has generally been done to offset: 1) lack of forage available for grazing due to stocking rate and/or climatic conditions, or 2) to enhance ADG from low nutritive value forages.

Introduction: The objective of this 2-yr study was to evaluate Dried Distillers Grain with Solubles supplement level on gain of steers stocked on Tifton 85 bermudagrass.

***Materials and Methods*:** Stocking of Tifton 85 bermudagrass pastures occurred in June of each year and was terminated in late September-early October. *Bos taurus* crossbred steers, n = 112 at 800 lb initial BW and ≈ 15 mo of age, were stratified by BW and randomly allocated to16 pastures. Treatments included 4 levels of DDGS SUP (0.00, 0.25, 0.50, or 1.00% BW) per hd daily. Granular DDGS with 2% limestone, 27% CP, 6.5% fat was the SUP ration and was group-fed daily. Limestone was added to the DDGS mixture at 2% due to the exceedingly high concentrations of P to balance Ca:P ratios. Forage in each pasture was hand-clipped in 1 ft^2 quadrats every 21-d for estimates of forage mass (Table 1). Forage for nutritive value was hand-plucked in pastures on 14-d intervals to mimic diet selection by cattle (Table 2). Pastures were fertilized with 21-8-17 fertilizer at a rate of 325 lb/ac at the beginning of the season, and 200 lb/ac of 34-0-0 applied twice (6-week intervals) during the grazing season in each year.

Results: Average daily gain (ADG) was greatest from steers receiving 1.00% BW SUP (2.9 lb/d), followed by 0.50 and 0.25% BW SUP (2.6 and 2.5 lb/d, respectively), and ADG was least from non-SUP (0%) steers (1.9 lb/d) (Table 3). A greater extra gain resulted from 1.00% BW SUP (1.1 lb/d) than from 0.50 or 0.25% BW SUP (0.8 and 0.7 lb/d, respectively), which did not differ. When expressed as a ratio of SUP to additional BW gain, ratios of 9.0, 6.0, and 3.7 lb:lb were realized for 1.00, 0.50, and 0.25% BW SUP, respectively. Pastures at 1.00% BW SUP were stocked with a greater animal density (4600 lb/ac) than 0.00, 0.25, or 0.50% BW SUP pastures (3800 lb/ac for all SUP treatments). Using 750 lb = 1 stocker steer, this resulted in average stocking rates of 5.1, 5.0, 5.1, and 6.2 hd/ac for 0.00, 0.25, 0.50, and 1.00% BW SUP, respectively. Gain per acre was greatest from pastures supplemented at 1.00% BW (1700 lb/ac), followed by 0.50 and 0.25% BW SUP (1200 and 1100 lb/ac, respectively) (Table 3). Gain per acre was least from non-SUP control pastures at 800 lb/ac.

Two-year season averages of forage mass, forage height, and forage allowance for Tifton 85 pastures with 4 levels of DDGS supplement are shown in Table 1. “Grazer steers” were used to regulate forage mass. Monthly nutritive value averaged over 2 years showed a predictable decline from June through September (Table 2). Crude protein was greatest in June and similar in July – September. The NDF and ADF values increased with the season.

Table 1. Two-year season averages of Tifton 85 bermudagrass parameters.

	Level of DDGS SUP			
Item	**0**	**0.25**	**0.50**	**1.00**
Forage mass (lb/ac)	3300	3111	3086	3652
Forage height (in)	10.9	10.6	10.4	11.7
Forage allowance lb DM:lb BW	0.95	0.88	0.84	0.87

Table 2. Two-year average nutritive value components of Tifton 85 bermudagrass during DDGS supplementation.

Nutritive component	June	July	August	September
		% DM		
Crude Protein	18.7	12.9	13.9	13.5
Neutral Detergent Fiber	69.7	73.5	71.8	72.8
Acid Detergent Fiber	32.3	36.7	37.4	38.2

Table 3. Performance of crossbred cattle grazing Tifton 85 (TIF) bermudagrass and supplemented with various levels of DDGS.

	Level of supplementation, % BW			
Item*	**0.00%**	**0.25%**	**0.50%**	**1.00%**
ADG, lb/d	1.85 c	2.46 b	2.57 b	2.88 a
Additional gain from supplement, lb/d	N/A‡	0.63 b	0.78 b	1.07 a
Average daily supplement fed, lb/hd	N/A‡	2.3 c	4.7 b	9.6 a
Supplemental feed:extra gain ratio, lb/lb†	N/A‡	3.7	6.0	9.0
Stocking density, lb BW/ac	3802 b	3746 b	3793 b	4619 a
Stocking rate, hd/ac#	5.1 b	5.0 b	5.1 b	6.2 a
Gain per unit area, lb/ac	756 c	1097 b	1199 b	1661 a

*Means within a row not followed by the same letter differ at $P < 0.05$.
†Response variable calculated from treatment means and not statistically analyzed.
‡Not applicable.
#Based on 1 animal = 750 lb.

Conclusions and Implications: Average daily gain and gain per acre were improved with any level of DDGS. The cost-effectiveness of level of supplement is dependent upon several factors including a) cost of supplement; b) supplement to extra gain ratio; c) method of delivery of supplement; d) management strategies for continued ownership; and e) accomplishment of gain/animal, gain/ac, and/or value of stockers for production or niche markets at termination of supplementation.

Effect of level of dried distillers grain supplement on crossbred stocker performance stocked on Coastal bermudagrass

W. B. Smith[1], J. P. Banta[2], J. L. Foster[3], L. A. Redmon[4], C. R. Long[6], L. O. Tedeschi[5], and F. M. Rouquette, Jr.[6]

[1]Department of Animal Science, Auburn University, Auburn, AL
[2]Department of Animal Science, Texas A&M AgriLife Extension, Overton, TX
[3]Texas A&M AgriLife Research, Beeville, TX
[4]Department of Soil and Crop Sciences, Texas A&M AgriLife Extension, College Station, TX
[5]Department of Animal Science, Texas A&M University, College Station, TX
[6] Texas A&M AgriLife Research, Overton, TX

Application: Supplementation of stocker cattle has generally been done to offset: 1) lack of forage available for grazing due to stocking rate and/or climatic conditions, or 2) to enhance ADG from low nutritive value forages.

Introduction: The objective of this 2-yr study was to evaluate Dried Distillers Grain with Solubles (DDGS) supplementation level (SUP) on gain of crossbred steers stocked on Coastal bermudagrass pastures during the summer.

***Materials and Methods*:** Stocking of Coastal bermudagrass pastures occurred at the Texas A&M AgriLife Research and Extension Center in Overton, TX, in June of each year and was terminated in late September or early October. Steers (n = 117, 750 lb initial BW, 15 mo of age), were stratified by BW and randomly allocated to 9 pastures. Each year 3 levels of DDGS SUP (0.00, 0.25, or 1.00% BW) were used. Steers were subsequently weighed, unshrunk, every 21 d. Forage in each pasture was hand-clipped in quadrats every 21-d for estimates of forage mass (Table 1). Forage for nutritive value was hand-plucked in pastures on 14-d intervals to mimic selection by cattle (Table 2). "Grazer steers" were added to each pasture as needed to create comparable forage mass among pastures. Granular DDGS (with 2% limestone, 27% CP, 6.5% fat) was group-fed daily. Limestone was added to the DDGS mixture at 2% due to the exceedingly high concentrations of P to balance Ca:P ratios. Pastures were fertilized with a 21-8-17 fertilizer blend at a rate of 325 lb/ac at the beginning of the season, and 200 lb/ac of 34-0-0 applied twice (6-week intervals) each year.

Results: Average daily gain was greatest from steers receiving 1.00% BW SUP (2.3 lb/d) and least from 0.25 and 0.00% BW SUP (1.6 and 1.5 lb/d, respectively) (Table 3). This resulted in a greater extra gain from supplemental feed from 1.00% BW SUP (0.74 lb/d) than from 0.25% BW SUP (0.02 lb/d). When expressed as a ratio of supplemental feed to additional BW gain, ratios of 11.8 lb:lb and 105 lb:lb occurred for 1.00 and 0.25% BW SUP, respectively. Pastures with SUP at 1.00% and 0.25% BW were stocked with a greater animal density (2900 and 2600 lb/ac, respectively) than 0.00 BW SUP pastures (2000 lb/ac). Using 750 lb = 1 stocker, this resulted in 2-yr stocking rates of 2.7, 3.4, and 3.9 hd/ac for 0.00, 0.25, and 1.00% BW SUP. Gain per acre was greatest from pastures supplemented at 1.00% BW (800 lb/ac) followed by 0.25% BW SUP (500 lb/ac). Gain per acre was least from non-SUP control pastures (400 lb/ac). Extra gain from supplemental feed was negligible from 0.25% BW SUP (0.04 lb/d) and 0.74 lb/d from SUP at 1.00% BW.

Table 1. Two-year season averages of Coastal bermudagrass parameters.

	Level of DDGS SUP		
Item	**0**	**0.25**	**1.00**
Forage mass (lb/ac)	2453	2246	2572
Forage height (in)	8	8.7	9.5
Forage allowance lb DM:lb BW	1.4	1.0	1.0

Table 2. Two-year average nutritive value components of Coastal bermudagrass during DDGS supplementation.

Nutritive component	June	July	August	September	October
			% DM		
Crude Protein	15.8	12.7	13.8	13.4	12.8
Neutral Detergent Fiber	69.4	70.6	70.4	71.1	71.5
Acid Detergent Fiber	33.3	35.1	35.7	35.6	37.9

Table 3. Performance measures of crossbred cattle grazing Coastal bermudagrass and supplemented with various levels of DDGS.*

	Level of supplementation, % BW		
Item	**0.00%**	**0.25%**	**1.00%**
ADG, lb/d	1.53 b	1.57 b	2.26 a
Additional gain from supplement, lb/d	N/A‡	0.02 b	0.74 a
Average daily supplement fed, lb/hd	N/A‡	2.1 b	8.7 a
Supplemental feed:extra gain ratio, lb/lb†	N/A‡	105	11.8
Stocking density, lb BW/ac	2005 b	2553 a	2930 a
Stocking rate, hd/ac#	2.7 b	3.4 a	3.9 a
Gain per unit area, lb/ac	400 c	500 b	847 a

*Means within a row not followed by the same letter differ at $P < 0.05$.
†Response variable calculated from treatment means and not statistically analyzed.
‡Not applicable.
#Based on 1 animal = 750 lb.

Conclusions and Implications: Supplementation with moderately high daily rates of DDGS (1% BW) may be useful for increased gain per animal and gain per acre. In this study, 1% DDGS was the most efficient use of supplementation for stockers on Coastal bermudagrass. Supplement choice (protein vs energy-based), daily amount of supplement, method of delivery of supplement, additional gain per pound of supplement, additional gain per animal, and additional gain per acre are major factors involved with whether supplementation is a best management strategy for economic stocker production.

Level of whole corn on gain of Brahman steers stocked on Tifton 85 bermudagrass and subsequent effects on feedlot gain and carcass traits

F.M. Rouquette, Jr[1], J.P. Banta[2], C.R. Long[1], K.L. Turner[1], K.D. Norman[1], J. Paschal[3], and R.D. Randel[1]

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

[2]Texas A&M AgriLife Extension, Overton, Texas, USA

[3]Formerly Texas A&M AgriLife Extension Service, Corpus Christi, Texas, USA

Application: Supplementation of stocker calves is used to enhance gain and/or adjust for stocking rates on pasture; little is known about effects on subsequent performance in the feedlot.

Introduction: Our objectives were to determine the influence of whole corn on performance of Brahman steers stocked on Tifton 85 bermudagrass [*Cynodon dactylon* (L.) Pers. X *Cynodon nlemfuensis* Vanderyst] (T85) and subsequent performance in feedlot and carcass traits.

Materials & Methods: For a 3-yr period, Brahman (*Bos indicus*) steers, 15 mo old and 600 lb body weight (BW), were stocked on T85 and received daily whole corn at 0 (PAS), 0.3% BW (SUP3), or 0.6% BW (SUP6). A fourth treatment included SUP6 at an increased stocking rate (SUP6SR). Crude protein of T85 has been documented to range from 18.5% in June to 13.5% in September. The 3-yr average SR of 600 lb steers was 4.5 steers/ac on PAS, SUP3, and SUP6, and 6 steers/ac on SUP6SR. At termination of stocking, steers were shipped 425 miles to a commercial feedlot in South Texas. Each year, steers were fed in the same pen until a visual assessment of about 0.5 in backfat was attained. At that time, steers were transported 40 miles to an abattoir for harvest and carcass trait evaluations.

Results: Average daily gain (ADG) on T85 was similar for SUP steers at 2.16 lb/d (SUP6), 1.98 lb/d (SUP3), and 1.98 lb/d (SUP6SR), but greater (P=.002) than PAS steers at 1.85 lb/d (Table 1.) Steer gain/ac was greatest (P=.001) for SUP6SR at 1098 lb/ac. Gain/ac was similar for SUP6 and SUP3 at 902 lb/ac and 840 lb/ac, respectively, and similar for SUP3 and PAS (768 lb/ac) (Table 1.) Weights off pasture tended to be greater (P=.083) for all SUP steers at 816 lb than PAS steers at 781 lb. Body condition score off pasture was similar for all SUP steers at 5.7 and different (P=.001) from PAS steers at 5.2.

Feedlot ADG was similar for steers on SUP3 (3.00 lb/d), PAS (2.95 lb/d), and SUP6SR (2.84 lb/d), but greater (P=.045) than steers on SUP6 (2.73 lb/d). These feedlot ADG exhibited some compensatory gain effects from pasture treatments. Off feedlot weights were similar at 1367 lb. There were no differences across treatments for steer hot carcass weight, 809 lb; 12th rib fat thickness, 0.45 in; marbling score, 395; calculated yield grade, 3.10; longissimus dorsi area, 13.2 in^2; or internal fat (Kidney-Pelvic-Heart), 1.92%.

Table 1. Effect of daily levels of whole corn on performance of Brahman steers on pasture.

	Supplement - % BW Daily			
Pasture Performance	**0%**	**0.3%**	**0.6%**	**0.6% + SR**
ADG (lb/d)	1.85 b*	1.98 a	2.16 a	1.98 a
SUP:Extra gain	N/A	12.5	13.8	39.3
Gain/ac (lb)	767 c	839 bc	901 b	1097 a
Off-Pasture BCS	5.2 b	5.6 a	5.8 a	5.7 a
Off-Pasture Wt (lb)	781 b	816 a	820 a	814 ab

* Numbers in a row for a performance trait followed by a different letter differ at P<0.01.

Table 2. Subsequent feedlot performance and carcass traits of Brahman steers.

	Supplement - % BW Daily			
Carcass Trait	**0%**	**0.3%**	**0.6%**	**0.6% + SR**
Days on Feed	194 a*	186 a	188 a	190 a
Off-Feedlot Wt (lb)	1374 ab	1385 a	1341 b	1360 ab
Feedlot ADG (lb/d)	2.95 a	3.00 a	2.73 b	2.84 ab
Hot Carcass Wt (lb)	809 a	823 a	796 a	811 a
Backfat Thickness (in)	0.46 a	0.45 a	0.41 a	0.45 a
KPH (%)	1.85 a	1.93 a	1.87 a	2.01 a
Ribeye Area (in^2)	13.16 a	13.08 a	13.26 a	13.21 a
Predicted Yield Grade	3.11 a	3.10 a	3.03 a	3.14 a
Marbling Score	392 a	406 a	398 a	384 a

* Numbers in a row for a performance trait followed by a different letter differ at P<0.01.

Conclusions and Implications: With SUP:extra gain at 12.5:1 for SUP3, 13.8:1 for SUP6, and 39.3:1 for SUP6SR, supplementation of whole corn for Brahman steers stocked on T85 was not as efficient as previous T85 x SUP experiments with DDGS. Whole corn may be the least expensive supplement to use since there are no costs for ration ingredients. Pasture costs of fertilizer, etc. are the same for all supplement treatments. Thus, cost comparisons include the ratio of supplement:extra gain attributed to whole corn and fertilization. Choice of level of supplementation may offer management options for specific classes of cattle and ownership-stocking strategies.

Mature Corriente steers and long-yearling crossbred steers stocked on Coastal bermudagrass pastures sod-seeded with rye-ryegrass prior to feedlot

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

Application: Bermudagrass pastures are often sod-seeded with cereal rye and annual ryegrass with or without supplementation to increase animal weight before feedlot.

Introduction: The objectives of this study were to document gain on pasture for mature Corriente steers for rodeo stock vs long-yearling crossbreds stocked on bermudagrass sod-seeded with rye-ryegrass with supplementation and subsequent feedlot gains and carcass traits.

Materials and Methods: Coastal bermudagrass pastures were sod-seeded with 'Elbon' rye and 'TAM-90' ryegrass in early Oct. Pastures were fertilized with 300 lb/ac 21-8-17 in mid-Nov and with 200 lb/ac 34-0-0 on Jan 6, Feb 23, and Apr 12. Forage mass was measured to ground level on each pasture at approximate 28-d intervals. Supplement treatments included: a) pasture only (PAS); b) 1 lb/hd/d cracked corn (CRN1); c) 2 lb/hd/d cracked corn (CRN2); d) CRN1 + 1 lb/hd/d Menhaden fishmeal (CFIS); and e) CRN1 + 1 lb/hd/d feathermeal (CFEA) in complete randomized design with 2 pasture replications. Percent CP of supplements approximated 9% for CRN, 35% for CFIS, and 47% for CFEA. Cattle were group-fed once daily. Corriente steers were estimated to be 3-5 years old, and crossbred steers were about 12-14 months old. Stocking was extended to June 2 on bermudagrass, and steers were transported to a commercial feedlot in Hereford, TX. Steers were harvested at an Amarillo abattoir and carcass traits measured.

Results: Crossbred steers had greater ADG than Corriente steers from 2-19 to 5-12 at 2.95 lb/d vs 2.72 lb/d, and from 2-19 to 6-2 at 2.53 lb/d vs 2.33 lb/d. Differences in ADG between cattle types were likely due to age and genetic potential for growth. There was a cattle type x supplement interaction for ADG. From 2-19 to 5-12, crossbreds had significant gain from CRN2 compared to PAS (Table 1). When stocked until Jun 2 on exclusive bermudagrass, Corrientes showed improved ADG from CFIS. Initial BCS was greater for crossbreds at 5.6 vs Corrientes at 3.3. Corrientes exhibited the greatest compensatory increase in BCS during grazing. Corriente feedlot ADG of 2.4 lb/d and feed:gain of 8.56:1 confirmed the biological inefficiencies and economic disadvantages of feedlot finishing (Table 2). While USDA Yield Grade was best for Corrientes, marbling and Quality Grades were similar for both cattle. The B Maturity score for Corriente steers due to age and skeletal development created a substantial economic discount.

Conclusion and Implications: Management strategies for Corrientes have the most potential economic rewards by grazing on sod-seeded rye-ryegrass pastures with or without supplementation and selling off bermudagrass pasture instead of finishing in a feedlot. Marketing of these mature steers would be as cull cows and bulls due to age and costs of gain per pound in the feedlot.

Table 1. Body condition score (BCS) and average daily gain (ADG) of Corriente and long-yearling steers on pasture with supplement.

	Supplement Treatments				
Steer performance traits	**PAS**	**CRN1**	**CRN2**	**CFIS**	**CFEA**
Corriente†					
BCS-initial	3.1 a	3.3 a	3.3 a	3.4 a	3.6 a
BCS-final	6.0 a	6.0 a	5.9 a	6.4 a	5.8 a
Body weight-initial (lb)	626 a	627 a	627 a	606 a	622 a
ADG: 2/19 to 5/12‡ (lb/d)	2.77 ab	2.51 b	2.74 ab	3.15 a	2.54 b
ADG: 2/19 to 6/2‡ (lb/d)	2.46 b	2.24 bc	2.43 b	2.78 a	2.07 c
Long-Yearling†					
BCS-initial	5.4 a	5.7 a	5.6 a	5.9 a	5.5 a
BCS-final	6.3 a	6.5 a	6.9 a	6.8 a	6.6 a
Body weight-initial (lb)	721 a	716 a	729 a	730 a	702 a
ADG: 2/19 to 5/12 (lb/d)	2.73 a	2.99 a	3.21 a	2.74 a	2.89 a
ADG:2/19 to 6/2 (lb/d)	2.42 a	2.63 a	2.79 a	2.34 a	2.47 a
Forage allowance§	1.86	2.03	1.98	2.03	2.18

† BCS, body weight, and ADG of Corriente steers differed from long-yearling steers ($P<.03$).
‡ ADG of Corriente steers differed between supplement treatments ($P<.03$).
§ Average forage allowance for treatment pastures; computed as lb forage DM : lb animal BW.

Table 2. Feedlot performance and carcass traits of Corriente and long-yearling steers.

Steer performance/traits	**Corrientes**	**Long-yearlings**
Number	41	50
Approximate age (mo)	36-60	16-18
Off truck weight (lb)†	862 b	930 a
Final live weight (lb) ‡	1180 b	1320 a
Feedlot ADG (lb/day) ‡	2.39 b	3.34 a
Feed:gain, dry†	8.56 b	6.13 a
Avg daily consumption (lb)	25.0	25.6
Estimated consumption (%BW)	2.45	2.27
Hot carcass weight (lb) ‡	707 b	812 a
Ribeye area (in^2)	12.9 a	13.2 a
Back fat (in) ‡	0.22 b	0.51 a
Kidney Pelvic Heart fat (%)	2.5 a	2.4 a
USDA yield grade‡	2.12 b	3.11 a
Adjusted preliminary yield grade‡	2.54 b	3.29 a
Marbling score	3.99 a	3.86 a
USDA quality grade¶	3.95 a	3.86 a
Maturity score	B	A

† Numbers in a row for specific traits followed by a different letter differ at $P<0.05$.
‡ Numbers in a row for specific traits followed by a different letter differ at $P<0.01$.
¶ USDA quality grade of > 350 is High Select and 400 is Low Choice.

Influence of stocking rates on weaning weights from fall and winter calving cows

Monte Rouquette, Jr. and Kelli Norman
Texas A&M AgriLife Research and Extension Center at Overton

Application: Numerous forages and pasture systems at Overton have been stocked with Fall and Winter calving cows at different stocking rates from 1969 to date.

Introduction: From 1969 to date, various warm-season perennial grasses have been evaluated for seasonal and total dry matter production and nutritive value. For pasture experiments, F-1 Hereford x Brahman (HXB) or Angus x Brahman (AXB) cows and their calves were used in stocking rate and stocking method studies. Using the comparison of forage allowance to cow and calf ADG, the relationship of stocking rate on animal performance can be documented for use in stocking strategies and management of pastures.

Materials and Methods: With overseeded bermudagrass pastures, active grazing is available from about mid-February to early October. Bred fall calving cows grazing from Feb to mid-June and winter calving cows grazing from July to Oct were stocked at three rates. During this 44-yr period, there were 5114 weaned calves used to summarize the effect of stocking rates on weaning weight x birth month. Calves were from HXB or AXB cows with sires that included Angus, Hereford, and Simmental.

Results: Table 1 shows the overall average weaning weights for steers and heifers grouped by birth month. The heaviest weaning weights were for fall-born calves born in September followed by October-born and November-born at 703, 657, and 619 lb, respectively. For winter calves, January-born had the heaviest weaning weight of 625 lb followed by February-born at 600 lb and March-born at 529 lb. Weaning weights were similar for calves born in November or January.

Table 2 shows weaning weights x birth month according to the assigned stocking rate for cows and calves. Steers and heifers on low stocked pastures weaned at heavier weights than calves on high stocked pastures. Weaning weights ranged from 755 lb for September-born and low stocking rates to 479 lb for March-born and high stocking rates.

Table 3 shows the weight per day of age, or approximate ADG, and age of calves at weaning by birth month and stocking rate. The highest weight per day of age from these 5114 calves ranged from about 2.77 to 2.92 lb/da and occurred at low stocking rates for calves born in February, March, September, October, and November, and at medium stocking rates for calves born in November.

Conclusions and Applications: For matching calving season with forages, management strategies must consider the 365-day pasture-animal costs and calf weight at the time of sale. Fall-born calves are normally weaned in mid- to late June and are usually older and heavier at weaning than winter- or spring-born calves. Winter-born and spring-born calves must be weaned in the fall before pasture conditions mandate the use of hay and supplement to over-winter dry, pregnant cows. Important considerations for calving season and age at weaning are related to matching the genotype x environment for cattle and for forages. Pasture management strategies of calving season and stocking rate can be designed for sustainable forages and optimum animal performance and economic rewards.

Table 1. Average weaning weights for fall and winter born steer and heifer calves.

Birth Month	Weaning Weight[1]
Winter	(lb)
January	625 c[2]
February	598 d
March	526 e
Fall	
September	703 a
October	656 b
November	618 c

[1] 5114 calves during 44 years.
[2] Weaning weights followed by a different letter differ at P < .05.

Table 2. Weaning weights for fall and winter born calves from three stocking rates during lactation.

	Weaning Weight[1] Stocking Rate		
Birth Month	Low	Medium	High
Winter		(lb)	
January	666 c[2]	635 d	573 f
February	656 c	599 e	537 h
March	564 fg	535 h	479 i
Fall			
September	755 a	698 b	655 c
October	714 b	660 c	594 e
November	691 bc	621 d	543 gh

[1] 5114 calves during 44 years
[2] Weaning weights followed by a different letter differ at P < .05.

Table 3. Weight per day of age (DOA) and age at weaning for fall and winter born calves from three stocking rates during lactation.

	Stocking Rate					
	Low		Medium		High	
Birth Month	Age	Wt/DOA	Age	Wt/DOA	Age	Wt/DOA
Winter	(d)	(lb/d)	(d)	(lb/d)	(d)	(lb/d)
January	251 d[2]	2.68 cd[3]	249 d	2.57 e	250 d	2.30 g
February	234 e	2.82 a	230 e	2.63 d	233 e	2.32 g
March	195 h	2.91 a	201 g	2.72 bc	200 gh	2.40 f
Fall						
September	273 a	2.77 ab	270 b	2.59 e	271 ab	2.42 f
October	258 c	2.78 ab	250 d	2.65 d	255 c	2.34 fg
November	236 e	2.92 a	221 f	2.82 a	234 f	2.44 f

[1] 5114 calves during 44 years
[2] Weaning ages followed by a different letter differ at P < .05.
[3] Weights per day of age followed by a different letter differ at P < .05.

Body condition of F-1 (Hereford or Angus x Brahman) cows at weaning: Effects on cow-calf performance and subsequent postpartum performance

Monte Rouquette, Jr.[1], Kelli D. Norman[1], David G. Riley[2], and Ronald D. Randel[1]
[1] Texas A&M AgriLife Research and Extension Center, Overton, TX
[2] Department of Animal Science, Texas A&M University, College Station

Application: Sustained cow-calf production is a function of the biological efficiency and economic reliability of a cow that calves and weans a calf every year.

Introduction: Our objectives were to document the effects of body condition score (BCS) of cows at weaning on cow and calf performance and subsequent postpartum attributes using a 34-yr dataset on stocking rates.

Materials and Methods: From 1986 through 2019 (34-yr), 3,728 mature, lactating F-1 (Hereford or Angus x Brahman) fall calving (FALL) and winter calving (WINTER) cows grazed bermudagrass and overseeded bermudagrass pastures on stocking rate studies. When grazing studies were terminated, all cows were categorized based on their BCS at time of weaning (BCS-WEAN). The BCS-WEAN categories were LOW (≤ 4), MEDIUM (5), and HIGH (≥ 6). Cows were also categorized based on age (AGE) using Age-of-Dam groupings defined by BIF: 2, 3, 4, 5-9, and ≥ 10 yr. Within BCS-WEAN groups and AGE for both FALL and WINTER cows, performance for cows and calves at weaning and subsequent postpartum traits and rebreeding were evaluated.

Results: The effects of BCS-WEAN and AGE on FALL cow and calf performance traits are shown in Table 1. For FALL cows (n= 1,665), actual cow BCS at weaning differed ($P < 0.01$) for the three BCS-WEAN categories of LOW, MEDIUM, and HIGH at 3.9, 5.1, and 6.4, respectively. Actual cow BCS at weaning for all AGE groups was similar at 5.2. The average age of FALL cows was 6.6 years and was similar for each BCS-WEAN category. Actual age of cow at weaning differed ($P < 0.01$) for the AGE categories of 3, 4, 5-9, and ≥ 10 at 3, 4, 7, and 11 years. For WINTER cows (n=2,063), actual BCS at weaning differed ($P<0.01$) for BCS-WEAN designations of LOW, MEDIUM, and HIGH at 3.8, 5.0, and 6.3, respectively (Table 2). Actual cow BCS at weaning was similar for all AGE groups at 5.0. Average age of these cows was approximately 6 years and varied ($P<0.01$) for each BCS-WEAN. Cow age was different ($P<0.01$) for each AGE group at 2, 3, 4, 7, and 11 yrs. At weaning, the BW of WINTER cows was different ($P<0.01$) for each BCS-WEAN at 468 kg (LOW), 499 kg (MEDIUM), and 539 kg (HIGH). Cow weight at weaning was also different ($P<0.01$) for AGE and ranged from 469 kg for 3 yr old cows to 518 kg for 5-9 yr old cows.

Application and Implementation: Brahman-influenced F-1 cows can regain body fat reserves and BW from time of weaning to time of calving without supplementation on actively growing bermudagrass pastures. After calving and with minimum to moderate supplementation, Brahman-influenced cows in the southeastern US can maintain 90% rebreeding and make positive contributions to the cow-calf production system with individual longevity of 13 to 15 years. It is not necessary to maintain BCS of 6 for mature cows, for example, after breeding to attain optimum calf weight gain per ha. The timing of body weight loss-gain and BCS loss-gain to meet approximate BCS ≥ 5 at time of calving for F-1 cows showed to be an acceptable management strategy to achieve a 365-d calving interval.

Table 1. Effect of cow body condition score (BCS) at weaning and age on Brahman-influenced F-1 cow and calf performance traits and rebreeding of fall calvers.

	Body Condition Score				Cow Age[1] (BIF), years				
Performance Trait	**LO ≤ 4**	**ME 5**	**HI ≥ 6**	**SEM**	**3**	**4**	**5-9**	**≥ 10**	**SEM**
Animals (n)	158	513	994		163	221	954	327	
Actual Cow BCS at Wean	3.9[c]	5.1[b]	6.4[a]	0.07	5.1[a]	5.2[a]	5.2[a]	5.2[a]	0.07
Cow Age at Wean (yr)	6.6[a]	6.6[a]	6.6[a]	0.5	3[d]	4[c]	7[b]	11[a]	0.12
Cow Weight at Wean (kg)	481[c]	523[b]	565[a]	9	480[c]	512[b]	550[a]	550[a]	9
Calf Weight at Wean (kg)	291[c]	304[b]	311[a]	6	295[b]	283[c]	312[a]	318[a]	7
Calf Weight per Day of Age	1.12[c]	1.17[b]	1.19[a]	0.02	1.13[b]	1.09[c]	1.20[a]	1.22[a]	0.03
Calf BCS at Wean	5.5[c]	5.7[b]	6.0[a]	0.09	5.8[a]	5.7[a]	5.7[a]	5.7[a]	0.10
Calf Birth to Wean (d)	261[a]	258[a]	259[a]	3	249[d]	255[c]	263[b]	271[a]	4
Cow BCS at Next Calving	5.7[b]	5.8[b]	6.1[a]	0.12	5.8[a]	5.9[a]	5.9[a]	5.8[a]	0.13
Cow BCS Change	1.7[a]	0.7[b]	-0.3[c]	0.10	0.6[a]	0.8[a]	0.8[a]	0.7[a]	0.11
Wean to Next Calve (d)	108[a]	109[a]	109[a]	3	124[a]	116[b]	102[c]	93[d]	4
Calf Birth Weight (kg)	40.5[a]	38.6[a]	39.5[a]	1.4	36.4[b]	40.5[a]	41.4[a]	40.5[a]	1.4
Calving Interval (d)	373[a]	372[a]	372[a]	3	392[a]	372[b]	365[c]	360[c]	3
Cows Rebreed %	89.2[a]	90.7[a]	92.8[a]	3.3	90.8[a]	93.2[a]	90.8[a]	91.7[a]	3.9

Table 2. Effect of cow body condition score (BCS) at weaning and age on Brahman-influenced F-1 cow and calf performance traits and rebreeding of winter calvers.

	Body Condition Score				Cow Age[1] (BIF), years					
Performance Trait	**LO ≤ 4**	**ME 5**	**HI ≥ 6**	**SEM**	**2**	**3**	**4**	**5-9**	**≥ 10**	**SEM**
Animals (n)	572	780	711		190	230	292	1101	250	
Actual Cow BCS at Wean	3.8[c]	5.0[b]	6.3[a]	0.02	5.0[a]	5.0[a]	5.0[a]	5.0[a]	5.0[a]	0.03
Cow Age at Wean (yr)	6.2[a]	6.0[b]	5.9[c]	0.06	2[e]	3[d]	4[c]	7[b]	11[a]	0.08
Cow Weight at Wean (kg)	458[c]	499[b]	539[a]	7	469[d]	489[c]	508[b]	518[a]	509[b]	7
Calf Weight at Wean (kg)	245[c]	257[b]	263[a]	5	226[d]	253[c]	265[b]	273[a]	260[bc]	5
Calf Weight per Day of Age	1.05[c]	1.10[b]	1.13[a]	0.02	0.96[d]	1.09[c]	1.14[b]	1.17[a]	1.11[bc]	0.02
Calf BCS at Wean	5.3[c]	5.6[b]	5.8[a]	0.07	5.7[a]	5.6[ab]	5.5[bc]	5.5[bc]	5.4[c]	0.09
Calf Birth to Wean (d)	230[a]	232[a]	231[a]	2	222[c]	230[b]	235[a]	235[a]	233[ab]	3
Cow BCS at Next Calving	5.3[b]	5.5[a]	5.6[a]	0.10	5.3[c]	5.5[ab]	5.5[ab]	5.6[a]	5.4[bc]	0.10
Cow BCS Change	1.4[a]	0.5[b]	-0.6[c]	0.10	0.3[b]	0.4[a]	0.5[a]	0.5[a]	0.4[a]	0.13
Wean to Next Calve (d)	136[a]	134[a]	133[a]	2.40	144[a]	138[b]	131[c]	128[d]	130[cd]	2.70
Calf Birth Weight (kg)	38.3[a]	38.5[a]	39.1[a]	0.08	37.4[b]	39.4[a]	39.4[a]	39.4[a]	37.4[b]	0.90
Calving Interval (d)	365[a]	362[ab]	360[b]	2	362[ab]	360[b]	358[b]	366[a]	366[a]	2
Cows Rebreed %	89.3[a]	89.3[a]	89.0[a]	2	91.7[a]	90.0[a]	88.4[ab]	92.6[a]	83.3[b]	2.70

[1]Cow age reported as shown by BIF

[abcde]Different letters in a row following a least square means within a BCS group or within a Cow Age group differ at $P < 0.05$.

Longevity and teeth condition of 14-year-old F-1 (Brahman x Hereford) cows

F.M. Rouquette, Jr., Kelli Norman and Charles Long
Texas A&M AgriLife Research and Extension Center at Overton

Application: Aging cows by tooth presence and wear condition is routinely done. Visual observation of mouth-teeth condition provides opportunities for cow retention decisions.

***Introduction*:** Longevity and productivity of F-1 (Brahman x Hereford or Brahman x Angus) cows have been well documented. Determining cow age using dentition and condition of mouth-teeth has been explored as culling or retention criteria for the cow herd.

***Materials and Methods*:** At the Texas A&M AgriLife Research and Extension Center at Overton, pasture research using F-1 (Hereford x Brahman, Brahman x Hereford, Angus x Brahman) cows was initiated in 1969 and continues to date. This forage x animal research project uses both fall- and winter-calving F-1 cows to evaluate forage productivity and persistence, forage nutritive value, and cow-calf responses to various stocking rates on pasture. An illustration of the longevity of F-1 cows used in stocking rate experiments is that of the status of mouth and teeth of 14-year-old cows after several years in pasture research.

Results: Table 1 shows the average lifetime production characteristics of 14-year-old F-1 (Brahman x Hereford) cows at time of dispersing from the project. This cow herd averaged 12 calves each, with calves averaging 83 pounds at birth (Simmental bulls), and 667 pounds at 263 days of age (weaning). The average weight of cows at weaning was 1192 lb, with a 56% calf:cow weight at weaning. At time of dispersing, this fall-calving cow herd was 97% pregnant.

Table 1. Production traits of 14-year-old F-1 (Brahman x Hereford) cows used in experiments.

Trait	Total/Average
Cow age	14
Number of calves	12
Calf birth wt (lb)	83
Calf age at wean (d)	263
Calf wean wt (lb)	667
Cow wt at wean (lb)	1192
Calf:cow wt at wean	56%
Calf wean wt (lb) at cow age 14	673
Pregnant at age 14	97%
Calving season	Fall

Table 2 shows the description of the mouth-teeth scores for these 14-year-old cows. There were 48% of these cows that were not missing any teeth, and they were scored as “solid” (6%) and "short and solid" (42%). There were 22% of the cows that were "short and solid" mouthed with only 1 missing tooth. Thus, 70% of these cows had 0 to 1 missing tooth at age 14. In this group, 6% had a "broken mouth" with 3 missing teeth, and 6% had a "smooth mouth" with only 1 tooth remaining.

Table 2. Description of mouth-teeth of 14-year-old F-1 (Brahman x Hereford) cows.

Description	No. teeth missing	Percent of cows
Solid	0	6
Short & Solid	0	42
Short & Solid	1	22
Short & Solid	2	8
Short & Solid	3	6
Short & Solid	4	3
Broken Mouth	3	6
Smooth Mouth	all but 1	6

The following photos provide illustrated examples of the mouth conditions and teeth scores for these 14-year-old cows.

Solid, none missing   Short-solid, none missing   Short-solid, 1 missing   Short-solid, 2 missing



Short-solid, 3 missing   Short-solid, 4 missing   Broken mouth, 3 missing   Smooth Mouth

Ackowledgements: Mr. M. J. Florence and Mr. Joel Kerby (whose hands are in the photos above).

Evaluation of two beef cow fixed-time AI protocols that utilize pre-synchronization

Jaclyn N. Ketchum[1,2], Lacey K. Quail[1,2], Kaitlin M. Epperson[1,2], Chloey P. Carson[2], Jerica J. J. Rich[3], Saulo Menegatti Zoca[4,10], Adalaide C. Kline[4], Taylor N. Andrews[4,9], Julie A. Walker[4], Pedro Levy Piza Fontes[5], Sandy K. Johnson[6], Megan P T. Owen[7], Kelsey M. Harvey[8], Adam F. Summers[9], George A. Perry[2]

[1]Texas A&M University Department of Animal Science, College Station, TX
[2]Texas A&M AgriLife Research, Overton, TX
[3]Arkansas State University College of Agriculture, Jonesboro, AR
[4]South Dakota State University Department of Animal Science, Brookings, SD
[5]University of Georgia Department of Animal and Dairy Science, Athens, GA
[6]Kansas State University Northwest Research & Extension Center, Colby, KS
[7]Texas A&M University-Commerce College of Agricultural Sciences and Natural Resources, Commerce, TX
[8]Mississippi State University Prairie Research Unit, Prairie, MS
[9]New Mexico State University Department of Animal and Range Sciences, Las Cruces, NM
[10]Department of Animal Science, University of Tennessee, Knoxville, TN

Application: Reproductive synchronization protocols provide every female the opportunity to conceive on the first day of the breeding season thus allowing for increased efficiency as calving intervals are tighter, calf crops are more uniform, and less labor is required compared to heat detection.

Introduction: Pre-synchronization has been evaluated as a method to improve synchrony of ovulatory follicles before fixed-time AI (FTAI). The objective was to compare FTAI results in beef cows from two protocols that utilize pre-synchronization.

Materials and Methods: Blood samples were collected on day -14 (day 0=CIDR removal) to determine progesterone concentration at the start of synchronization (P4start: ≥1ng/mL=high, <1ng/mL=low). In a subset (n=1,032), an additional blood sample was taken between day -21 and -29 to determine cyclicity. Cows (n=1,119), from 21 herds, were grouped by days postpartum and age and randomly assigned to one of two protocols. Cows assigned to the PG 6-day CIDR & FTAI protocol (PG6d) received prostaglandin F2α (PG) on day -9, CIDR insertion and GnRH on day -6, and CIDR removal and PG on day 0. Cows assigned to the 7&7 Synch protocol (7&7) were administered PG and CIDR insertion on day -14, GnRH on day -7, CIDR removal and PG on day 0. For both protocols, FTAI occurred coincident with GnRH 66 hours after second PG. Pregnancy status was determined by transrectal ultrasonography 30-40 days following FTAI. The GLIMMIX procedure of SAS (9.4) was used to detect differences in estrus response and pregnancy success with herd included as a random variable.

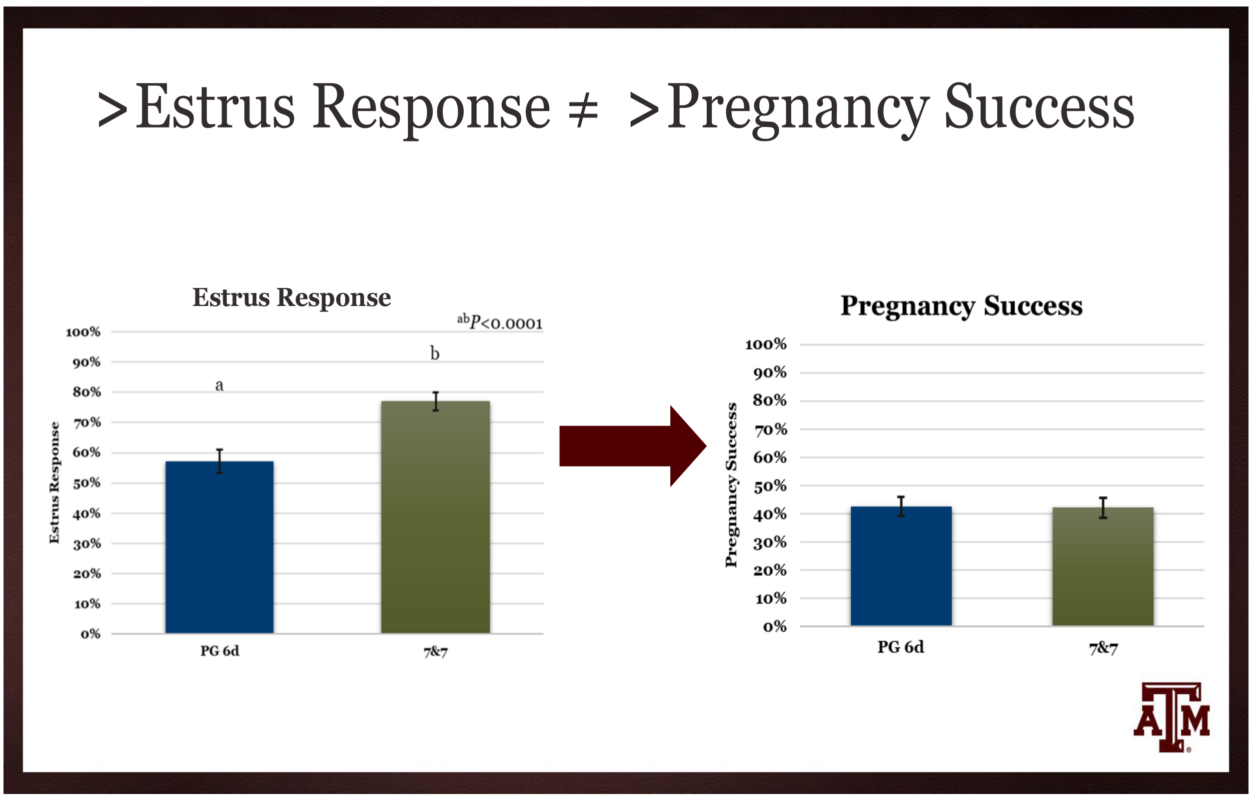
Results: Estrus response (0 to 66 h) was influenced by treatment ($P<0.01$; PG6d=60±5% and 7&7=74±4%), Body Condition Score ($P<0.01$), cycling status ($P=0.03$), P4start ($P<0.01$), and a

P4start by treatment interaction (P<0.001; PG6d-highP4=62±6%, PG6d-lowP4=58±6%, 7&7-highP4=84±3%, 7&7-lowP4=60±6%). Pregnancy success was influenced by estrus expression (P<0.01), and a treatment by P4start interaction (P=0.04; PG6d-highP4=58±5%, PG6d-lowP4=39±7%, 7&7-highP4=49±5%, 7&7-lowP4=55±8%) but was not influenced by treatment (P=0.45; PG6d=49±4% and 7&7=52±4%).

Conclusion: Effectiveness of pre-synchronization method depends on a cows' physiological status at the beginning of the protocol. The 7&7 protocol increased estrus response compared to PG6d, but there was no difference in pregnancy success.

Acknowledgements: Multistate Hatch project 9835, Zoetis Animal Health for the donation of CIDRs, GnRH, and Prostaglandin, Estrotect for the donation of Estrotect estrus detection patches.

Figures and Tables:



Synchronization and seasonality effects on follicular development, estrus expression, and pregnancy in Brahman females

Lacey K. Quail[1,2], Kaitlin M. Epperson[1,2], Jaclyn N. Ketchum[1,2], Chloey P. Carson[1], Charles R. Long[1], George A. Perry[1]

[1]Texas A&M AgriLife Research, Overton, TX
[2]Department of Animal Science, Texas A&M University, College Station, TX

Application: Control of follicular development is essential for estrous synchronization. This experiment determined differences in follicular development during synchronization in Brahman females.

Introduction: Adoption of synchronization of estrus and artificial insemination (AI) into existing beef herds has heavily relied on fixed-time artificial insemination (FTAI) protocols as they result in similar pregnancy rates compared with protocols involving detection of estrus (Larson et al., 2006). However, Brahman cattle are physiologically unique, and have more ovarian follicles, smaller corpora lutea with decreased progesterone, and ovulate smaller follicles (Segerson et al., 1984; Alvarez et al., 2000; Bó et al., 2007).

Materials and Methods: Cows (n=219) and heifers (n=90) in Fall (n=170) and Spring (n=139) were synchronized with a CIDR insert and administration of GnRH or PG treatment on d0 (1/2GnRH: n=106, GnRH: n=103, PG: n=100), and CIDR removal and PG administration on d6 followed by estrus detection and AI for 96h. Blood samples were collected on d0, d6, and at 48h/AI to determine circulating progesterone (P4) concentrations. Transrectal ovarian ultrasonography occurred daily. Cows were grouped by CL presence (d0CL, d6CL) and P4 concentrations (d0P4, d6P4, AIP4, Low<1 ng/mL, High≥1 ng/mL) on d0 and d6. The GLIMMIX procedure of SAS was used to analyze follicular wave initiation, wave emergence day, estrus expression, and pregnancy success.

Results: There were significant interactions of treatment by d0CL (P=0.0237), and season by d0P4 (P=0.0118) on wave initiation. Cows receiving 1/2GnRH with a CL on d0 (97±2%) and Fall cows having High d0P4 (96±3%) had the greatest probability of wave initiation. Age significantly impacted wave initiation (P=0.0213; heifers: 93±4%, cows: 79±5%). Interactions of treatment by season (P=0.0405) and treatment by d0CL (P=0.0379) significantly impacted wave emergence timing. Season (P<0.0001; Fall: 23±5%, Spring: 65±6%; Figure 1), and the interactions of treatment by d0P4 (P=0.0291) and new wave by d0P4 (P=0.0357) influenced estrus expression. Cows receiving 1/2GnRH with High d0P4 and cows with High d0P4 that initiated a new wave had the greatest probability of estrus expression. Pregnancy rate differed by estrus expression (P=0.0055; no estrus=25±6%, estrus=54±8%; Figure 2) and semen type (P=0.0105; conventional=52±9%, sexed=26±6%; Figure 3), and tended to differ by AIP4 (P=0.0570; Low=30±7%, High=48±8%).

Conclusion: These results suggest that differences in follicular development and behavioral estrus in synchronized Brahman females may be due to seasonality and endogenous progesterone production.

Acknowledgements: Multistate Hatch project 9835

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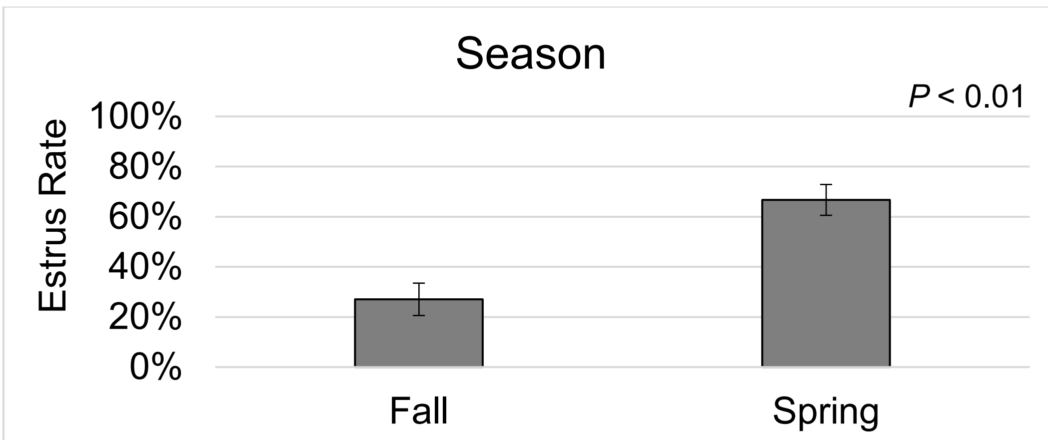

Figure 1: Rate of expression of estrus for Brahman cattle in the Fall (15%) and Spring (65%) seasons.

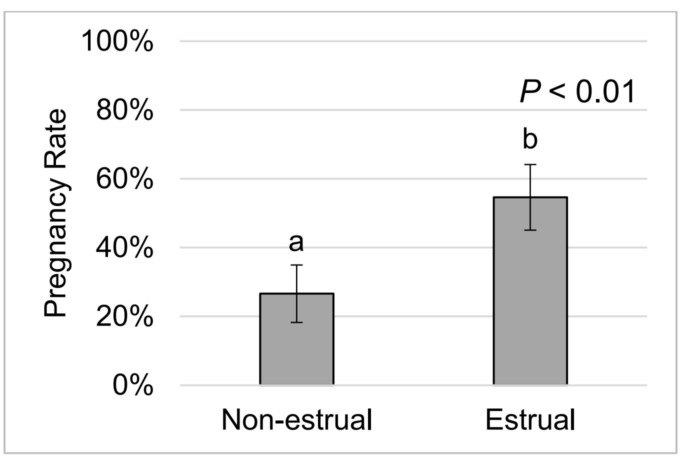

Figure 1: Pregnancy rates for estrual (54%) and non-estrual (25%) cattle.

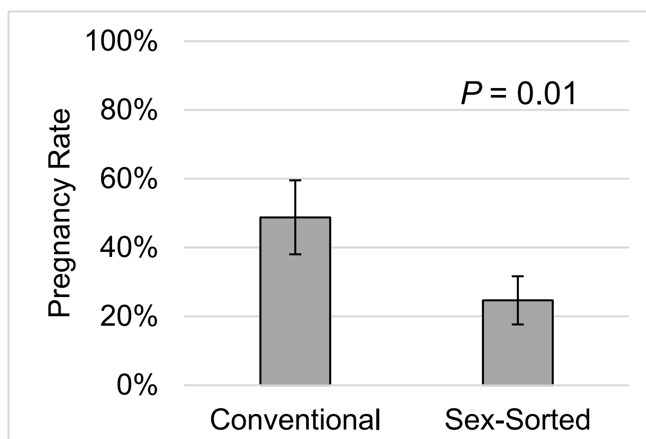

Figure 1: Pregnancy rates for conventional (52%) and sex-sorted (26%) semen.

Cost and profit per pregnancy associated with estrous synchronization utilizing estrus detection and/or fixed-time artificial insemination

Lacey K. Quail[1,2], Kaitlin M. Epperson[1,2], Jaclyn N. Ketchum[1,2], Chloey P. Carson[2], Jerica J. J. Rich[3], Julie A. Walker[4], Saulo Menegatti Zoca[5], George A. Perry[2]

[1]Department of Animal Science, Texas A&M University, College Station, TX
[2]Texas A&M AgriLife Research, Overton, TX
[3]College of Agriculture, Arkansas State University, Jonesboro, AR
[4]Department of Animal Science, South Dakota State University, Brookings, SD
[5]Department of Animal Science, University of Tennessee, Knoxville, TN

Application: This experiment aimed to compare synchronization cost associated with two protocols: one utilizing estrus detection (6d; PG 6-d CIDR®+TAI) and one utilizing strictly fixed-time artificial insemination (FTAI) (7d; 7-d CO-Synch+CIDR®).

Introduction: While estrus expression improves pregnancy success, detection of estrus and subsequent insemination in a synchronization protocol is time and labor intensive. Adoption of synchronization of estrus and artificial insemination (AI) into existing beef herds has heavily relied on fixed-time artificial insemination (FTAI) protocols as they result in similar pregnancy rates compared with protocols involving detection of estrus (Larson et al., 2006), yet do not require the added labor of estrus detection. Nevertheless, overall reproductive management program profitability hinges on many factors including pharmaceuticals involved, required labor, estrus detection aids, estrus detection rate, and pregnancy rate (Holmann et al., 1987).

Materials and Methods: Cows and heifers (n=657) from 10 herds in three states were grouped by days postpartum and age, and randomly assigned to one of two protocols. Cows and heifers assigned to the 6d protocol were administered prostaglandin $F_{2\alpha}$ (PGF) on d-9, CIDR® insertion and administration of gonadotropin-releasing hormone (GnRH1) on d-6, and CIDR® removal and PGF administration on d0. Cows and heifers assigned to the 6d protocol were subsequently grouped into three treatments based on presence and/or timing of estrus and insemination (PG1: Insemination before CIDR® insertion, n=136; PG2: Insemination after CIDR® removal, n=26; T6: Insemination at TAI, n=166). Cows and heifers assigned to the 7d protocol (T7: Insemination at FTAI, n=329) were administered GnRH1 and CIDR® insertion on d-7, followed by CIDR® removal and PGF administration on d0. For all animals, FTAI and GnRH2 administration occurred at 54h (heifers) or 66h (cows) after CIDR® removal. Pregnancy was determined from d30 to d40 after FTAI by transrectal ultrasonography. Total cost and profit per pregnancy was calculated for herds of 30, 100, 300, and 500 females with varying estrus response and pregnancy rates. Expenditures were calculated assuming synchronization costs (PG1=$46.15, PG2=$75.05, T6=$77.91, T7=$73.72), general labor cost considering herd size and handling days, as well as estrus detection labor cost assuming $10.00 per h, a 95% overall herd pregnancy rate, a 1:40 bull:cow ratio, and average bull purchase price of $3,000.00. Revenue was estimated assuming a maximum 205-d weaning age, 1.09 kg/d gain, $200.00/45.4 kg, and 85% weaning rate. Differences in estrus response and pregnancy rate were determined using the GLIMMIX procedure of SAS (v9.4), including herd as a random variable.

Results: Estrus response was greater (P<0.0001) in females assigned to the 6d (73±4%) compared to the 7d (53±4%) protocol; however, pregnancy success was similar among treatment groups (P=0.32; PG1=45±4%, PG2=58±10%, T6=46±4%, T7=52±3%). At the observed estrus response and pregnancy rate for each treatment group, the 6d protocol resulted in a similar or decreased cost per pregnancy [herds of: 30=$0.51, 100=($4.20), 300=($5.57), and 500=($5.92) females] and increased profit per pregnancy [herds of: 30=$6.28, 100=$22.14, 300=$16.59, and 500=$13.39 females] compared to the 7d protocol.

Conclusion: These results suggest that labor associated with the detection of estrus may be offset by the proportion of calves subsequently born earlier within the calving season, allowing for improvements to profitability, especially in larger herds.

Acknowledgements: Multistate Hatch project 9835, Zoetis Animal Health for the donation of CIDRs, GnRH, and Prostaglandin, Estrotect for the donation of Estrotect estrus detection patches.

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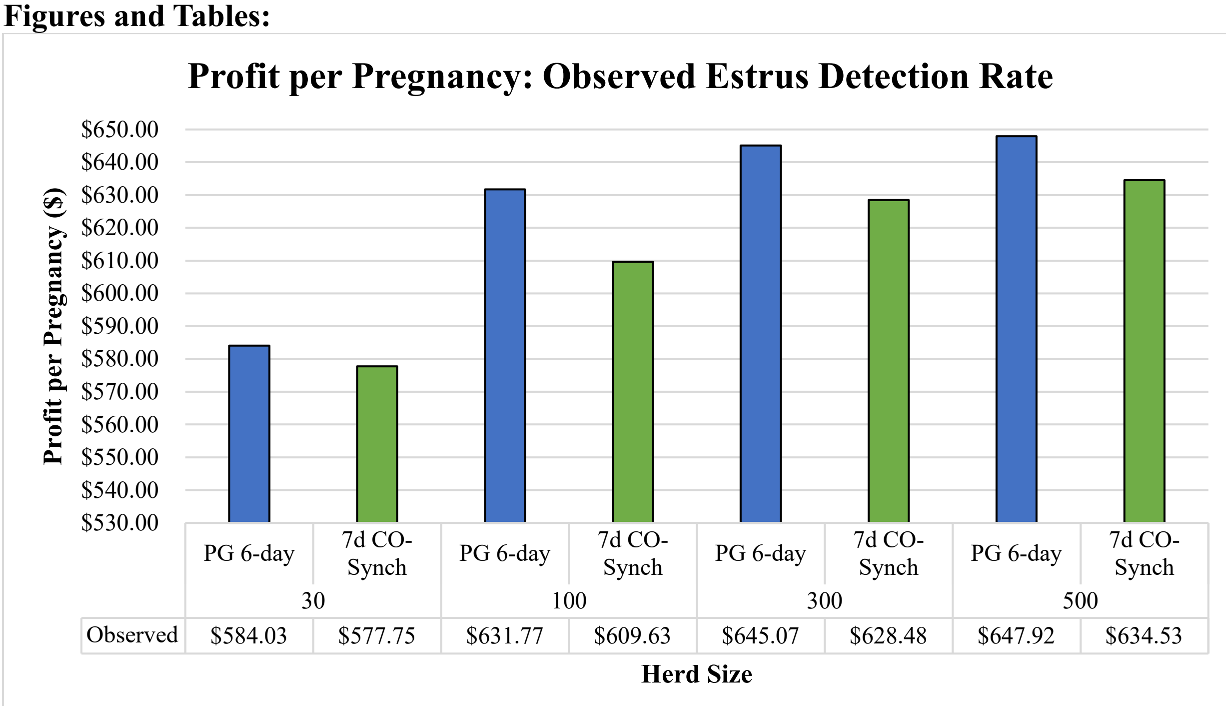

Figure 2: Profit per pregnancy at the observed rates of detection of estrus and pregnancy for each protocol.

Importance of estrual activity on pregnancy establishment and maintenance following timed embryo transfer in beef cattle

Lacey K. Quail[1], Jaclyn N. Ketchum[1], Kaitlin M. Epperson[1], Saulo Menegatti Zoca[2], Jerica J. J. Rich[3], Abby L. Zezeski[4], Taylor N. Andrews[5], Adalaide C. Kline[5], Michael F. Smith[6], Makayla A. Ogg[7], George A. Perry[8], Thomas W. Geary[4]

[1]Department of Animal Science, Texas A&M University, College Station, TX, USA
[2]Department of Animal Science, University of Tennessee, Knoxville, TN, USA
[3]College of Agriculture, Arkansas State University, Jonesboro, AR, USA
[4]USDA-ARS, Fort Keogh Livestock and Range Research Laboratory, Miles City, MT, USA
[5]Department of Animal Science, South Dakota State University, Brookings SD, USA
[6]University of Missouri Division of Animal Sciences, Columbia, MO, USA
[7]Department of Animal and Range Sciences, Montana State University, Bozeman, MT, USA
[8]Texas A&M AgriLife Research and Extension Center, Overton, TX, USA

Application: Determine the timepoint of pregnancy most influenced by estrual activity and how it relates to pregnancy success.

Introduction: Cows expressing estrus prior to fixed-time artificial insemination had a 27% increase in pregnancy success compared to non-estrual cows (Richardson et al., 2016). Preovulatory estradiol concentrations associated with estrus improved fertilization success, embryo quality, uterine environment, and pregnancy maintenance (Atkins et al., 2013; Larimore et al., 2015; Northrop et al., 2018). The objective of this experiment was to analyze pregnancy loss from day 7 to 90 by estrual status prior to embryo transfer.

Materials and Methods: Cows (n=604) were synchronized using the 7-day CO-Synch+CIDR® protocol and grouped by estrus expression prior to day 0 (Estrus: n=198), with non-estrual animals receiving GnRH and randomly assigned to estradiol (E2: n=202; 0.1mg estradiol 17-β) or no treatment (GnRH: n=204) on day 0. On day 7, all cows received an *in vivo* produced embryo of similar grade and stage, and estrual status was retrospectively determined using Estrotect® patch change (day 0 to 7) [E2-Estrual (E2E): n=177, E2-Non-estrual (E2N): n=25, GnRH-Estrual (GnRHE): n=110, GnRH-Non-estrual (GnRHN): n=93]. Pregnancy was determined on day 19, 24, 30, 55, and 90 by interferon-stimulated gene expression, pregnancy-associated glycoprotein abundance, progesterone concentration, and/or transrectal ultrasonography. Pregnancy was analyzed using PROC GLIMMIX with treatment, year, replicate, and the interaction of year and replicate as fixed effects. Pregnancy was analyzed as probability of survival using PROC LIFETEST.

Results: The proportion of pregnant cows was similar between Estrus, E2E, E2N, GnRHE, and GnRHN on day 19 ($P = 0.37$), day 55 ($P = 0.14$), and day 90 ($P = 0.13$), while tending to differ ($P = 0.07$) on day 24 (Figure 1). On day 30, pregnancy status differed ($P = 0.04$) between Estrus, E2E, E2N, GnRHE, and GnRHN, as Estrus and E2E had increased pregnancy rates compared with GnRHN ($P \leq 0.02$; Estrus: 41 ± 4%, E2E: 38 ± 4%, GnRHN: 24 ± 4%). Estrus and E2E cows had similar ($P = 0.48$) pregnancy rates on day 30. E2N cows tended ($P = 0.09$) to have decreased pregnancy rates compared with Estrus cows, and had similar pregnancy rates to E2E, GnRHE, and GnRHN cows ($P \geq 0.17$). GnRHE cows were intermediate and similar to Estrus and

E2E cows as well as to E2N and GnRHN cows ($P \geq 0.13$). Pregnancy survival tended to differ (P=0.06) between treatments from day 7 to 90.

Conclusion: Cows expressing behavioral estrus prior to embryo transfer (from day -2 to 7) had greater pregnancy success during periods of conceptus attachment and tended to have greater embryo/fetal survival to day 90 compared to non-estrual cows.

Acknowledgements: USDA-NIFA:2019-67015-29411, and Multistate Hatch project 9835

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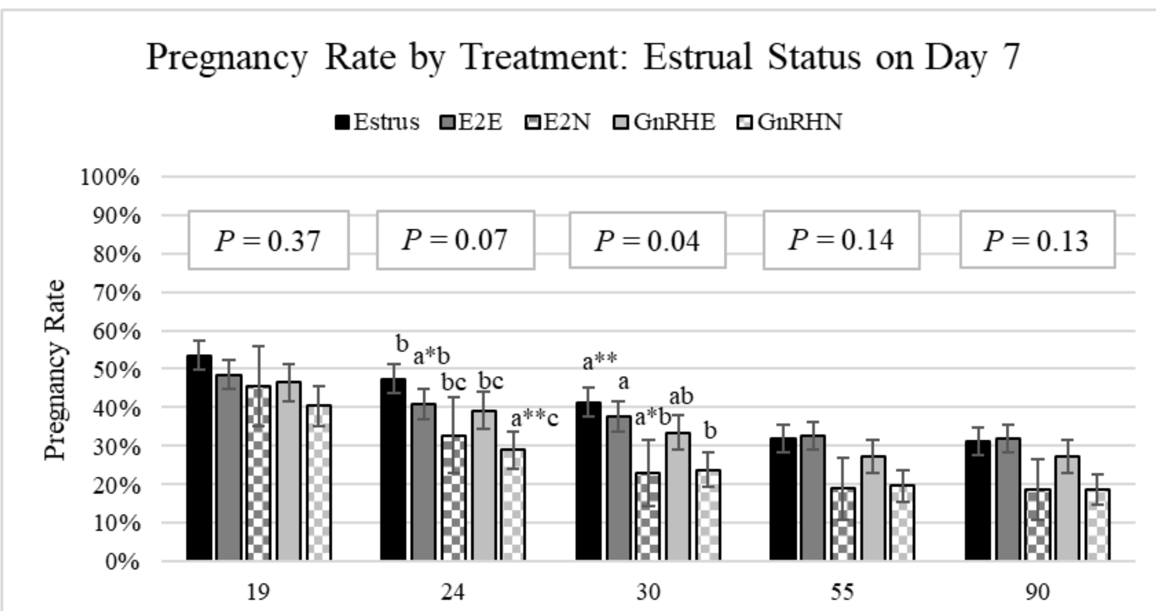

Treatment	Day of Pregnancy				
Estrus	54 ± 4 %	47 ± 4 %	41 ± 4 %	32 ± 3 %	31 ± 4 %
E2E	49 ± 4 %	41 ± 4 %	38 ± 4 %	33 ± 4 %	32 ± 4 %
E2N	46 ± 10 %	33 ± 10 %	23 ± 9 %	19 ± 8 %	19 ± 8 %
GnRHE	46 ± 5 %	39 ± 5 %	34 ± 5 %	27 ± 4 %	27 ± 4 %
GnRHN	40 ± 5 %	29 ± 5 %	24 ± 4 %	20 ± 4 %	19 ± 4 %

Figure 3: Pregnancy rates for each treatment on day 19, 24, 30, 55, and 90 of gestation after embryo transfer.

Preovulatory estradiol concentrations influence oviductal gene expression

Lacey K. Quail[1,2], Robert A. Cushman[3], Brittney N. Keel[3], Anthony K. McNeel[3], Michael G. Gonda[4] and George A. Perry[1]

[1]Texas A&M AgriLife Research, Overton, TX
[2]Texas A&M University Department of Animal Science, College Station, TX
[3]USDA-ARS, Meat Animal Research Center, Clay Center, NE
[4]South Dakota State University Department of Animal Science, Brookings, SD

Application: Considering the oviduct is the site of fertilization and early embryo development and it produces factors unique from the uterine environment that directly control the paracrine environment of the developing embryo, the objective of this experiment was to investigate differences in oviductal mRNA expression in animals with high or low circulating concentrations of estradiol at the time of artificial insemination.

Introduction: Behavioral estrus in beef cows is associated with increased circulating concentrations of estradiol and a 27% increase in pregnancy success to artificial insemination (AI) compared to beef cows that did not express behavioral estrus (Richardson et al., 2016). Preovulatory estradiol concentrations have been associated with alterations to the uterine environment as well as endometrial gene expression; however, less is known about the impact of preovulatory estradiol on the oviductal environment.

Materials and Methods: Beef cows (n = 6) were synchronized using the 7-d CO-Synch protocol with GnRH administration on d-9, PG administration on d-2, and GnRH administration and AI at d0. Daily blood samples were collected from d-9 to d1 to determine circulating estradiol concentrations. Cows were classified as having high or low circulating concentrations of estradiol at the time of AI (High = 10.12 ± 0.62 pg/ml, n = 3; Low = 5.97 ± 0.62 pg/ml, n = 3; $P < 0.01$). Twenty-four hours after AI, oviducts were collected from cows at slaughter. Total cellular RNA was isolated from the ampullary-isthmic junction and isthmus regions of the oviduct, treated with DNAase, and RNA-seq was performed. Paired end libraries were constructed using Truseq 2.0 RNA-seq library prep kits and sequenced on a Hi-seq 2000. Sequencing reads from cDNA were trimmed using Trimmomatic. Paired end reads were mapped to the reference bovine genome (*Bos taurus* ARS-UCD1.2) using HISAT2 version 2.2.0. Transcripts were assembled and gene counts were obtained using StringTie version 1.3.3. Differentially expressed genes were identified using DESeq2. Differences in transcript abundance were considered significant when the adjusted FDR $P \leq 0.05$. Differentially expressed and annotated genes were then submitted for pathway analysis via DAVID 6.8.

Results: At the ampullary-isthmic junction, 1386 genes were up-regulated, and 61 genes were down-regulated in High cows compared to Low cows (Figure 1). At the isthmus region, 349 genes were up-regulated, and 202 genes were down-regulated in High cows compared to Low cows (Figure 2). Perhaps most notably, at the ampullary-isthmic junction, differential gene expression significantly influenced metabolic ($P = 2.1 \times 10^{-4}$), VEGF signaling ($P = 5.3 \times 10^{-4}$), mTOR signaling ($P = 5.6 \times 10^{-3}$), GnRH signaling ($P = 6.7 \times 10^{-3}$), estrogen signaling ($P = 9.1 \times 10^{-3}$), Notch signaling ($P = 9.8 \times 10^{-3}$), and prolactin signaling ($P = 1.2 \times 10^{-2}$) KEGG pathways. With components influencing embryo development, differential gene expression in cows with high circulating concentrations of estradiol significantly influenced focal ($P = 8.9 \times 10^{-5}$) and cell adhesion ($P = 5.9 \times 10^{-2}$) KEGG pathways in the isthmus.

Conclusion: Preovulatory estradiol concentrations were associated with gene expression in the oviduct that likely influences fertilization and early embryonic development through components of metabolic, growth factor signaling, hormone signaling, and cell adhesion pathways. These pathways are expected to contribute to increased overall pregnancy success observed in animals with high circulating concentrations of estradiol at the time of artificial insemination.

Acknowledgements: Multistate Hatch project 9835

Figures and Tables:

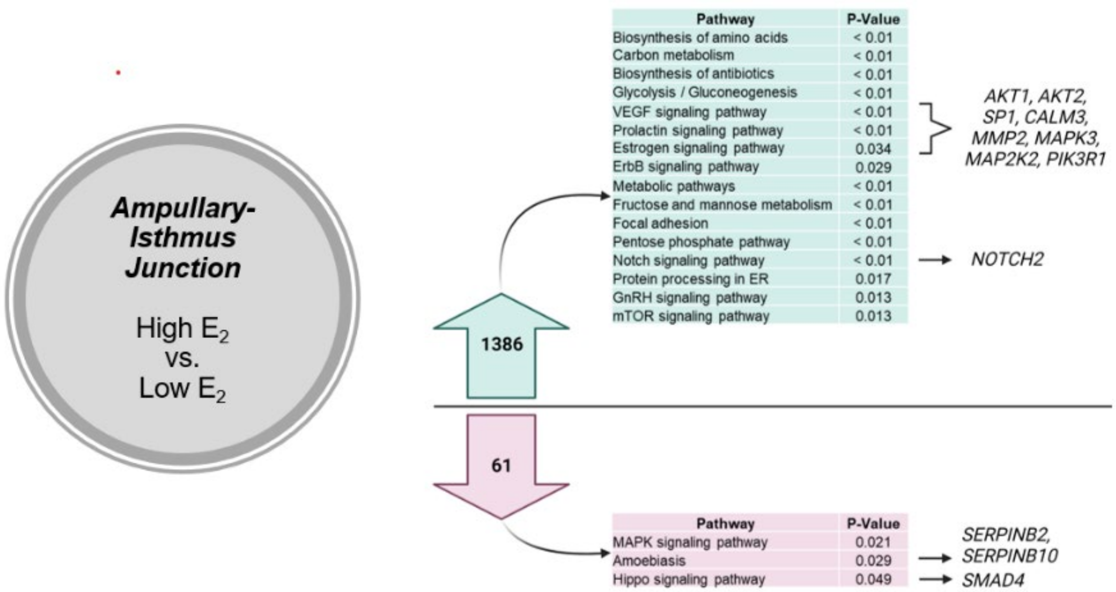

Figure 4: Differentially expressed genes at the Ampullary-Isthmic Junction of cows with High compared with Low preovulatory estradiol.

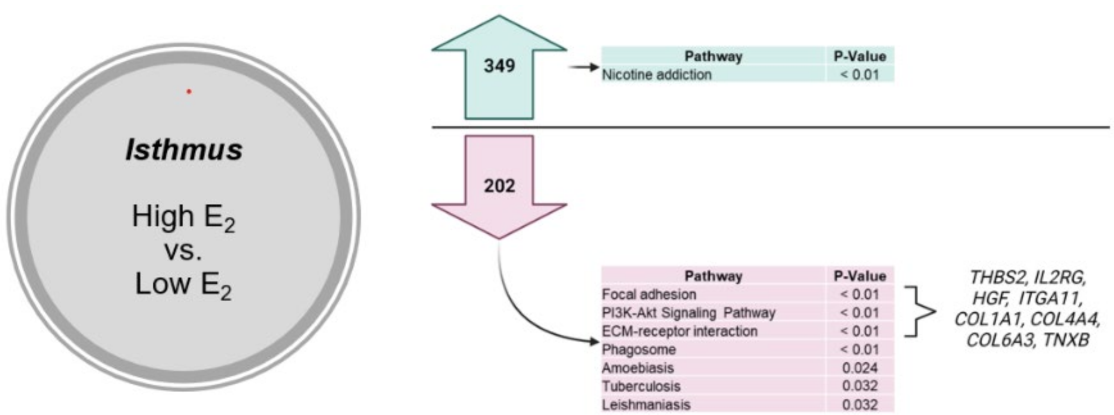

Figure 2: Differentially expressed genes in the Isthmus of cows with High compared with Low preovulatory estradiol.

Influence of preovulatory estradiol concentrations on the localization of prostaglandin E_2 synthase and prostaglandin E_2 receptor 2 in the bovine oviduct

L. K. Quail[1,2], E.L. Larimore[3], O.L. Amundson[3], A.K. McNeel[4], R.A. Cushman[4], G.A. Perry[1]

[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Department of Animal Science, Texas A&M University, College Station, TX
[3]Department of Animal Science, South Dakota State University, Brookings, SD
[4]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE, USA

Application: Investigation of prostaglandin E_2 (PGE) production and signaling potential within the contralateral oviduct of cows in response to increased preovulatory estradiol concentrations are necessary to further understand how preovulatory estradiol is impacting the oviductal environment and fertility in beef cows.

Introduction: In the oviduct, PGE regulates the anti-inflammatory response by down-regulating expression of known pro-inflammatory cytokines such as Tumor Necrosis Factor and Interleukin-1-beta (Yousef et al., 2016), and subsequently, protects sperm from phagocytosis around the time of fertilization (reviewed by Niringiyumukiza et al., 2018).

Materials and Methods: Beef cows (n = 32) were synchronized using the 7-day CO-Synch protocol. The expression of estrus was monitored using estrus detection aids and blood samples were collected every three hours from PGF administration (day 0/hour 0) to hour 33, and then again at the time of slaughter (hour 36 to 42). Cows were classified based on peak estradiol concentrations as High (n = 4; ≥ 6.0 pg/mL) or Low (n = 5; ≤ 4.5 pg/mL). Only cows that initiated a new follicular wave by day -4 were slaughtered for the collection of oviducts (n = 9). The contralateral oviduct was fixed in paraformaldehyde and embedded in paraffin for immunolocalization of prostaglandin E_2 synthase (PTGES) and prostaglandin E_2 receptor 2 (PTGER2). The expression of oviductal PTGES and PTGER2 was quantified using Image J software. Intensities of PTGES and PTGER2 protein in the contralateral oviduct of cows with High and Low peak estradiol concentrations were analyzed as a repeated measure using the MIXED procedure of SAS (v9.4) with treatment, section, and the interaction of treatment by section as fixed effects using the Autoregressive covariance structure.

Results:
Cows with High peak estradiol concentrations tended ($P = 0.10$; High: 0.29 ± 0.07, Low: 0.08 ± 0.07) to have more intense immunoreactivity for PTGES protein compared with cows with Low peak estradiol (Figure 1); however, intensity of immunoreactivity of PTGER2 protein did not differ between cows with High and Low peak estradiol concentrations ($P = 0.83$; Figure 2).

Conclusion: In conclusion, PTGES and PTGER2 are localized to the entire oviduct during the peri-ovulation period, and peak concentrations of estradiol prior to ovulation influenced the intensity of immunoreactive PTGES protein in the contralateral bovine oviduct.

Acknowledgements: USDA-NIFA:2019-67015-29411 and Multistate Hatch project 9835

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Figures and Tables:

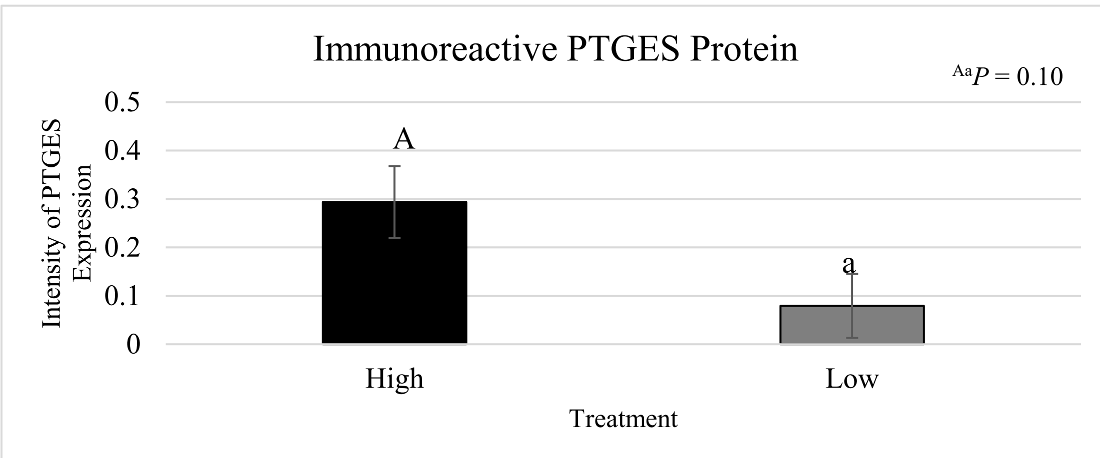

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Figure 5: Cows with High (≥ 6.0 pg/mL) peak estradiol concentrations tended (P = 0.10; High=0.29±0.07, Low=0.08±0.07) to have more intense expression of immunoreactive PTGES protein compared to Low cows (≤ 4.5 pg/mL).

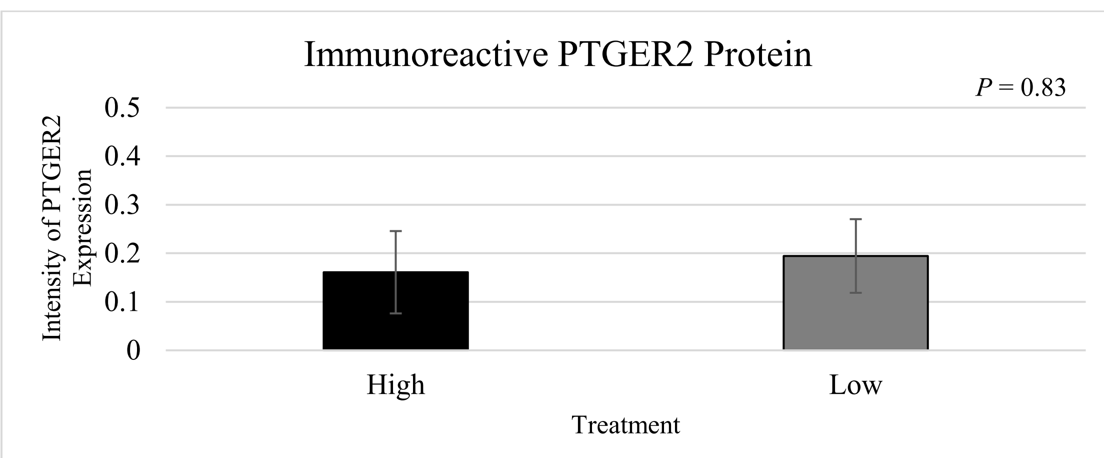


Figure 6: There was no difference (P = 0.83; High=0.16±0.08, Low=0.19±0.08) in intensity of immunoreactive PTGER2 protein between cows with High (≥ 6.0 pg/mL) or Low peak estradiol concentrations (≤ 4.5 pg/mL).

Prenatal transportation stress did not impact ovarian follicle count for three generations of female Brahman offspring

Lacey K. Quail[1,2], Ronald D. Randel[1], Thomas H. Welsh Jr.[2], Robert A. Cushman[3], Hannah K. Yake[3], Rui A. d′Orey Branco[1], Donald A. Neuendorff[1], Charles R. Long[1], George A. Perry[1]

[1]Texas A&M AgriLife Research and Extension Center, Overton, TX 75684
[2]Texas A&M University, College Station, TX 77843
[3]USDA-ARS, Meat Animal Research Center, Clay Center, NE 68933

Applications: Pregnant cows are often transported by trailer to allow for additional feed or at the time of sale, and there are many critical developmental events that occur during gestation that may impact the fertility of future generations. This project analyzed the number of follicles on the ovaries of cattle (indicative of fertility) due to prenatal transportation stress.

Introduction: Calves from transported cows had greater concentrations of cortisol, a stress hormone, when restrained in a chute, and cleared cortisol at a slower rate than calves from non-transported dams. Considering this relationship between several organs in the reproductive system, investigating other factors influencing reproduction is needed in calves exposed to transportation stress while *in utero*.

Materials and Methods: Brahman cows were transported for 2 hours on day 60, 80, 120, and 140 (± 5 days) of gestation. Offspring from transported (Stressed, n = 19) or non-transported (Control, n = 15) cows were slaughtered at 5 years (Replication 1, n = 14) or ovariectomized at 8 years old (Replication 2, n = 20). A portion of ovary was collected, serially sectioned, and stained. Numbers of total, primordial, primary, secondary, and antral follicles were determined per section. Total ovarian follicle count for each stage was calculated using ovary dimensions. The MIXED procedure of SAS was used to analyze ovarian follicle count with treatment, replicate, and the interaction as fixed effects.

Results: There was no effect of treatment ($P \geq 0.27$) on the number of primordial, primary, secondary, antral, or total follicles per mm^2 of ovarian tissue (Figure 1). Age significantly impacted the number of follicles ($P<0.0001$), such that females in Replicate 2 (25 days old) had greater numbers of primordial, primary, secondary, antral, and total follicles compared to females in Replicate 1 (5 years old) and Replicate 3 (8 years old; Table 1). Antral follicle numbers determined by ultrasonography tended to be correlated with total ovarian follicle numbers determined by histology ($n = 20$, $r = 0.6735$, $P = 0.10$).

Conclusion: The number of follicles (of any size) on the ovary were not affected by prenatal transportation but were affected by age as the number of follicles decreased as cows got older. These results suggest potential fertility of cows may not be impacted by exposure to prenatal transportation stress. Additionally, the total number of follicles that a cow has on her ovary is correlated with the numbers of follicles that can be observed by ultrasound.

Acknowledgements: This work was supported by Texas A&M AgriLife Research, Western Regional Project, United States TEX03212, Hatch Projects, United States H-9022, the TAMU One Health Initiative, United States, and NIFA, United States Award #2018-67 015-28 131. This work was funded in part by ARS Project, United States number 3040-31 000-096-00D to Robert A. Cushman and Hannah K. Yake.

Figures and Tables:

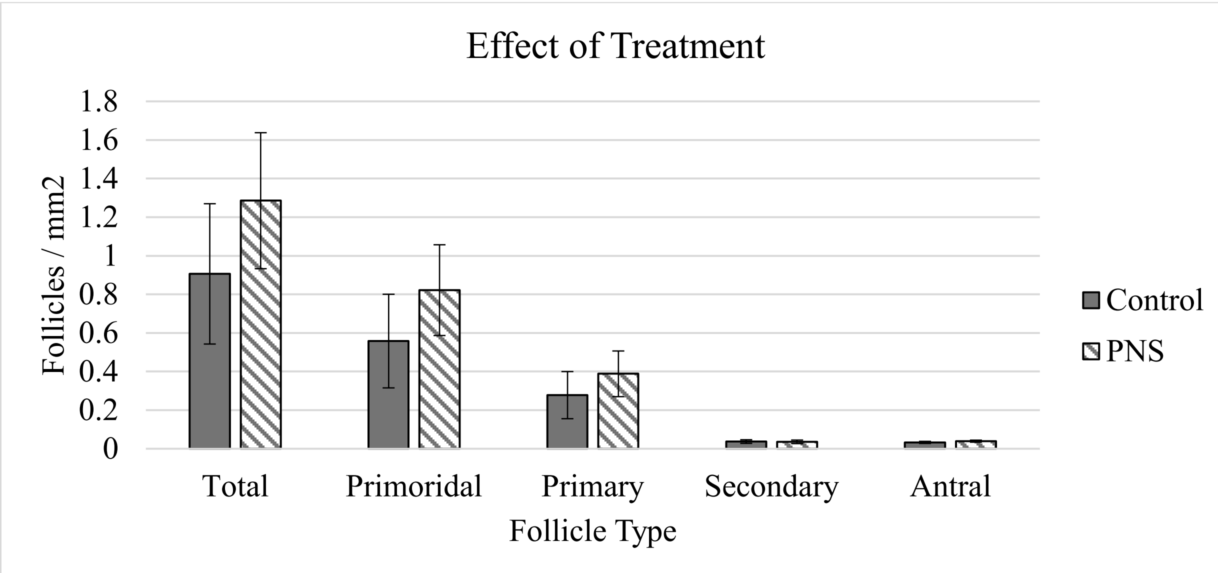


Figure 7: Mean number of total, primordial, primary, secondary, and antral follicles (per mm^2) for calves born to transported (PNS) and non-transported (control) cows.

Table 1
Mean numbers of follicles (per mm^2) for each age category

	Age (d)			*P* - value
	25	1825	2920	
Follicle category	Mean ± SE	Mean ± SE	Mean ± SE	
Primordial	1.99 ± 0.30 [a]	0.04 ± 0.31 [b]	0.04 ± 0.27 [b]	< 0.0001
Primary	0.94 ± 0.15 [a]	0.04 ± 0.16 [b]	0.02 ± 0.13 [b]	< 0.001
Secondary	0.10 ± 0.01 [a]	0.01 ± 0.01 [b]	0.01 ± 0.01 [b]	< 0.0001
Antral	0.06 ± 0.01 [a]	0.03 ± 0.01 [b]	0.02 ± 0.01 [b]	< 0.01
Total	3.09 ± 0.45 [a]	0.12 ± 0.47 [b]	0.08 ± 0.40 [b]	< 0.0001

Evaluation of semen characteristics during pubescent maturation of Brahman bulls

Caleta M. Willis[1,2,3], Jaclyn N. Ketchum[1,2], Kaitlin M. Epperson[1,2], Lacey K. Quail[1,2], Chloey P. Carson[2], Charles C. Love[4], Karl C. Kerns[5], Charles R. Long[2], Ronald D. Randel[2], Thomas H. Welsh, Jr.[1], George A. Perry[2]

[1]Department of Animal Science, Texas A&M University, College Station, TX
[2]Texas A&M AgriLife Research, Overton, TX
[3]Department of Agricultural and Environmental Sciences, Abilene Christian University, Abilene, TX
[4]Department of Large Animal Clinical Sciences, Texas A&M University, College Station, TX
[5]Department of Animal Science, Iowa State University, Ames, Iowa

Application: During sexual maturity, identifying the time period when changes occur in bovine semen characteristics that hinder reproductive efficiency will improve effectiveness of breeding procedures.

Introduction: Given that there are numerous factors that influence reproductive efficiency, the purpose of this study was to compare semen characteristics [motility, viability, chromatin structure, mitochondrial membrane potential (MMP), and/or reactive oxygen species (ROS)] at different stages during sexual development of bulls.

Materials and Methods: Semen collected from Brahman bulls (n=23) at six-week intervals was classified based on motility and concentration as prepubertal (< 10% and < 50 million), peripubertal (≥ 10% or ≥ 50 million), pubertal (≥ 10% and ≥ 50 million), or sexually mature (≥ 30% or ≥ 500 million). Propidium iodide dye and SYBR-14 stain were used to determine viability at collection, after thawing, and after a three-hour stress test. The proportion of sperm with damaged chromatin was identified via the Sperm Chromatin Structure Assay. Mitochondrial membrane potential was determined with JC-1, while the percentage of sperm with elevated ROS was determined by sufficient H_2O_2 to convert 2',7'-dichlorodihydrofluorescein (H_2DCFDA) to dichlorofluorescein (DCF) and sufficient superoxide (•O_2) to convert hydroethidine to ethidium. Statistical analysis (PROC GLIMMIX; SAS 9.4) included the fixed effect of time on maturation parameters. Significance was declared at $P < 0.05$.

Results: Scrotal circumference ($P < 0.0003$; Figure 1) and motility [at collection ($P < 0.001$; Figure 2) and post thaw ($P < 0.03$)] increased as bulls matured. The proportion of viable sperm cells with high MMP was greater ($P < 0.01$; Figure 3) in early peripubertal collections (low motility) compared to pubertal and mature collections. The proportion of viable sperm (fresh, post thaw, and post stress; Figure 4) did not differ ($P > 0.05$) among collections. Nor did stage of sexual maturity affect the proportion of sperm cells with damaged chromatin ($P > 0.05$), or the proportion of viable sperm cells with high ROS ($P > 0.05$).

Conclusion: Scrotal circumference, motility (at collection and post thaw), as well as MMP differed between stages of sexual maturity. Motility and MMP inversely changed with sexual maturity (decreasing as bulls matured). However, neither viability, chromatin structure, nor amount of ROS differed between stages of sexual maturity.

Acknowledgements: USDA-NIFA grant 2019-67015-2957, Western Regional Project W-4112, and Multistate Hatch TEXO-9835, and the Texas A&M School of Veterinary Medicine Equine Theriogenology Lab.

Figures and Tables:

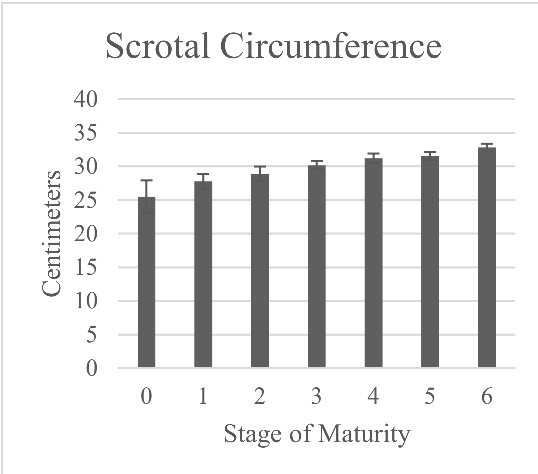


Figure 1. Scrotal circumference increased as bull sexual maturity increased from prepubertal (stage 0) to sexually mature (stage 6)

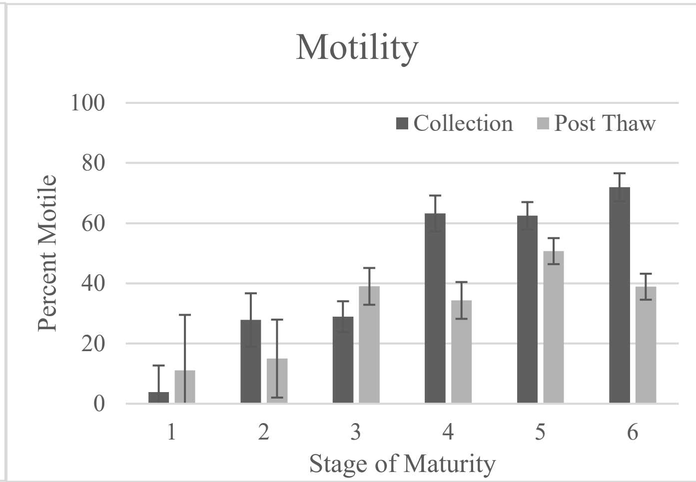


Figure 2. Motility increased as bull sexual maturity increased from prepubertal (stage 1) to sexually mature (stage 6)

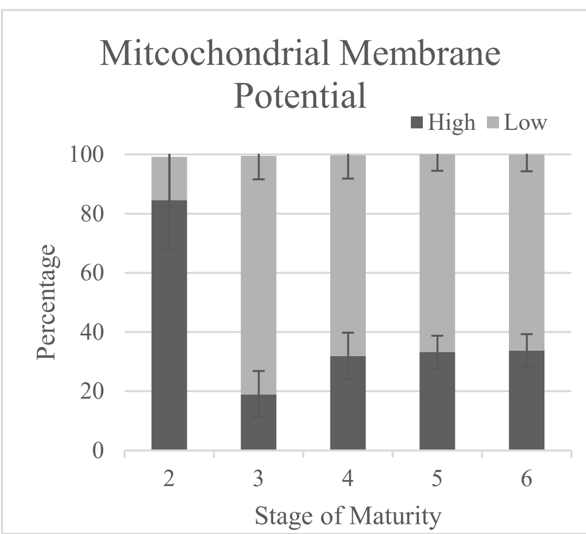


Figure 3. Mitochondrial membrane potential decreased as bull sexual maturity increased from peripubertal (stage 2) to sexually mature (stage 6)

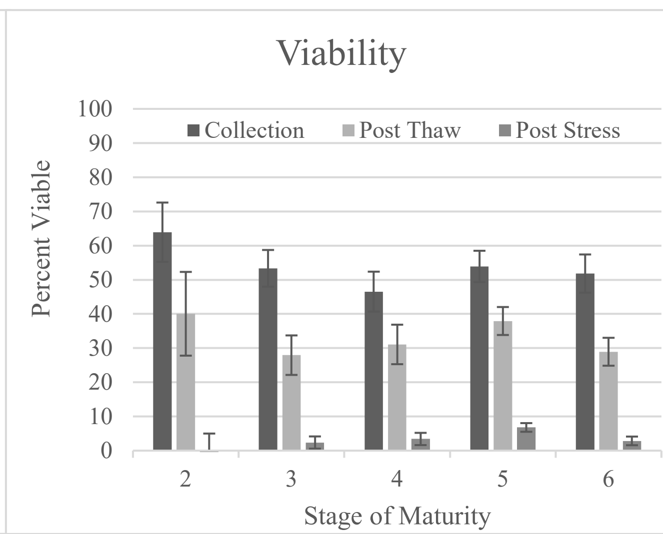


Figure 4. Viability changes at collection, post thaw, and post stress as bull sexual maturity increased from peripubertal (stage 2) to sexually mature (stage 6)

Evaluation of semen characteristics during pubescent maturation after prenatally induced stress of Brahman bulls

Caleta M. Willis[1,2,3], Jaclyn N. Ketchum[1,2], Kaitlin M. Epperson[1,2], Lacey K. Quail[1,2], Chloey P. Carson[2], Charles C. Love[4], Karl C. Kerns[5], Charles R. Long[2], Ronald D. Randel[2], Thomas H. Welsh, Jr.[1], George A. Perry[2]

[1]Department of Animal Science, Texas A&M University, College Station, TX
[2]Texas A&M AgriLife Research, Overton, TX
[3]Department of Agricultural and Environmental Sciences, Abilene Christian University, Abilene, TX
[4]Department of Large Animal Clinical Sciences, Texas A&M University, College Station, TX
[5]Department of Animal Science, Iowa State University, Ames, Iowa

Application: Determining if stress that occurred while a calf is *in utero* impacted semen characteristics and hindered reproductive efficiency.

Introduction: The purpose of this study was to compare semen characteristics [motility, viability, chromatin structure, mitochondrial membrane potential (MMP), and/or reactive oxygen species (ROS)] from samples taken during sexual development of prenatally stressed bulls to determine any negative impacts of stress on male offspring while in utero.

Materials and Methods: Prenatal stress was achieved by transporting Brahman dams for 2h on day 60, 80, 100, 120, and 140 (±5 days) of gestation. Semen was collected at six-week intervals from males born to transported (PNS; n=11) or non-transported (CON; n=12) dams to classify bulls as prepubertal (<10% motile and <50 million per mL), peripubertal (≥10% motile or ≥50 million per mL), pubertal (≥10% motile and ≥50 million per mL), or sexually mature (≥30% motile or ≥500 million per mL). Sperm characteristics were determined by staining sperm with specific dyes [viability - Propidium iodide and SYBR-14; Mitochondrial membrane potential (MMP) – JC-1; DNA damage – Aracidine orange; ROS –H_2DCFDA to DCF and conversion of hydroethidine to ethidium] and analyzing it on an Amnis FlowSight flow cytometer. Treatment differences were determined by analysis of repeated measures (PROC MIXED) and chi-square (PROC FREQ) in SAS.

Results: There was a weak tendency ($P = 0.14$) for more CON bulls to reach puberty (100%) compared to PNS bulls (82%), but no difference ($P = 1.0$) in percentage reaching sexual maturity by 22 months of age (82% and 82%). Scrotal circumference ($P < 0.01$; Figure 1) and motility [at collection ($P < 0.01$; Figure 2) and post thaw ($P = 0.05$)] increased as bulls matured but was not impacted by treatment ($P > 0.86$) or treatment by time ($P > 0.60$). Sperm viability (at collection, post-thawing, and post-stress test) was not impacted by treatment ($P > 0.20$), time ($P > 0.53$), or treatment by time (P > 0.50). The proportion of viable sperm with high MMP was not impacted by treatment ($P = 0.70$) or treatment by time ($P = 0.49$) but was increased ($P = 0.03$; Figure 3) in early peripubertal collections compared to pubertal or mature collections. The proportion of sperm with damaged DNA was decreased in PNS (1.6±0.3%; $P = 0.04$) versus CON (2.4±0.2%) but not impacted by time ($P = 0.47$) or treatment by time ($P = 0.41$). Percentage of sperm with elevated ROS (H_2O_2 and $•O_2$) was not impacted by treatment ($P > 0.33$), time ($P > 0.17$), or treatment by time ($P > 0.41$).

Conclusion: Prenatal stress tended to reduce the proportion of bulls that reached puberty by 22 months of age. Prenatal stress also impacted the proportion of sperm with DNA damage, but did not impact scrotal circumference, motility, MMP, or ROS. Scrotal circumference, motility, and MMP differed between stages of sexual maturity, but did not impact ROS. In summary, PNS may impact the ability to reach puberty, but did not impact sperm characteristics.

Acknowledgements: USDA-NIFA grant 2019-67015-2957, Western Regional Project W-4112, and Multistate Hatch TEXO-9835

Figures and Tables:

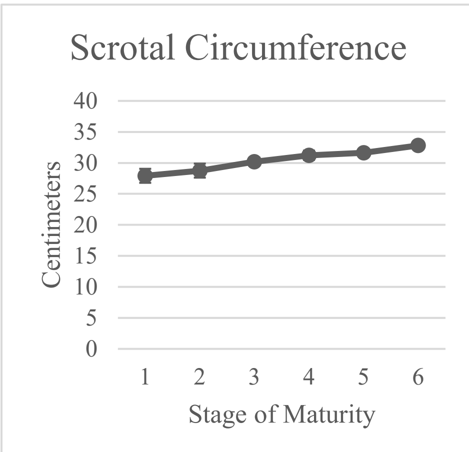


Figure 1. Scrotal circumference increased as bull sexual maturity increased from prepubertal (stage 1) to sexually mature (stage 6)

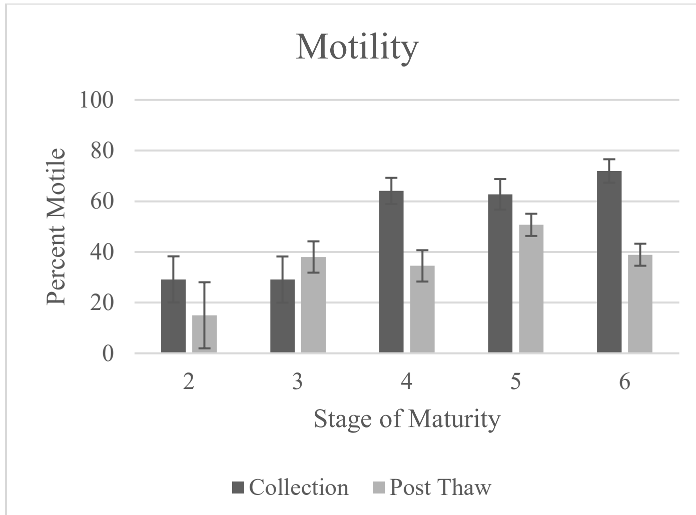


Figure 2. Sperm motility increased as bull sexual maturity increased from peripubertal (stage 2) to sexually mature (stage 6)

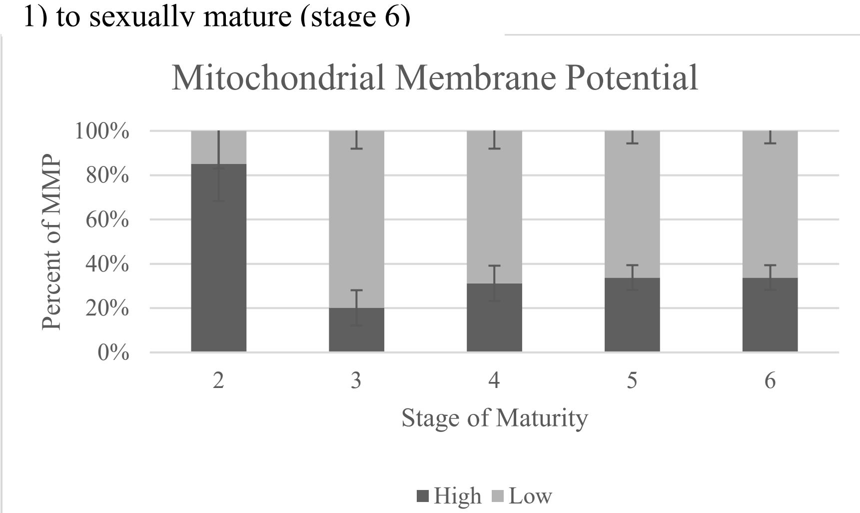


Figure 3. Mitochondrial membrane potential decreased as bull sexual maturity increased from peripubertal (stage 2) to sexually mature (stage 6)

Prenatally stressed Brahman bulls produced embryos with decreased embryonic development

Jaclyn N. Ketchum[*], Jessica N. Drum[#], M. Sofia Ortega[#], Charles R. Long[||], Thomas H. Welsh, Jr. [*], Ronald D. Randel[||], George A. Perry[||]

[*]Texas A&M University, Department of Animal Science, College Station, TX
[#]University of Missouri, Division of Animal Sciences, Columbia, MO
[||]Texas A&M AgriLife Research, Overton, TX

Application: While hard to estimate, the cost of stress to the beef industry is unignorable; however, it is also an unavoidable challenge. Thus, an important function of livestock management is capitalizing on advantageous adaptations to stress while avoiding detrimental adaptation.

Introduction: First, gaining the understanding of what adaptations are detrimental versus advantageous is required. The objective of this experiment was to determine if semen collected from prenatally stressed (PNS) Brahman bulls altered early embryonic development compared to control (CON) bulls.

Materials and Methods: Prenatal stress was achieved by transporting Brahman dams for 2 hours on day 60, 80, 100, 120, and 140 (± 5 days) of gestation (Figure 1). Semen collected from sexually mature male offspring born to transported (PNS; n=4) or non-transported (CON; n=5) dams was purified from frozen-thawed straws using a gradient [50% (v/v) and 90% (v/v)] of Isolate (Irvine Scientific, Santa Ana, CA), washed two times by centrifugation using SP-TALP and diluted in IVF-TALP to a final concentration of 1×10^6/ml in the fertilization dish to fertilize abattoir derived cumulus oocytes complexes (n=81-100/bull in 2 wells) in an *in vitro* setting to monitor early embryonic development. Fertilization took place for 18-20 hours (day 0). Then, putative zygotes were cultured for 8 days. Cleavage was recorded on day 3, the number of 1, 2-6, 8-16, or 16-32 cell embryos was recorded on day 5, and the number of blastocysts and degenerated embryos was recorded on day 8. A subset of blastocysts from PNS (n=12) or CON (n=23) bulls were immunolabelled to differentiate inner cell mass (ICM) and trophectoderm (TE). Additionally, SYBR-14 and Propidium Iodide (PI; LIVE/DEAD™ Sperm Viability Kit [L7011, Molecular Probes, Inc. Eugene, OR]) were used to determine the proportion of sperm cells that were living or that had disrupted membranes, respectfully. Differences in early embryonic development, ICM:TE ratios, proportion of live sperm cells, and proportion of sperm cells with disrupted membranes were determined using the GLIMMIX procedure in SAS (9.4) with well as a fixed effect.

Results: The proportion of live sperm cells did not differ (P=0.3340) between treatments nor did the proportion of sperm cells with disrupted membranes (P=0.3440). On day 3, the percentage of oocytes that cleaved did not differ (P=0.2660) between treatments. Treatment also had no effect on the percentage of 1 (P=0.1622), 2-6 (P=0.1138), 8-16 (P=0.2722), or 16-32 (P=0.5586) cell stage embryos on day 5 nor the percentage of degenerated embryos (P=0.1130). However, the percentage of embryos that developed to a blastocyst by day 8 differed (*P*=0.0291) between treatments such that oocytes fertilized by sperm produced by PNS bulls (28%) were less likely to advance to the blastocyst stage compared to CON bulls (35%; Figure 2)). The ICM:TE ratio did not differ (*P*=0.6484) between treatments.

Conclusions: PNS Brahman bulls do not have an obvious problem with fertilization but may produce sperm with epigenetic modifications that hinder blastocyst formation.

Acknowledgements: Texas A&M School of Veterinary Medicine Equine Theriogenology Lab, Supported by the USDA-NIFA [2018-67015-28131], Multistate Hatch project 9835, Western Regional Projects 4173 and 4212, Hatch Projects H-9022, Texas A&M University One Health Initiative, and Texas A&M AgriLife Research, Overton.

Figures and Tables:

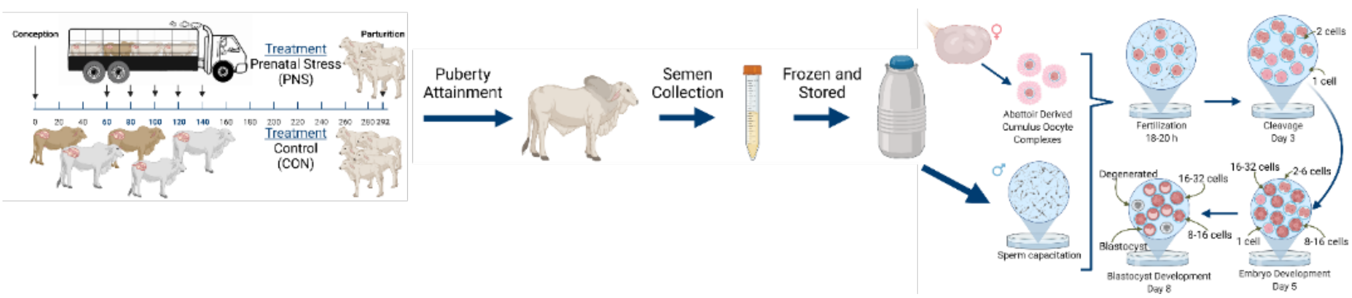


Figure 1. Prenatal stress was achieved by transporting Brahman dams for 2 hours on day 60, 80, 100, 120, and 140 (± 5 days) of gestation. When bulls reached sexual maturity, semen was collected and frozen. Semen was then thawed and used to fertilize mature oocytes.

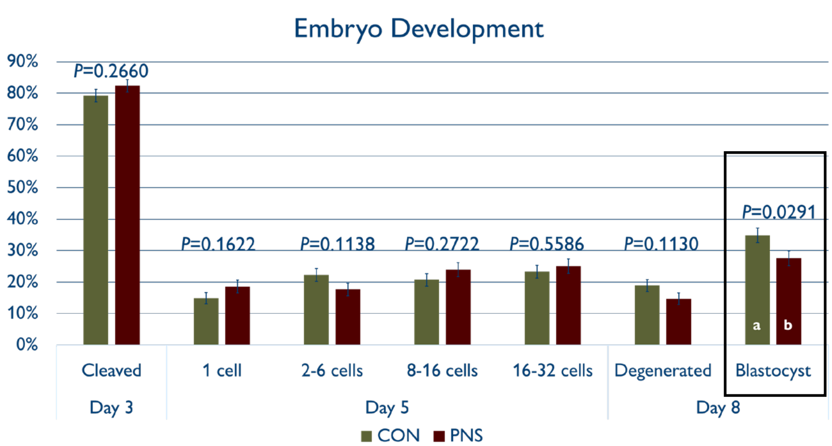


Figure 2. Impact of semen from prenatally stressed bulls on embryo development.

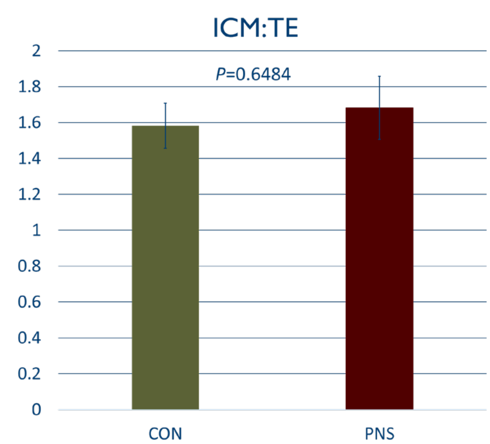


Figure 3. Impact of semen from prenatally stressed bulls on the ration of cells from the inner cell mass (ICM) to cell from the trophectoderm (TE)embryo development.

Comparison of DNA methylation patterns in sperm collected from Brahman bulls with differences in embryo development

Jaclyn N. Ketchum[1,5], Jessica N. Drum[2,3], Caleta M. Willis[1,5], Chloey P. Carson[5], M. Sofia Ortega[2,4], Karl. C. Kerns[6], Charles R. Long[5], Charles C. Love[7],Thomas H. Welsh, Jr. [1], Ronald D. Randel[5], George A. Perry[5]

[1]Texas A&M University, Department of Animal Science, College Station, TX
[2]University of Missouri, Division of Animal Sciences, Columbia, MO
[3]South Dakota State University, Department of Animal Science, Brookings, SD
[4]University of Wisconsin Madison, Animal & Dairy Science, Madison, WI
[5]Texas A&M AgriLife Research, Overton, TX
[6]Department of Animal Science, Iowa State University, Ames, Iowa, USA
[7]Department of Large Animal Clinical Sciences, Texas A&M University, College Station, TX, USA

Application: Gaining understanding of the mechanisms hindering reproductive efficiency among bulls with similar semen characteristics but differences in fertility will help us understand how to better identify sub-fertile bulls.

Introduction: Among bulls that pass a breeding soundness exam, there is still variability in their fertility. It is easy to identify infertile bulls as they do not pass a breeding soundness exam; however, sub-fertile bulls are harder to identify. Methylation of the DNA allows for genes to be turned on or off without impact the genetic code. The objective of this study was to determine if methylation patterns in sperm differed between bulls with good vs poor embryo development and thus could help explain the variation we see in the fertility of bulls.

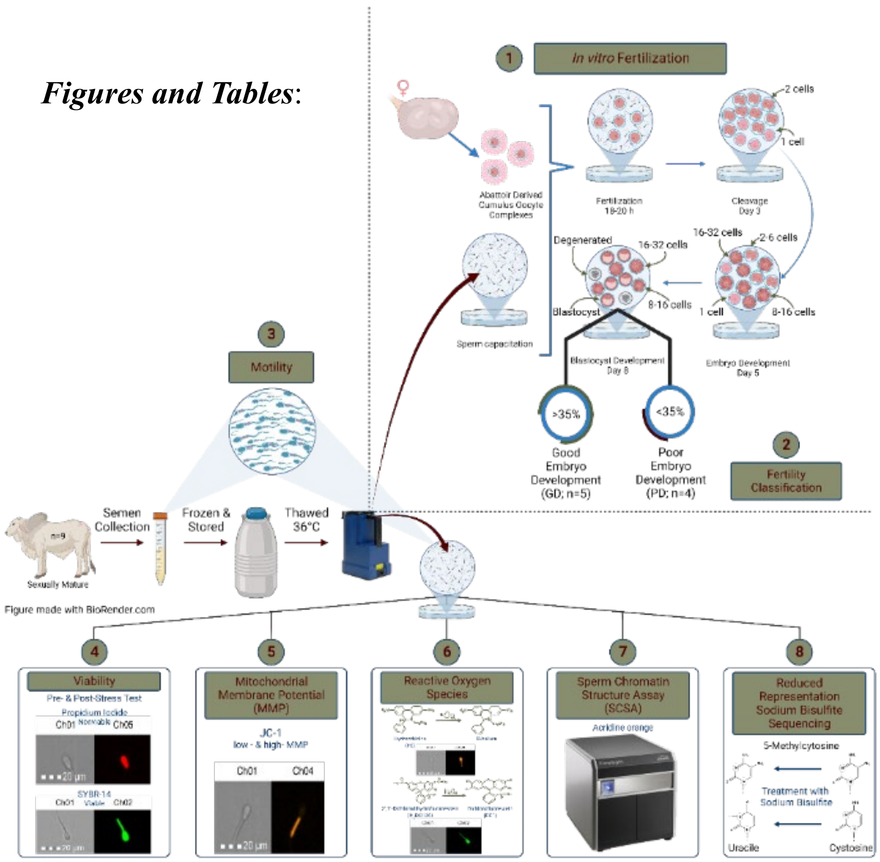
Materials and Methods: Semen collected from sexually mature Brahman bulls was purified from frozen-thawed straws using a gradient [50% (v/v) and 90% (v/v)] of Isolate, and used to fertilize abattoir-derived cumulus oocyte complexes (n=81-100/bull in 2 wells). Number of blastocysts were recorded on d8, and bulls were classified as Good (GD; >35% blastocyst rate; n=5) or Poor (PD; <33% blastocyst rate; n=4) embryo development. Methylation of sperm DNA was assessed by reduced representation sodium bisulfite sequencing. Differences in methylation were determined with the Dispersion Shrinkage for Sequencing method in conjunction with Wald test. Differentially methylated cytosines and regions located in promoters were analyzed to reveal associated gene ontology terms. Proportion of sperm cells that were viable (prior to and after a three-hour stress test), with elevated *reactive oxygen species* (*ROS*), and with damaged chromatin was determined. Statistical analysis (PROC GLIMMIX) included the fixed effect of embryo development classification which was considered significant at $P<0.05$. Mean separation was performed using LSmeans.

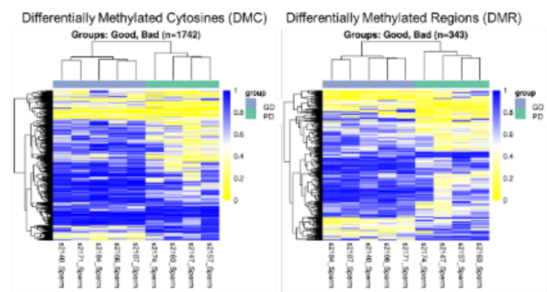
Results: The proportion of viable ($P>0.21$; GD=46±5%; PD=36±5%) sperm cells did not differ prior to the stress test. Post-stress test, PD bulls had more viable sperm cells ($P<0.02$; 37±3%) than GD (25±2%) bulls. There was no difference between GD and PD for ROS (H_2O_2; $P>0.16$ and $\bullet O_2$; $P>0.59$). Proportion of sperm cells with damaged chromatin was greater ($P<0.01$) in PD (3±0.3%) than GD bulls (1±0.01%). Differentially methylated cytosines numbered 1,742 and there were 343 regions when GD bulls were compared to PD bulls. There were 17 hyper- and 10 hypo-methylated promoters. Hypomethylated promoters were associated with cell differentiation, developmental processes, and lineage determination. Hypermethylated promoters were associated with decreased OCT4 and NANOG protein expression and epigenetic regulation of gene expression, DNA methylation, chromatin organization, and mRNA splicing.

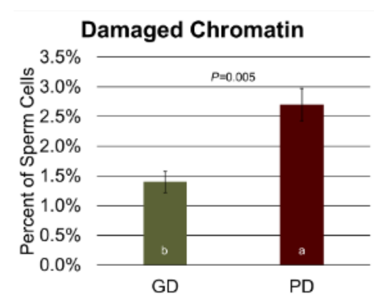
Conclusion: In summary, differences in embryo development are likely not due to semen characteristics, but methylation patterns in sperm may play a major role in early embryo development as they were different between bulls with good versus poor embryo development.

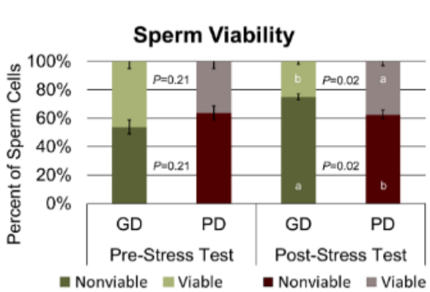
Acknowledgements: Texas A&M School of Veterinary Medicine Equine Theriogenology Lab, Supported by the USDA-NIFA [2018-67015-28131], Multistate Hatch project 9835, Western Regional Projects 4173 and 4212, Hatch Projects H-9022, Texas A&M University One Health Initiative, and Texas A&M AgriLife Research, Overton.

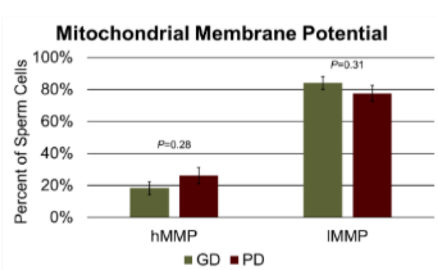
Figures and Tables:

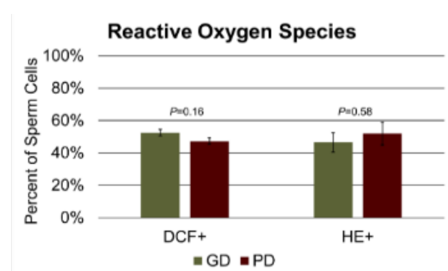












Influence of commercial inactivated and modified-live virus vaccination at time of AI on corpus luteum development and function in beef cattle

Kaitlin M. Epperson[1,2,3], Jerica J. J. Rich[4,5], Saulo Menegatti Zoca[5,6], Lacey K. Quail[1,2], Taylor N. Andrews[5], Adalaide C. Kline[5], Frank J. White[7], Russell F. Daly[8], Robert A. Cushman[9], Alexandria. P. Snider[9], and George A. Perry[2]

[1]Texas A&M University Department of Animal Science, College Station, TX 77843
[2]Texas A&M AgriLife Research, Overton, TX 75684
[3]Northwest Missouri State University School of Agricultural Sciences, Maryville, MO 64468
[4]Arkansas State University College of Agriculture, Jonesboro, AR 72467
[5]South Dakota State University Department of Animal Science, Brookings, SD 57007
[6]University of Tennessee, Department of Animal Science, Knoxville, TN 37996
[7]Elanco Animal Health, Greenfield, IN 46140
[8]South Dakota State University Department of Veterinary & Biomedical Sciences, Brookings, SD 57007
[9]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE 68933

Application: Vaccines provide an important component for protection from reproductive pathogens, and commercially available modified-live virus (MLV) vaccines offer a heightened cell mediated immune response and do not require the booster administration required by inactivated vaccines.

Introduction: The administration of MLV vaccines shortly before the start of the breeding season have been reported to have detrimental effects on fertility. They have been reported to cause disruptions in estrous cyclicity and reduced conception rates following administration shortly before the breeding season.

Materials and Methods: On day 0, synchronized beef cows were treated with MLV (n = 70; BoviShield Gold FP5VL5), inactivated virus vaccine (IVV; n = 16; ViraShield 6VL5HB), or were unvaccinated controls (n = 5). Plasma was collected from treated animals on day 0 and every other day through day 22. Plasma was analyzed for concentrations of progesterone and 15 cytokines. Between day 10 and 13, selected females (n = 13) were ovariectomized; controls were slaughtered on day 15/16 to obtain corpora lutea (CL) for histological evaluation.

Results: There were reduced numbers of large luteal cells (LLC) in MLV compared to IVV and controls ($P < 0.0001$), but IVV were similar to controls ($P = 0.11$; Table 1). MLV had decreased LLC percentage compared to controls, and IVV were intermediate ($P < 0.0001$, MLV: 1.57 ± 0.33%, IVV: 2.99 ± 0.30%, Control: 6.45 ± 0.33%). Based on progesterone concentrations, 24% MLV and 0% IVV had an abnormal cycle following vaccination. Overall, MLV had reduced progesterone concentrations ($P = 0.02$; MLV: 3.61 ± 0.22; IVV: 4.81 ± 0.46ng/mL). The new CL that formed following an abnormal cycle in MLV had the greatest percentage (35.56 ± 5.5%) of apoptotic cells. Treatment by cycle status interaction, and time significantly affected IFN-γ, IP-10, MIP-1β, and MCP-1 ($P < 0.03$), with several time points having elevated concentrations in abnormally cycling MLV animals.

Conclusion: This study illustrates the detrimental effects that occur to the CL following administration of a commercial MLV vaccine around the time of estrus. The increased apoptosis and reduced percentage of large luteal cells provide an explanation for the incidence of abnormal estrous cycles and decreased production of progesterone reported in bovine females that received the MLV vaccine. The cytokine profiles indicate an upregulated inflammatory immune response caused by MLV administration.

Acknowledgements: This research was funded by Elanco Animal Health, Multistate Hatch project 9835, USDA-NIFA-AFRI grant 2019-67012-34749 (APS) and ARS project number 3040-31630-001-000D (RAC and APS).

Figures and Tables:

Table 1. Histological and apoptotic evaluation of the corpus luteum.

	MLV[a]-new CL[b]	MLV-old CL	IVV[c]	Control	*P*-value
Large luteal cell number	5.11 ± 0.86^{x}	3.74 ± 0.73^{x}	12.33 ± 0.79^{y}	14.22 ± 0.86^{y}	< 0.0001
Total cell number	342.69 ± 15.72^{x}	339.51 ± 13.28^{x}	451.73 ± 14.35^{y}	233.34 ± 15.72^{z}	< 0.0001
Large luteal cell, %	1.57 ± 0.33^{x}	1.24 ± 0.28^{x}	2.99 ± 0.3^{y}	6.45 ± 0.33^{z}	< 0.0001
Luteal apoptosis, %	35.56 ± 0.06^{x}	7.06 ± 0.05^{y}	4.25 ± 0.05^{y}	--	< 0.0001

[a]Modified-live virus vaccine (MLV)
[b]Corpus Luteum (CL)
[c]Inactivated virus vaccine (IVV)
Different ^{xyz}superscripts within rows depict statistical differences ($P \leq 0.05$) between treatments.

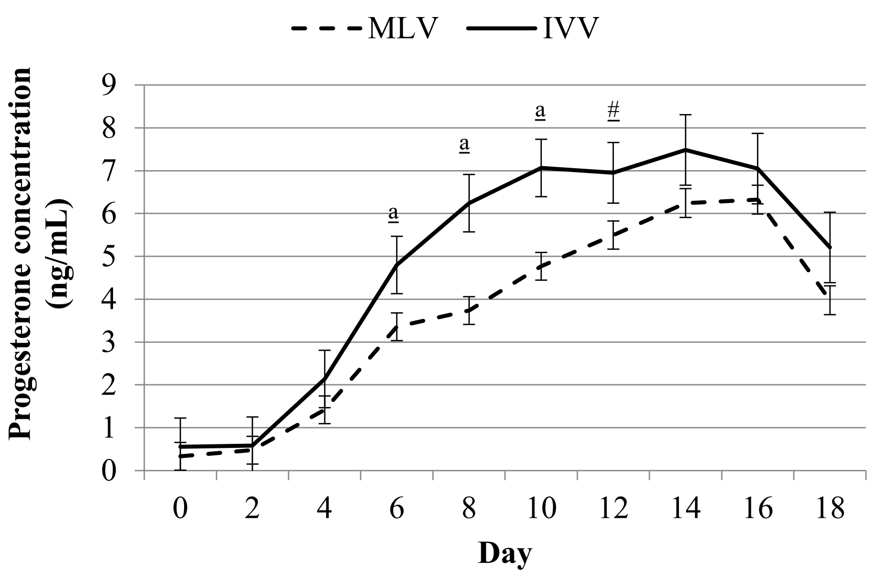


Figure 1. The influence of the interaction of treatment and time on circulating concentrations of progesterone (ng/mL) among bovine females administered either a modified-live virus vaccine (MLV) or inactivated virus vaccine (IVV) on d 0 ($P = 0.05$). Data points marked with an [a]superscript denote statistical differences ($P \leq 0.05$) between treatments within day, while those marked with a [#]superscript tend to be different ($0.05 < P \leq 0.10$).

Characterization of immune cell populations induced from two types of pre-breeding vaccination in *Bos indicus* beef cattle

Kaitlin M. Epperson[1,2], Jaclyn N. Ketchum[1,2], Lacey K. Quail[1,2], Chloey P. Carson[2], Charles R. Long[2], and GeorgeA. Perry[2]

[1]Department of Animal Science, Texas A&M University, College Station, TX, USA
[2]Texas A&M AgriLife Research and Extension Center, Overton, TX, USA

Application: Peripheral leukocytes are specific immune cells that play a critical role in immunity and herd health. This project characterized changes in peripheral leukocyte populations following two types of pre-breeding vaccinations administered around time of estrus.

Introduction: A tight relationship exists between the immune system and ovarian function; identification of leukocytes specifically involved in vaccine response would narrow research focus to which cells may be eliciting negative effects on the corpus luteum after vaccination. Our objective was to characterize the immune response and identify changes in select leukocyte populations after two types of vaccination.

Materials and Methods: Brahman and Brahman-cross females (n=22) were given prostaglandin F2α on d-3 to induce luteolysis. On d0, cows were administered treatment; modified-live virus vaccination (MLV; BoviShield Gold FP5VL5), inactivated virus vaccination (IV; ViraShield 6VL5HB), or saline (CON). Blood samples were collected into K3-EDTA containing conicals to isolate peripheral blood mononuclear cells (PBMC) on d0, 4, 6, 8, 10, 14 from all animals, and from different subsets (n=10) on 28, 46, and 65. Density gradient centrifugation with Ficoll Paque-PLUS allowed for collection of PBMC, which were incubated with antibodies for surface cell markers CD4, CD8, CD25, CD14, CD86, and CD335. Propidium iodide was added to assess cell viability and permit gating of live cells. Antibody stained PBMC were evaluated with an Amnis FlowSight flow cytometer and data processed with IDEAS 6.2 software. Approximately 10,000 events were acquired in the single cell gate per sample. Percentages of leukocytes from d0-14 were analyzed in SAS as a repeated measure using the MIXED procedure, including treatment, day, and their interaction in the model. Populations on d28, 46, and 65 were each evaluated by an ANOVA using the MIXED procedure.

Results: Treatment alone had no effect on populations of measured leukocytes ($P \geq 0.25$), but populations of CD14+, CD335+, CD86+CD335-, CD4+, CD8+, CD25+, and CD25+CD4+ differed over time ($P \leq 0.03$; Table 1). The interaction of treatment and time affected CD14+ (monocyte), CD25+ (activated T-cell) and CD25+CD4+ (T-regulatory) cells ($P \leq 0.05$). On d2, MLV females had an elevated monocyte population compared to CON. Percentage of activated T-cells decreased from d0 to 2 in all treatments and gradually returned to levels similar on d0. T-regulatory cells were variable over time but were similar within each sample day among treatments. Cytotoxic T-cells (CD8+) on d28 were increased in vaccine treatments ($P \leq 0.03$) compared to CON (Figure 1) and natural killer cells (CD335+; Figure 2) on d46 were decreased in vaccine treatments ($P \leq 0.03$) compared to CON. T-helper cells (CD4+) and cytotoxic T-cells tended to be decreased on d65 and d46, respectively, in vaccinated animals (P=0.08).

Conclusion: Leukocyte populations are affected by vaccination, therefore, in understanding the expected changes which occur following pre-breeding vaccination, efforts to isolate leukocyte involvement in ovarian regulation can be identified.

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

Figures and Tables:

Table 1. Analysis of leukocyte populations over time by repeated measure from days 0 to 14 in all study animals (n = 22)

	***P*-value**		
Cell Type	**Treatment**	**Day**	**Treatment*Day**
Antigen Presenting Cells (APCs)	0.61	<0.0001	0.02
Natural killer cells	0.25	0.03	0.27
Activated APCs	0.35	0.0006	0.56
T-helper cells	0.27	0.006	0.14
Cytotoxic T-cells (CTLs)	0.80	<0.0001	0.16
Activated T-cells	0.84	<0.0001	0.01
Activated CTLs	0.89	0.41	0.14
Activated T-helper (T-regulatory)	0.96	0.0005	0.05

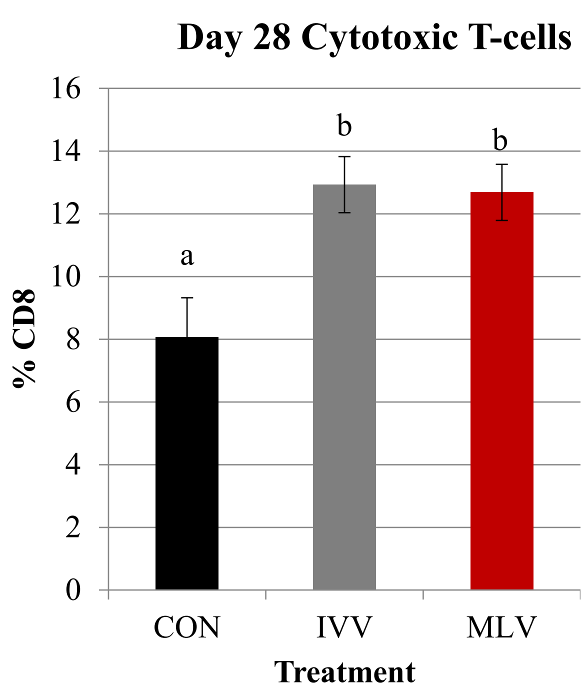


Figure 1. Impact of vaccination on peripheral populations of Cytotoxic T-cells (CD8+) on day 28 after vaccination.

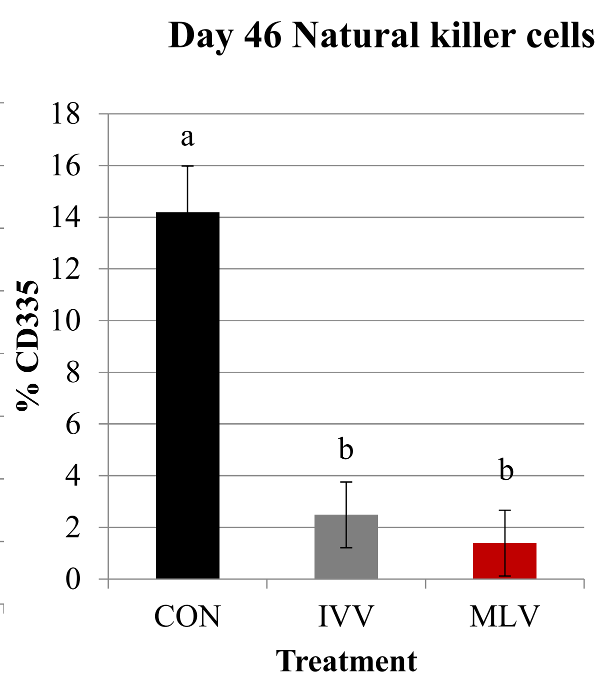


Figure 2. Impact of vaccination on peripheral populations of Natural Killer cells (CD335+) on day 46 after vaccination.

Combination and individual vaccines for bovine viral diarrhea virus and infectious bovine rhinotracheitis effects on reproductive cyclicity and immune response

Sarah G. Blaske[1,2], Jaclyn N. Ketchum[1,2], Lacey K. Quail[1,2], Ana Clara D. Mattos[3], Alexandria P. Snider[4], Chloey P. Carson[2], Charles R. Long[2], and George A. Perry[2]

[1]Department of Animal Science, Texas A&M University, College Station, TX
[2]Texas A&M AgriLife Research and Extension Center, Overton, TX
[3]Animal Reproduction Department, University of São Paulo, Pirassununga, SP, Brazil
[4]United States Department of Agriculture, Agricultural Research Service, U.S. Meat Research, Clay Center, NE

Application: Infectious diseases threaten reproductive efficiency and herd health; however, vaccinations may actually induce consequences they are designed to prevent. This study analyzed reproductive cyclicity and immune function following two different vaccinations.

Introduction: There is evidence that vaccinations impact the bovine reproductive system, but the mechanisms behind these impacts are unknown. Investigation of how compounded vaccines impact immune response and reproductive function may reveal how these two systems work together. The objective of this research was to identify immunological and estrous cycle differences between animals following vaccination for Bovine Viral Diarrhea Virus (BVDV) and/or Infectious Bovine Rhinotracheitis (IBR).

Materials and Methods: Brahman cows (n = 15) were administered prostaglandin F2α to regress the presence of a corpus luteum on day -3. Animals were immunized (2mL I.M.) with one of three treatments: 1) a combination Modified Live Vaccine (MLV) for BVDV and IBR (BVD+IBR; n = 5), 2) a MLV for BVDV only (BVD; n = 5), or 3) sterile saline (CON; n = 5) on day 0. Blood samples were collected on days -3, 0, 2, 4, 6, 8, 10, and 14 post vaccination and peripheral blood mononuclear cells (PBMC) were isolated. Samples collected on days -3, 0, and 14 were processed for serum. PBMCs were incubated with propidium iodide and antibodies for specific surface cell markers (CD4, CD8, CD25, CD14, CD86, and CD335). An Amnis FlowSight flow cytometer was used to determine the percentage of each cell type. Antibody concentrations for BVDV and IBR were determined in serum samples. 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 antibody titers, PBMC populations, and cytokine concentrations were analyzed as repeated measures using PROC MIXED (SASv9.4).

Results: Forty percent of the BVD+IBR treated animals expressed an abnormal cycle based on progesterone and estradiol concentrations, but no animals in the BVD or CON treatments had abnormal cycles. There was an effect of treatment on BVD titer concentration with BVD animals having greater titer concentrations than CON (P=0.02), but similar concentrations to BVD+IBR (P=0.18). There was also a treatment by time interaction on IBR titers (P<0.0001; Figure 1) with

BVD+IBR animals having greater titer concentration on day 14 and 45 compared to both BVD and CON animals. Treatment had no effect on leukocyte populations (*P*≥0.1409), but all populations differed over time (*P*≤0.0045). Antigen presenting cells (CD14+) and natural killer cells (CD335+) were affected by a treatment by time interaction (*P*≤0.0479). Antigen presenting cells were increased in BVD animals on days 2, 4, 8, and 14 compared to CON, but CON had a greater population of natural killer cells compared to both BVD and BVD+IBR on day 10 after vaccination. There tended to be or was a significant treatment by day interaction on IL-1α (*P*=0.08), IL-1β (*P*=0.03; Figure 2), IL-10 (*P*=0.06), IFN-γ (*P*=0.05), IP-10 (*P*=0.02), MIP-1α (*P*=0.02), MIP-1 β (*P*=0.01), TNFα (*P*=0.01), and VEGFA (*P*=0.03). After vaccination, IL-1α, IL-10, IL-1β, and MIP-1 β increased in BVD+IBR animals from day 0 to 4 or 6 then decreased, but not in CON or BVD animals. VEGFA; however, was elevated in control compared to BVD and BVD+IBR animals.

Conclusion: Forty percent of animals vaccinated with both IBR and BVD experienced an abnormal estrus cycle, but no BVD or CON animals had an abnormal cycle. A specific immune response was generated in response to vaccination with BVD or BVD+IBR. Select cytokines were also affected differently by vaccination treatments. These data demonstrate the intricate relationship between the immune system and reproductive function. USDA is an equal opportunity provider and employer.

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

Figures and Tables:

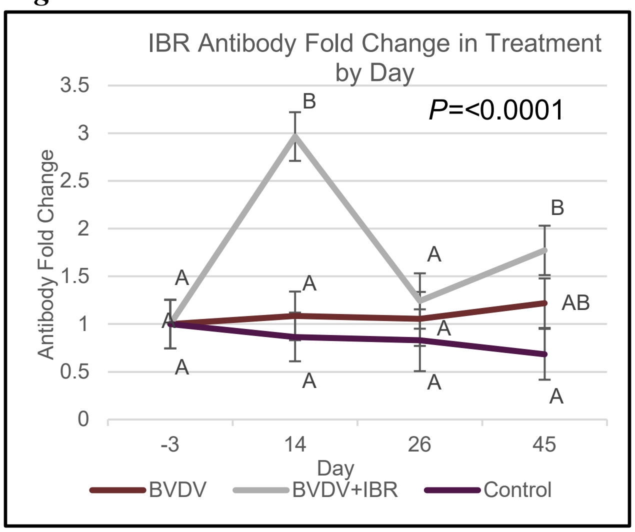


Figure 1. Changes in IBR antibody concentrations following vaccination with BVD, BVD+IBR, or CON. Treatments within a day that have different superscripts are different (P<0.05).

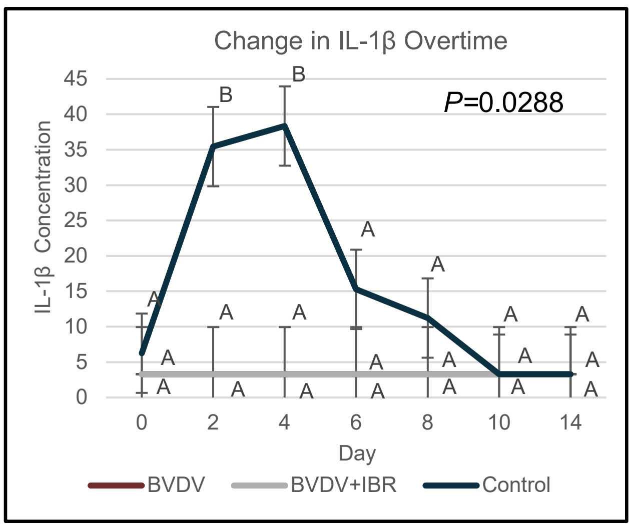


Figure 2. Changes in concentrations of IL-1β following vaccination with BVD, BVD+IBR, or CON. Treatments within a day that have different superscripts are different (P<0.05).

Impact of ambient temperature on bovine viral diarrhea virus and infectious bovine rhinotracheitis vaccine response

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

[1]Department of Animal Science, Texas A&M University, College Station, TX, USA
[2]Texas A&M AgriLife Research and Extension Center, Overton, TX, USA

Application: The immune system utilizes various cell-types and antibodies to create a defense mechanism against diseases. This research was conducted to evaluate how seasonal ambient temperature impacted antibody production and changes in immune cell populations following a pre-breeding vaccination.

Introduction: Vaccines are created to help the immune system fight pathogens faster and more effectively, but little is known on how season of the year impacts the immune response to vaccination. To avoid negative consequences on reproductive success, producers may need to administer vaccines at a different time of year. Our objective was to evaluate the impact seasonal ambient temperate has on post-vaccination antibody production and immune cell populations.

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). Blood samples were collected on days -3, 0, 2, 4, 6, 8, 10, and 14 post vaccination and peripheral blood mononuclear cells (PBMC) were isolated. Serum samples were collected on days -3, 0, and 14. PBMCs were incubated with propidium iodide and antibodies for specific surface cell markers (CD4, CD8, CD25, CD14, CD86, and CD335). An Amnis FlowSight flow cytometer was used to determine the percentage of each cell type. Concentrations of antibodies for Bovine Viral Diarrhea Virus (BVDV) and Infectious Bovine Rhinotracheitis (IBR) were determined in serum samples. Differences in antibody titers and PBMC populations were analyzed as repeated measures using PROC MIXED (SASv9.4).

Results: There were no differences in IBR ($P = 0.2$) or BVDV ($P = 0.47$) antibody concentrations between seasons. Percentage of antigen presenting cells (CD14+) was greater in the Summer compared to the Fall ($P = 0.01$; Summer = 11.7±1%; Fall = 7.3±1.1%), but natural killer cells (CD335+) were greater in the Fall compared to the Summer ($P = 0.002$; Summer = 0.6±0.6%; Fall = 4.4±0.7%). There was a significant treatment by time interaction for antigen presenting cells ($P = 0.04$), T-helper cells (CD4+; $P = 0.01$), activated T-helper cells (CD4+CD25+; $P \leq 0.0001$), activated cytotoxic T-cells (CD8+CD25+; $P = 0.03$), activated T-cells (CD25+; $P \leq 0.0001$), and natural killer cells ($P \leq 0.0001$), but there was no difference between seasons in activated antigen presenting cells (CD14+CD86+; $P = 0.19$). From pre-vaccination to day 14, natural killer cells were elevated during the Fall compared to the Summer on all days ($P = 0.04$). Antigen presenting cells were greater in the Summer compared to the Fall on days 4, 10 and 14 ($P < 0.02$). T-helper cells, activated T-helper cells, activated cytotoxic T-cells, and activated T-cells increased post-vaccination in the Fall, but did not change during the Summer.

Conclusion: Ambient temperatures did not directly impact production of IBR or BVDV antibodies; however, both seasons had increases in concentrations of antibodies in response to vaccination. In contrast, particular populations of leukocytes displayed differences between summer and fall. This suggests an ambient temperature effect but warrants further research to understand the leukocyte activity.

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

Figures and Tables:

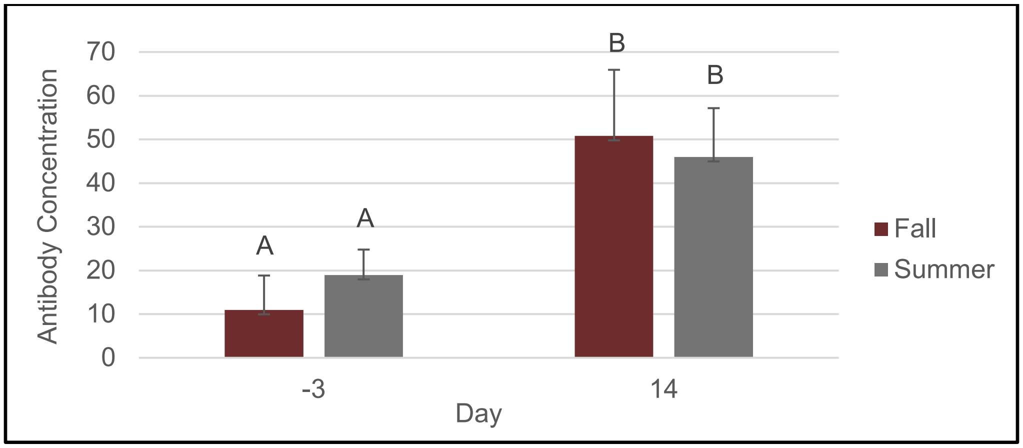


Figure 1: A comparison of BVDV antibody concentrations for cows vaccinated in the fall and summer for day -3 and 14.

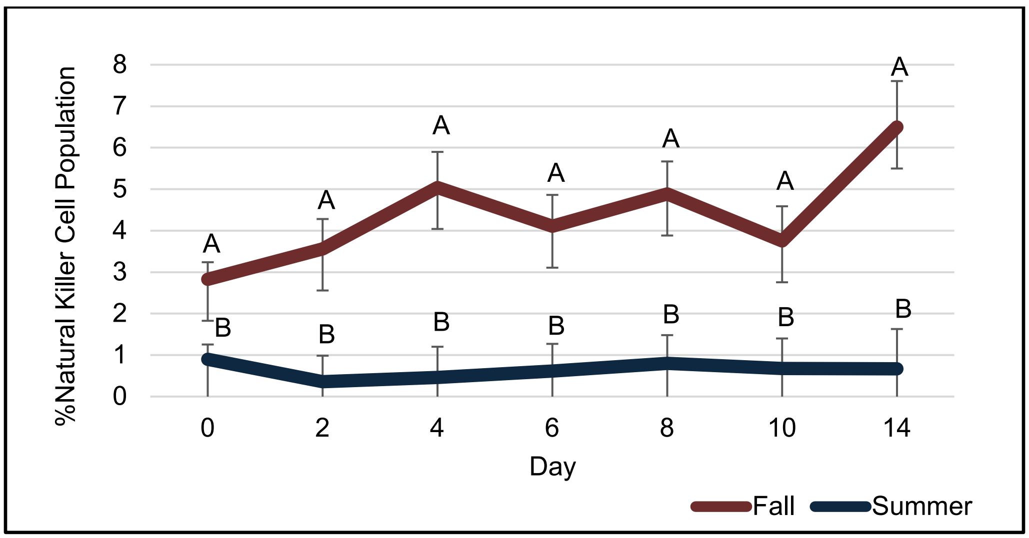


Figure 2: Natural killer cell population percentage over time among cows vaccinated in the summer and fall (P = <0.001).

Impact of refugia in a cow herd on efficacy of deworming treatments over a three-year period of time

Chloey P. Carson[1,] Sarah G. Blaske[1,2], Kaitlin M. Epperson[1,2], Jaclyn N. Ketchum[1,2], Lacey K. Quail[1,2], Thomas B. Hairgrove[2], Charles R. Long[1], and George A. Perry[1]

[1]Texas A&M AgriLife Research and Extension Center, Overton, TX, USA
[2]Department of Animal Science, Texas A&M University, College Station, TX, USA

Application: Anthelmintics, commonly referred to as dewormers, have been used for years to improve the health and performance of cattle. The misuse of these dewormers can inadvertently lead to a large population of resistant parasites, making dewormers less effective for parasite reduction.

Introduction: The two most common classes of dewormers are benzimidazoles (Synanthic®, Safeguard®, Panacur®, Valbazen®, etc.) and macrocyclic lactones (Ivermectin®, LongRange®, Cydectin®, Dectomax®, etc.). Many producers deworm their entire herds multiple times a year with the same dewormer. While the intention behind this practice is to eradicate the parasite population within the herd, many times this practice can cause more harm than good. This is due to treating cattle that may not require treatment, using a dewormer that has low efficacy within a herd, and/or by killing susceptible parasites but allowing any resistant parasites to survive and multiply (**Figure 1**). Our objective was to determine whether anthelmintic resistance changed within the Texas A&M Overton herd with the administration of several deworming methods.

Materials and Methods: The management practice of deworming all animals multiple times a year was changed to incorporate refugia into the mature cow herd. For a three-year period of time, cows in the reproductive herd that were 18 months and older were assigned to one of two treatments 1) young cows (≤ 4 years of age) were dewormed once a year with a benzimidazole or 2) older cows (> 4 years of age) were not dewormed. Over the course of three years, a total of 470 calves at weaning were randomly assigned to one of six anthelmintic treatments: received a benzimidazole (Synanthic® 22.5% or Safeguard®), received a macrocyclic lactone (Dectomax® or LongRange®), received a combination of the two (LongRange® and Synanthic®) or received no anthelmintic (Controls). Fecal samples were collected pre-treatment and 14- or 28-days post-treatment dependent on treatment, and at 42 days post-deworming. A fecal egg count was performed on each sample to determine parasite eggs per gram of feces (eggs/g; EPG). Resistance was calculated using the Fecal Egg Count Reduction Test (FECRT):

% RESISTANCE = (post-treatment EPG - pre-treatment EPG) / (pre-treatment EPG) x 100

Results: Over the three-year period of this study there was a significant difference between the efficacy of each of the treatments. Benzimidazoles and the combination treatment were more effective than macrocyclic lactones alone ($P < 0.01$), and all dewormers were more effective than not deworming at all ($P < 0.01$). There was, however, no change in percent decrease for any treatment over the course of the study (treatment by year; $P = 0.25$; **Figure 2**).

Conclusion: With several deworming products used, there was no change in the percent reduction/resistance to any deworming protocol during this study. Thus, incorporating refugia did not change the efficacy of any of the tested dewormers over the three-years of this study. Future research will focus on screening animals prior to assigning a deworming treatment in order to increase parasite refugia.

Acknowledgements: This research was supported by donations from Boehringer Ingelheim (Synanthic and LongRange) and Multistate Hatch project 9835.

Figures and Tables:

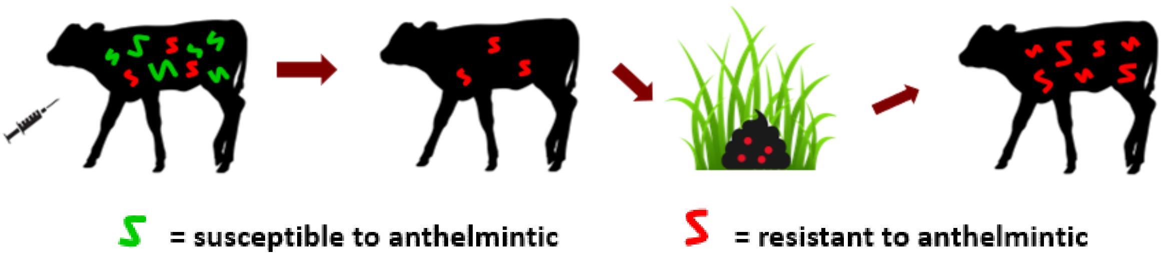


Figure 1: Over time, anthelmintic resistance can increase within a pasture and/or herd. Through continuous anthelmintic treatment with the same compound, susceptible parasites are killed off, leaving only resistant parasites behind. This leads to larger numbers of resistant parasites, which can pose a problem for producers.

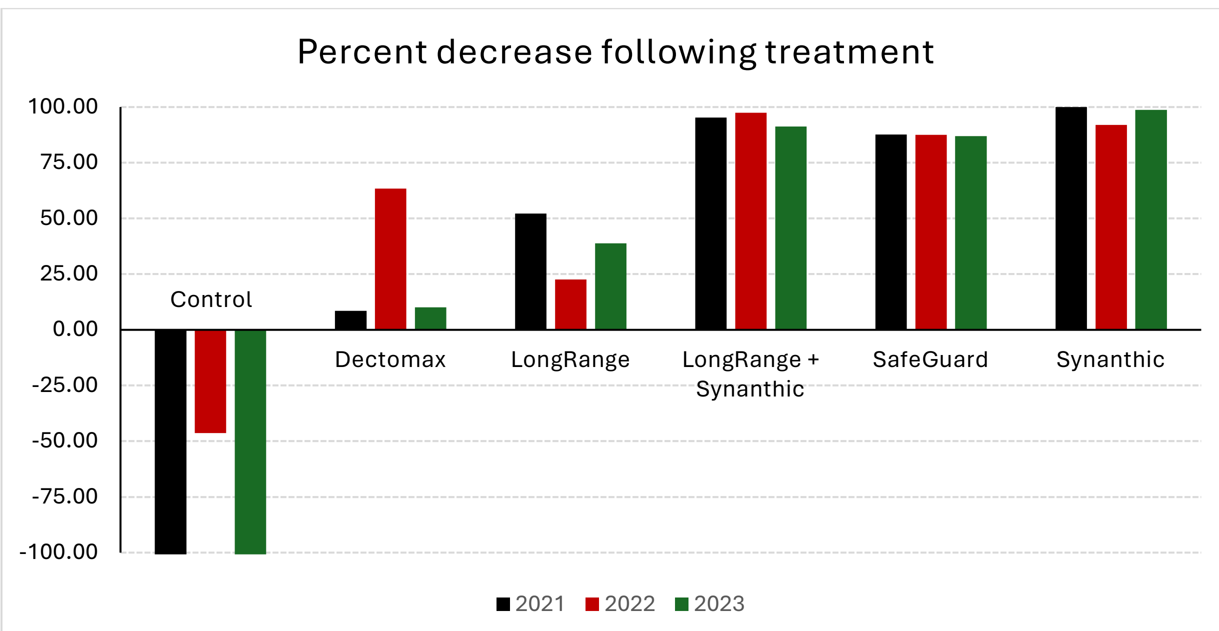


Figure 2: The percent decrease in parasite population between the five administered treatments compared to controls (not dewormed) over the course of the three-year study. It should be noted that 2022 was a drought year, which influenced parasite load due to forage height and availability. Controls had increased percentages of EPG for all years of the study.

Investigation of the epigenetic effects of prenatal stress on Brahman calves

T. Welsh Jr.[1,2], R. D. Randel[1,3], D.G. Riley[1,2], R.C. Cardoso[1,2], G. A. Perry[1,3], and C. R. Long[1,3]
[1]Department of Animal Science, Texas A&M AgriLife Research, [2]College Station and [3]Overton

Introduction: The American beef industry's motivation to identify stressors and alleviate their mechanisms of action is based on an affinity for animals coupled with the increased cognizance of stress' relationship with health, productivity, product quality, as well as workplace and animal safety. The concept that one's health begins *in utero* recognizes that prenatal stimuli may also shape the health, well-being, and performance of one's descendants. Animal agriculture is not stress-free. Many production practices such as weaning, ear tagging, branding, castration and vaccination may elicit physiological and behavioral responses in calves. Other factors such as social mixing and transportation may activate coping or behavioral reactions with associated physiological responses. Calves may experience stress prenatally via environmental or managerial stressors encountered by pregnant cows (e.g., handling, transportation, changing nutrient environment, heat stress). We developed a prenatal transportation stress model 30 years ago; it uses a consistent method of hauling pregnant cows to impose stress upon the cow to affect physiological and behavioral systems of the developing calf.

Justification: Global competitiveness of U.S. agriculture urgently needs an enhanced understanding of the critical biological and physiological mechanisms underlying animal production. The concept of *"no production without reproduction"* is underscored by recognition that the livestock industry loses over $1 billion dollars annually due to reproductive inefficiencies. Sustainable competitiveness of U.S. animal agriculture depends on reproductive efficiency of food animals. Regarding cattle, the Brahman breed is vital to the beef industry in the tropical areas of the world and the Southern United States as the nine states of Texas, New Mexico, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Georgia, and Florida comprise 37.1% of the U.S. beef cow herd (approximately 10.893 million head). Our ongoing study of epigenetic marks on the DNA in specific cells and tissues of a tropically adapted breed that is a prominent source of hybrid vigor for commercial cross-bred beef cattle is highly relevant, especially in view of climate variability predictions. As one's health begins *in utero*, our project represents a foundational step for the investigation of how induced epigenetic changes impact the germline and long-term productivity of bulls and cows (Figure 1).

Epigenetics: The concept that the nature of one's life is shaped by the interaction of genetic and environmental factors was expanded by Waddington's concept of the *'epigenotype'*, the complex developmental processes that link an animal's genotype and phenotype. Epigenetics encompasses the study of stable and heritable chemical modifications of DNA that affect gene expression, including methylation of DNA. The Brahman herd at the Texas A&M AgriLife Research Center represents a unique resource. Tissue and DNA samples have been obtained from each calf, and calves have been phenotyped for temperament, growth, immune, endocrine, reproductive, and stress response traits over the past 20 years. Results that encompassed basic and applied research at the molecular (DNA methylation, RNA-Seq), cellular (spermatozoa, pre-implantation embryos), and organ system (testis) levels are summarized in the following section.

Summary of our prior studies that applied the prenatal transportation stress model. In the early 1990s we developed a prenatal transportation stress (PNS) model to investigate the impacts of *in utero* stress on postnatal stress responsiveness, immune function, and behavior of bulls and heifers. More recently we generated PNS and Control calf crops in 2012, 2018, and 2021 to study enduring transgenerational effects of prenatal stress on health, growth, and reproductive traits. Stress-related hormones are associated with energy mobilization, protein degradation, reduced fertility, and blunted immunity. The PNS calves were more stress responsive than Control calves through weaning (elevated temperament and adrenocortical function). In response to restraint stress, PNS calves at 10- and 150-d of age maintained elevated plasma cortisol for a longer duration. PNS increased pituitary gland weight in fetal calves and slowed clearance of exogenous cortisol in suckling calves. PNS bull calves had an enhanced pro-inflammatory response (TNF-α, IFN-γ) to an endotoxin challenge compared to non-stressed calves. With USDA grant support we reported that PNS induced differential DNA methylation of genes related to the physiological control of behavior, immune function, and stress response in suckling Brahman heifer and bull calves. The persistence of PNS-induced differences in leukocyte DNA methylation and its concordance with gene expression was observed in cows up to 5 years of age. We recently reported increased temperament, elevated serum cortisol, and diminished leukocyte telomere length in 25-day-old PNS heifers and bulls (telomeres are DNA's protective caps at the ends of chromosomes). Changes in behavior and stress responsiveness are the early, notable outcomes of prenatal stress. Our current research found metabolomic differences in PNS calves (i.e., increased energy metabolites) and differential expression in the adrenal gland of genes associated with energetics, nitrogen balance, and immune system pathways. Though the mechanisms controlling these alterations are unclear, a challenged fetal environment is linked to changes in DNA methylation, which may modulate postnatal physiological functions.

Future Work: The enduring effect of stress was recognized by Hans Selye (known as the father of stress biology): *"Every stress leaves an indelible scar, and the organism pays for its survival after a stressful situation"*. In the case of prenatal stress, the 'scars' may be epigenetic marks and the payment may be the biological and economic consequences of impaired health. We are investigating how stress encountered by a dam during gestation elicits epigenetic changes in the calf's developing cells, changes which may elicit postnatal effects. Economic and animal welfare considerations are the impetus to reduce negative effects of stressors. An increased understanding of genetic and environmental interactions will lead to the development of alternative management practices to improve health, growth and performance of beef cattle.

Acknowledgement: The authors thank their collaborators, staff, students and the support of USDA-NIFA (2018-67015-281312; 2019-67015-2957), Western Regional Projects TEX03212, Hatch Project TEX09377, Multistate Project W4173, Texas A&M University One Health Initiative, and Texas A&M AgriLife Research, Overton.

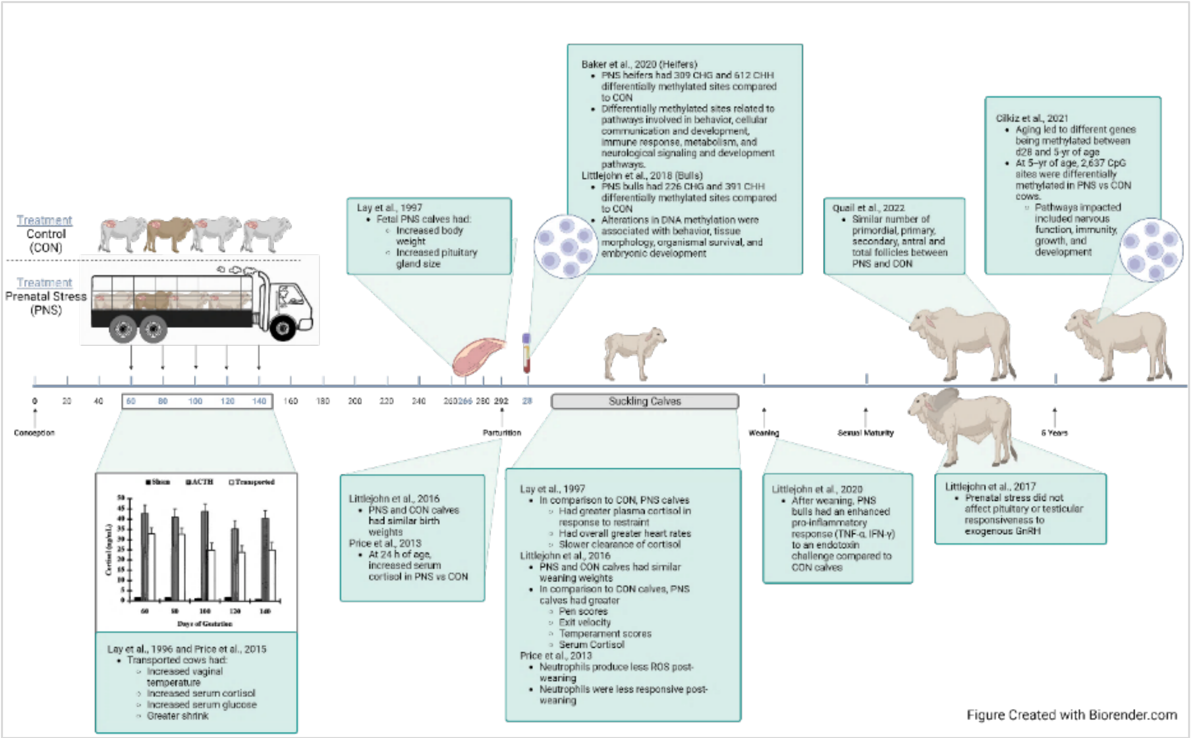


Figure 8. Diagrammatic summary of our studies that assessed endocrine, behavioral, immune, and epigenetic influences of *in utero* stress (i.e., prenatal transportation stress) on calves.

Abstracts on parameters of cattle grazing on pasture and range

Effect of Stocking Rate During Gestation on Subsequent Performance of Growing Beef Cattle

D. R. Tolleson[1], F. M. Rouquette[2], K. Norman[2], C. R. Long[2]

[1] Texas A&M AgriLife Research, Sonora TX; [2] Texas A&M AgriLife Research, Overton TX

Beef cows in the southeastern United States are likely maintained on pasture during mid-gestation, a critical period for fetal development of traits important to performance of the growing/finishing calf. Climate projections are for increased warming with highly variable precipitation in this region. Forage quantity and quality are affected by temperature and precipitation. Thus, in order to obtain a better understanding of downstream effects from cow nutrition during gestation on subsequent performance of growing cattle, we analyzed 579 records of crossbred steers and heifers born (fall and winter) to cows grazing typical forages in Overton, Texas. Cows were involved in a long-term stocking rate study and were assigned to either high (H; 4 cow/calf ha^{-1}) or low (L; 2 cow/calf ha^{-1}) treatment groups. Cow body condition scores (BCS; 1–9) were collected at breeding and weaning. Calves produced were pastured from weaning to approximately 1 to 1.5 yr of age, then shipped to a commercial feedlot and subsequently slaughtered at a commercial facility. Calf data included birth weight, weaning weight (~240 d), yearling weight, on-feed weight, final pre-harvest weight, hot carcass weight (all weights in kg), dressing percentage, marbling score, yield grade, backfat thickness (cm), ribeye area (cm^2), and kidney-pelvic-heart fat (%). Differences ($P < 0.05$) between treatment

groups were determined by a general linear model in SAS with stocking rate as the main effect. Mean separation was accomplished using Tukey's test. Cow BCS (H; 4.27 ± 0.06 vs L; 5.64 ± 0.07, $P < 0.0001$), final pre-harvest weight (H; 594.80 ± 6.18 kg vs L; 619.85 ± 6.12 kg, $P < 0.005$), hot carcass weight (H; 366.60 ± 3.89 kg vs L; 383.17 ± 3.74, $P < 0.003$), and ribeye area (H; 90.52 ± 0.90 cm^2 vs L; 93.74 ± 1.03 cm^2, $P < 0.03$) were all lower in H than L. Calf weaning weight followed a similar trend (H; 289.24 ± 2.58 kg vs L; 296.56 ± 3.08 kg, $P < 0.07$). Diminished nutritional provision to the fetus during mid-gestation was apparently manifest as epigenetic effects on offspring performance.

Nutritional Monitoring of Prenatally Stressed and Translocated Brahman Heifers

D. R. Tolleson[1], R. D. Randel[2], G. A. Perry[2], J. M. Diaz[1], H. D. Starns[1], C. W. Knight[3], C. R. Long[2], N. E. Garza[1], S. L. Beall[1], D. A. Neuendorff[2], T. H. Welsh Jr[4]

[1]Texas A&M AgriLife Research, Sonora TX; [2]Texas A&M AgriLife Research, Overton TX; [3]University of Maine, Orono ME; [4]Texas A&M Univ. Animal Science Dept., College Station TX

One drought mitigation strategy is transporting livestock to non-drought locations. Our objective was to evaluate the effects of prenatal stress and translocation on growing Bos indicus heifers. Twelve heifers born in spring 2019 at Overton, TX (1245 mm annual precipitation) were transported ~700 km to Sonora, TX (610 mm annual precipitation) in April 2020. Six heifers (283±10 kg) were born to dams subjected to transportation stress during mid-gestation (PNS) and 6 (279±17 kg) were born to non-stressed dams (CON). Heifers grazed a series of 24-ha native range pastures (aboveground forage biomass; 1508±390 kg/ha) and were sampled (non-shrunk BW/BCS score, feces) at 2-wk intervals from May through September. Fecal samples were collected from the ground or the rectum of each animal and stored at -20^{o} C until processed for near infrared spectroscopy (NIRS) and prediction of diet crude protein (CP) and digestible organic matter (DOM). Inputs to a grazing animal nutrition model for prediction of BW included diet CP and DOM, age, and weather. Differences between groups for BW and nutritional parameters were determined by analysis of variance or paired t-test. Both groups gained BW (22±4 kg) throughout the study, there were no differences ($P > 0.1$) due to treatment. Diet CP and DOM were affected by date ($P < 0.01$) as diet quality declined from spring to fall. Percent diet CP was greater ($P < 0.05$) in PNS than CON, especially during July and August (6.94±0.10 vs 6.23±0.17, respectively). Corresponding values for diet DOM were (59.53±0.55 vs 59.14±0.43, respectively; $P = 0.09$). Observed vs model-predicted weight was different ($P < 0.05$) for both groups when using CP-based outputs, but not when using metabolizable protein-based outputs ($P > 0.1$). In summary, PNS heifers selected a diet of greater CP than CON, and tended to select a diet greater in DOM.

Relationships between Diet Quality and Serum Metabolic Indicators in Prenatally Stressed Growing Bos Indicus Heifers

D. R. Tolleson[1], R. D. Randel[2], G. A. Perry[2], C. W. Knight[3], C. R. Long[2], T. H. Welsh Jr[4]

[1]Texas A&M AgriLife Research, Sonora TX; [2]Texas A&M AgriLife Research, Overton TX; [3]University of Maine, Orono ME; [4]Texas A&M Univ. Animal Science Dept., College Station TX

Our research group has previously reported on grazing behavior, diet selection, and weight change in prenatally stressed and translocated Brahman heifers grazing native rangeland. Our current objective was to evaluate relationships between diet quality and metabolic indicators. Twelve yearling heifers were transported ~700 km from Overton, TX to Sonora, TX. Six heifers (283±10 kg) were born to dams subjected to transportation stress during mid-gestation (PNS) and 6 (279±17 kg) were born to non-stressed dams (CON). Heifers grazed a series of 24-ha native range pastures and were sampled (BW, BCS score, blood, and feces) at 2-wk intervals from May through September. Fecal samples collected from the ground or the rectum of each animal were stored at -20º C until processed for near infrared reflectance spectroscopy prediction of diet crude protein (CP) and digestible organic matter (DOM). Blood was obtained via coccygeal venipuncture and processed to yield serum. Serum analyses were obtained from the Texas A&M Veterinary Medical Diagnostic Laboratory. Relationships between constituents of interest were determined by linear regression. Significance was considered to be $P < 0.05$. Blood urea nitrogen (BUN; mg/dL) was greater ($P = 0.04$) in PNS (8.39±0.32) than CON (7.39±0.33). Positive correlations were found between CP and BUN (RSQ = 0.76, SE = 1.25 mg/dL; $P < 0.001$), albumin (RSQ = 0.57, SE = 0.06 mg/dL; $P < 0.01$), and average daily gain (RSQ = 0.63, SE = 0.47 kg; $P < 0.01$). Similar relationships were observed between DOM and glucose (RSQ = 0.64, SE = 3.91 mg/dL; $P < 0.01$), cholesterol (RSQ = 0.37, SE = 5.47 mg/dL; $P < 0.05$), and average daily gain (RSQ = 0.47, SE = 0.56 kg; $P < 0.01$). PNS affected circulating nitrogen concentration. Diet quality was related to weight gain and serum indicators of nutritional status.

Effect of Prenatal Stress on Metabolism of Heifers Translocated to an Unfamiliar Environment

D. R. Tolleson[1], R. D. Randel[2], G. A. Perry[2], C. W. Knight[3], C. R. Long[2], T. H. Welsh Jr[4]

[1]Texas A&M AgriLife Research, Sonora TX; [2]Texas A&M AgriLife Research, Overton TX; [3]University of Maine, Orono ME; [4]Texas A&M Univ. Animal Science Dept., College Station TX

Objective: To evaluate the effects of translocation to an unfamiliar grazing environment in prenatally stressed (PNS) versus control (CON) yearling Brahman heifers. We have previously reported that these PNS heifers traveled farther each day and farther from water than CON. The PNS group selected a higher quality diet than CON but weight gain was not different between the two groups. Methods: Twelve half-sibling heifers (~12 months of age and 280±10 kg) born in spring 2019 at Overton, TX (1245 mm annual precipitation) were transported ~700 km southwest to Sonora, TX (610 mm annual precipitation) in April 2020. Six heifers were born to dams subjected to transportation stress during mid-gestation and six were born to non-stressed dams. Heifers grazed a series of 24-ha native range pastures (aboveground forage biomass; 1508±390 kg/ha). Serum samples, via coccygeal venipuncture, were obtained at 2-wk intervals from May through September. Differences between groups for metabolic parameters (albumin, blood urea nitrogen [BUN], glucose, cholesterol, beta hydroxybutyrate, and non-esterified fatty acids [NEFA]) were determined by a mixed model with treatment fixed and date repeated. Statistical significance was determined at $P < 0.05$. Results: Only BUN (mg/dL) differed ($P = 0.04$) between PNS (8.39±0.32) and CON (7.39±33). Albumin and glucose were numerically greater in PNS versus CON, while cholesterol and NEFA were numerically lower. Conclusions: Prenatal transportation stress enhanced adaptations to subsequent stressful situations in growing heifers via grazing behavior and diet selection. These adaptations resulted in greater circulating nitrogen concentration but did not result in greater weight gain. Further work with more animals and larger landscapes is required to determine how prenatal stress may fit grazing animals for future stress.

The Interaction of Prenatal Stress and Translocation to an Unfamiliar Landscape on Grazing Behavior in Brahman Heifers

C. W. Knight[3], D. R. Tolleson[1], T. H. Welsh Jr[4], H. D. Starns[1], N. E. Garza[1], J. M. Diaz[1], S. L. Beall[1], C. R. Long[2], D. A. Neuendorff[2], R. D. Randel[2]

[1]Texas A&M AgriLife Research, Sonora TX; [2]Texas A&M AgriLife Research, Overton TX; [3]University of Maine, Orono ME; [4]Texas A&M Univ. Animal Science Dept., College Station TX

Stress experienced by the dam during gestation affects subsequent physiological functions in the offspring. Transportation is a stressor for livestock. Increasing climate variability (drought) may result in an increase in livestock being moved from "dry" to "wet" locations. The effects of prenatal transportation stress on offspring grazing behavior is unknown. We utilized 12 Brahman (Bos indicus) heifers (~12 mo, 300 kg); 6 from dams subjected to transportation stress during mid-gestation (PNS) and 6 from non-stressed dams (CON), in an effort to determine the interaction between prenatal stress and translocation to an unfamiliar landscape on grazing behavior. Heifers were moved from Overton Texas (32.3 N, 95.0 W; 1245 mm annual precipitation) to Sonora Texas (30.6 N, 100.6 W; 610 mm annual precipitation) in April, 2020. Each treatment group grazed a separate but adjoining 24-ha pasture during 2 experimental grazing periods (28 d). GPS location data were collected from 21 July 2020 to 18 August 2020. Distance from water, elevation, slope, distance traveled, and rate of travel data were collected every 10 min. Prior 90-day precipitation was 356 mm for Period 1 and 164 mm for Period 2. Dry matter standing crop ($P > 0.1$) was 1265 ± 138 and 1060 ± 199 kg/ha for the PNS and CON pastures respectively in mid-Period 1; 849 ± 137 and 1134 ± 180 kg/ha in mid-Period 2. No differences were detected between CON and PNS heifers for rate of travel, maximum distance spent from water, or slope and elevation utilization ($P>0.1$). On average, PNS heifers spent time 116 m further from water than CON ($P = 0.003$). In addition, PNS heifers tended to travel further per day,4264 m, when compared to CON heifers, 3377 m ($P =0.064$). Prenatal stress appeared to manifest in grazing behavior differences in these Brahman heifers.

Developing models that could estimate the nutritive value of bermudagrass forage on a daily basis during the livestock grazing season

Prem Woli[1], Francis M. Rouquette Jr.[1], Charles R. Long[1], Luis O. Tedeschi[2]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Animal Nutrition Department, Texas A&M University, College Station, TX

Application: By incorporating the daily change trends of crude protein (CP), neutral detergent fiber (NDF), lignin, and ash values of bermudagrass forage that we identified into a nutritive value prediction system, the users of the system could make accurate estimates of daily total digestible nutrients (TDN). These nutritive value models could be a valuable asset in more accurately studying the impacts of various management strategies and environmental factors on forage nutritive value and animal performance.

Introduction: Given the fact that forage nutritive values change during the grazing season due to changes in weather and plant maturity, we hypothesized that the CP, NDF, lignin, ash, and TDN concentrations of a pasture forage would change daily. Accordingly, we developed models to estimate the daily values of CP, NDF, lignin, and ash concentrations of bermudagrass forage during the grazing season, which could be used in summative equations to estimate daily TDN values.

Materials and Methods: The CP, NDF, lignin, and ash concentrations of bermudagrass forage spanning several years and comprising 59 to 1146 observations, depending on the variable, were obtained from Overton, TX. Those forage samples comprised hand-plucked plant parts intended to estimate animal-selected diets. Then, an empirical model for each nutritive variable was developed with the day of year as an input variable (Fig. 1). Next, by incorporating these models into a pre-existing summative equation, daily values of bermudagrass TDN were estimated. Finally, the nutritive value models were evaluated by comparing the predicted values of TDN with the observed ones.

Results: The nutritive value models that were developed to estimate the CP, NDF, lignin, and ash concentrations of bermudagrass pasture on a daily basis were as follows:
$CP_i = 39.5 - 0.2095\boldsymbol{i} + 0.0004\boldsymbol{i}^2$,
$NDF_i = 13.9 + 0.4713\boldsymbol{i} - 0.00095\boldsymbol{i}^2$,
$Lignin_i = -2.2 + 0.0564\boldsymbol{i} - 0.00011\boldsymbol{i}^2$,
$Ash_i = 5.9 - 0.007\boldsymbol{i}$,
where the $\boldsymbol{i}$ stands for the i-th day of year (between 90 and 300) during the grazing season. The evaluation results indicated that the nutritive value models were reliable (Table 1).

Conclusion: This work developed models to estimate the daily values of CP, TDN, lignin, and ash concentrations for bermudagrass forage during the grazing season and use them in estimating daily TDN. The daily nutritive value models will help accomplish the goal of more accurately predicting expected daily gains from stocker cattle on bermudagrass pastures by providing the knowledge of day-to-day animal requirements and changes in forage nutritive values.

Acknowledgements: Funding for the long-term experiments was provided by Texas A&M AgriLife Research at Overton. Special appreciation is extended to Kelli Norman, Gary Nimr, Joel Kerby, and Kyle Turner for collecting and storing the data.

Figures and Tables:

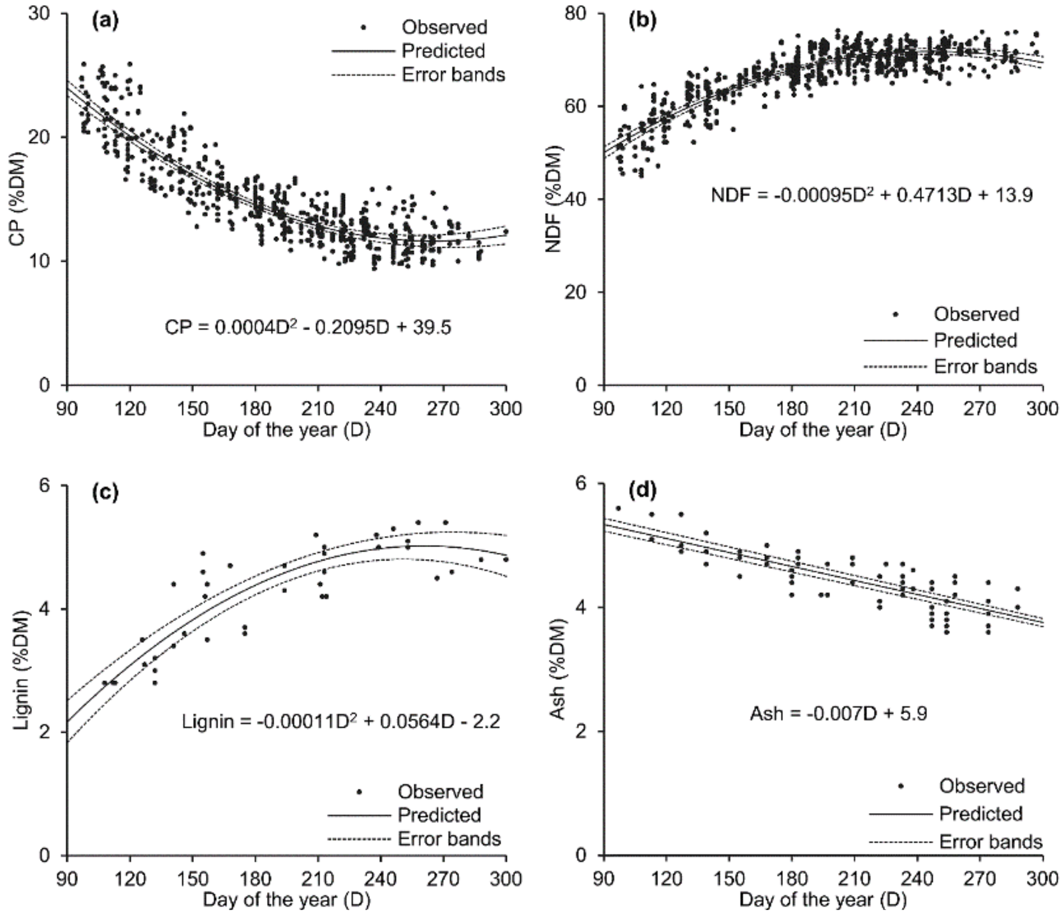


Figure 1. The observed and predicted values of CP, NDF, lignin, and ash concentrations of bermudagrass forage during the grazing season (Apr 1 to Nov 15) at Overton, TX. The dotted lines above and below the predicted lines are the confidence intervals at the 95% level.

Table 1. The performance of different models to predict the forage nutritive value of Coastal bermudagrass as shown by the Willmott index (WI), modeling efficiency (ME), R^2, root mean square error (RMSE), and percent error (PE)

Nutritive value model	**WI**	**ME**	**R^2**	**RMSE**	**PE**
CP_i[1] = 39.5 - 0.2095i + 0.0004i^2	0.95	0.83	0.85	1.65	10.9
NDF_i = 13.9 + 0.4713i - 0.00095i^2	0.92	0.70	0.73	3.08	4.6
Lig_i = -2.2 + 0.0564i - 0.00011i^2	0.90	0.64	0.67	0.41	8.8
Ash_i = 5.9 – 0.007i	0.87	0.64	0.65	0.29	6.6
TDN_i = f(Ash_i, CP_i, Lig_i, NDF_i)	0.93	0.72	0.78	1.39	2.3

[1] The subscript **i** stands for the i-th day of the year.

Incorporating a variable structural coefficient into the summative equation for estimating daily total digestible nutrients for bermudagrass pasture more accurately

Prem Woli[1], Francis M. Rouquette, Jr.[1], Charles R. Long[1], Luis O. Tedeschi[2], Guillermo Scaglia[3]
[1] Texas A&M AgriLife Research and Extension Center, Overton, TX
[2] Department of Animal Science, Texas A&M University, College Station, TX
[3] LSU AgCenter Iberia/Dean Lee Research Station, Alexandria, LA

Application: For estimating the total digestible nutrients (TDN) concentrations of a warm-season perennial grass and energy available for grazing cattle, the forage-beef modeling community and commercial laboratories have been using the summative equation with its structural coefficient containing a fixed value as a standard method. However, since the animal nutrition and growth processes are continuous due to changes in season, weather, and forage/animal maturity, the variable structural coefficient model that we incorporated into the summative equation has provided scientists and the stakeholders with an option for estimating TDN more accurately.

Introduction: In forage-animal nutrition modeling, diet energy is estimated mainly from the forage TDN, which in turn is often estimated using summative equations. Early summative equations contained a structural coefficient (SC) with a constant value to reflect an association between lignin and cell wall components. However, for forages with nutritive values that keep changing during the grazing season owing to changes in weather and plant maturity, a constant SC value could add a systematic bias to prediction because it is associated with the variable lignin-to-NDF ratio. Thus, we developed a model that could estimate SC on a daily basis.

Materials and Methods: To develop the variable SC model, first, a number of TDN curves with different values of SC ranging from -0.6 to 2.2 were created by computing the daily values of bermudagrass TDN during the grazing season. Second, the trendline of the observed TDN values was superimposed on those TDN curves (Fig. 1). Third, the day of year (DOY) values associated with the intersections between the trendline and the TDN curves were noted. Finally, by regressing the DOY values against the associated SC values, the variable SC model to estimate SC as a function of DOY was developed (Fig. 2).

Results: The developed model that can estimate the daily values of SC for bermudagrass pasture during the grazing season is as follows.
$SC_i = -0.0051\boldsymbol{i} - \frac{614}{\boldsymbol{i}} + 5.79$, where **i** stands for the i-th day of year (between 100 and 300). Evaluation results indicated that the summative TDN equation with the variable SC model was able to mimic the observed values of TDN satisfactorily (Fig. 3). Unlike the constant SC, the variable SC predicted more closely the forage nutritive value throughout the grazing season.

Conclusion: This study demonstrated that since the nutritive value of a pasture forage changes continuously during the grazing season due to changes in weather and plant maturity, the SC had to be variable. Accordingly, we developed a model to estimate SC on a daily basis, and thus modified the summative equation to estimate the daily values of TDN during the grazing season.

Acknowledgements: This work was funded by Texas A&M AgriLife Research at Overton.

Figures and Tables:

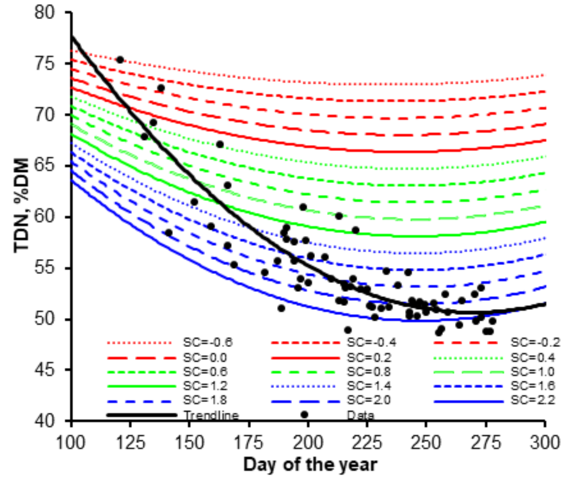


Figure 1. The observed, trendline, and estimated values of TDN with various values of structural coefficient (SC) for bermudagrass pasture grazed in the southern US during April-October.

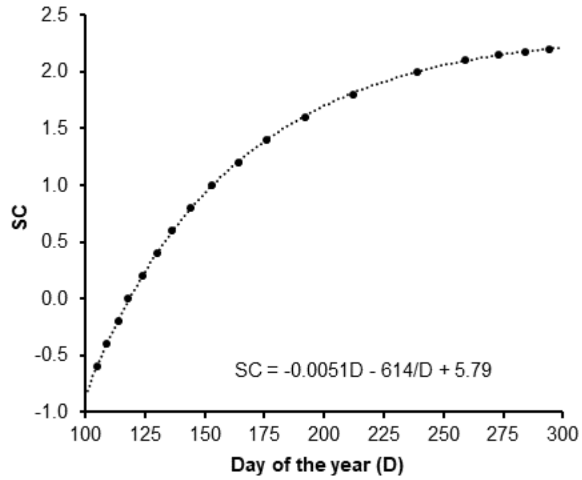


Figure 2. Values of structural coefficient (SC) for various days of year during April-October

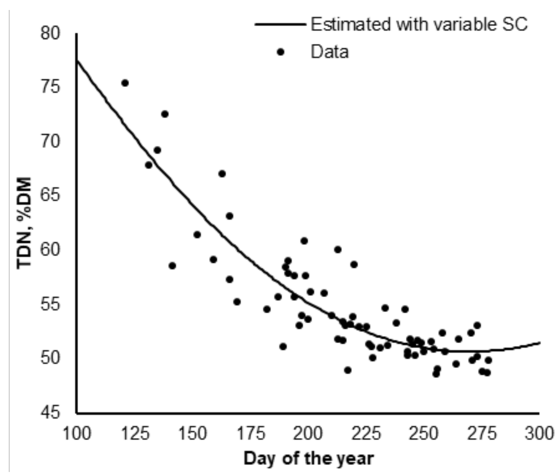


Figure 3. The observed and estimated values of bermudagrass TDN during April-October

Developing a daily gain model for stockers grazing bermudagrass in the southern United States by modifying the NRC (1984) weight gain model

Prem Woli[1], Francis M. Rouquette, Jr.[1], Charles R. Long[1], Luis O. Tedeschi[2], Guillermo Scaglia[3]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Department of Animal Science, Texas A&M University, College Station, TX
[3]Department of Animal Sciences, North Dakota State University, Fargo, ND

Application: This work developed a daily weight gain model for large-frame stockers grazing bermudagrass in the southern US by assembling some of the classic works in forage-beef modeling from the last 50 years and incorporating some adjustments for grazing bermudagrass. By predicting the daily performance of grazing stockers, the daily gain model may significantly contribute to forage-beef modeling for scientists and economic implications for stakeholders. The model may be useful to accurately reflect the impacts of daily weather conditions, forage nutritive values, seasonality, and plant and animal maturity on animal performance.

Introduction: The energy requirements, feed intake, and performance of grazing animals vary daily due to changes in weather, forage nutritive values, and plant/animal maturity throughout the grazing season. Hence, realistic simulations of daily animal performance can be made only by the models that can address these changes. Given the dearth of simple, user-friendly models of this kind, especially for pastures, this work developed a daily gain model for large-frame stockers grazing bermudagrass in the southern US.

Materials and Methods: For model development, we first assembled some of the classic works in forage-beef modeling in the last 50 years into the National Research Council (1984) weight gain model. Then, we tested it using the average daily gain (ADG) data obtained from several locations in the southern US, involving 9,567 stockers. The results showed that the performance of the NRC model was poor as it consistently underpredicted ADG throughout the grazing season (Fig. 1). To improve the predictive accuracy of the NRC model under bermudagrass grazing conditions, we made an adjustment to it by adding the daily departures of the modeled values from the data trendline. Subsequently, we tested the revised model against an independent set of ADG data, involving 4783 stockers.

Results: The values of various metrics used to evaluate the model demonstrated that the revised model mimicked the pattern of observed ADG data satisfactorily (Fig. 2). Unlike the original model, the revised model predicted more closely the ADG value throughout the grazing season.

Conclusion: The revised model is simpler than the existing mechanistic weight gain models, which are hard to interpret and challenging to apply as they require a myriad of inputs and parameters that are difficult for users to obtain or even to justify because of the spatial variability of animals, soils, and diverse management practices. Thus, the revised model could be more accurate and convenient for the users who have interest in biological and economic applications.

Acknowledgements: Partial funding for this work was provided by Texas A&M AgriLife Research at Overton.

Figures and Tables:

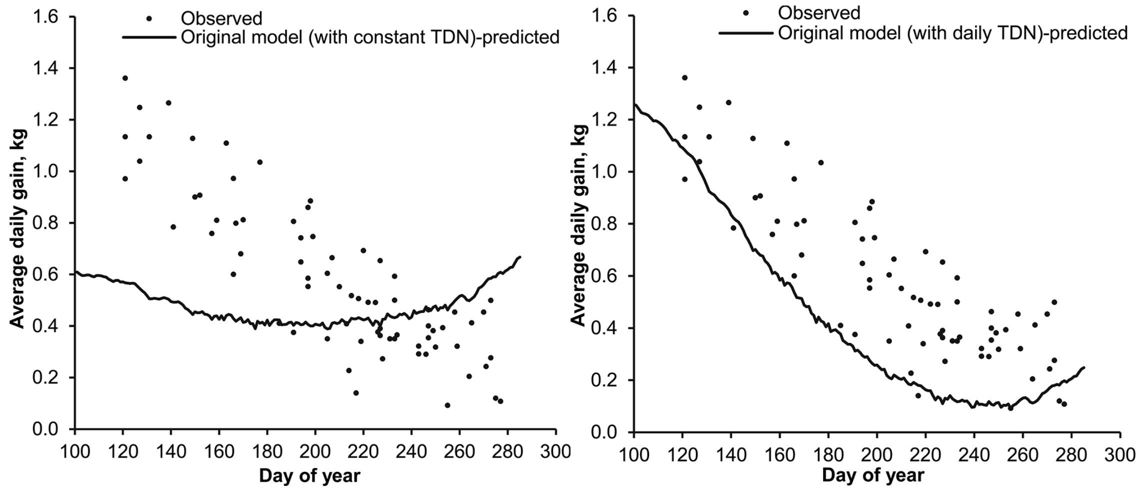


Figure 1. The observed average daily gain values and those predicted by the original weight gain model with constant TDN (left panel) and daily TDN (right panel) for large-frame stockers grazing bermudagrass in the southern US during May 1 through October 7.

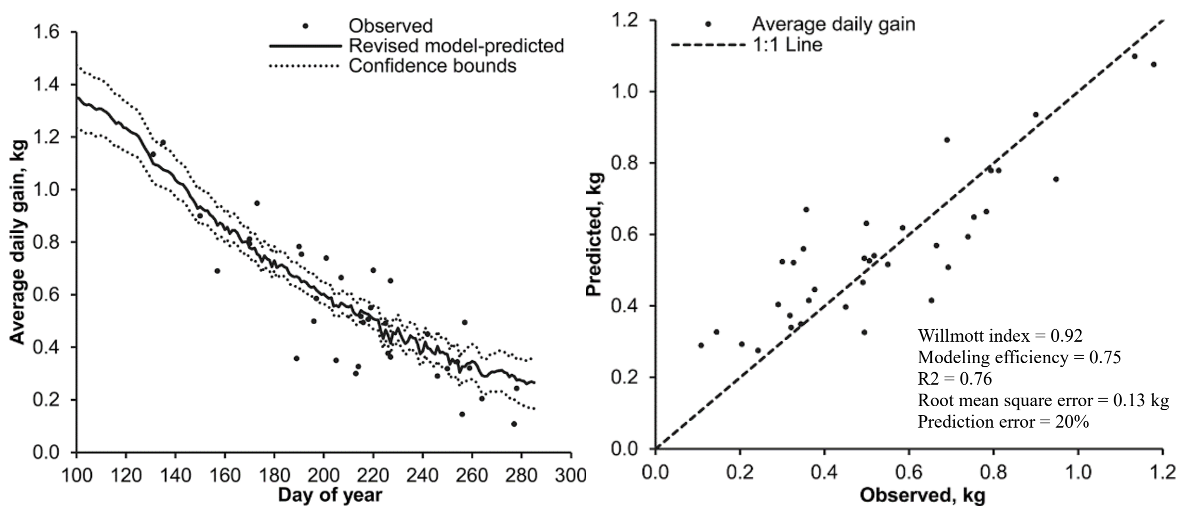


Figure 2. The observed and the revised model-predicted values of average daily gain for large-frame stockers grazing bermudagrass in the southern US during May 1 to October 7.
The right panel also shows the performance of the revised model.

Devising the pasture factor for estimating daily herbage intake of stockers grazing bermudagrass pasture as influenced by herbage mass and nutritive value

Prem Woli[1], Charles R. Long[1], Luis O. Tedeschi[2], Francis M. Rouquette Jr.[1]
[1]Texas A&M AgriLife Research and Extension center, Overton, TX
[2]Department of Animal Science, Texas A&M University, College Station, TX

Application: By incorporating an equation for pasture factor (PF), a fractional multiplier of potential herbage intake as influenced by herbage mass, into an herbage intake prediction system, the scientific community and relevant stakeholders can more accurately study the impacts of various management and environmental factors on daily herbage mass, herbage intake, and animal performance.

Introduction: The PF must represent the effects of both herbage mass and nutritive value. This study developed a 3-dimensional herbage mass-nutritive value-based PF that could be used in a daily gain model for estimating the herbage intake of stockers grazing bermudagrass.

Materials and Methods: We first derived an herbage allowance-based PF equation to account for the effects of stocking rate and animal body weight on herbage intake. We then calculated the values of critical herbage allowance (CHA), the herbage allowance (HA) below which herbage intake becomes limiting, for low, mid, and high nutritive values of bermudagrass from literature. Then, we evaluated the CHA values using data collected from humid, warm-climate regions. By regressing the CHA values against the calculated values of total digestible nutrients (TDN), a proxy for nutritive value, we then developed an equation to compute CHA from daily TDN.

Results: We derived the following equation to estimate PF from the herbage allowance and nutritive value of bermudagrass on a daily basis during the grazing season:

$$PF = \begin{cases} \frac{2HA}{CHA} - \frac{HA^2}{CHA^2}, & \text{if HA is less than CHA} \\ 1, & \text{otherwise} \end{cases}$$

We found 3.5, 2.3, and 1.3 kg DM per kg stocker body weight as the CHA values for low, medium, and high bermudagrass nutritive value, respectively (Fig. 1). We obtained the following equation to estimate daily CHA from bermudagrass TDN (Fig. 2):

$${}^{c}HA_i = 0.001TDN_i^{\,2} - 0.22TDN_i + 11.375.$$

Results showed that PF would be zero at zero HA and increase toward one with an increase in herbage allowance for all TDN values, with a steeper slope for a higher TDN value (Fig. 3).

Conclusion: Demonstrating that the herbage intake of stockers grazing bermudagrass pasture could be estimated as a function of herbage allowance and nutritive value on a daily basis, we developed the herbage allowance-nutritive value-based pasture factor for calculating the intake constrained by herbage mass. This pasture factor accounts for the 3-dimensional effects of stocking rate, animal BW, and herbage nutritive value on herbage mass and intake.

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Figures and Tables:

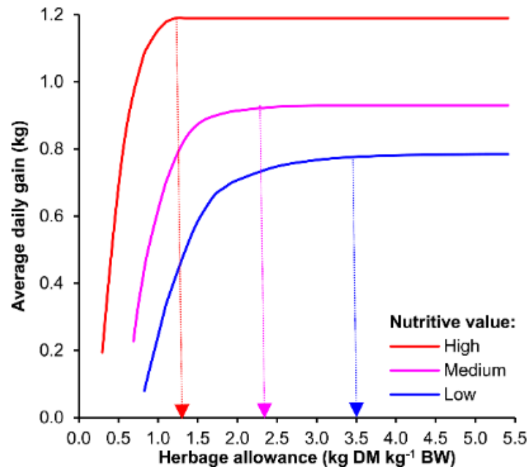

Figure 1. The bermudagrass herbage mass-stocker ADG relationships in the southern US as influenced by nutritive value, with vertical lines pointing to the critical herbage allowance values

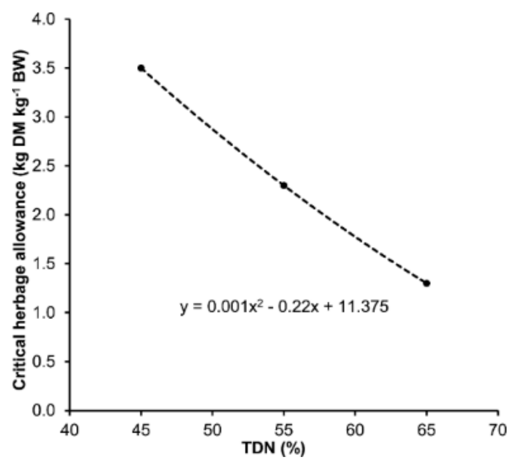

Figure 2. The critical herbage allowance (CHA) of warm-season perennial grass pasture grazed by stockers in the southern US as a function of TDN

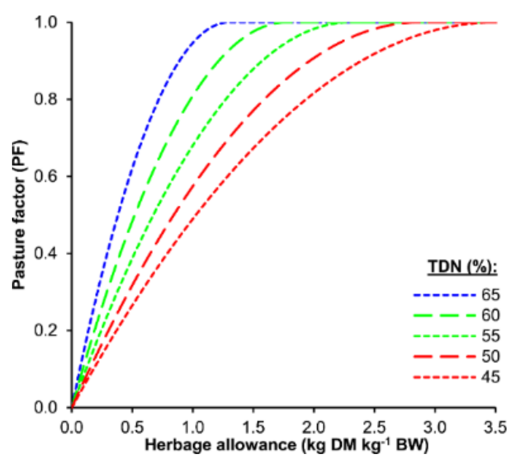

Figure 3. Response of the pasture factor to the herbage allowance and nutritive value (TDN) of warm-season perennial grasses (*Cynodon sp.*)

Predicting the daily gain of stockers grazing bermudagrass as influenced by age and body condition at the onset of grazing

Prem Woli[1], Charles. R. Long[1], Luis O. Tedeschi[2], Francis M. Rouquette Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Department of Animal Science, Texas A&M University, College Station, TX

Application: By incorporating the age-body condition adjustment factor (ABCF) into an average daily gain (ADG) prediction system, the scientific community and stakeholders can more accurately assess the effects of these attributes on animal performance and develop appropriate purchase pricing and supplementation strategies before and during stocking.

Introduction: No simple, reliable procedure exists for grazing stockers that can account for the variation in ADG based on their age and body condition at the onset of stocking on pastures. This study aimed to devise such a procedure for stockers grazing bermudagrass in the southeastern US.

Materials and Methods: Data on the ADG of stockers grazing bermudagrass in the southern US were obtained from multiple sources for various scenarios of initial age by body condition, involving a total of 2,816 calves. Then, an ABCF for each age by body condition scenario was calculated by dividing its ADG by the ADG of calves 7 to 10 mo old with body condition score (BCS) of 5, a standard age × BCS scenario. Finally, an ABCF equation was derived by regressing the ABCF values against the BCS values under each age group (Fig. 1).

Results: We derived the following ABCF equation to estimate the ADG of a stocker grazing bermudagrass pasture as $ADG' = ADG \times ABC_f$, where

$$ABCF = \begin{cases} -0.0281BCS + 0.7018 & \text{if age is 4 to 6 months} \\ -0.0500BCS + 1.2500 & \text{if age is 6 to 10 months} \\ -0.0614BCS + 1.5351 & \text{if age is 10 to 15 months} \end{cases},$$

where ADG and ADG', respectively, are the stocker's ADG before and after accounting for its initial age and BCS; BCS is the stocker's BCS at the onset of the gain phase ($3 \le BCS \le 9$); and age is the stocker's age (month) at this time. The ABCF value less than one would indicate reduced to no compensation and greater than one would indicate enhanced compensation. A larger ABCF value would suggest better compensatory gain.

Conclusion: The ADG of stockers grazing bermudagrass pasture during the growing season could be accurately estimated as a function of its age and body condition at the onset of the grazing season using an adjustment factor that accounts for the 2-dimensional effects of age and body condition on animal gain (Fig. 2).

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

Figures and Tables:

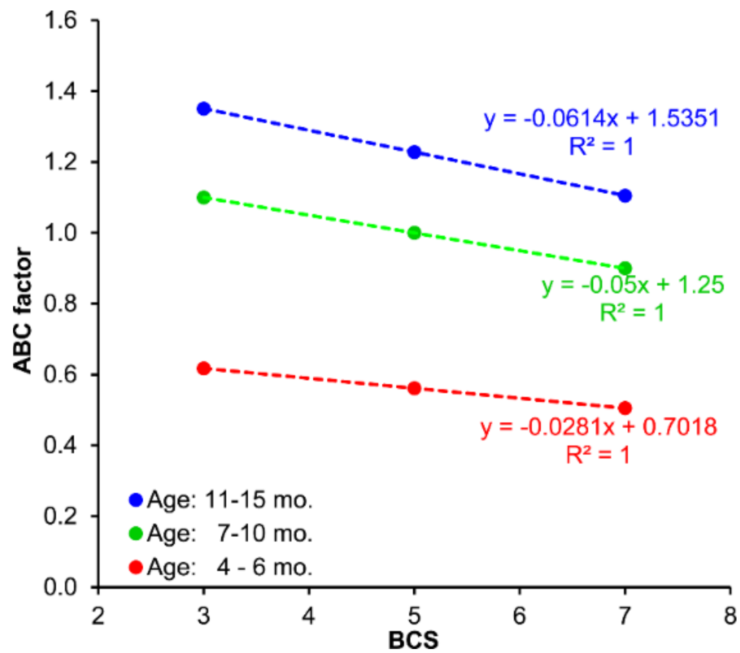

Figure 1. Relationship between the initial age (month) and condition score (BCS) of stockers grazing bermudagrass and the age-body condition factor (ABCF).

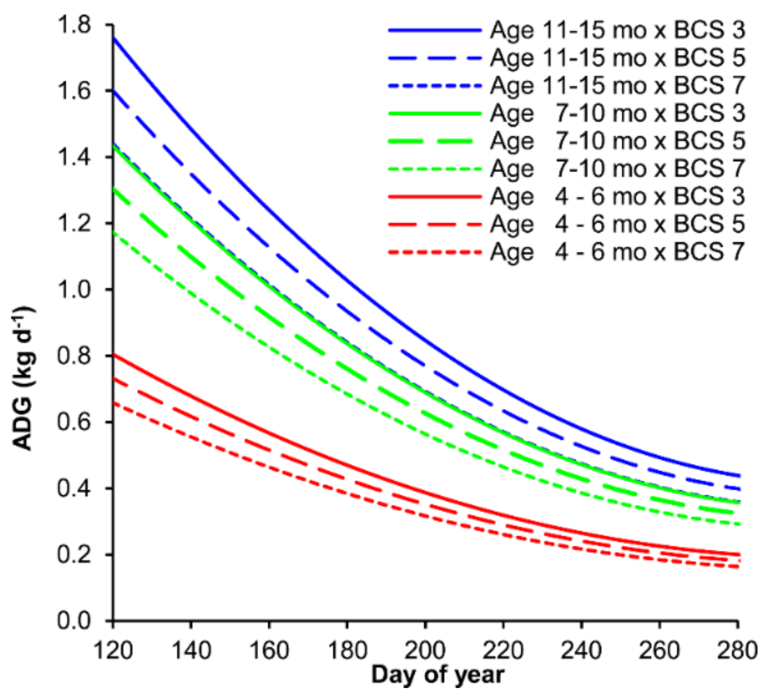

Figure 2. The ADG (kg/day) of stockers during the bermudagrass grazing season as influenced by their initial age (month) and body condition score (BCS).

Bermudagrass biomass and nitrate leaching responses to clipping frequency, soil type, and El Niño-Southern Oscillation as simulated by a crop model

Prem Woli[1], Francis M. Rouquette Jr.[1], Charles R. Long[1], Prasanna Gowda[2], Diego N. L. Pequeno[3]

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

[2]Grazinglands Research Laboratory, El Reno, OK

[3]Agrilcultural & Biological Engineering Dept., University of Florida, Gainesville, FL

Application: The findings of this study may be helpful to Coastal bermudagrass forage producers in the southern US in identifying soil- and weather-specific clipping frequencies for optimizing forage production while minimizing the nitrate contamination of groundwater.

Introduction: Coastal bermudagrass is the basic forage for many livestock production systems in the southern US. The agro-environmental studies on this grass, however, are limited for this region. This study, using the Decision Support System for Agrotechnology Transfer (DSSAT) suite of crop models, assessed the bermudagrass dry matter (DM) yield and N leaching responses to clipping interval, soil type, and El Niño-Southern Oscillation (ENSO) in the Pineywoods region of Texas.

Materials and Methods: This study was performed using simulation modeling. Using DSSAT and historical daily weather data spanning 74 years (1942-2015) from Overton, TX, an annual DM yield (the cumulative yield from all the clippings in a season) for bermudagrass and the associated annual amount of N leached were simulated for each of the 74 seasons for 10 scenarios comprising five clipping intervals (2, 3, 4, 5, and 6 week) and two soil types (Darco and Kirvin). Clipping interval was defined as the period between two consecutive clippings. For ENSO analyses, simulated DM yield and N leaching loss for each year were assigned to a specific ENSO phase: El Niño, La Niña, or Neutral.

Results: The study results showed that with an increase in clipping interval, DM yield increased, whereas N leaching decreased, each at a diminishing rate (Figs. 1, 2, and 3). Bermudagrass DM yields were less, whereas N leaching was greater over a soil with high runoff potential (Darco) compared with a soil whose runoff potential was moderate (Kirvin). Of the three ENSO phases, El Niño was associated with the lowest DM yields and the greatest N leaching.

Conclusion: The study results indicated that Coastal bermudagrass forage biomass production in the Pineywoods region of the southern US in an El Niño year could be the least of all ENSO phases, irrespective of the clipping interval and the soil type. The results suggested that using clipping intervals shorter than 4 weeks on any soil in any year might not be beneficial from both agronomic and environmental points of view.

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Figures and Tables:

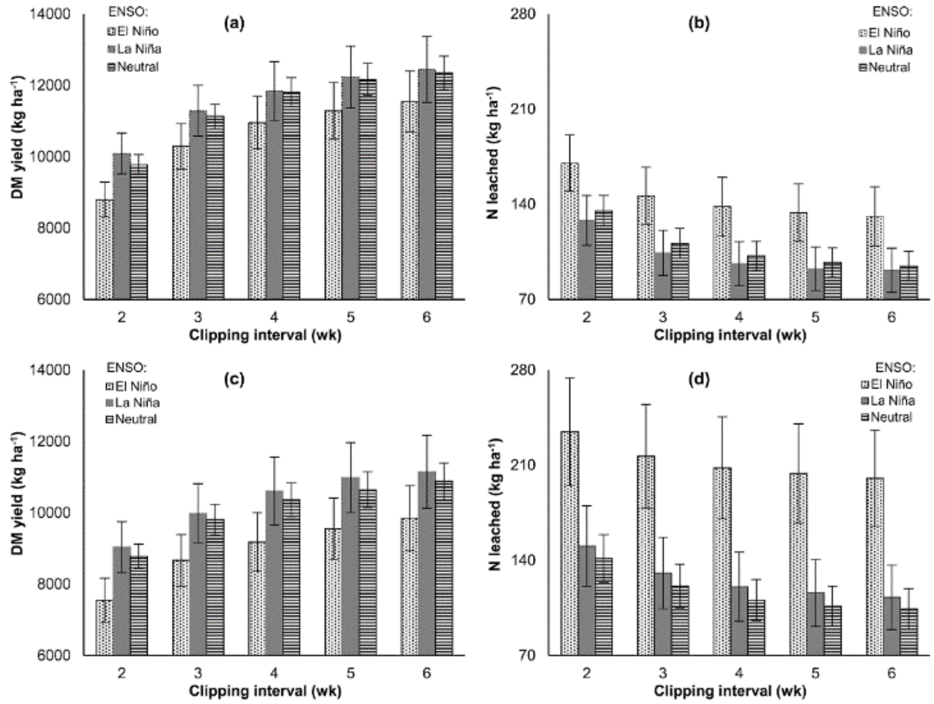

Figure 1. Responses of annual average bermudagrass DM yield and N leaching to clipping interval as influenced by ENSO and soil type. Figs. (a) and (b) belong to the Darco soil and figs. (c) and (d) to the Kirvin soil at Overton, TX.

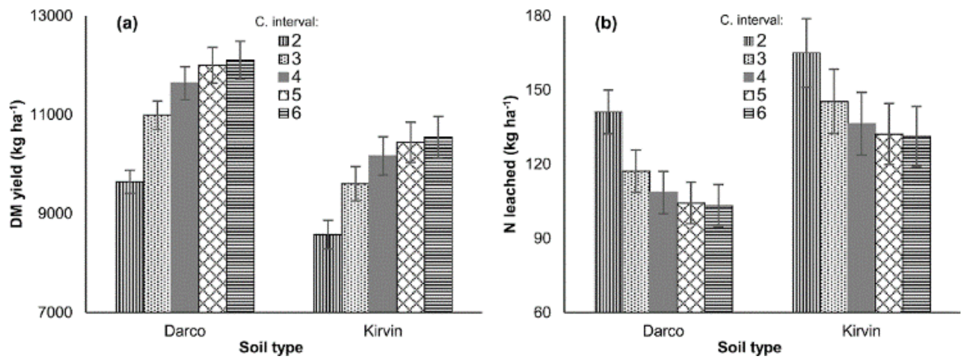

Figure 2. Responses of annual average a) bermudagrass DM yield and b) N leaching to soil type as influenced by clipping interval (week) at Overton, TX.

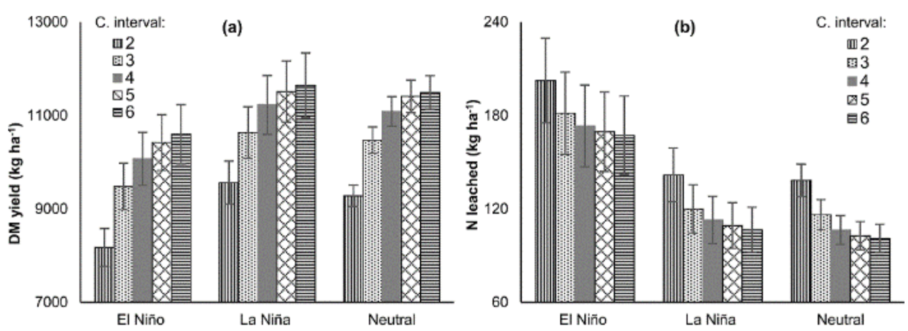

Figure 3. Responses of annual average (a) bermudagrass DM yield and (b) N leaching to ENSO as influenced by clipping interval (week) at Overton, TX.

The responses of bermudagrass biomass to N application rate, soil type, and El Niño-Southern Oscillation as simulated by a crop model

Prem Woli[1], Francis M. Rouquette Jr.[1], Charles R. Long[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: This study found that soil water holding capacity (WHC) is a significant variable controlling the bermudagrass biomass simulation accuracy of crop models, especially related to N processes. This study encourages crop modelers to check thoroughly the consistency of textural and WHC values of the soil being used and give leverage to WHC. Bermudagrass forage growers in the Pineywoods region of Texas need to be attentive to probabilities for rainfall events and recognize the El Niño-Southern Oscillation (ENSO) effects as influenced by soil type and N application rate to avert the risks of crop failure and economic loss.

Introduction: The perennial warm-season forage model in the Decision Support System for Agrotechnology Transfer (DSSAT) suite of crop models is new. Studies involving the use of this model for predicting biomass production for a perennial grass such as bermudagrass are few. By conducting a series of simulation investigations, this work examined the DSSAT forage model for simulating Coastal bermudagrass biomass response to N as affected by soil and climate variability in the southern US.

Materials and Methods: In this study, a series of investigations (simulations) were performed, in which the objective of and the method used for the following investigation would depend on the outcomes of the preceding investigation until the main issue arisen during the first investigation had been resolved. The validity and accuracy of the simulated biomass that corresponded to the observed biomass was the factor that stimulated further investigations, which were: biomass response to N > the plateau response on a sandy loam soil > soil texture effects > soil fertility effects > soil water holding capacity (WHC) effects > combined effects of soil fertility and WHC > DSSAT sensitivity to WHC > ENSO impacts.

Results: Results indicated that the DSSAT forage model predicted the biomass response to N reasonably well. However, the accuracy of simulations was linked primarily to the WHC of the soil used. A seemingly small difference in WHC, such as 0.03 mm/mm, made a significant difference in the biomass response to N rate by a margin of about 3 Mg/ha (Fig. 1). These results indicated that providing more leverage to WHC than to the soil name, texture, or type being used for simulations could provide more accurate results. The simulations further indicated that bermudagrass production in the southern US could be impacted by ENSO, with the La Niña and El Niño phases providing above-normal and below-normal production, respectively (Fig. 2). The rate of increase in biomass with an increase in N rate was higher under La Niña than under El Niño. The impact of ENSO was greater on a soil with a coarser texture.

Conclusion: The study found that the functions and processes associated with soil WHC were reasonably represented in the DSSAT forage model and that WHC is a significant variable controlling the accuracy of bermudagrass biomass simulations especially related to N processes. The simulation results showed that the ENSO effect on bermudagrass production was large under no N-limiting conditions as the primary driving factor to the variability was weather. Under N-limiting conditions, the variability was small as N limitation masked some weather effects. Soil type had no influence on the variability when N was not a limiting factor. Soil properties masked some weather effects only when N was limiting.

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Figures and Tables:

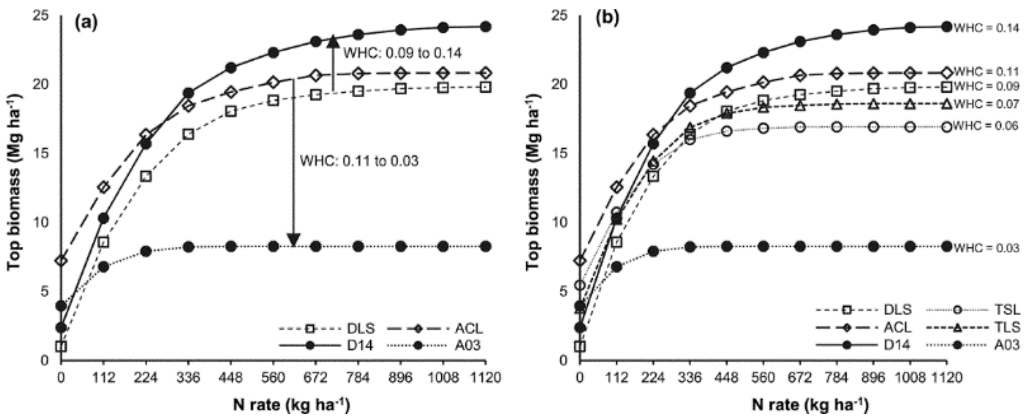


Figure 1. The DSSAT-simulated bermudagrass biomass response to N rate for various soils (ACL = Abilene clay loam, A03 = ACL with water holding capacity (WHC) lowered to 0.03 mm/mm, DLS = Darco loamy sand, D14 = DLS with WHC raised to 0.14 mm/mm, TLS = Tifton loamy sand, TSL = Tifton sandy loam) at Overton, TX.

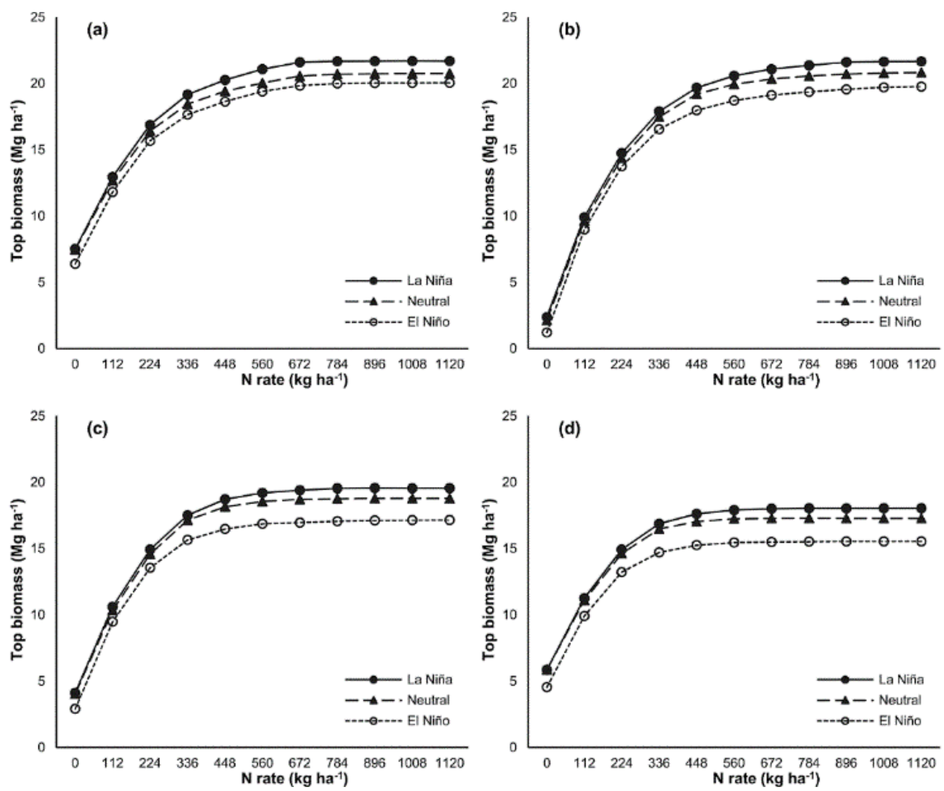


Figure 2. The DSSAT-simulated bermudagrass biomass response to N rate as influenced by El Niño-Southern Oscillation (ENSO; with three phases El Niño, La Niña, and Neutral) for four soils in the southern US: (a) Abilene clay loam, (b) Darco loamy sand, (c) Tifton loamy sand, and (d) Tifton sandy loam.

Developing a forage wheat model for simulating winter wheat forage production in the southern United States

Prem Woli[1], Francis M. Rouquette, Jr.[1], Gerard R. Smith[1], Charles R. Long[1], L. R. Nelson[2]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Department of Soil & Crop Sciences, Texas A&M University, College Station, TX

Application: A forage wheat model was developed and incorporated into the DSSAT (Decision Support System for Agrotechnology Transfer) suite of crop models. The new forage wheat model simulated options for biological efficiencies in which management strategies could be implemented for optimum economic returns. The findings of this study might assist winter wheat forage growers in the Pineywoods region of Texas in identifying soil type-, planting date-, and weather-specific N application rates to optimize forage production.

Introduction: Winter wheat is an important component of pastures in the southern US. Using the DSSAT system, this study examined winter wheat biomass response to N application rate as influenced by soil, planting date, drought, and climate variability for the Pineywoods region of Texas after developing a new forage wheat model and incorporating it into the DSSAT system.

Materials and Methods: The original DSSAT wheat model is for grain production; thus, it cannot simulate forage production with multiple harvests in the wheat growing season. For forage simulation, a new forage wheat model was developed by modifying the original wheat model through the incorporation of a new subroutine that could account for multiple harvests of wheat biomass during the season. Once the model was developed, wheat biomass was simulated for various scenarios comprising two soils, three planting dates, seven N rates, and 74 years of weather data from Overton, TX.

Results: The model evaluation results indicated that the overall performance of the forage wheat model was satisfactory (Fig. 1). The biomass response to N rate was represented by a one-phase exponential association (Fig. 2). Biomass generally peaked at 135 kg N/ha on the finer, more fertile Lilbert soil, and at 269 kg N/ha on the coarser, less fertile Darco soil. Biomass decreased with a delay in planting date at N rates greater than 135 kg N/ha for Lilbert and at N rates greater than 202 kg N/ha for Darco. The effect of drought during September-October was greater for a higher N rate, the Darco soil, and an earlier planting date. The effect of drought during March-April was greatest at 135 kg N/ha, and was greater on Darco with up to 45% reduction in biomass compared with 35% on Lilbert. Biomass reduction was up to 45% for the mid-October planting and 32% for the mid-September planting. Climate variability did not significantly impact winter wheat biomass yields.

Conclusion: A new forage wheat model was developed and incorporated into the DSSAT suite of crop models. The forage wheat simulation modeling results showed that in terms of biomass response to N rate, the difference between soils having different texture and inherent fertility levels decreased with a delay in planting date. The effect of planting date on biomass was significant only at N rates greater than 67 kg/ha. With a delay in planting, biomass started decreasing at lower N rates on a finer, inherently more fertile soil with a shallower E horizon.

Acknowledgements: This study was financed by Texas A&M AgriLife Research at Overton.

Figures and Tables:

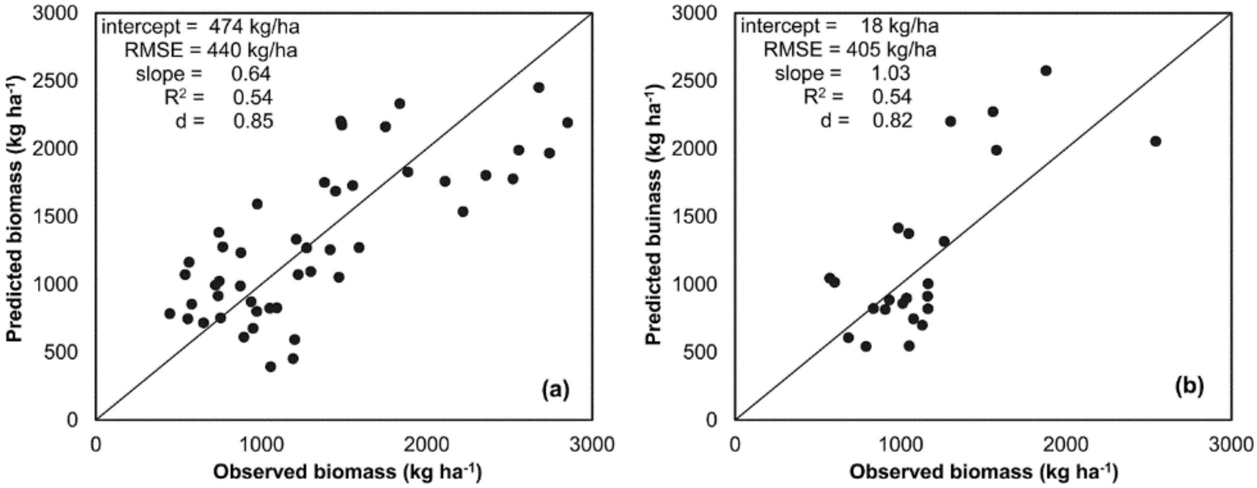


Figure 1. The model-predicted vs. observed values of forage wheat biomass associated with the (a) development and (b) evaluation of the forage wheat model (based on data from Overton, TX).

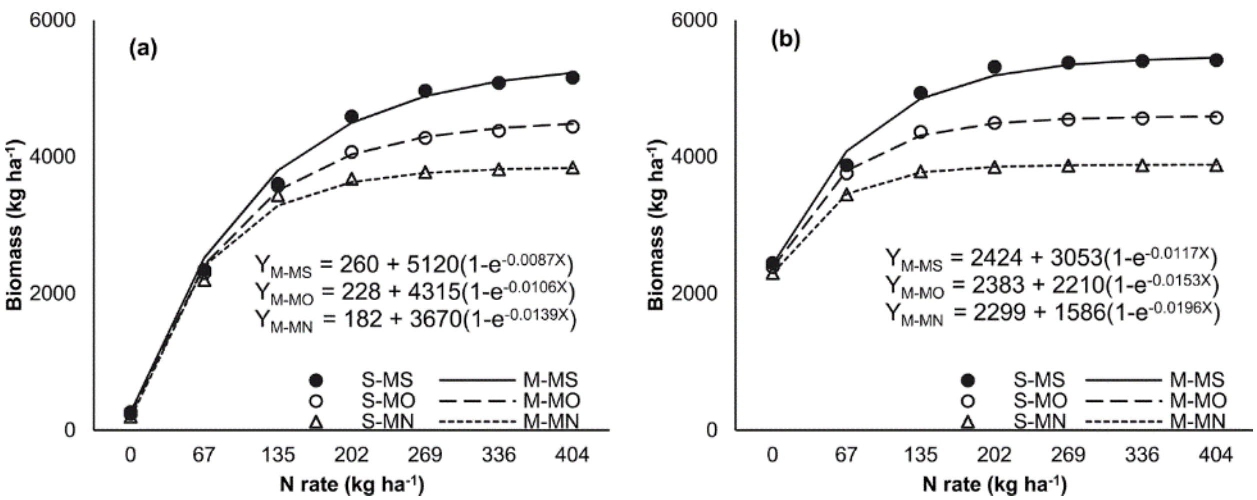


Figure 2. Forage wheat biomass response to N application rate for three planting dates – mid-September (MS), mid-October (MO), and mid-November (MN) – on: (a) Darco and (b) Lilbert soils. The S- and M- in the figure legends denote simulated and modeled values, respectively.

Evaluating cowpea-wheat double cropping systems in the Pineywoods region of the southern United States

Prem Woli[1], Gerald R. Smith[1], Charles R. Long[1], Francis M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: This work involving wheat grain production in a double-cropping system with cowpea in the Pineywoods region of the southern US demonstrated that, given increased costs of inputs and N fertilizers, cowpea-wheat double cropping using reduced N fertilizer inputs could improve the efficiency and profitability of cowpea-wheat production systems, compared to the fallow-wheat system, in this region.

Introduction: Information is limited on the potential of cowpea-wheat double cropping in the southern US, particularly the Pineywoods region, to enhance soil health and increase net returns. This study assessed the effects of soil type, N application rate, and climate variability, particularly El Niño-Southern Oscillation (ENSO), on the grain yields of double-cropped cowpea and winter wheat in the Pineywoods region of the southern US.

Materials and Methods: The Decision Support System for Agrotechnology Transfer (DSSAT) crop model was used to simulate grain yields for cowpea and winter wheat for 12 scenarios comprising two sequences (cowpea-wheat double crop and fallow-wheat), two soils (Darco and Lilbert), and three N application rates for wheat (0, 100, and 200 kg N/ha). For ENSO analyses, the yields of cowpea, cowpea-wheat, and fallow-wheat that were simulated for each of the 80 years (1942-2021) were assigned to an ENSO phase – El Niño, La Niña, or Neutral.

Results: Yields of wheat that followed cowpea (^{c}wheat) were greater than those that followed fallow (^{f}wheat) (Fig.1, Table 1). The soil type effects on ^{c}wheat and ^{f}wheat yields decreased with an increase in N rate. The soil type effect on cowpea yields was greater during La Niña. The ENSO impact on cowpea yields was greater on the less fertile Darco soil. The yields of ^{c}wheat and ^{f}wheat increased with an increase in N rate up to 100 and 200 kg/ha, respectively. The yield response of ^{c}wheat to N rate was less than that of ^{f}wheat. The N rate effects on ^{c}wheat and ^{f}wheat yields were greater on Darco and under El Niño. The yields of cowpea were greatest under El Niño, whereas those of wheat were greatest under La Niña. The ENSO effect on cowpea yields was greater on Darco. With an increase in N rate, the effect of ENSO was diminished.

Conclusion: This study illustrated the biological efficiency of the legume-preceding wheat compared to the fallow-wheat system in the Pineywoods region, especially under zero N fertilization. Grain yield-oriented wheat crop management strategies in this region need to be attentive to ENSO forecasts and adjust soil type-specific N application rates with the ENSO phase to avert risks of crop failure and economic loss.

Acknowledgements: Partial funding for this work was provided by Texas A&M AgriLife Research at Overton.

Figures and Tables:

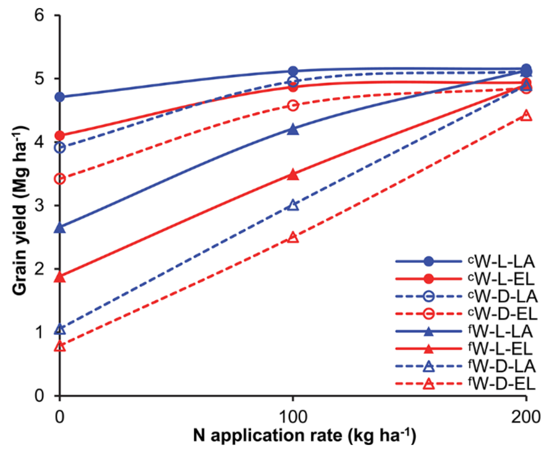


Figure 1. Grain yields of wheat preceded by cowpea (cW) or fallow (fW) as influenced by soil type [Darco (D) vs. Lilbert (L)] and ENSO [La Niña (LA) vs. El Niño (EL)] at Overton. Legend cW-L-LA, for instance, corresponds to yields of wheat following cowpea on Lilbert soil during La Niña phase.

Table 1. The effects of ENSO on cowpea and wheat grain yields as influenced by soil type x N rate interactions over 80 years long-term weather at Overton, TX

			Yield (kg ha^{-1})		
Soil	N rate	ENSO	Cowpea	cWheat†	fWheat
Darco	0	El Niño	980[a‡]	3422[b]	793[b]
		La Niña	687[b]	3915[a]	1060[a]
		Neutral	922[ab]	3812[a]	979[ab]
	100	El Niño	983[a]	4578[a]	2504[b]
		La Niña	700[b]	4957[a]	3013[a]
		Neutral	959[ab]	4692[a]	2898[a]
	200	El Niño	981[a]	4850[a]	4428[a]
		La Niña	715[b]	5110[a]	4899[a]
		Neutral	988[ab]	4871[a]	4542[a]
Lilbert	0	El Niño	1094[a]	4104[b]	1886[b]
		La Niña	842[b]	4711[a]	2662[a]
		Neutral	1055[ab]	4587[a]	2492[a]
	100	El Niño	1095[a]	4867[a]	3498[b]
		La Niña	878[b]	5119[a]	4212[a]
		Neutral	1078[ab]	4886[a]	4026[a]
	200	El Niño	1105[a]	4939[a]	4904[a]
		La Niña	892[b]	5158[a]	5129[a]
		Neutral	1092[ab]	4908[a]	4858[a]

†cwheat = wheat preceded by cowpea, fwheat = wheat preceded by fallow
‡Means followed by the same letter across ENSO phases (vertically) within a soil-N rate-crop combination are not significantly different at $\alpha = 0.1$.

Studying the feasibility of cowpea-wheat double cropping in the Llano Estacado region of the southern United States

Prem Woli[1], Gerald R. Smith[1], Charles R. Long[1], Jackie C. Rudd[2], Qingwu Xue[2], Francis M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX
[2]Texas A&M AgriLife Research and Extension Center, Amarillo, TX

Application: There is an increasing awareness and need for adopting and incorporating summer legume cover crops in long-time, mono-cropped grain production regions for potential reduction of soil erosion and improvement of soil health. The successes and constraints for double-cropping cowpea with wheat for grain crops in the semiarid region of the southern US found by this study could be extended to the use of cowpeas as only a cover crop without the expectation for a grain double crop.

Introduction: Information is limited on the potential of double-cropping cowpea and wheat in Llano Estacado, a semiarid region of the southern US. Using the Decision Support System for Agrotechnology Transfer (DSSAT) suite of crop models and weather data of 80 years (1942-2021) from Amarillo, TX, this work assessed the possibility of cowpea-wheat double-cropping in this region for grain purpose as affected by planting date and N application rate.

Materials and Methods: Using DSSAT, grain yields for cowpea and wheat were simulated for the Llano Estacado region for various scenarios comprising three cropping systems (cowpea-wheat [^{c}wheat], fallow-wheat [^{f}wheat], fallow-cowpea [^{f}cowpea]), three N application rates for wheat (0, 50, 100 kg/ha), four planting dates for cowpea (Jun 1, Jun 15, Jul 1, Jul 15), and six planting dates for wheat (Sep 15, Sep 30, Oct 15, Oct 30, Nov 15, Nov 30). The ^{f}wheat yields were regressed against planting dates by N application rates, whereas those of ^{f}cowpea were regressed against planting dates. For ^{c}wheat, since the objective was to assess the potential success and yields of cowpea-wheat double cropping as affected by planting dates and N application rate, DSSAT was run for 80 years for each of the 72 double-cropping scenarios (4 x 6 planting dates x 3 N rates). For each scenario, the possibility of a successful cowpea-wheat double-crop in this region was obtained by counting the number of seasons with wheat following cowpea successively and then dividing that number by the total 80 seasons. The associated average yield of each crop involved in double-cropping for each scenario was obtained by summing up yields in the successful double-crop years and then dividing the sum by 80. For unsuccessful double-crop years, the yields of each crop were assumed to be zero.

Results: The feasibility of double-cropping varied from 0 to 65% (Fig. 1). The possibility was less with systems comprising earlier planting dates of wheat and later planting dates of cowpea. Cowpea-wheat double-cropping could be beneficial only when no N was applied and with wheat planted on October 15 or later. At zero N, the double-crops of cowpea planted on July 15 and wheat planted on November 30 were the most beneficial of all the 72 double-cropping systems evaluated. With a delay in planting cowpea, the possibility of beneficial double-cropping systems decreased. At N rates other than zero, fallow-wheat monocropping systems were more beneficial than cowpea-wheat double-cropping systems, and the benefit was greater at a higher N rate. At 100 kg N/ha, the monocrop of wheat planted on October 15 was the most beneficial of all the 94 systems studied (Fig. 2). Wheat yields produced under monocropping systems were greater than those produced under double-cropping systems for any cowpea planting date. Cowpea yields produced under monocropping systems were greater than those produced under any double-cropping system.

Conclusion: Environmental conditions in semi-arid regions impose limits on the physical production and economic success of cropping systems. This study has revealed some latent opportunities and potential obstacles for double-cropping a summer legume with the long-time, standard winter wheat crop under limited and restricted soil moisture conditions.

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

Figures and Tables:

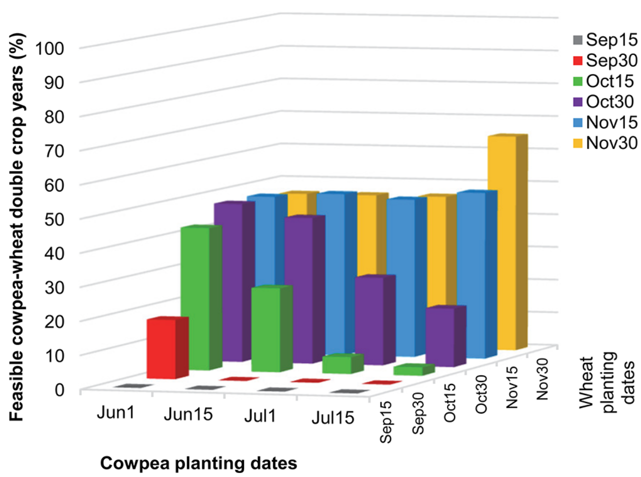


Figure 1. Feasible cowpea-wheat double-cropping years in the Llano Estacado region of the southern US as affected by planting dates.

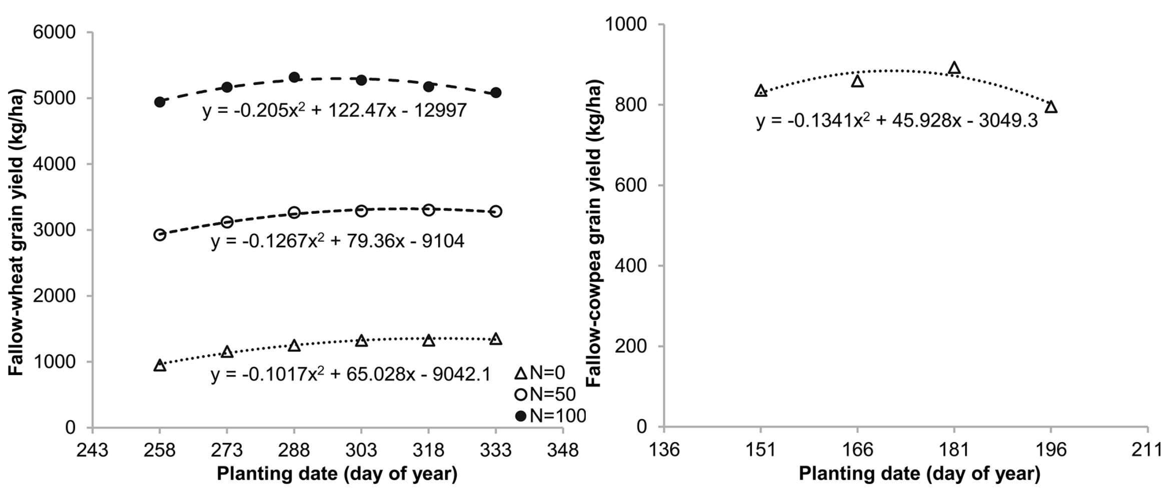


Figure 2. Responses of fallow-wheat and fallow-cowpea grain yields to planting date and N application rate in the Llano Estacado region of the southern US.

Exploring the climate variability effects on the grain yields of cowpea and winter wheat in the Llano Estacado region of the southern United States

Prem Woli[1], Gerald R. Smith[1], Charles R. Long[1], Francis M. Rouquette, Jr.[1]
[1]Texas A&M AgriLife Research and Extension Center, Overton, TX

Application: Cowpea-wheat double cropping management strategies in Llano Estacado, a semi-arid region of southern US, need to be attentive to probabilities for rainfall events and recognize the El Niño-Southern Oscillation (ENSO) phase that will coincide with potential planting dates and be influenced by N application rates to avert the risks of crop failure and economic loss.

Introduction: Information is limited on the effects of climate variability on cowpea and winter wheat grain yields in the semi-arid region of Llano Estacado in the southern US. Using the Decision Support System for Agrotechnology Transfer (DSSAT) suite of crop models and weather data spanning 81 years (1942-2022) from Amarillo, TX, this work assessed the impact of El Niño-Southern Oscillation (ENSO) on the grain yields of these crops in the Llano Estacado region as affected by cowpea and wheat planting dates and N application rate for wheat.

Materials and Methods: Using DSSAT, the grain yields of cowpea and winter wheat under three cropping systems – mono-cropped cowpea, mono-cropped wheat, and double-cropped cowpea-wheat – were simulated for many scenarios comprising four planting dates for cowpea (Jun 1, Jun 15, Jul 1, and Jul 15), six planting dates for wheat (Sep 15, Sep 30, Oct 15, Oct 30, Nov 15, and Nov 30), and three N application rates to wheat (0, 50, and 100 kg N/ha). For ENSO analyses, the grain yields of mono-cropped cowpea, mono-cropped wheat, and double-cropped wheat each that were simulated for each of 81 seasons were assigned to a specific ENSO phase: El Niño, La Niña, or Neutral.

Results: Simulated results showed that the El Niño phase of ENSO produced about 30% more yields of mono-cropped cowpea than those produced under the La Niña phase, especially with the cowpeas planted in July. The cowpea yields under El Niño were about 10% more than the 81-year average normal yield, whereas those under La Niña were about 20% less (Fig. 1). At the N rates of 0, 50, and 100 kg/ha, regardless of wheat planting dates, the El Niño years produced, respectively, about 8%, 40%, and 60% higher wheat yields than those produced in the La Niña years, and about 5%, 20%, and 27% more than the 81-year average normal yield (Fig. 2). In the La Niña years, the wheat yields at 0, 50, and 100 kg N/ha were, respectively, about 5%, 15%, and 20% less than the normal yield with similar N levels. The impact of ENSO on wheat yields under cowpea-wheat double-cropping systems was significant especially for the wheat crops planted on October 15 (October 30) or later following the cowpea crops planted in June (July). At zero N, the mono-cropped wheat yields were not impacted by ENSO due to N limitation. However, the double-cropped wheat yields were impacted by ENSO even when no N fertilizer was applied due to high soil N status caused by N transfer from cowpea residues and roots.

Conclusion: In the Llano Estacado region, this study suggested more successful cowpea production with mid-July planting dates during El Niño. The avoidance of planting cowpeas during La Niña would also substantially reduce risk and losses. Most commercial wheat operations in this region do not apply N fertilizer; thus, attention to ENSO phase may not be deemed as an important management strategy. However, the recognition of El Niño could provide incentive to add N fertilizer to substantially increase grain yields by 40% to 60%. For a double-cropping cowpea-wheat system for cover crop and/or grain production, the transfer of cowpea-origin N for wheat could provide a significant production enhancement during El Niño.

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

Figures and Tables:

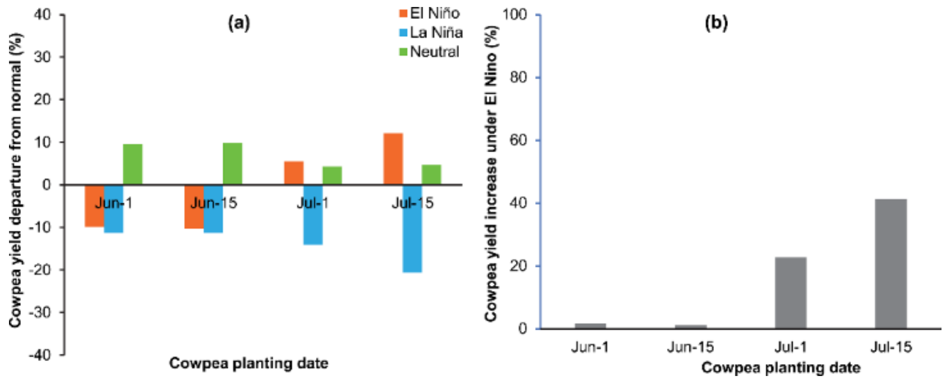


Figure 1. (a) Departure of cowpea grain yields produced under an El Niño-Southern Oscillation phase (El Niño, La Niña, or Neutral) from the normal (an 81-year average) yield for each cowpea planting date; and (b) increase in cowpea yields under El Niño relative to La Niña in the Llano Estacado region of the southern US.

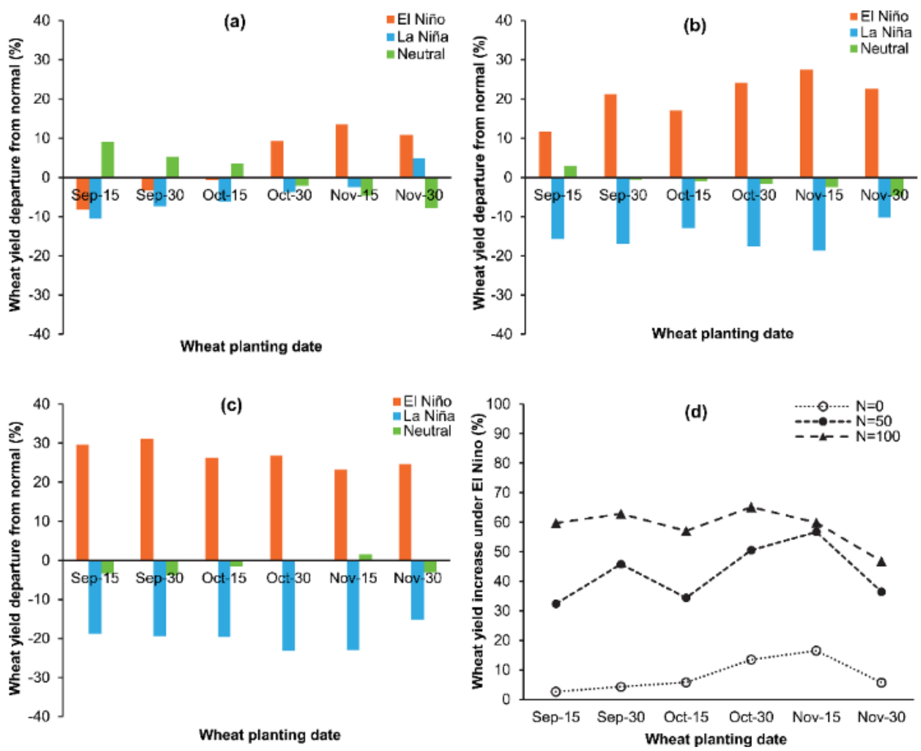


Figure 2. Departure of mono-cropped wheat grain yields produced under an El Niño, La Niña, or Neutral phase from the 81-year average normal yield for each planting date at the N application rate of: (a) 0 (b) 50, and (c) 100 kg ha^{-1}; and (d) increase in wheat yields under El Niño relative to La Niña for each planting date-N rate combination in the Llano Estacado region of the southern US

Determining the distribution and phenology of EPM in East Texas

Rafia Khan, Ph.D, Assistant Professor & Extension Entomologist
Texas A&M AgriLife Research and Extension Center at Overton

Introduction: The European pepper moth (EPM) (*Duponchelia fovealis*) is an invasive species in the US with a wide host range. This moth is native to the Mediterranean region of Europe. The species was first identified in California in 2004 and has now become established in several states including Texas. The life cycle of EPM consists of an egg, larva, pupa, and adult. The larva of this insect can feed on roots, stems, leaves, flowers, buds, etc. The infested plants may show webs, frass, injured leaves, and girdled stems. This pest can be an economic pest for Texas as the state's green industry is growing. In the present study, we conducted a field study to monitor EPM's activity to understand their distribution and phenology in East Texas.

Material and methods:
The time and location of the study, plant hosts: We conducted a monitoring study to understand the presence and distribution of European pepper moth (EPM) in different counties in Texas. Cherokee, Smith, and Van Zandt counties in East Texas were chosen as there are varieties of nursery operations that are active.

Traps: We started with three different traps such as yellow sticky cards, Pherocon bucket trap (Model#3337-02, yellow, white, green, Trece Inc., OK, USA), and Pherocon VI Delta traps with white liners (Model#33315-30, orange, Trece Inc., OK, USA) to monitor the presence, distribution, and phenology of EPM. The yellow sticky cards were placed with a metal hook and were not associated with any pheromone. The bucket and delta traps were hung with metal fishhooks and tied with zip-ties with the hooks. The Pherocon EPM lure (Model TC/CO-3287-25, Trece Inc., OK, USA) was placed in the bucket and delta trap. In each monitoring site, we placed five traps of each type 20 ft apart in open pad areas and inside the greenhouse. Traps were monitored from May 2023 to September 2023. We used sticky tape inside the bucket traps and white sticky liners inside the delta traps to catch EPM. The sticky tape and sticky white liners as well as pheromone caps were replaced biweekly. The sticky cards/liners were marked with the date, number of traps, host plant, place, etc.

Results:
Presence of EPM in East Texas: EPM activity was observed in three locations in Cherokee County and one in Van Zandt County. Only the male moths were attracted to the pheromone traps. The average number of adult EPM (male) ranged from 0.00 to 5.80 per trap.

Efficacy of traps: Among the three traps tested, the Pherocon VI Delta traps with white liners were the most effective in catching EPM adult males.

Phenology of EPM:
During our pheromone trap monitoring study from May to September 2023, we observed higher EPM activity in May and lower activity during August in one study site. In another study site, lower activity was observed during summer months.

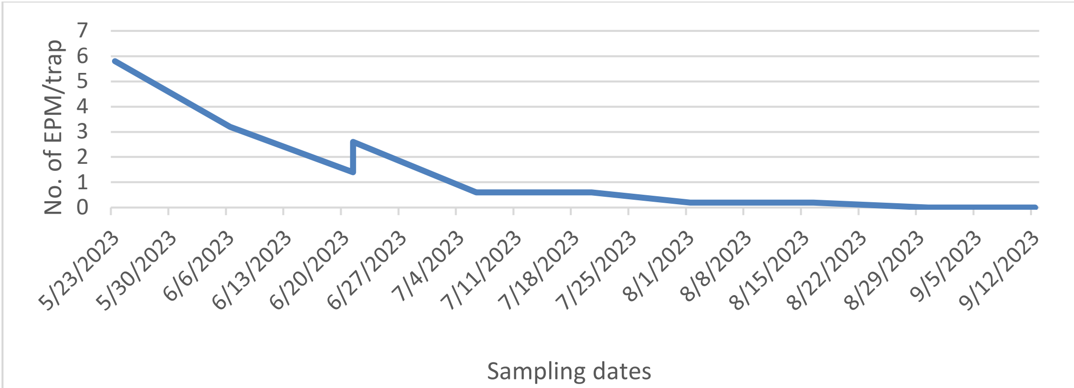


Figure 1. The abundance of EPM/trap on different sampling dates in location number 1 in Cherokee County

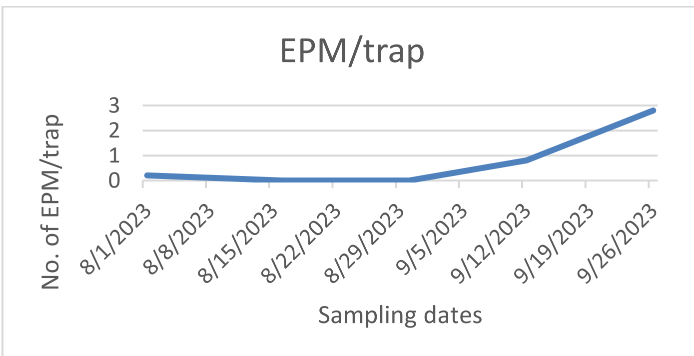


Figure 2. The abundance of EPM/trap on different sampling dates in location number 2 in Cherokee County

Determining the abundance of thrips in ornamental plants

Rafia Khan, Ph.D., Assistant Professor & Extension Entomologist
Texas A&M AgriLife Research and Extension Center at Overton

Introduction:
Thrips are common insects in ornamental and nursery crops. They are small insects with piercing-sucking mouthparts. The life cycle of thrips consists of an egg, larva, prepupa, pupa, and adult. Both larval stages and adults feed on plant sap from leaves, stems, flowers, and buds. Their feeding injury causes chlorosis and necrosis in plants, weakens the plant, and reduces the productivity or aesthetic value of the plant. Also, females lay their eggs inside the plant tissue causing stippling. Thrips can feed on a wide variety of crops and wild hosts. In this study, we conducted a greenhouse study to determine the thrips abundance in different ornamental plants.

Material and methods:

The time and location of the study, plant hosts: We conducted a study in the greenhouse at the Overton Research and Extension Center, TX, to understand the thrips population in different ornamental plants. We selected Chrysanthemum, Petunia, Vervain, Lantana, and Dianthus as plant hosts.

Sampling for thrips

The experiment was conducted by following a randomized complete block design and was replicated four times. Five and five leaves were collected from each experimental plot/plant species. Leaves or flowers were collected randomly 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 leaf sample: Thrips population was low in ornamental leaves. Mostly thrips larvae were observed in the leaf samples.

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.

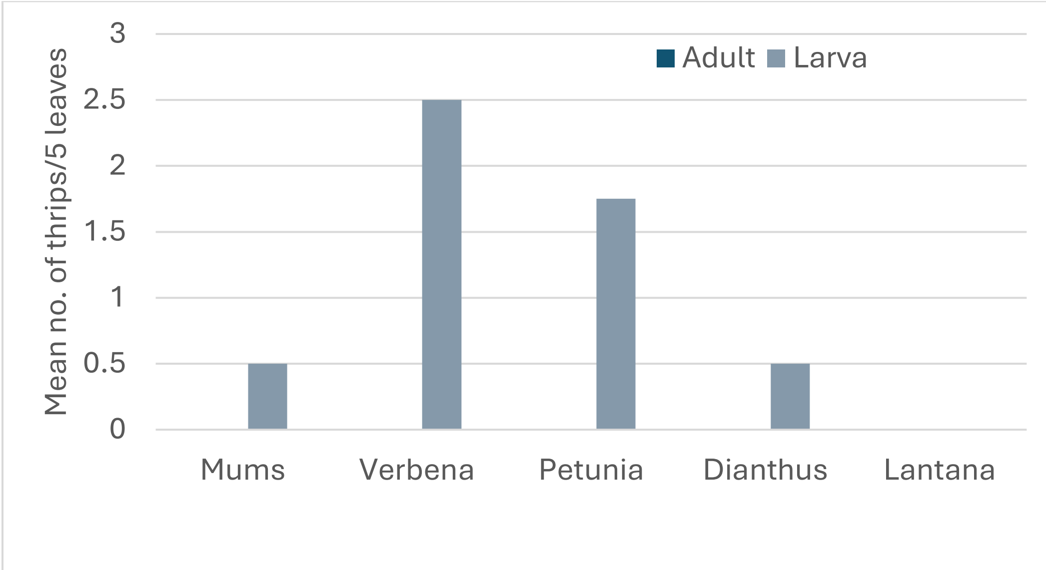


Figure 1. Thrips population in ornamental plants from leaf sample

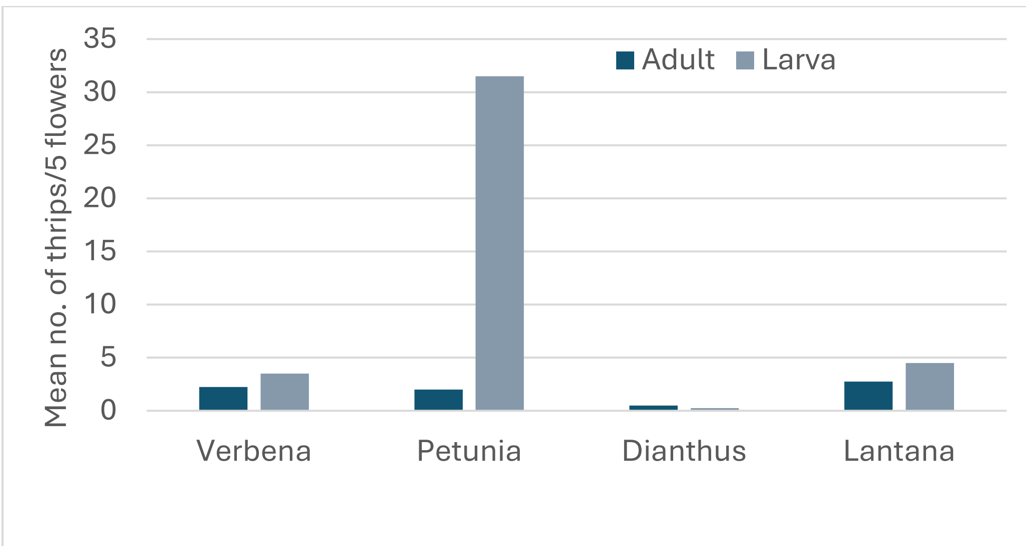
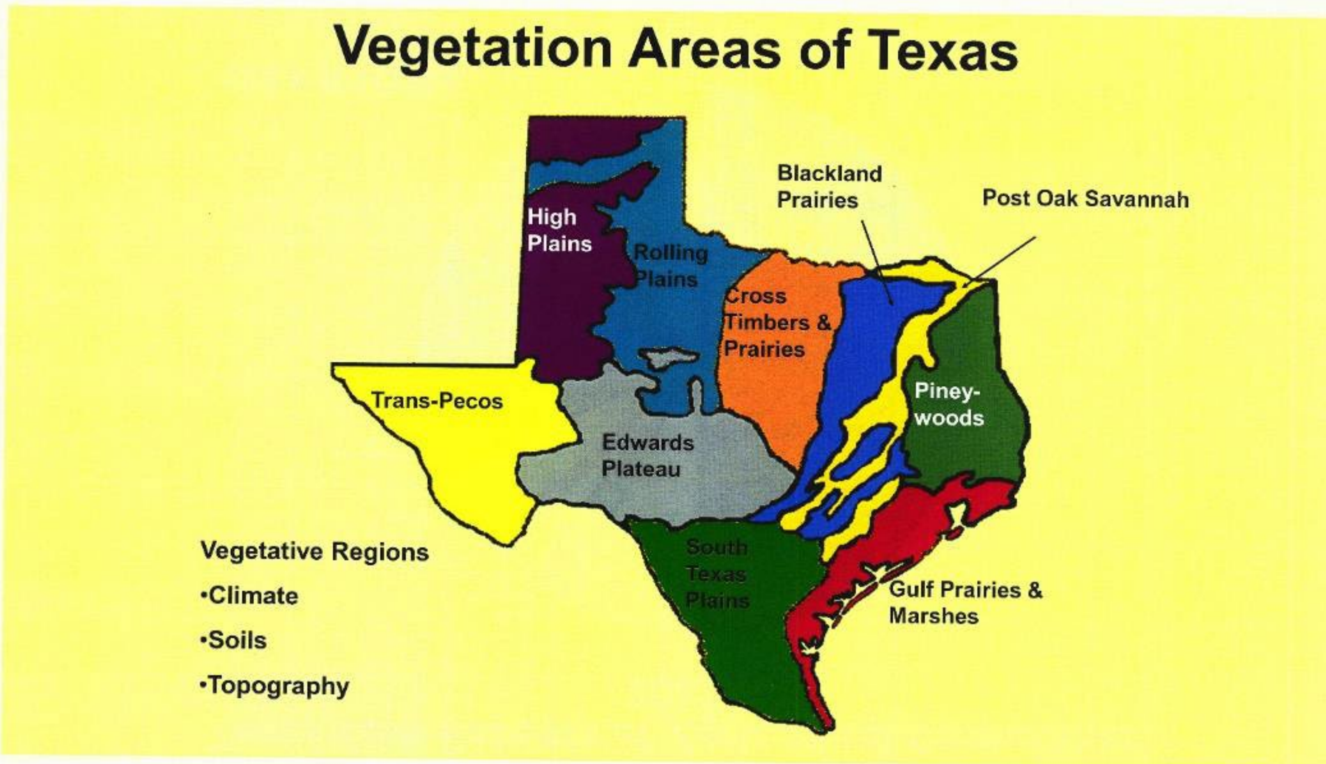
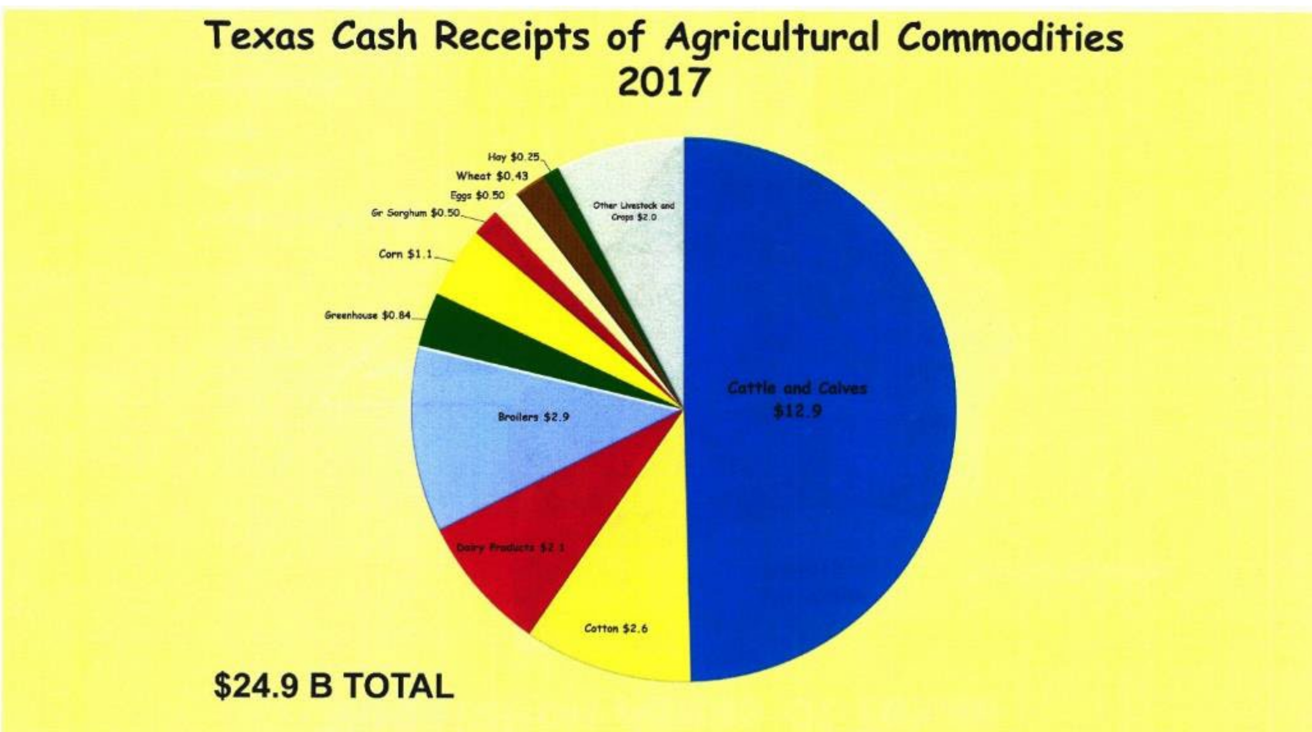


Figure 2. Thrips population in ornamental plants from flower sample


Vegetation Areas of Texas
High Plains
Rolling Plains
Cross Timbers & Prairies
Blackland Prairies
Post Oak Savannah
Trans-Pecos
Edwards Plateau
Piney-woods
South Texas Plains
Gulf Prairies & Marshes
Vegetative Regions
•Climate
•Soils
•Topography


Texas Cash Receipts of Agricultural Commodities
2017
Hay $0.25
Wheat $0.43
Eggs $0.50
Gr Sorghum $0.50
Corn $1.1
Greenhouse $0.84
Other Livestock and Crops $2.0
Broilers $2.9
Cattle and Calves $12.9
Dairy Products $2.1
Cotton $2.6
$24.9 B TOTAL


ELBON
Rye
TX-RYE-12
Rye