Proceedings 61st

Southern Pasture & Forage Crop Improvement Conference 2007

Tallahassee, Florida

May 30-June 1, 2007

Ramada Conference Center, Tallahassee, FL

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Forages on the World Wide Web

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This presentation would better be titled "World Wide Web: A personal journey by a computer illiterate redneck". I have been intimidated by, and somewhat slow to adopt, all the "electronic technology", however, I can safely say that the World Wide Web and other new technology (e-mail, PowerPoint's, etc.) has had a greater impact on my forage extension program than anything in my thirty-three year career.

My first experience with "Forages and the Web" came in 1997 while serving as Chairman of the Technology Transfer Session of the International Grassland Congress. I invited Dr. David Hannaway from Oregon State University to make a presentation at the Congress on "Forage Information Systems on the World Wide Web." I was very impressed with Dave's presentation, but never dreamed just what an impact this technology would have on forages. It is truly amazing just how much has changed in only ten years. As an example, I simply used the Google search engine to check for a few forage-related terms (Table 1). Results of this very small search revealed a range in results from 441,000 for bermudagrass to 269 million for hay.

Table 1. Forages on the Web.

Topic	Number of Results
Forages	2,080,000
Southern Forages	1,190,000
Pasture	13,800,000
Southern Pasture	1,210,000
Bermudagrass	441,000
Alfalfa	6,870,000
Grazing	15,200,000
Forage Seeding Rates	408,000
Pasture Fertilization	491,000
Hay	269,000,000

SOURCE: www.google.com

In 1998, Dr. Don Ball (Auburn University) and I were invited to speak on "Technology Transfer from an Extension Agronomist Perspective" at the Australian Society of Agronomy Meetings. In preparation for that meeting, Don and I collected as much information and statistics pertaining to electronic technology as we could find. In 1998, only eleven percent of farmers in the USA had computers. Less than half used the computer for day-to-day forage-livestock purposes. Uses cited were weather, markets, and record keeping. During this past winter meeting season, I surveyed all who attended our Master Cattleman and Master Grazer programs. Approximately ninety-one percent of farmers surveyed indicated they have access to a computer, and forty-five percent had used the Kentucky Forage Website at least once in the last six weeks. In addition, twenty years ago, approximately sixty percent of forage inquiries that I received were via letters, thirty-five percent via phone, and five percent by personal contacts. Today, less than five percent are via letter, over sixty percent by e-mail, and approximately thirty plus percent by phone (incoming percentage via cell phone) and the remainder personal contacts.

Easy Access

The technology allows tremendous freedom. No longer do we have to have traditional office hours. I communicate via cell phone from remote pasture locations. Most all hotels I stay in have wireless internet. You can get international phone cards for most cell phones and use them literally around the world. I traveled to four different countries during this past year and had wireless internet in all hotel rooms in each country.

At present, most states in the Southeast have Forage or Forage-Livestock websites. In Kentucky, we dragged our feet in getting one developed, primarily because I didn't have a clue on how to do it. Eventually, I sought help and brought the Kentucky Forage Homepage on line in 2004. At present, we have had over 25,000 visitors. In terms of number of people reached, it is the single most important forage education activity we have done in our Kentucky Forage Program. On our site (which I heavily borrowed ideas from colleagues throughout the USA) we have our monthly newsletter, publications, events, contact information, and links.

Concerns

The WWW and all its ramifications have brought about tremendous change in how we go about our day-to-day activities. Information from around the world is just a mouse click away. With all the positive aspects of this technology many concerns have also surfaced.

1) Credibility: "If it is on the web, it must be true." We deal with issues every week where a testimonial from one observation in one location can carry as much credibility as a three year replicated, multi-state, peer reviewed scientific study. (Especially if it is hidden so deep in a scientific journal that has only been read by fifty people and requires converting back to English and someone to explain the complex statistics, while the testimonial is in well written multi-color with interactive graphics).

2) Time Management: Most Forage Extension Specialists are overwhelmed every morning when they open their e-mail and find sometimes a hundred plus messages. Our e-mail address can be obtained by a quick Google search. It's so easy for anyone to ask questions on any forage-related subject. We experience frustration getting e-mails with simple questions like: "Dr. Lacefield, I'm

> preparing to develop an intensive grazing system and would like your ideas on how many paddocks, how big, what species, seeding rate and date. Should I apply fertilizer? Do I aerate all of the pasture every year or just some? I plan on harvesting hay on some of the paddocks and would like to know what type equipment is best. I am confused as to what species of animals I can make the most money with, my neighbor says goats are best. The e-mail was signed, Barry."

In this day of world wide access I couldn't assume Barry was from Kentucky or actually even living in the USA. There was nothing else in the e-mail – no phone number, no address. In the old days I could at least look at the envelope and see where it was mailed from. The above is an actual e-mail received in January, 2005.

Another concern is by-passing the County Agents. It is so easy for farmers, industry personnel, commodity groups and others to go directly to specialists or researchers. By-passing the County Agents and all the resources at the local level can weaken the overall system while creating more work for specialists.

Resources

Staying up-to-date on computer hardware and software at a time when that information is doubling every eighteen months is near impossible and very expensive. To offset some of my expenses, I will be having a yard sale soon selling 35mm cameras, overhead projectors and slide projectors. Many of us have also found challenges in getting adequate training for ourselves and our staff as well.

Summary

Many changes have occurred during my extension career, but none has impacted my extension forage program as much as the worldwide web and all its ramifications. Digital cameras, PowerPoint, home pages, Google, Yahoo (and the list goes on) has changed the way we do forage extension educational work. Keeping up on the latest hardware, software, money and time, and getting adequate training are frustrating and challenging. Other issues concerning information credibility, having time to respond adequately to large numbers of e-mails and cell phone messages continues to present challenges. These continue to be exciting times with many opportunities, challenges and opportunities. Having had the fortunate experience of working in the Southeast for thirty-three years, I don't know what the future holds, but I have confidence that the Forage Specialists who participate in SPFCIC will respond enthusiastically, efficiently and effectively.

References

Lacefield, G.D. 1997. Technology Transfer. Proc. XVIII International Grassland Congress, Winnipeg, Manitoba and Saskatoon, Canada.

Lacefield, G.D., D.M. Ball, J. Gerrish and D. Hannaway. 1998. Technology Transfer: Perception of Extension Agronomist. 9th Australian Society of Agronomy, Wagga Wagga, Australia. 1988 P. 45-50.

http://www.Google.com

Hannaway, D.B. 1997. Evolving Information Technologies and Their Importance to Forages. Invited paper. IN: Proc. of the 18th International Grasslands Congress, Saskatoon, Canada, June 8-19.

Hannaway, D.B., C.P.Q. Daly, D.F. Chapman, B.B. Baker, and A.S. Cooper. 2005. Computer-based Forage Management Tools: Historical, Current, and Future Applications. Pp. 389-402. IN: Proc. of the 20th International Grassland Congress. June 26-July 1, Dublin, Ireland.

An Update on Hay Quality and the Southeastern Hay Contest

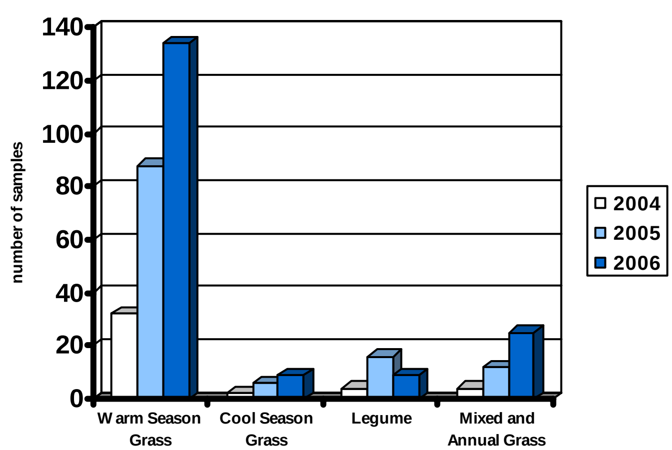
J. Andrae, A. Blount, D. Ball, K. Campbell, R. Franks,
D. Hancock, and D. Mayo.
Clemson University, University of Florida, Auburn University and University of Georgia

The majority of farmers in the southeastern US do not sample their hay. Many do not base management decisions on hay quality. One reason that hay sampling is not conducted frequently is that producers have little incentive to market hay based on quality. The Relative Forage Quality (RFQ) index was developed by the University of Wisconsin to predict the fiber digestibility and animal intake of harvested crops and consists of a single, easy-to-interpret number relating quality of a forage sample to that of full bloom alfalfa hay. Unfortunately, these equations were not originally applicable to warm season forages like bermudagrass, bahiagrass or perennial peanut. Warm season forage crops have recently been added to this forage quality index so a useful equation is now available for producers in the southeastern United States. Several hundred warm season samples have since been used to develop an RFQ equation for bermudagrass and other warm season forages. Currently, all forage sample results from the University of Georgia Feed and Forage Testing Lab in Athens contain an estimate of Relative Forage Quality. This value is a single, easy to interpret number that improves producer understanding of forage quality and should help to establish a fair market value for the product.

To promote the usefulness of the RFQ index and educate producers on the value of producing high-quality forages, a multi-state hay show called the Southeastern Hay Contest was initiated in 2003. The contest is open to producers across the southeastern United States and hay entries are placed solely on their RFQ score. Six categories including warm season perennial grass hay, cool season perennial grass hay, mixed hay, legume hay, legume baleage and grass baleage are evaluated.

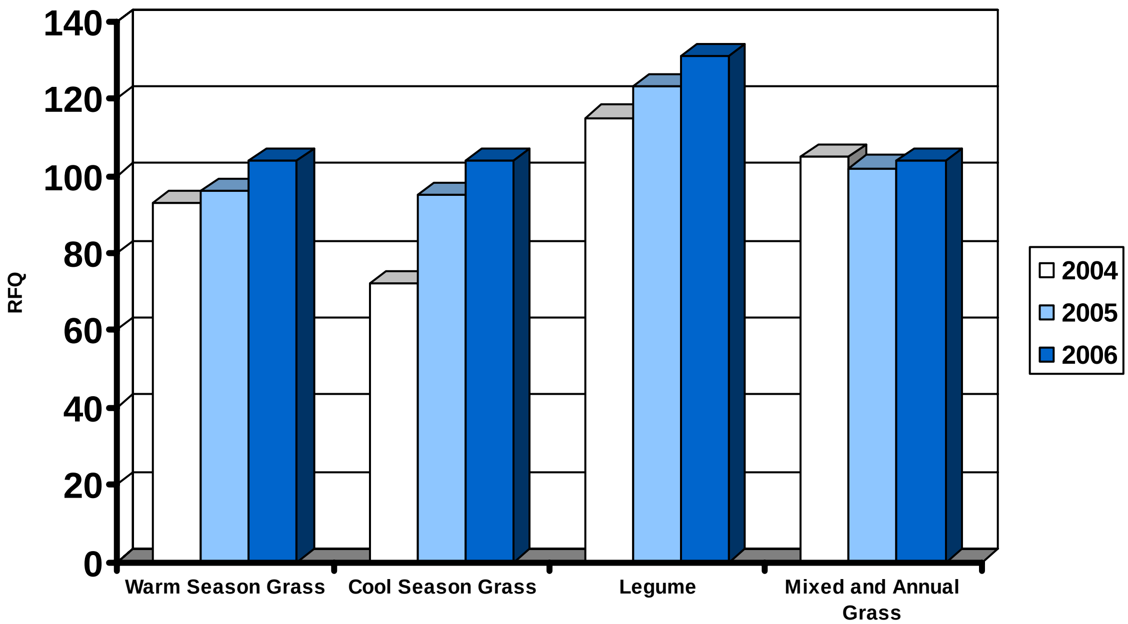
The hay contest has continued to grow over the past three years, with sample numbers increasing from approximately 40 total in 2003 to 197 total in 2006. The majority of these samples are of bermudagrass hay; however, the numbers of round bale silage entries continues to increase every year. Figure 1 gives the number of entries received in each hay category over the past three years.

Figure 1. Number of hay samples submitted to the Southeastern Hay Contest. 2004-2006.



Interestingly, the quality of forage samples submitted to the contest has also tended to improve over the past three years. The average RFQ has improved in three of the four hay categories in each of the contest years (Figure 2). Hopefully, this indicates improvements in producer forage management practices.

Figure 2. Average Relative Forage Quality of individual hay categories from 2003-2006.



Many excellent hay and baleage samples were received from Florida, Georgia, Alabama and South Carolina this year. Contest winners by entry category are listed at the end of this document in Table 1.

We hope to use this hay contest as a tool to (1) increase producer awareness of management factors that affect hay quality, (2) improve the accuracy of warm season forage analysis, (3) simplify hay quality measures to allow easy interpretation and comparison of harvests and (4) ultimately develop a quality-based hay market in the Southeastern U.S.

We intend to continue this hay contest in upcoming years and encourage all producers to enter hay samples beginning next summer. Entry is open to all producers and cost will be the same as for a standard NIR hay analysis including nitrates- $10. Contact your local county agent for entry forms next hay season.

Table 1. Category winners from the 2006 Southeastern Hay Contest. Total Samples Entered = 197.

	Farm	Crude Protein, %	TDN, %	RFQ
Warm Season Grass Hay	**Overall Range**	**5.8-16.2**	**51-70**	**61-155**
1st place	John Case Dade Co, GA	12.4	68	155
2nd place	Jerome Bunn Monroe Co, GA	15.6	70	141
3rd place	Rusty Bean (GA), Ed Trice (GA)	14.5 12.7	67 67	139 139
Legume Hay	**Overall Range**	**9.8-21.6**	**59-70**	**98-180**
1st place	Mark Harris Huntsville, AL	21.6	67	180
2nd place	Richard Cone Madison Co, FL	17.0	70	155
3rd place	Hudson Farms, Madison Co, FL	13.8	67	145
Cool Season Grass Hay	**Overall Range**	**6.4-12.1**	**52-62**	**80-116**
1st place	Sid Hetzler Walker Co, GA	10.1	58	116
2nd place	Split Tree Farm Walker Co, GA	11.4	62	108
3rd place	Luke Gray Dade Co, GA	10.6	60	108
Mixed Hay	**Overall Range**	**5.0-19.8**	**45-69**	**50-164**
1st place	Bill Jackson Washington Co, GA	13.1	68	164
2nd place	Joe Armstrong Grady Co, GA	15.9	66	162
3rd place	Ed Trice Upson Co, GA	16.6	69	155
Grass Baleage	**Overall Range**	**7.9-17.7**	**51-65**	**53-128**
1st place	Troy Platt Madison Co, FL	12.0	58	128
2nd place	Greenview Farms Inc. Wayne County, GA	13.2	64	119
3rd place	Troy Platt Madison Co, FL	10.6	54	111
Legume Baleage	**Overall Range**	**11.4-15.9**	**56-68**	**95-215**
1st place	Troy Platt Madison Co, FL	15.9	68	215
2nd place	Sundown Farms Madison Co, FL	13.1	67	140
3rd place	Troy Platt Madison Co, Fl	15.7	67	137

Bermudagrass Fertilization Strategies in Tennessee

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The University of Tennessee

Over the last several years, bermudagrass has become a increasingly popular forage crop for Tennessee producers. The large horse industry has increased the demand for high quality hay. In addition, a decrease in tobacco acreage and an increase in the number of producers getting out of the dairy business has resulted in an increase people producing hay for the horse market. The availability and promotion of new bermudagrass varieties has resulted in a large number of acres of bermudagrass being planted specifically for the horse hay market.

There has been limited research on bermudagrass in Tennessee. Fertility trials from several years ago indicated that approximately 360 lb of N could be applied in split applications to achieve maximum yield (Figure 1).

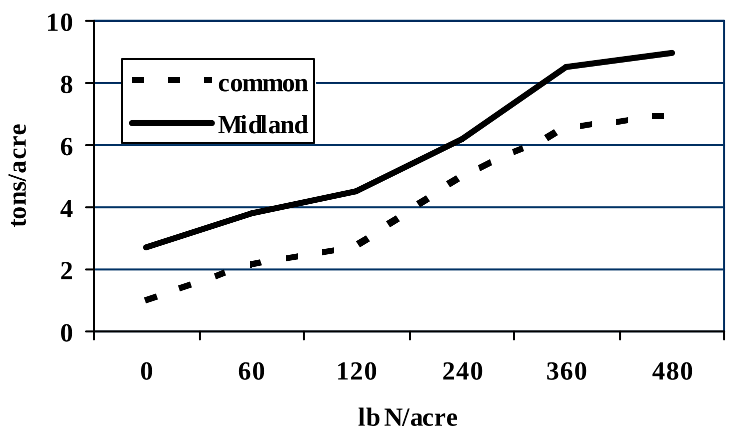

Figure 1. Yield of two bermudagrass varieties at various nitrogen rates. (Fribourg and co-workers. 1980. TN Farm and Home Sci. Report 114.)

Recommendations for bermudagrass fertilization have been based on this research, as well as other work done across the Southeast. Most producers have been interested in the high yields that can be obtained with bermudagrass, so their fertilization programs often included up to 400 pounds of nitrogen split into four applications.

As more producers began submitting bermudagrass samples for analysis through the UT Forage Testing Laboratory, lab workers began a routine screen for nitrates in bermudagrass samples. It was surprising that over 70 percent of the samples tested positive for nitrates. Samples that tested positive in the screening process were then analyzed for nitrate level determination. This information is important due to the toxicity of nitrate to ruminant animals, and to the fact that all nitrogen, regardless of the form, is used in the calculation of crude protein for the forage analysis. This crude protein calculation may lead some producers to assume their bermudagrass cutting had an excellent protein level, when in reality some of the nitrogen that was counted as protein was in the nitrate form (Figure 2).

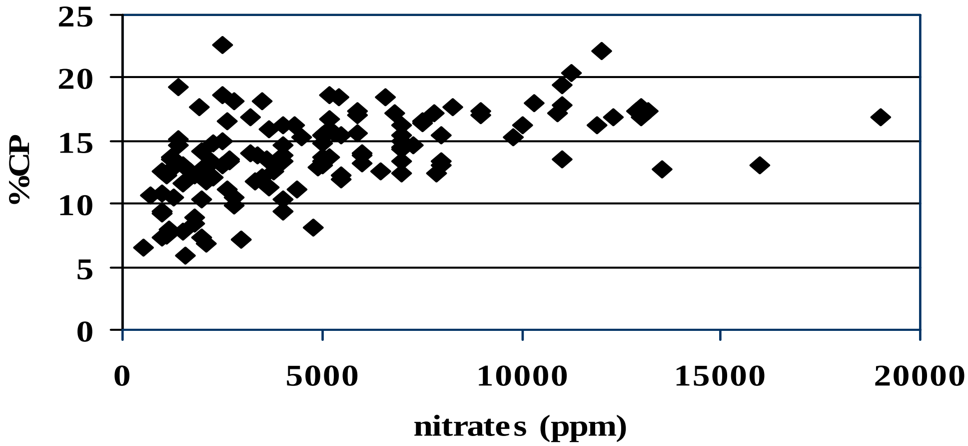

Figure 2. Relationship between nitrate level and crude protein level in bermudagrass samples submitted to the UT Forage Testing Laboratory.

The large number of samples testing positive for nitrates raised the concern of forage professionals in the state. Further research in the area of bermudagrass fertility indicated that nitrogen fertilization recommendations need to be further defined (Figure 3).

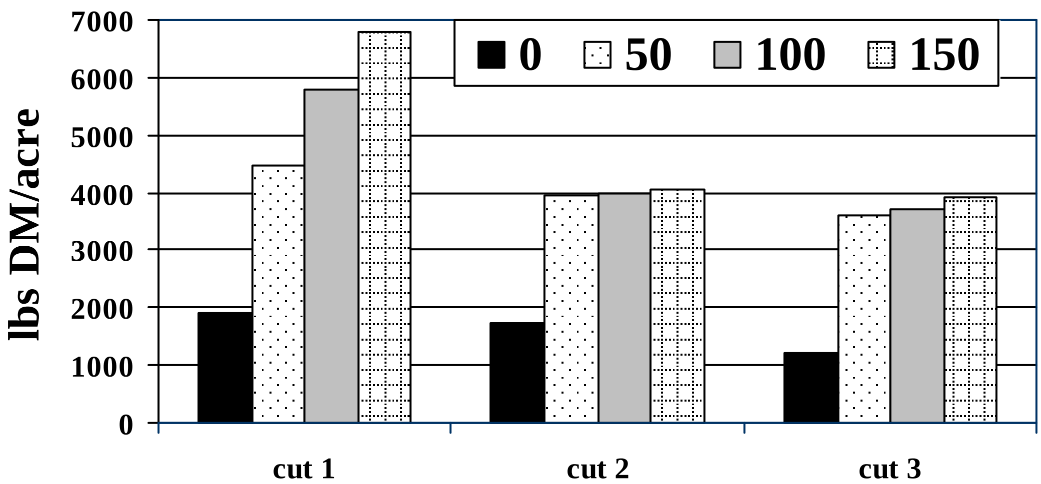

Figure 3. Relationship between nitrogen fertilization rate and yield for bermudagrass. (Cripps. MS Thesis. 1998. TN Tech.)

This data illustrated that heavy nitrogen fertilization rates could be used early in the growing season. But later applications need to reduced, due to limited increase in yield with heavy N fertilization.

Current recommendations encourage producers to apply up to 150 lb of N early in the season, but no more than 50-75 lb of N per acre with later cuttings. Producers are encouraged to only apply more than this if soil moisture conditions are such that bermudagarass growth is not limited.

Extension Programs Involving Growing Forages for Wildlife

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Beef cattle producers and wildlife managers, i.e. hunters share a common goal. Both are seeing the benefits of growing forages to meet the nutritional requirements of the animals they manage on their properties. Forages were once exclusively grown for the livestock industry, but in many areas of the Southeast planting and managing forages for wildlife have taken "center stage".

In a recent issue of *Hay and Forage Grower Magazine,* Dr. Don Ball, Auburn forage specialist says," In some Alabama counties, more forage seed is being sold for wildlife plantings than for livestock production". Dr. Ann Blount, University of Florida forage specialist adds, "I think it's pretty safe to say that a large portion of the forage seed being sold in many parts of the southeastern U.S. today is being used for wildlife purposes – everything from planting food plots for deer and turkeys to establishing cover for quail and other species". Bryan Murphy states in the newly released Quality Deer Management Association publication *Quality Food Plots,* "Food plots are the hottest topic among whitetail hunters today". In the late 1970's interest in planting forages in food plots for deer increased, especially in the Southeast. In 1988 the Whitetail Institute introduced a new product, Imperial Whitetail clover, and as they say," The rest is history".

A Changing Environment

As an Extension educator, knowing and understanding the needs of your clientele is a key component in developing and delivering educational programs that meet the expectations of your audience. There is probably no other agency or industry that has experienced more change in the last 10 to 15 years than Extension and agriculture, at least in the southeastern U.S. As commodity prices declined, production cost increased and the farming sector was decimated by back-to-back droughts. Much open farmland was planted to pine trees or lay fallow. We went from producing row crops and forages to producing timber and wildlife in a very short period of time. The needs of our clientele changed.

Extension agents went from being asked, "Which clover should I introduce into my bermudagrass pastures to increase the rate of gain on my steers and heifers" to "What is the best clover variety to plant for my deer herd to increase antler size." Only a few years ago forage species such as lablab, chicory, and aeschynomene were not in the vocabulary of most Extension agents, mine included!! Many university soil test labs have only recently developed specific crop codes and fertility recommendations for these" Johnny-come-lately forages" of the wildlife world. Alfalfa, the queen of forages, is making its début with hunters and wildlife managers at present. I have received numerous calls from deer hunters wanting to know about Roundup Ready alfalfa, and I predict that in the not-too-distant future a sizeable portion of the RR alfalfa varieties planted in the southeastern Coastal Plains will be in wildlife food plots.

Big Bucks Bring Big Bucks

Hunting is big business in the US. According to the US Fish and Wildlife Service National Survey of Fishing, Hunting and Wildlife Associated Recreation nationwide, 13 million hunters spent $20.6 billion on hunting in 2001. Hunters spent $4 billion just on land leasing and ownership - 19 % of their total expenditures. Today numerous companies, especially seed companies are committing large amounts of revenue and resources to capture a share of this market. All one has to do is conduct an internet search for “wildlife food plots” to get some idea of the magnitude of the wildlife seed industry.

According to John Carpenter, national sales manager with Pennington Seed Company, there is growing interest in actively managing property for wildlife-related recreational activities like hunting, photography and wildlife viewing. “An upsurge in interest in hunting has a lot to do with it”. In many areas of the Coastal Plains of South Carolina, the expense to hunters for leasing land for hunting rivals what farmers are paying to farm the land. Hunting leases and fee hunting are an important source of income for many landowners. For years farmers have complained about crop damage by wildlife such as deer, but to some, deer can be a pest with a value. Quality food plots can increase not only the leasing value of hunting land, they can also increase the quantity and quality of the wildlife on these properties.

Meeting the Needs

Providing landowners, hunters and wildlife managers with the latest and most up-to-date information on growing forages for wildlife can be challenging and is requiring more of the time of many agricultural Extension agents. Many of the individuals requesting information and assistance on growing and managing forages for wildlife have little or no agricultural background and have limited knowledge of the practices it requires to become a successful “food plot farmer”. In order to successfully answer the questions that arise about wildlife food plots one must: a) have more knowledge or experience on the subject matter that those asking the question or b) know where to find that information.

To that end, a wildlife food plot demonstration and educational short course(Food Plots 101- A Wildlife Management Short Course) was developed as a means of educating hunters, landowners and wildlife managers as well as extension agents in the proper establishment and management of forage species for wildlife. This natural resources educational program consists of 6 hours of classroom instruction covering topics such as soils and soil fertility, site selection, forage species selection, establishment and management of forage species, weed and insect control, sprayer calibration, selecting wildlife food plot equipment, management of native and natural plant species for deer and turkey, and dove field management.

Warm season and cool season forage species were planted for wildlife at demonstration sites, and field tours were conducted to show wildlife food plot managers the results of the demonstrations. Forage species were evaluated for ease of establishment, persistence, nutritional quality, adaptability to local soil and climatic conditions, and wildlife preference or usage. Various pieces of wildlife food plot tillage and planting equipment, for ATV's and tractors were used to demonstrate the importance of seed bed preparation. Both conventional and no-till methods were used. Weed control demonstrations were conducted utilizing labeled herbicides.

Field tours were conducted in the late summer to view warm season plantings and in early spring to view cool season plantings. Forage analysis was utilized to determine nutritional quality (crude protein and digestibility). Exclusion cages were employed to gauge wildlife usage. Single forage species as well as commercial mixes were planted and evaluated at three sites including two farms in Colleton County and the Edisto Research and Education Center near Blackville in Barnwell, South Carolina. Demonstration areas totaled 40 acres. Plot sizes ranged from 0.20 acre to 2 acres in size, depending on the number of species planting and funding.

Objectives and Options

If your objectives are to only harvest wildlife (deer or turkey) most any forage species that will produce foliage during the hunting season will suffice. If your goal is to produce a year round source of palatable, nutritious food for wildlife you will need a more intensive approach to forage selection. Young quail chicks and turkey poults require protein, most often found in the form of insects they get while "bugging" in food plots. White-tail does also require a diet high in protein, especially in the last trimester of pregnancy and during lactation to ensure healthy fawns. Bucks require a diet of at least 17 % crude protein for antler development. So what choices does the food plot manager have when it comes to selecting forages for wildlife? Some good choices are listed in Table 1.

Results-What did we learn from wildlife food plot demonstrations?

When it comes to selecting a forage species for wildlife food plot planting soil type directly influences moisture and nutrient holding capacity and is one of the most important factors in a successful wildlife food plot program. Unfortunately, it is also one of the most overlooked components in many cases.

One of the most frequently asked questions by food plot managers is," what do you recommend for planting on sandy soils"? Avoid planting perennial clover on sandy soils.
Perennials are better suited for heavy soils with better moisture holding capacity. Chicory has a deep tap root and shows some drought tolerance.

If one must plant clovers on sandy soils try crimson clover or arrowleaf clover. However, there are some soils that just aren't suited for clovers, annuals or perennials! Plant these drought-prone sites to cool season grasses like small grains. Rye shows more drought tolerance than wheat or oats, and rainfall is usually higher in winter months than during the summer. Warm season options for sandy soils include alyceclover, cowpeas, and lablab, each of which exhibit more

TABLE 1. SELECTED SPECIES THAT ARE USEFUL IN WILDLIFE FOOD PLOTS IN THE COASTAL PLAINS

Warm Season Food Plot Species	**Cool Season Food Plot Species**
Legumes	**Legumes**
Alyceclover	Alfalfa
Aeschynomene	Austrian winter pea
Cowpeas	Lupine
Soybeans	
Lablab	**Clover**
Hairy vetch*	Crimson
Velvet beans	Ladino
Hairy Indigo*	Arrowleaf
	Durana white
Other	Red
Buckwheat	Subterranean
Sunflowers	Berseem
Chufa**	
	Small Grains
	Rye, Wheat, Oats, Tritcale
	Brassicas
	Kale, Rape, Turnips
	Others
	Chicory
	Small burnet*

* These forages were not included in the forage demonstrations but show promise as wildlife food plot species.
** Chufa is not considered a forage crop but was included in the demonstration plots since it is highly preferred by turkeys.

drought tolerance than soybeans or aeschynomene. Keep aeschynomene on soils with more moisture holding capacity. Hairy indigo may also be an option for sandy drought prone soils.

Another frequently asked question is, “ What can I plant that deer won’t wipe out in two nights”? The answer is,” Plant something that deer like not love!” Although highly preferred by deer, aeschynomene shows good tolerance to heavy browsing as compared to young soybeans or cowpeas. Alyceclover is an example of a crop that deer consume but do not devour. Lablab will stand grazing pressure but should be protected for 4 to 5 weeks after emergence. Plant a large enough area to produce some tonnage. With deer you cannot control the amount of forage they consume without repellents or fencing.

If you are not going to properly lime and fertilize your forage crops you are setting yourself up for failure. Take a soil test and follow recommendations, especially when planting legumes.

One of the most important lessons learned from our demonstrations was the importance of seeding or planting depth. Small seed must be planted at the optimum planting depth to ensure good emergence. Table 2. Illustrates this point.

TABLE 2. INFLUENCES OF SEEDING DEPTH ON ALFALFA ESTABLISHMENT IN SANDY, LOAM AND CLAY SOILS.

	Seeding Depth Critical with Small Seed			
	Depth (in.)			
SOIL	**0.5**	**1.0**	**1.5**	**2.0**
	--------- # of alfalfa plants per 100 seed ----------			
Sandy	**71**	**73**	**55**	**40**
Loam	**59**	**55**	**32**	**16**
Clay	**52**	**48**	**28**	**13**

Source: Sund et al.1966

It seems that everyone in the wildlife food plot business has a “silver bullet” for sale. Many advertise their products as ways to make wildlife “run faster, jump higher, and leap tall buildings in a single bound”. Well not really, but you get the idea. Oats have always been a preferred forage of many wildlife species, especially deer. There are many varieties available to food plot managers that are advertised for their superior performance characteristics. But are they truly superior and how will they perform in your environment? Table 3. provides results of a one year oat variety demonstration in which crude protein and digestibility were evaluated.

Mixes of different forage species have several advantages over single species plantings. Mixes spread the risk of stand loss due to factors like drought and winterkill. Mixes also extend the availability of forage to wildlife. For example, crimson clover is an excellent clover for wildlife plantings, but it matures early, late April or May in South Carolina. By adding arrowleaf clover to the mix you can get at least 30 more days of forage production. Mixes also pose some challenges like seeding at the proper depth when planting different size seeds found in some mixtures. Most food plot managers have difficulty planting a seed mix that contains a small seeded legume like white clover (which has 800,000 seed per pound and should be planted at 1/8th to 1/4th inch deep) and a larger seeded variety such as Austrian winter peas that has 2400 seed per pound and can be planted at 1 to 1.5 inches deep.

TABLE 3. CRUDE PROTEIN (CP) AND TOTAL DIGESTIBLE NUTRIENTS (TDN) IN VARIOUS OAT VARIETIES

	2004 Oat Variety Demonstration	
Variety	**CP @ 100% DM**	**%TDN**
Naked Oats	28.4	74.5
Plot Spike	24.9	73.5
Magnum 2000	27.8	73.4
Buck Forage Oats	23.4	73.6
Coker 820	27.3	72.9

Planting date: 10-22-04
Sampling date: 12-13-04
Plots were replicated 3 times and P and K applied according to soil test results.
N supplied by 2 years of crimson clover.
The greatest difference in these oats varieties in this particular demonstration was the cost of the seed.

Components of mixes should have similar soil type requirements. For example, chicory and alfalfa prefer well drained soils and brassicas tend to prefer a soil with more moisture holding capacity. Aschyenomene grows best on wetter soils and alyceclover works on sandy soils. Mixes limit weed control options such as herbicides. For example, one of my favorite warm season mixes for deer food plots is soybeans, cowpeas, sunflowers, and buckwheat. There are several herbicides labeled for use on soybeans, cowpeas and sunflowers but none for buckwheat.

The Food Plots 101 Short Course has been an excellent means of educating landowners and wildlife managers. It covers all the bases of sound food plot management and is very popular with natural resources clientele. The first session covers Soils and Soil Fertility and Selecting and Managing Wildlife Food Plot Species. The second session covers Weed Control in Wildlife Food plots and Managing Native/ Natural Plant Species for Deer and Turkeys. The third session covers Doves and Dove Field Management This 6 hour short course has been attended by first time food plot managers, experienced farmers, owners and managers of large plantations, professional foresters, commercial seed company representatives, small landowners, and hunters.

In 2006 a youth component was added. 4-H'ers attended a demonstration and presentation on establishing wildlife food plots at a week long wildlife 4-H camp at Webb Wildlife Center in Hampton County S.C. They acquire "hands-on experience with fertilizing and planting food plots as well forage species identification. The short course and field tours are excellent fund raisers for agents. Earlier this year 25 wildlife managers from 6 counties paid $90.00 each to attend Food Plots 101 in Orangeburg County, S.C. Sponsors contributed $400.00 towards meal expenses.

Summary of Evaluations for Food Plots 101

Jan. 22, 23 & 25 2007

1. How useful to you was the information presented in this program?
82% very useful 15% somewhat 3% didn't know

2. Did the program meet your needs?
97% yes, 3% didn't know

3. Did you gain any new knowledge by participating in this program?
97% yes, 3% didn't know

4. Will the knowledge gained by attending this program help you save money?
61% yes, 8% no, 31% didn't know

5. If yes, how much? Responses were: $500- $600, lots, $3, Don't know, Plan to spend more, Not sure, $1000, $200 plus, $800-$1000, $1500/ yr. $280. $500-$1000, $200, $1000's, No Clue!

6. How do you plan to use the information presented in this program? Responses were: Deer & dove plots, Improve food plot mixes, Begin a food plot program on my property, Better educate landowners of property I manage, Improve seed selection vs. soil characteristics, This program will be the basis of all my food plots, Improve native vegetation on my property, Enhance deer/ turkey growth on my property, Utilize soil sampling, Improve family property for wildlife, Aid in my business decisions concerning food plots, Just starting in food plots- no experience, Manage CRP openings

Summary- Successful Wildlife Food Plots

Lime, fertilize and properly amend the soil prior to planting
Plant on time in a well prepared seed bed with adequate moisture
Match forage species to soil type and local climatic conditions
Control weeds and pest
Record wildlife usage and forage quality
Don't be afraid to try new forage species to find what works best for you
If you are an educator, meetings, field tours and demonstrations to educate your clientele.

Conducting Applied Research with County Agents

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The rationale of conducting forage applied research in cooperation with county agents is to have an on-site resource that would allow making inferences about a forage practice or treatment in addition to demonstrating a particular practice.

Non-replicated demonstration plots have been traditionally used in extension efforts involving forages. These demonstrations areas or parcels are single, sole plots that showcase in many instances the latest in crop technology, allow for hands-on experience as well as direct contact with specialists and county agents. Single demonstration plots are a potent mean of conveying or illustrating a technique (such as the critical planting depth for bahiagrass or bermudagrass seeds, timing of fertilizer application, inoculation of legumes, stubble needed for a particular species, etc) but they are non-replicated and, therefore, lack error measurement and the control that is brought by replication. Demonstrations plots, however, fall short in situations where you want to make generalizations, or draw conclusions based on data collected from those plots. To properly make an inference or estimate a relationship between two or more variables, a measurement of fluctuations in observations, or error, is needed (Montgomery, 1997). This error measurement is only achieved through replication.

The purpose of using replicated applied research in outreach settings in cooperation with county agents is not to substitute for basic research but to complement those efforts through outreach by addressing, in a scientific manner, pressing issues for ranchers and farmers. Core investigators may address similar topics; some of their objectives may include more intricate aspects of the research necessary to respond to many underlying questions that usually require more treatments or levels of the factor being studied thus requiring more human and monetary resources.

To be effective, the proposed applied research needs the participation of the county agent, the producer or cooperator, and planning and coordination from the forage specialist (Newman et al., 2006). They need to follow some guidelines which are crucial for this type of study to be successful. First, the protocol for research needs to be simple in plot and design layout. Where traditional research will procure as many replicates as possible, applied research in extension settings need to be kept, in many instances, to the minimum replicates. The resources and objectives are geared to comply with the necessary replication but because the priority use is for outreach, less would imply more efficient use of the resources; also, they would combine blocks for data collection and sections for demonstration. Second, the cooperator or producer where the trial is to be implemented needs to be reliable and committed to facilitate the resources (land, animals, machinery, etc) throughout the duration of the research. Third, a close follow-up is necessary with county faculty because county extension agents, on their day-to-day work, need to multitask and cover a wide array of topics. Forage specialists must keep a close track of applied research progress, and coordination between agents and specialists is critical.

While addressing practical problems, applied research/demonstrations can serve multiple purposes within the outreach roadmap. This extension resource can be used for:
a) Demonstration of practices, b) on-site in-service training of agents, c) team teaching, with county faculty, in support of county Extension programs, d) at hand-resource for documentation of materials (photograph opportunity) to be used in educational programs (workshops, short courses, demonstrations, etc.), e) generation of extension publications, and f) generation of applied research publications. An example of such avenue for publications is the electronic journal Forage and Grazinglands, part of the Plant Management Network which targets applied issues in forage and grazing land production (Plant management network, 2007).

Participating agents in their second year have expressed that the applied research/demonstration setup has: a) provided "a tremendous amount of knowledge in the forages and research area", b) generated applied research results that relates to their county vicinity, c) created the opportunity to show first hand the possibilities of substituting N fertilization with the implementation of clovers in the grazing program of the county, d) shown the possibly best adapted cool-season forages for the area, and e) most importantly, it has allowed them and the producers to be part of this process.

References:

Montgomery, D.C. 1997. Chp. 2. Simple comparative experiments. Design and analysis of experiments. 4th ed. John Wiley & Sons. New York.

Newman, Y.C, J.P. Muir, and L. Redmon. 2006. Forage applied research/demonstrations plots – new partnership with county agents. ASA-CSSA-SSA abstract.

Plant Management Network 2007. http://www.forageandgrazinglands.org;

IS THERE A FUTURE FOR FORAGE EXTENSION?

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The title for this talk suggests that some of you younger folks may be out of a job as forage extension specialists in the future. This is a possible worst case scenario, but it doesn't need to happen. I would like to address three aspects of this potential problem. 1. Why forage extension funding can be expected to decrease or end. 2. Forage extension needs will increase but change. 3. How forage extension will be funded in the future. When planning for the future, it might be well to remember the wise words of Edmund Burke, "You can never plan the future by the past."

Why forage extension funding can be expected to decrease or end.

This sounds like the attitude of a pessimistic old man. My Uncle Sophus, who had a small dairy farm near our farm, was a born pessimist. Even when adequate rainfall had crops looking good, he would always predict that it can't last as it will get dry again. He was also the last farmer to adopt any new innovation as he knew it wouldn't work. In contrast, I am an optimist and believe strongly in forage extension, but I do think we need to be realistic and examine some major problems that face us in respect to future funding.

National and state funding of forage extension in the future is in jeopardy for a variety of reasons:

1. Government spending and borrowing has gone on at an accelerating rate in recent years, resulting in an unprecedented national debt of over **seven trillion dollars**. Interest payments on this money owed to China, Middle Eastern oil countries, and others take an increasing chunk out of our national budget.

2. Our population continues to have a higher percentage of elderly people, requiring more money for Social Security and Medicare. Health care costs for indigent people continue to rise. Veterans benefit costs add more pressure to the budget. A huge array of entitlement costs consume an increasing percentage of both national and state government budgets.

3. Confidence in the USA dollar has fallen, resulting in its depreciation compared to major foreign currencies.

4. We will become a poorer nation as energy and food costs rise and consume a greater portion of consumer income. Voter resistance to higher taxes will put pressure on governments.

5. The heady days of wild spending by Congress are over as they will be forced to reduce spending by cutting programs. Politicians will find it easiest to cut programs that affect the

fewest voters. Agriculture is a likely target, especially in funding areas without a strong commodity lobby like those of corn, soybean, cotton, or sugar. Forages are not notable for having a strong national lobby! Even a stronger American Forage and Grassland Council lobby is not likely to be sufficient. If you think elimination of extension funding unlikely in the future, consider that it has already happened in countries like New Zealand and England that had excellent extension services. It can happen here! The axe is most likely to fall on extension funding in the Federal budget, with funding continuing only in states having a strong agricultural base or better economies.

Forage extension needs will increase but will change.

Funding or no funding, there is no question that livestock producers will have a greater need of professional extension help in the future. Continuing education programs will be needed for livestock producers. Major changes will occur in the needs of clientele being served. It would be foolish to try predicting how grassland use and ruminant livestock production will change but there are some omens of the future:

1. Limited, but growing, production of pasture-finished (usually with some grain) “natural” beef without hormone feeding will require extension advice for high quality, well-managed pastures.

2. Continued global warming will cause shifts in adaptation of cool and warm season forage species. Forecasts for the southeastern USA are for hotter summers, shorter winters, and more erratic distribution of rainfall, thus resulting in greater stress on forage plants. My personal observations in Georgia indicate that during the past 15 years there has been a northward movement of bahiagrass and bermudagrass into areas previously dominated by tall fescue. Cultivars with less cold tolerance such as Tifton 85 bermudagrass are now adapted farther north than previously. These changes will affect livestock production systems where extension assistance would be useful.

3. Legumes will play a much bigger role in future pasture production as nitrogen fertilizer costs remain high. Successful legume production requires better management than grass-nitrogen fertilizer systems. Superior persistent pasture legume cultivars are available but increased stress from warmer and drier conditions may make them less well adapted in the future. More stress-tolerant cool and warm season legumes will be needed in the future. However, development of these legumes is problematical since state and federal funding of forage breeding has declined.

4. Increasing cost of feed grains, energy costs, equipment, and waste disposal will put pressure on feedlot dairy production, making irrigated grazing dairies a cheaper and easier way to produce milk in the southern USA. This requires expertise in maintenance and grazing management of high quality pastures during much of the lactation cycle. Extension advice will be needed on problems such as surplus forage for stored feed, cooling of cows with misters, fencing systems, and legume systems.

5. It is likely that the use of forages planted for wildlife food plots will continue to grow. The challenges of difficult environmental sites require extension expertise that is often lacking by

many managers. This is a major area of growth as natural areas are utilized for hunting and for nature lovers who enjoy wildlife.

6. As methodology improves for cellulosic ethanol production, agronomic advice will be needed to produce the crops used for this purpose. For example, switchgrass could be a major enterprise on large land areas not well suited to other crop production. Extension expertise will be important for successful production of this high-yielding energy crop, which has much greater potential than utilizing corn, a valuable feed and food crop, for ethanol production.

7. Since the average age of experienced livestock producers in the USA is over 60 years, it is likely that many future novice producers will lack this knowledge base and be in need of forage expertise from extension.

How forage extension will be funded in the future.

Most Southern forage extension specialists receive only a token amount of support money for travel and other expenses. Unless they are content to remain in their offices, they must secure small grants from industry and commodity groups to support their visits to farms and meetings in and out of their state. Many also do applied research that requires additional grant money. As Federal monies for extension dry up, some states are likely to close out extension positions as retirements occur. This has already occurred. Tenure is likely to be abolished at universities in the future, which would make it much easier for administrators to terminate a faculty member when budgets are short. It has been suggested that extension should be self-supporting with a user-pay fee system to support salaries of extension specialists. I think we recognize the difficulties of operating such a system within a university.

Before we address options for funding forage extension specialists in the future, let's look at what makes extension so successful in the USA.

1. Most counties have one or more extension workers to serve clients with free information. At present, there is a trend toward appointing regional agents that work as forage and livestock production specialists in several counties. This facilitates the development and delivery of educational programs. It is an effective system but difficult to initiate as there is often strong political resistance to such a system.

2. Extension specialists are available to assist county and regional agents, providing expertise to solve special problems and find solutions.

3. Educational meetings are held to update agents and train producers in improved technology.

4. Information on cultivars, fertilizers, pesticides, or other products is based on field testing and is **unbiased**. Producers have come to trust extension to give them good recommendations that are not biased in favoring a particular name brand.

5. Information is available in various forms at county extension offices and on internet web sites.

6. Extension offers leadership in developing state grassland councils and other organizations for educational meetings and interaction with other producers.

7. Extension services are free and paid for through taxes.

With such a fabulous program of service, it seems a pity to see it to destroyed through lack of funding. It is critical that a serious effort be made in each state to do a more effective job of lobbying to preserve this program as long as possible. State AFGC grassland councils need to become more visible and let **both rural and urban** politicians know the value of forages in their state. Grasslands are important to our society, but the average urban person hardly knows we exist. They may not even know what the words "forage crops" mean. The future of forage extension specialists is at risk in some states. The financial crunch is coming and we need to be prepared. I am hopeful that with strong effort, extension can have a future once our case is made.

However, even with strong lobbying efforts, it is possible that extension will be wiped out in years to come. If that happens, what are the options in providing reliable forage management information to producers?

1. Private consultants are touted as a solution. The difficulty with this is that producers have come to expect extension information to be free and most are not willing to pay for it as is the case with consultants in the business and industrial world. The New Zealand experience of terminating extension saw a proliferation of ex-extension agents who went into the consulting business but soon found that a lot of their old clients were not willing to pay for their help. Many, especially larger producers, were willing to hire experienced competent consultants, but the majority were not. The number of private consultants eventually declined. I suspect that we would have a similar experience. Thus, the majority of producers would be untouched by paid consultants.

2. Consulting companies would likely develop and provide a range of consultants with different kinds of expertise. They could provide a range of services that might be more appealing to a producer. A group practice would also attract well qualified persons and might help ensure that they operate more as professionals.

3. Private seed, fertilizer, pesticide, and fence companies currently provide extension information and would do so in the future. There is no doubt that well trained persons from a company could be of great assistance in helping producers to soil test and fertilize, plant correctly, and manage grazing of pastures. Unfortunately, some would be more sales persons than advisors and not have adequate updated training. More serious is that one would not expect these people to be totally unbiased in their recommendations of cultivars and other products.

4. Commodity groups, marketing organizations, or business cooperatives could employ extension specialists to serve their member producers as advisors, provide educational material, and operate training classes. This system has been highly successful in New Zealand where the Dairy Board milk marketing organization provides extension specialists to serve its dairy farmer members. Such a program never developed among New Zealand sheep and beef cattle farmers.

In Brazil, well-trained extension specialists are employed by large farmer-owned cooperative soybean, corn, and sugarcane processing and marketing organizations to provide a high level of service to their farmer clientele. In the USA, such an internal extension program operates quite successfully in the broiler industry where feed and poultry meat processing and marketing companies provide service to their poultry farmers.

In the USA, large milk processing and marketing companies could provide extension assistance to their dairy farmers if there were no publicly supported service. In the wildlife area, wild turkey or white tail deer organizations could provide extension advisors to their members. It is difficult to see how it would function for beef cow-calf producers unless they would be willing to pay an annual fee for service, which seems highly unlikely. Overall, destruction of the extension service will not only eliminate potential jobs for talented and well-trained forage extension specialists but also lower management and agricultural production efficiency.

The future of forage extension.

The heady days of adequate funding for excellent forage extension programs are over. In the future, severe federal deficits will reduce and may eventually eliminate funds for forage extension. It is likely that extension funding at the state level will also be reduced and may even be eliminated in some states unless grassland lobby groups can mount effective support campaigns. Forage extension programs have had a notable record of accomplishment in the past and they are needed in the future. Changes in grassland production and utilization will need extension expertise even more in the future. If public funding is not continued in the future, there are some alternatives but none of them are a good substitute for the present publicly supported extension system. Younger forage extension specialists are likely to face new challenges and changes in their careers. Many will have rewarding and exciting careers but it will be survival of the fittest in a tough world.

Developing Legumes for use in Forage and Biomass Production Systems

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El Reno, OK and Louisiana State University Agricultural Center, Winnsboro, LA, respectively.

Introduction

Identification and development of introduced or native legumes with forage, biomass or nitrogen producing potential continues to be a priority need (USDA ARS legume workshop, Chicago, IL, 2004). Traditional forage legumes, such as white clover, red clover, and alfalfa continue to be important forage crops and may provide direct biomass production potential or utility as a companion crop and nitrogen source for grass based biomass production systems. Numerous plant introductions of both native and introduced legume species are available for evaluation. However, most applied breeding programs do not have the resources to systematically evaluate large numbers of these species for their agronomic or biomass potential. The legume program at El Reno, Oklahoma, has focused primarily on alfalfa, white clover and bundleflower with lesser emphasis on red clover and *Trifolium rubens*.

Grazon P+D Tolerant White Clover Research

This project was initiated in response to a request from the Louisiana Cattleman's Association for research and development of a Grazon tolerant white clover for use in pastures. This research was funded in part by the Louisiana Cattleman's Association.

Phase I of the project was to identify plants that demonstrated tolerance to the herbicide Grazon P+D. The parent population was 1964 LA S-1 breeder's seed. Thirty-three white clover plants were identified as having possible tolerance to Grazon P+D and transplanted to pots for maintenance.

Plants that had survived Grazon P+D exposure in tissue culture were moved to El Reno, Oklahoma on July 15, 2003. During the 2003/2004 season, plants were maintained in the greenhouse and propagated by stolons to increase the number of plants. On 17 March, 2004, four randomly assigned replications of each surviving plant were established in an isolated nursery at the USDA-ARS-Grazinglands Research Center. Cross-pollinated seed was harvested separately from each plant at El Reno between June 7 and June 30, 2004.

Seed from each of these plants was used to start progeny plants during the 2004/2005 greenhouse season. A total of 1800 plants were grown in the greenhouse. Nine hundred of these plants were sent to Winnsboro, Louisiana, for establishment and evaluation and the remainder was transplanted at El Reno. Three replications with 2 blocks per replication were established at each location. After establishment, one block of each replication at each location was treated with Grazon P+D and evaluated for survival. There were no surviving plants at Winnsboro but after three spray events there were surviving plants at El Reno. Survival ranged from a high of 6.5 (GR94) to a low of 0.5 plants per row (Osceola). Mean survival of sprayed plants was 3.6 plants per row compared to the unsprayed survival rate of 9.4 plants per row. At Winnsboro, although all plants treated with Grazon P+D exhibited effects from the treatment, part of the lack of survival may have been due to extremely dry conditions. The non-sprayed plants were exhibiting drought symptoms soon after treatment and failed to survive. On January 23 and 25, 2006, surviving plants from the El Reno location were transferred from the field trial to the greenhouse. The control cultivars, LA-S1 and Osceola, had survival rates of 20 and 6.7%, respectively. The best selected line had a survival rate of 46.7% after being sprayed with Grazon P+D at three separate intervals. A field nursery of the plants was established on April 27, 2006. Due to the extremely dry and hot summer at El Reno no seed was produced in 2006. However, with irrigation plants have survived well and were flowering profusely by April 2007. Seed will be obtained from individual plants and bulked to produce a synthetic population for further evaluation.

Evaluation of methodology for production of alfalfa synthetic populations

Alfalfa yields increased slowly rate for many years. Performance of synthetic populations has been known to decrease with subsequent generations of seed increase and is presumable the result of inbreeding. This study was designed to determine the degree of self pollination among selected clones and the relative impact of this self pollination on population performance.

Two alfalfa populations were developed over a period of 10 years beginning with 8 surviving plants selected in 1993 from a large alfalfa trial at Winnsboro, Louisiana. After several cycles of crossing and full sib evaluations at several locations in Louisiana, 31 clones were selected – 15 from population A and 16 from population B – for development of synthetic populations and production of progeny families for future evaluation.

To produce synthetic seed, 32 replications of all 31 clones were established at El Reno, OK, on 17 – 18 March 2004. Seed was harvested from individual plants for four replications in 2005 and 2006. The remaining seed was bulked. During 2004/2005 all 31 clones were grown in the greenhouse and the relative seed set from self pollination was determined for each clone.

Four replications with 10 plants per row were established on 15 May 2006 for half-sib progeny evaluation of each of the 31 parent clones. Self progeny was included from 10 of the 31 parent clones. These latter clones were selected on basis of viable self seed production. Populations for evaluation were formed by taking equal amounts of seed from clones based on self seed production, field seed production, and a height and weight index. These populations are being compared to a control synthetic derived from bulked seed of all 31 clones. Four replications of each population were seeded in 1 meter rows on 25 Sep 2006.

The result of analysis of the first year's seed production in the field revealed no correlation between germination and seed yield. It was anticipated that clones with a greater capacity for producing self-pollinated seed would also produce more seed per clone in the field. However, this was not the case and a comparison of clonal field seed production with the level of observed self pollination and seed set from greenhouse evaluation did not demonstrate any correlation between the two. The percentage of seed contribution was based entirely on in-field seed production which was highly variable. All progeny rows were harvested on 1 August and 14 September to determine yield. There was no difference among entries for plant survival and there was no harvest by entry difference for plant weight. The range in mean weight per plant varied from a high of 181.4 g (HS209) to a low of 61.8 (S115). Most of the self progeny lines did not perform well. However, S204 was not different from the top yielding half-sib line (158.4 g). Evaluation of these lines will continue in 2007 and harvest of synthetic populations will be initiated in spring of 2007.

Bundleflower evaluation and selection for companion cropping with switchgrass

On 6 May 2004, 1000 space plants, derived from a common source of Illinois bundleflower and from seed collected along the Pease River near Vernon, Texas, were transplanted to a filed nursery at El Reno, Oklahoma. Plants were spaced 2' on center within rows ands rows were 2' on center.

Seed was harvested from selected plants beginning on 2 August 2004. Seed was harvested at weekly intervals until 26 August. Ten plants were selected at each harvest date resulting in 50 plants representing 5 maturity ranges. Plants were visually selected for color, upright growth habit and overall vigor. Selections from Pease River were the latest maturing and comprised the last group harvested.

On 9 June 2005, replicated progeny rows from the 50 plants identified in 2004, were transplanted into two replications of 10 plants each. Plants were 2' on center within rows and rows were 2' on center. On 20 July and 2 August, 2006, Plants were evaluated for maturity, height, and survival. Thirteen lines were selected and seed was harvested and bulked by row and family. Seed from the tallest line, BF50 (Pease River) was used to establish a companion planting with switchgrass in April 2007. Depending upon results from this study, seed may be increased from this line for further evaluation.

Trifolium rubens evaluation

Ten accessions of *Trifolium rubens* (L.) were evaluated for morphological, reproductive, and agronomic diversity. Available seed, provided by the Regional Plant Introduction Station, Pullman, WA, ranged from 30 to 100 seed per accession. Seedlings from each accession were established at El Reno, OK, on 5 May 2004. Establishment year plant survival (95%) and two year survival on 5 April 2006 (83.5%) were not different among accessions. Differences were observed among accessions for all vegetative characters including height, vigor, growth habit and leaf characteristics. Dry matter yield per plant averaged 67.1 g and ranged from 48.6 to 86.6 g (542923 and 325507, respectively). Neutral detergent fiber varied among accessions, averaging 492 g kg^{-1} and ranging from 469 (255396) to 505 g kg^{-1} (542847). Harvest dry matter, crude protein, and acid detergent fiber were not different. Flowering was determinate and flowering date, percent plants in flower, and seed production varied among accessions. Seed per plant ranged from 0 to 0.6g per plant in the establishment year (accessions 255396 and 314123 respectively) and from 0 to 27.5 seed per flower in 2005 (accessions 255396 and 314123, respectively). Overall survival and the useful variation observed indicate agronomic potential for this species.

Superior plants were identified from 2 accessions and seed increased for evaluation of replicated progeny rows at 3 locations. Four replications of 10 plants per replication were established in April and May of 2007.

Lessons Learned in 32 Years of Forage Breeding in Florida

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I am generally not one to wax philosophical, but when Ray Smith called and asked me to speak to the Southern Forage Breeders Workgroup, on "any topic you wish", this seemed to be a good opportunity to share some "wisdom". I arrived at the University of Florida in April of 1975, thus I have just passed my 32nd anniversary, and maybe that qualifies me as a senior statesman. The "Lessons" I share below are probably not unique, and others could probably develop their own set of "Lessons", but for now these are mine, with illustrated examples from my research experiences.

Lesson 1. You are not nearly as smart as you thought you were coming out of grad school!

Believing that I had excellent graduate training at the University of Kentucky, I arrived at the University of Florida, only to be told that my first breeding project was to be improvement of the tropical grass *Hemarthria altissima* (Poir.) Stapf & C. E. Hubb. In all my 27 years of life to this point including 8 years of higher education, I had never even heard of this plant, and what was worse, the locals could not even agree on a common name to use for it (choices included alta grass, hemgrass, hemarthria, mafia grass, and limpograss - the one finally agreed on). Nevertheless we did have a diverse collection of germplasm that showed a large amount of variability (another lesson one should learn very early, but it did not make my top ten list). Thus we started a program of germplasm evaluation (no breeding involved at this point). It was learning about tropical grasses by doing!

At about this same time I was introduced to plant parasitic nematodes. I believe in my undergraduate plant pathology class we may have spent one day on this topic, but here at Florida they had a half a department devoted to these critters (Entomology and Nematology Department), and they seemed to feed on most every plant one tried to grow in Florida. So I soon found a cooperator in Nematology (see Lesson 3) and we screened the limpograss collection for response to sting nematode (*Belonolaimus longicaudatus*) (Quesenberry and Dunn, 1981). From the relationship with this cooperator, Dr. R. A. (Bob) Dunn, I also learned about root-knot nematodes (*Meloidogyne* spp.) (RKN) (another nematode I knew nothing about, but that was a major pest on many plant species in Florida) and we soon began a ten year program of recurrent selection for RKN resistance in red clover that ultimately led to the release of the cultivars 'Cherokee' and 'Southern Belle' (Quesenberry et al., 1993, Quesenberry et al., 2005). Now many years later, I've come to realize that there is much more that I don't know and one's goal must be to be a life-long learner!

Lesson 2. Be sure you have well defined objectives that are "easily measured".

This is illustrated with the release of 'Floralta' limpograss. There was a simple stated objective - We need a limpograss that has improved persistence under grazing. With a group of selections that has passed through Phase 2 of our selection program (Quesenberry et al., 1977), Dr W. R. (Bill) Ocumpaugh (Lesson 3) and I initiated a mob grazing experiment and within two years had identified the selection that was ultimately released as Floralta (it yielded well and persisted whereas several others were mostly dead = easily measured) (Quesenberry et al., 1984, 1987). More will be said about this cultivar under Lesson 5. Likewise, RKN response is relatively easy to measure (you just examine the roots and rate of galling and egg mass production = easily measured). Dr. D. D. (David) Baltensperger (see Lesson 3) and I worked out a technique for screening large number of plants for response to various RKN species (Quesenberry, et al., 1986). Over the years this technique generated many publications and has been used in the development of at least four different cultivars (Baltensperger et al., 1985; Call et al., 1996, 1997; Kouame et al., 1995, 1997, 1998; Quesenberry and Dunn, 1987; Quesenberry et al., 1989, 1993, 1997, 2005; Soffes et al., 1983; Zimmet et al., 1986; Taylor et al., 1986). Someone once said, "Give me a screen with the 'right size/shape hole' and I can select for almost anything." Identifying important (yield and production limiting) traits that can be screened for across large numbers of individuals will always be critical for successful forage breeders.

Lesson 3. Good friends, cooperators, and technical support are important.

Part of what needs to said here has already been mentioned above in Lessons 1 and 2, but I would be neglect not to mention a host of other folks. I've certainly learned that successful forage plant breeders need many cooperators. What follows is an incomplete lists of the many that have assisted in my program over the past 32 years. These include forage management agronomists (Leonard Dunavin, Rob Kalmbacher, Al Kretschmer, Paul Mislevy, Bill Ocumpaugh, Gordon Prine, Charles Ruelke, Lynn Sollenberger, Bob Stanley, and Jeff Steiner), fellow breeders (David Baltensperger, Joe Bouton, Byron Burson, Glen Burton, Wayne Hanna, Jorge Mosjidis, Gary Peterson, Dick Smith, G. Ray Smith, Norman Taylor, and David Wofford), international colleagues (Bruce Cook, Mark Hutton, John Miles, Liana Jank, Daniel Real, Warren Williams, and many others), even some administrators (Jerry Bennett, Charles Dean, Joe Joyce, and Coleman Ward), and I'm sure I have left out many others. One of the most important elements to long term success in forage breeding is strong and long tenured technical support. I have been very fortunate to have five individuals in my 32 year career at Florida without whom much of what has been accomplished would not have been possible. Deep gratitude is expressed to Dick Booth, Judy Dampier, Renee Kratka, David Moon, and Loan Ngo).

Lesson 4. Clovers can be important in the Deep South, but they have their problems.

This lesson perhaps is best illustrated with Cherokee and Southern Belle red clover (Quesenberry and Blount, 2006; Quesenberry et al., 1993, 2005). Under optimal conditions of rainfall we have measured yields that rival those of the upper Midwest and producers have successfully made excellent red clover hay in Alachua County that brings top dollar at local sales outlets. Some of these producers think we have worked magic on red clover. Improving RKN resistance and selection for early spring production (non-dormancy) has had major impact on the adaptation of red clover for the southeastern USA. Similar success has been observed with Osceola white clover released from the UF/IFAS Agronomy department (Baltensperger et al., 1984). Conversely, even when doing everything that I thought I knew to do right (see Lesson 1) I have had near complete failures of red clover and white clover small plots and producers have also suffered similar problems. The 2006-07 season in north Florida was one of those "bad" years, and you will not be seeing clover plots on the tour at Marianna this year. Even with extensive nematology, pathology, agronomic, and other input we do not have a consensus on the cause(s) for some of these failures.

Lesson 5. Your most successful cultivar likely will not be the one you thought.

When Floralta limpograss was released (Quesenberry et al., 1984), I do not think any of the developers expected it to become the "success" that it is today. Although several years were required for it to "take-off", we now estimate that there may be as much as 100,000 hectares of Floralta in central and south Florida. Several large ranches developed methods for mechanizing planting which greatly improved is use. This cultivar has certainly found a niche for fall-winter forage production for the beef cow-calf producers. Conversely, Cherokee red clover, has probably never been planted on more than 10,000 acres in any one year, although over the years it has made substantial contributions for those producers that have learned where it fits into their production system. This lesson is likely a corollary to Lesson 1 - not being as smart as we thought we were.

Lesson 6. Grant $$ may not result in cultivar releases (but they may get you promoted and tenured).

Shortly after I arrived at Florida, nitrogen fixation by tropical grasses associated with *Azospirillum lipoferum* was a major topic of interest (Smith et al., 1976) with federal funding agencies (USAID), and a team of Florida investigators including myself obtained significant grants dollars to support this research. This collateral funding enhanced some of my early breeding projects, but was not for cultivar development. Later funding for tropical legume evaluation was obtained from USDA-CSREES special grants for Tropical and Sub-Tropical Agricultural Research (TSTAR), but again no cultivars have resulted from these projects (although a rhizoma perennial peanut release is pending). Nevertheless, a resume showing multiple millions of dollars in grant support over a career will be important for tenure, promotion, and special pay increases! My lesson from these experiences is that grants may detract from overall plant breeding objectives, but they are critical to succeed in an academic environment.

I would be remiss not to voice a concern that long term plant breeding programs will not be sustained by short term grant funding. Current "hot-topic" issues funding often draws funding from sustained long terms programs that ultimately deliver broadly-adapted cultivars. Quality science should always triumph in funding decisions, but certainly there is a need for breeders to be attuned to creative opportunities for funding programs. Royalties from previous successful releases may offset some of the lows in sustained funding.

Lesson 7. Marketing may be more important than breeding.

A primary illustration of this lesson is 'Osceola' white clover (Baltensperger, et al., 1984). The initial rights to production and marketing of this cultivar were assigned to a company that had limited experience in clovers (and who ultimately got completely out of the forage breeding business). Little seed was produced or sold. A second company had one individual that aggressively marketed this cultivar, and over the past 15 years it is estimated to have been planted on over 2.5 million acres in the USA. Other cultivars that had similar good agronomic attributes and broad environmental adaptation have not enjoyed such success, often due to poor or limited marketing efforts. A good production, distribution, and marketing company is equally as important as a superior cultivar.

Lesson 8. Be nice to your graduate students, they may be your next cooperator or boss.

In the past 32 years at Florida I have chaired or co-chaired almost 30 graduate committees, and have served on well over 75 committees. The great majority of these have been excellent high quality students. Many have enjoyed great success in their own programs after completing their student tenure at Florida and some have passed by their former mentor. One of these is Dr. Chris Deren, who after a number of years as a successful sugarcane and rice breeder at the UF/IFAS Everglades Research & Education Center at Belle Glade, Florida, is currently serving as the Director of the University of Arkansas, Rice Research and Extension Center at Stuttgart. Another is Dr. Neysa Call, who after completing a MS with me at Florida moved to North Carolina, for a Ph.D. and is currently a employed as a Legislative Policy Analyst in the Office of Legislative and Public Affairs of the US National Science Foundation in Washington, DC. One who has become a valued cooperator is Dr. Ann Blount who after a 10 year career as a research associate with the UF/IFAS North Florida REC in Small Grains Breeding Program, now is pushing me along with a tetraploid bahiagrass breeding program and has chaired two student committees where I have served as the on-campus co-chair. Through some changes in faculty, I was fortunate to be asked to serve as co-chair of the Ph.D. program for Dr. Lynn Sollenberger in forage management. After completing his degree at UF we were fortunate to hire him on the faculty and about a year ago he assumed the role of Associate Chair of Agronomy - my associate-boss. As most of you know he is recognized around the world for his pasture management research program.

One of the great strengths of the Land Grant College System is the interaction of teaching, research, and extension. I feel that first and foremost I am a teacher - even my children will agree with that! The ability to incorporate real world examples from breeding experiences into classroom teaching has certainly been a strength of my career. Numerous students have shown those “ah-ha moments” in the classroom when real photos and data have illustrated a textbook concept. Working with students has been and continues to be a highlight of my breeding career.

Lesson 9. What goes around may come around so don’t forget those lessons learned.

After the release of Floralta limpograss in 1984, I made the decision that limpograss did not merit additional breeding effort (this was before we saw how wide spread it would be planted). In a Florida Cattleman’s Research Council meeting a few years ago the interest in additional limpograss cultivars was put forth as a priority. In 2005-06 we initiated a small program of producing hybrids with the objective of improving the nutritive value (IVOMD) while maintaining persistence. Currently 51 hybrids are under Phase 2 evaluation at the UF/IFAS Range Cattle REC at Ona, at the Agronomy Forage Research Unit near Gainesville and at the North Florida REC at Marianna. Thus, I am having to remember all I learned and mostly forgot about how limpograss grows and needs to be managed in an evaluation program. Breeding vegetatively propagated species is a different game.

Lesson 10. Don’t forget your family and friends and stay humble.

Most of you who know me well, recognize that my family (especially Joyce) usually travels with me to most scientific meetings. Likewise, those in Florida know that she and the children have been hauled around the state to look at forages from Pensacola to Immoklee and beyond. I firmly believe that becoming too focused on one’s research if “bad for your health” and for the health of your family. We have taken two sabbatical leaves while at Florida (and should have taken more). The family struggled and prospered through both of them, but looking back would not take anything for the experiences. Good and life-long friendships were made at both locations. We have attended every International Grassland Congress since 1981 (Lexington, KY, USA; Kyoto, Japan; Nice, France; Palmerston North, New Zealand and Rockhampton, Australia; Winnipeg and Saskatoon, Canada; Sao Pedro, Sao Paulo, Brazil; and Dublin, Ireland and Aberystwyth, Wales), and virtually all national ASA/CSSA/SSSA meetings since 1975, as well as numerous *Trifolium* conferences and regional project meetings. Such trips make life worthwhile, strengthens families and nurtures friendships.

In the waning years of my breeding career I have become more active in CSSA and will begin a three year term as President-elect/ President/ Past-president in November 2007. I am hopeful that some of the lessons learned above will be useful in this new leadership role. I'm sure my family and friends will provide encouragement and support and also see that I remember Lesson 1! I trust that you may find one or more of these instructive in your forage breeding endeavors.

References

Baltensperger, D.D., C.E. Dean, E.S. Horner, L.S. Dunavin, W.R. Ocumpaugh, and P. Mislevy. 1984. 'Osceola' white clover. UF/IFAS Circular S-311.

Baltensperger, D.D., K.H. Quesenberry, R.A. Dunn, and M.D. Abd-Elgawad. 1985. Root-knot nematode interaction with berseem clover and other temperate forage legumes. Crop Sci. 25:848-851.

Call, N.M., K.H. Quesenberry, and R.A. Dunn. 1996. *Meloidogyne arenaria* development in three clover populations. Crop Sci. 36:1393-1397.

Call, N.M., K.H. Quesenberry, and R.A. Dunn. 1997. *Meloidogyne javanica* development in three clover populations. Crop Sci. 37:265-269.

Kouame, C.N., K.H. Quesenberry, and R.A. Dunn. 1995. Evaluation of African *Trifolium* germplasm for reaction to root-knot nematodes. Afro-Asian J. Nematol. 5:110-112.

Kouame, C.N., K.H. Quesenberry, and R.A. Dunn. 1997. Response to root-knot nematodes of a germplasm collection of red clover and related species. Genet. Resour. & Crop Evol. 44:439-445.

Kouame, C.N., K.H. Quesenberry, D.S. Wofford and R.A. Dunn. 1998. Genetic diversity for root-knot nematode resistance in white clover and related species. Genet. Resour. & Crop Evol. 45:1-8.

Quesenberry, K.H., D.D. Baltensperger, and R.A. Dunn. 1986. Screening *Trifolium* spp. for response to *Meloidogyne* spp. Crop Sci. 26:61-64.

Quesenberry, K.H., D.D. Baltensperger, R.A. Dunn, C.J. Wilcox, and S.R. Hardy. 1989. Selection for root-knot tolerance in red clover. Crop Sci. 29:62-65.

Quesenberry, K.H., and A.R. Blount. 2006. Southern Belle and Cherokee red clover in Florida. IFAS Extension Publication SS-AGR-40.

Quesenberry, K.H., A.R. Blount, L.S. Dunavin, and P. Mislevy. 2005 Registration of 'Southern Belle' red clover. Crop Sci. 45:2123-2124.

Quesenberry, K.H., N.M. Call, D.E. Moon, and R.A. Dunn. 1997. Response of native eastern North American *Trifolium* spp. to root-knot nematodes. Crop Sci. 37:270-274.

Quesenberry, K.H., and R.A. Dunn. 1978. Differential responses of *Hemathria* genotypes to sting nematodes in a greenhouse screening trial. Soil Crop Sci. Soc. Fla. Proc. 37:58-61.

Quesenberry, K.H., and R.A. Dunn. 1987. Variability among *Desmodium* species for response to root-knot nematodes. Crop Sci. 27:1234-1237.

Quesenberry, K.H., W.R. Ocumpaugh, O.C. Ruelke, L.S. Dunavin, and P. Mislevy. 1984. Floralta - A limpograss selected for yield and persistence in pastures. UF/IFAS Circular S-312.

Quesenberry, K.H., W.R. Ocumpaugh, O.C. Ruelke, L.S. Dunavin, and P. Mislevy. 1987. Registration of Floralta limpograss. Crop Sci. 27:1087.

Quesenberry, K.H., G.M. Prine, O.C. Ruelke, L.S. Dunavin, and P. Mislevy. 1993. Registration of 'Cherokee' red clover. Crop Sci. 33:208-209.

Quesenberry, K.H., R.L. Smith, S.C. Schank, and W.R. Ocumpaugh. 1977. Tropical grass breeding and early generation testing with grazing animals. p. 100-103. Proc. 34th Southern Pasture and Forage Crop Improvement Conference, Auburn University, Auburn, Alabama. 12-14 April 1977.

Smith, R.L., J.H. Bouton, S.C. Schank, K.H. Quesenberry, M.E. Tyler, J.R. Milan, M.H. Gaskins, and R.C. Littell. 1976. Nitrogen fixation in grasses inoculated with *Spirillum lipoferum*. Science 193:1003-1005.

Soffes, A.R., K.H. Quesenberry, and R.A. Dunn. 1983. Tolerance to two species of root-knot nematode, *Meloidogyne* spp., in Leucaena. Leucaena Research Reports. 4:92.

Taylor, S.G., D.D. Baltensperger, K.H. Quesenberry, and R.A. Dunn. 1986. Variability in *Meloidogyne* resistance within the genus *Alysicarpus*. Crop Sci. 26:501-505.

Zimmet, A.R., K.H. Quesenberry, and R.A. Dunn. 1986. Evaluation of *Leucaena* species germplasm for genetic resistance to *Meloidogyne incognita* and *M. javanica*. Nematropica 16:99-108.

Filling the Niche: Looking at Alternative Uses and Species of Forage Crops

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The forage breeding program at Tifton, Georgia has a long, notable history that began with the release of 'Coastal' Bermudagrass (*Cynodon* spp.) in 1943, which is now planted on 10 million acres, nation wide. Forage releases have continued with 'Tifton 85' bermudagrass, 'Tifton 9' bahiagrass (*Paspalum notatum* Flügge) and 'Tifleaf 3' pearl millet (*Pennisetum glaucum* L.), by Drs. Glenn Burton and Wayne Hanna. This program has often looked at species or uses that were not immediately viewed as the most appropriate use of resources, but ultimately proved invaluable to the agricultural economy of the southeastern United States. While work in the traditional program areas of forage and turf improvement of bermudagrass, bahiagrass, and pearl millet for the southeast continues, new application such as efforts to develop bio-energy feedstocks as well as the study of new species is also underway.

Numerous studies of biomass production, nutritive value, and harvest frequency response to nitrogen in Bermudagrass were done starting as early as 1956 (Taliaferro et al. 2004). The majority of this work focused on maximizing production, rather than for optimization through increasing nitrogen use efficiency by the plant. Nitrogen use efficiency for turf grass applications has been defined in two ways: the first is the percentage of nitrogen per dry weight of plant matter (Jiang et al. 2002), and the second defines it as percent of applied nitrogen recovered by plant roots (Bowman et al. 2002). Bowen et al. (2002) reported nitrogen recovery ranging from 63% to 84% for six warm season grasses. Significant species and cultivar differences have been reported for the amount of nitrogen recovered by each of three different cool-season grass species (Liu and Hull, 2006). While differences among warm-season grass species for nitrogen use-efficiency have been reported detailed cultivar studies such as those for cool-season grass species have not been reported. The goal of this research work is to do a large scale survey of available bermudagrass to determine availability of genotypes which allow for the development of plant types with increased nitrogen use efficiency.

Pearl millet as a forage is an annual of note in the southeast with dry matter yields of 11,000 kg ha $^{-1}$ and digestibility of 500-600 g kg^{-1} (Hanna et al. 2004). Developments of brown midrib (bmr) types with reduced lignin for increased digestibility are a major focus of the current program. To date, six elite cytoplasmic male sterile females and eleven restorer lines expressing the gene reported by Cherney et al. 1988, have been developed and are utilized in seven elite hybrids currently under field performance testing. Traits under evaluation are digestibility, yield, disease/insect resistance, and drought tolerance. Additionally more then 3000 early generation bmr inbreds expressing a gene identified at Tifton in germplasm from Burkina Faso that also include a trait for stay-green are also being tested.

Bio-energy feedstock improvement of Napiergrass (*Pennisetum purpureum* Schumach.) is also currently underway. 'Merkeron' napiergrass has yielded 28,748 kg ha^{-1} versus 15,570 kg ha^{-1} for 'Tifton 85' bermudagrass and 13,254 kg ha^{-1} for 'Alamo' switchgrass in Georgia suggesting it would be a good bio-energy feed stock for the southeast (Bouton, 2002). One of the draw backs to this species, however, is lower lignocellulose digestibility. Personal communication with Wayne Hanna has further indicated that the A' genome of Napiergrass may be masked by the B genome of Napiergrass. Study of gene expression is set to determine the validity of this hypothesis as well as attempt to improve the quality of napiergrass. Fritz et al. (1981) was able to successfully move the recessive bmr trait from diploid sorghum to tetraploid sudangrass. If the A' genome is not masked, bmr napiergrass could be developed as a bio-energy feed stock. Currently, approximately 1000 pearl millet X napiergrass F_1 crosses are being grown out in the greenhouse. These hybrids include pearl millet females expressing the recessive bmr gene and a dominant red leaf trait to determine the viability of A genome genes moved from pearl millet to napiergrass. The digestibility of the hybrids could be improved if the A genome proves not to be masked.

Rhizoma peanut (*Arachis glabrata* Benth.) is a tropical legume that combines both high nutritive value and long-term persistence under a wide range of grazing and harvested hay systems. Rhizoma peanut is planted in the Gulf Coast region with the majority of acreage occurring in Florida and Georgia in USDA winter hardiness growing zones 8b and higher (Williams et al. 2002). Forage production for the horse (*Equus caballus* L.) hay market is currently providing some growers with economic returns approaching seven hundred dollars an acre once the field reaches maturity, which occurs at approximately three years (Lacy 2006). Winter survivability of Florigraze has been reported as far north as Fort Valley, GA (32°33'N, 83°54'W) and two plant introductions have shown promise as far north as Stephenville, TX (32o N, 98o W) (Terrill et al.1996; T.J. Butler, personal communication). The northern limits of this species have not been determined as yet and it is the goal of this research to test multiple germplasm lines to determine if there is potential to expand production of Rhizoma peanut to USDA winter hardiness growing zones 8a and 7b.

References:

Bouton J., 2002. Final Report for 1996 to 2001; *In: Bioenergy Crop Breeding and Production Research in the Southeast*, ORNL/SUB-02-19XSV810C/01.

Bowman, D.C., C.T. Cherney, and T.W. Rufty, Jr. 2002. Fate and transport of nitrogen applied to six warm-season turfgrasses. Crop Sci. 42:833-841.

Cherney, J.H., J.D. Axtell, M.M. Hassen, and K.S. Anliker. 1988. Forage quality characterization of a chemically induced brown-midrib mutant in pearl millet. Crop Sci. 28:783-787.

Fritz, J.O., R.P.Cantrell, V.L. Lechtenberg, J.D. Axtell, and J.M. Hertel. 1981. Brown midrib mutants in sudangrass and grain sorghum. Crop Sci. 21:706-709.

Hanna, W.W., D.D. Baltensperger, and A. Seetharam. 2004. Pearl Millet and Other Millets. *In* L.E. Moser et al. (ed.) Warm-Season Grasses. ASA, CSSA, and SSSA, Madison Wisconsin.

Jiang, J. R.J. Hull, and W.M. Sullivan. 2002. Nitrate uptake and reduction in C3 and C4 Grasses. Journal of plant Nutrition. 25(6)1303-1314.

Lacy, R.C. 2006. Economic Considerations in Producing Perennial Peanut Hay. Departmental bulletin AGECON-06-113. Department of Agricultural and Applied Economics. University of Georgia. June.

Liu, H. and R.J. Hull. 2006. Comparing cultivars of three cool-season turfgrasses for nitrogen recovery in clippings. HortScience. 41(3):827-831.

Taliaferro, C.M., F.M. Rouquette, Jr., P.Mislevy. 2004. Bermudagrass and Stargrass. p.417-475. *In* Moser et al. (ed.) Warm-season (C4) Grasses. ASA,CSSA, and SSSA, Madison, WI.

Terrill, T.H., S. Gelaye, S. Mahotiere, E.A. Amoah, S.Miller, R. N. Gates, and W.R.Windham. 1996. Rhizoma Peanut and Alfalfa Productivity and Nutrient Composition in Central Georgia. Agron J. 88: 485-488.

Williams, M.J., E. Valencia, and L.E. Sollenberger. 2002. No-Till Establishment Of Rhizoma Peanut. Agron. J. 94:1350-1354.

Forage legumes for Texas and the US southern region

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Abstract. The combinations of infertile soil, fungal and virus diseases, nematode infestations, drought conditions, warm-season grass competition and temperature extremes often cause forage legumes to be unreliable in Texas and across the US southern region. Classical plant breeding and germplasm introduction has been used in concert to address these problems over the past 25 years. Apache arrowleaf clover (*Trifolium vesiculosum*) was developed through six cycles of recurrent selection for tolerance to bean yellow mosaic virus (BYMV). Concurrent selection in arrowleaf clover for resistance to fungal seedling diseases and tolerance to BYMV is in progress. Overton R18 rose clover (*T. hirtum*) is a cold tolerant, late flowering cultivar developed from a Spanish plant introduction. Crosses between rose clover lines with diverse origins (Turkey and Spain) have generated segregating families with variable permutations of cold tolerance, winter dormancy and date of flowering. A breeding program is in progress to develop cultivars of annual white-flowered sweetclover (*Melilotus alba*) with low coumarin, multi-stemmed crowns and rust (*Uromyces striatus*) resistance. Other breeding programs in progress include white clover (*T. repens*), crimson clover (*T. incarnatum*), red clover (*T. pretense*), ball clover (*T. nigrescens*), lablab (*Lablab purpureus*) and cowpea (*Vigna unguiculata*).

Forage legumes offer great potential to improve grassland agriculture but are often unreliable in adverse environments. The Texas Agricultural Experiment Station (TAES) Forage Legume Breeding Program is directed at development of improved cultivars for Texas and the US southern region. The primary objective is the improvement of annual clovers and other annual forage legumes for overseeding on warm season perennial grass pastures, including soils ranging from acidic sandy loams to alkaline clays.

Arrowleaf clover. ‘Apache’ arrowleaf clover was developed through six cycles of selection for tolerance to bean yellow mosaic virus (BYMV) disease and was released by TAES in 2001 (Smith et al. 2004). The base population for the development of Apache had 78 half-sib arrowleaf families from a field selection program that used the arrowleaf cultivars ‘Yuchi’, ‘Meechee’ and ‘Amclo’ as initial germplasm (Pemberton et al., 1989). Four cycles of restricted recurrent phenotypic selection for tolerance to BYMV were conducted under greenhouse conditions using mechanical inoculation with BYMV-KY204-1. Two additional cycles of selection were made in the field, also using mechanical inoculation with BYMV-KY204-1. Twenty-one plants were identified in cycle 6 that survived field BYMV infection in combination with severe root rot disease. These selections were evaluated for seed production, which ranged from none to 81 g/plant. Based on seed production, the best eight half-sib families were bulked and breeder seed was produced in Oregon in 1999.

The most striking response of arrowleaf clover to infection with BYMV is a rapid, systemic wilting beginning on the youngest growth 8-13 d post-inoculation and resulting in plant death. The inheritance of resistance to BYMV-induced lethal wilt is conferred by the recessive allele of the lethal wilt gene in arrowleaf clover (Pemberton et al., 1991). The dominant allele, *L*, imparting the systemic wilting response to BYMV, is present in 15-23% of the Yuchi arrowleaf clover population. One cycle of selection, using mechanical inoculation with BYMV-KY204-1, eliminated the susceptible (*LL* and *Ll*) genotypes (Pemberton et al., 1994).

The development of BYMV tolerance was demonstrated with arrowleaf families from 4 cycles of selection where four BYMV disease symptoms (dwarfing, rugosity, chlorosis and mosaic) and dry matter production were evaluated. Level of improvement per cycle varied by component but selection clearly improved the ability of arrowleaf clover to tolerate BYMV infection (Pemberton et al., 1994).

Apache flowers 10-14 d earlier than Yuchi and has slightly larger (18%) seed than Yuchi. Seed color of Apache ranges from yellow to red to black, and is generally darker than Yuchi seed. Apache has the same seed colors as Yuchi but with a higher percent black seed. Black seed occurrence in Apache is about 25% compared to about 2% in Yuchi. Flower color is white with older florets turning light pink and is identical to Yuchi. In five trials from 2000 – 2001, Apache forage production was equal to Yuchi or higher (3 locations; P=0.05). Apache was generally more (3 locations; P=0.05) productive in early spring harvests (March – mid April) than Yuchi with forage yield increases ranging from 100% to 38%.

Research in progress with arrowleaf clover includes evaluation of calf gains on Apache pastures, selection for resistance to *Pythium ultimum* and selection for tolerance to acid soils and high aluminum.

Rose clover. Rose clover is a self-pollinated winter annual forage legume. Commercial cultivars of rose clover include 'Hykon', 'Kondinin', 'Monte Frio' and 'Overton R18'. Hykon and Kondinin are Australian cultivars (Bailey 1967) with origins that trace back to ‘Wilton’ rose clover (Love, 1952) and both have very little winter dormancy or cold tolerance. Monte Frio is a cold-tolerant cultivar developed in California. Overton R18 rose clover was released in 1991 by TAES, and was selected for a high level of cold tolerance and improved forage production (Smith et al., 1992). This cultivar is a single plant selection from a mixed PI line introduced from Spain.

Overton R18 has survived winters and been productive in central Oklahoma and in some years southern Kansas and southern Missouri. However, Overton R18 is probably more cold tolerant (Nunes and Smith 2003) and more winter dormant than is needed for northeast Texas climatic conditions. Overton R18 reseeds well and is cold tolerant in Old World bluestem (*Bothriochloa* spp.) pastures in the Southern Great Plains (Volesky et al., 1995). In this study, two-month-old seedlings of Overton R18 survived record Oklahoma low temperatures in December with minimum temperatures reaching -27 C. In the same study, plant counts 3 and 4 years after the initial seeding averaged 22 plants/m^2 for rose clover, compared to 3 plants/m^2 for vetch.

A rose clover with less winter dormancy and better cool-season forage production than Overton R18 is needed. This reduction in winter dormancy must be balanced with enough cold tolerance to survive the winter season in the U. S. southern region. Crosses were made between Hykon or Kondinin and Overton R18. The F_2 and F_3 generations from these crosses were evaluated in northeast Texas for winter growth, cold damage and date of flowering (Smith and Rouquette 2001). Minimum temperatures dropped below –8 C on 3 days in Jan. 1996 and below -

6.5 C on 3 days in Feb. 1996. These low temperatures caused severe damage to Hykon and Kondinin rose clover and resulted in stand losses of 69 and 46%, respectively. Cold damage to Overton R18 was moderate and stand loss was 28%. Four rose clover F_3 lines were identified with minor winter damage, less than 20% stand loss and winter growth equal to Hykon. There is genetic potential in rose clover for improved combinations of late maturity, full season forage production and tolerance to northeast Texas winter temperatures.

Current research with rose clover is directed toward evaluation of Rhizobium strain effectiveness. Rose clover inoculants available in the US do not allow this clover to achieve full nitrogen fixation and forage production potential.

Sweetclover. Annual sweetclover is a forage legume that is very well adapted to the blackland and prairie soils of the US Southern Great Plains. A breeding program was initiated to produce improved cultivars of annual sweetclover with both low coumarin and reduced stem size. Denta is a low coumarin biennial and Emerald is a multi-stemmed annual sweetclover. Hand crosses and bee cage crosses were made in 2001 between Denta and Emerald. A concurrent seedling screen was successful in the intermediate stage of this sweetclover breeding program to develop F_3 families with both low coumarin and multi-stemmed crowns (Smith and Evers 2005). Forage evaluations trials, including two experimental sweetclovers from this program, were planted in central Texas in Oct. 2005.

Rust has been reported on sweetclover in Kansas (Stuteville 2002) and sweetclover rust in Texas has been tentatively identified as *Uromyces striatus.* Twenty-five sweetclover plant introduction (PI) lines were evaluated for rust reaction at Beeville, Texas in 2004 and 5 PI lines were re-evaluated in 2005 and compared to the check cultivar Hubam. Four biennial lines and one annual line were noted as variable in reaction to sweetclover rust, but Hubam was highly susceptible. Percent resistant plants ranged from 24 to 78 for the five PI lines. Breeding is in progress to combine rust resistance, low coumarin and multi-stem traits into new cultivars of annual sweetclover.

Other cool-season forage legumes. Cultivar development programs are in place with crimson, ball, white and red clover. The general objective is improvement of reliability for these forages in Texas pasture systems. This involves various selection programs to manipulate of date of flowering, hard seed content, seed production, perennial survival and annual reseeding.

Tropical forage legumes. Cowpea and lablab are useful annual forage plants for fast-growing summer pastures that can be used to supplement cattle grazing warm season perennial grasses. These summer legumes are also useful as browse for native white-tailed deer. Breeding programs are in progress to develop improved cultivars of both lablab and cowpea with improved forage and seed production traits and root-knot nematode resistance. ‘Rio Verde’ lablab was developed through selection for tolerance to defoliation, forage production potential and Texas seed production (Smith, 2007). This new cultivar was developed at Overton, Texas and released by TAES in 2006. Rio Verde is the first lablab cultivar developed in the US and also has the value-added trait of Texas seed production.

References

Bailey, E.T. 1967. The history, characteristics, and potential of Kondinin rose clover. Journal of Agriculture Western Australia 9:372-373.

Love, R. M. 1952. Range improvement experiments on the Arthur E. Brown ranch. California Journal of Range Management. 5:120-123.
Nunes, M.E.S. and G.R. Smith. 2003. Electrolyte leakage assay capable of quantifying freezing resistance in rose clover. Crop Science 43:1349-1357.
Pemberton, I.J., G.R. Smith, and M.R. McLaughlin. 1989. Evaluation of arrowleaf clover for tolerance to bean yellow mosaic virus. Phytopathology 79:230-234.
Pemberton, I.J., M.R. McLaughlin, and G.R.Smith. 1991. Inheritance of resistance to virus-induced lethal wilt in arrowleaf clover. Phytopathology 81:1001-1005.
Pemberton, I.J., M.R. McLaughlin, and G.R. Smith.1994. Recurrent selection for tolerance to bean yellow mosaic virus in arrowleaf clover. Crop Science 34:1157-1163
Smith, G.R. and G.W. Evers. 2005. Concurrent selection for low coumarin and multi-stemmed crowns in annual sweetclover. Proceedings XX International Grassland Congess, Dublin, Ireland
Smith, G.R., F.M. Rouquette, Jr., and I.J. Pemberton. 2004. Registration of Apache arrowleaf clover. Crop Science 44:1018
Smith, G.R., F.M.Rouquette, Jr., and I.J. Pemberton. 2007. Registration of Rio Verde lablab. Crop Science (submitted)
Smith, G.R. and F.M. Rouquette, Jr., 2001. Improvement of rose clover winter forage production. Proceedings XIX International Grassland Congress, Piracicaba, Brazil
Smith, G.R.,F.M. Rouquette, Jr., G.W. Evers, M.A. Hussey, W.R. Ocumpaugh, J.C. Read, and A. M. Schubert. 1992. Registration of Overton R18 rose clover. Crop Science 32:1507.
Stuteville, D.L. 2002. First report of *Uromyces striatus* on white sweetclover in Kansas. Plant Disease 86:1404
Volesky, J.D., D.P. Mowrey, and G.R.Smith. 1995. Performance of rose clover and vetch interseeded into old world bluestem. Journal of Range Managenent. 49:448-451.

Current Assessment of Dedicated Bioenergy Feedstock Crops for Southeastern United States

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Renewable fuel production has become an important topic in the United States over the past few years. Increased ethanol production and use as fuel, in particular, is seen as a means of reducing the nation's dependence on petroleum. Brazil has become independent from petroleum imports by converting carbohydrates (primarily sucrose) from sugar cane to ethanol. Currently, ethanol is produces from grain starch (corn) in the United States. However, only a small percentage of the nation's ethanol needs can be supplied by starch-based ethanol (NRDC 2006). To achieve the goal of displacing 30% of the nation's current gasoline use by 2030 a study by the United States Departments of Energy and Agriculture concluded that over a billion tons of biomass would be required (Perlack et al. 2005). Most of this would be by developing more efficient means of converting biomass (as defined by cell wall lignocellulose) to bioenergy.

Besides improving industrial conversion processes, it is also important to improve plant feedstock crops through breeding and efficient production practices. High biomass yields and decreased production costs are first priorities. Biomass must be plentiful, cheap and within a short distance from the processing plant. Designing plants that maintain yields but have reduced recalcitrance to cell wall breakdown is a challenge to plant breeders. Different crop species have potential of being candidates for dedicated bioenergy feedstock crops for Southeastern Unites States.

Besides switchgrass (*Panicum virgatum*), napiergrass (*Pennisetum purpureum*), Miscanthus (*Micanthus x giganteus*), energy cane (*Saccharum* sp.), giant reed (*Arundo donax*) and even bermudagrass (*Cynodon* sp.) are being considered as potential feedstock grasses for conversion to ethanol or bio-energy. In a test at Tifton, Georgia napiergrass (var. Merkeron) (27,764 kg ha^{-1}) out-yielded Tifton 85 bermudagrass (17,578 kg ha^{-1}) and Alamo switchgrass (16,220 kg ha^{-1}) (Bouton, 2002). Yields of napiergrass lines tested in southern and central Florida, grown on a range of soil and cultural practices including sewage effluent and phosphate mining sites, were between 30 and 60 Mg ha^{-1} yr^{-1} (Prine et al. 1997). Napiergrass yields in northern areas of the South have ranged from the 20 to 30 Mg ha^{-1} yr^{-1} (Prine et al. 1991). Giant reed continued to increase in yield after 6 years up to 35 Mg ha^{-1} yr^{-1} in 2004 at Auburn, Alabama with no fertilizer inputs (Bransby personal communication).

A replicated field study was established in Tifton in the fall of 2005. Napiergrass and energy cane had the highest dry matter yields and significantly better than switchgrass after the first year (Table 1). Giant reed plants were established with plants generated from tissue culture and did not reach full height by the time of harvest.

Feedstock quality is also an important attribute for a viable industry. There are two general methods of biomass conversion to energy. The first process is saccharification and fermentation, similar to what is used in the starch to ethanol industry. Saccharification requires various pre-treatments to convert cellulose and hemi-cellulose to free sugars for fermentation. The presence and binding with lignin can often hinder efficient conversion to sugars. Leaf and stem material from bermudagrass, napiergrass and giant reed were compared for their relative efficiency of conversion to ethanol. Tifton 85 bermudagrass was superior to the other grasses when evaluated with a dilute acid pretreatment followed by simultaneous saccharification and fermentation (SSF) (Table 2). There appears to be some correlation between forage digestibility and fiber with conversion efficiency. Further studies have begun to determine this relationship with bermudagrass germplasm that has wide variation in digestibility and fiber attributes.

The second major biomass conversion process is via thermochemical breakdown of lignocellulose to fuels, chemicals, and power using gasification and pyrolyis to produce gases such as carbon monoxide, carbon dioxide and hydrogen or pyrolysis oils. Thermochemical conversion technologies convert biomass and its residues to fuels, chemicals, and power using gasification and pyrolysis technologies. For this process feedstocks are not limited by fiber variability or lignin content. For example, there is no difference between Tifton 85 and Coastal bermudagrass in the amount of non-condensable gas or bio-oils when subjected to pyrolysis at different temperatures (Boateng et al. 2005).

Genetic improvement of dedicated bioenergy crops will require breeding and selection for higher dry matter yield as well as phenotypic traits that allow for improved processing and conversion efficiency. Depending on the conversion process, plants may be bred for higher or lower lignin content as well as specific cell-wall component traits.

Table 1. Dry matter yields of potential energy crops established in October of 2005 and harvested December 5, 2006 at Tifton, GA.

Species	Genotype	Dry matter yield (kg/ha)
Pennisetum purpureum	N 51	34,582 a
Pennisetum purpureum	Merkeron	28,475 b
Saccharum sp.	L 79-1002	27,147 b
Panicum virgatum	GA-993	8,784 c
Panicum virgatum	GA-001	8,587 c
Arundo donax	ADF	6,738 c
Arundo donax	ADE	6,528 c
Arundo donax	ADS	4,964 c

Table 2. *In vitro* Dry Matter digestibility (IVDMD), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and ethanol production of leaf and stem tissues of 12 week old bermudagrass, and mature napiergrass and giant reed grown at Tifton, GA. 2004.

Species	Genotype	Tissue	% IVDMD	NDF	ADF	ADL	Ethanol mg/g
Cynodon sp.	Tifton 85	Leaf	47.1 c	77.6 g	35.0 abc	2.93 a	139.6 a
Cynodon sp.	Tifton 85	Stem	49.2 c	77.5 g	37.2 cd	4.04 b	141.1 a
Cynodon sp.	Coastal	Leaf	35.4 e	77.0 fg	33.7 ab	3.85 b	121.7 b
Arundo donax	Cicily	Leaf	54.1 b	67.6 ab	36.7 bcd	3.82 b	109.0 bc
Pennisetum purpureum	Merkeron	Leaf	58.5 a	69.4 bc	36.0 abcd	3.04 a	106.7 bc
Pennisetum purpureum	Merkeron	Stem	43.5 d	74.2 def	48.1 ef	6.95 c	105.3 c
Pennisetum purpureum	N 190	Leaf	46.8 c	73.0 de	38.3 d	3.53 ab	96.7 cd
Arundo donax	Fitzgerald	Leaf	52.4 b	65.5 a	33.7 a	4.14 b	84.8 d
Pennisetum purpureum	N 190	Stem	35.9 e	74.1 def	49.1 f	7.90 d	84.0 d
Arundo donax	Fitzgerald	Stem	22.6 g	75.4 efg	49.9 f	8.98 e	47.2 e
Arundo donax	Cicily	Stem	29.0 f	71.9 cd	45.9 e	8.67 e	44.2 e

Means with the same letter are not significantly different. (p=.05)

References

Boateng, A.A., W.F. Anderson, and J.G. Phillips. 2007. Production of bermudagrass for bio-fuels: Effect of two genotypes on pyrolysis product yield. Energy and Fuels 21:1183-1187.

Bouton J., 2002. Final Report for 1996 to 2001; *In: Bioenergy Crop Breeding and Production Research in the Southeast*, ORNL/SUB-02-19XSV810C/01

NRDC. 2006. Ethanol: Energy well spent. A survey of studies published since 1990. Natural Resources Defense council and Climate Solutions, New York City (www.nrdc.org/air/transportation/ethanol/ethanol.pdf).

NREL. 2007. Thermochemical conversion technologies – projects. http://www.nrel.gov/biomass/proj_thermochemical_conversion.html

Perlack, R.D., Wright, L.L., Turhollow, A.F., Graham, R.L., Stokes, B.J., and Erbach, D.C. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply. DOE/GO-10200502135, Oak Ridge Nnational Laboratory, Oak Ridge, TN. (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

Prine, G.M., P. Mislevy, R.L. Stanley, Jr., L.S. Dunavin and D.I. Bransby. 1991. Field production of energycane elephantgrass and sorghum in southeastern United States. In D.L. Klass (ed.) Proc. Final Program of Conference on Energy from Biomass and Wastes XV. Paper No. 24, 8p.

Prine, G.M., J.A. Stricker and W.V. McConnell. 1997. Opportunities for bioenergy development in lower south USA. Proc. 3rd Biomass Conference of the America: Making a Business from Biomass in Energy, Environment, Chemicals, Fibers and Materials. Vol. 1:227-235.

Proceedings 61st *Southern Pasture & Forage Crop Improvement Conference, 2007*
Ecology/Physiology Work Group

Application of plant genomics to enhance ethanol production from biomass crops

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There has been a growing interest in the production of transportation fuels from renewable resources as a result of political and environmental concerns. In the United States the majority of fuel ethanol is currently produced from microbial fermentation of sugars derived from the enzymatic hydrolysis of corn starch. Grain supplies will, however, be insufficient to meet anticipated demands of ethanol. Alternative crops that can be used for ethanol production include species that produce sugar such as sugar cane, sweet sorghum, and sugar beet, as well as crops that produce large amounts of vegetative biomass. Vegetative biomass, such as corn and sorghum stover, consists largely of plant cell walls. The plant cell walls is a complex matrix that contains the polysaccharides cellulose and hemicellulose, as well as the phenolic polymer lignin, hydroxycinnamic acids, pectin, and proteins. Enzymatic hydrolysis of lignocellulosic biomass results in the formation of monomeric sugars that can be fermented by microorganisms to ethanol or other chemical feedstocks. While production of so-called cellulosic ethanol from stover is feasible from an energy balance perspective, its production is currently not economically competitive. Along with improvements in bioprocessing, enhancing the yield and composition of the biomass has the potential to make ethanol production considerably more cost-effective.

In order to enhance biomass crops, it will be necessary to obtain a better understanding of how cell wall composition and structure affect the efficiency of enzymatic hydrolysis. It will also be necessary to identify and develop traits that enhance biomass conversion efficiency and increase biomass yield. This process can be expedited through the development of rapid screening protocols to evaluate biomass conversion efficiency.

Several genetic resources are available to improve corn and sorghum as sources of lignocellulosic biomass. This includes the use of existing mutants, forward and reverse genetics to obtain novel mutants, and transgenic approaches in which the expression of genes of interest is modified. Plant breeding can be implemented to improve biomass yield, biomass quality, and biomass conversion efficiency, either through selection among progeny obtained by crossing parents with desirable traits, or as a way to enhance the agronomic performance of promising mutants and transgenics.

This presentation will focus on the identification of novel cell wall mutants of corn. A high-throughput screen aimed at the identification of changes in chemical composition was developed to evaluate a large population of genetically uniform corn families in which mutations were introduced through the action of transposable elements. A set of 39 mutants with so-called spectrotypes, but otherwise no distinct visual phenotype were identified, and some of these mutants look promising with respect to cellulosic ethanol production.

This presentation will also focus on the development of *brown midrib* sweet sorghum as a dual-source feedstock for ethanol production. Under this scenario sugar-rich juice from the stalk will be directly processed into ethanol through microbial fermentation, while the sorghum bagasse is processed for the production of cellulosic ethanol. The *brown midrib* trait enhances the yield of cellulosic ethanol because hydrolysis of the resulting bagasse yields more fermentable sugars. We are using comparative genomics approaches and the recently released sorghum genome sequence to identify and isolate the genes underlying these useful traits. The genetic variation is then exploited for the development of allele-specific molecular markers that can expedite plant breeding efforts.

CURRENT APPLICATIONS TO ALLEVIATE ANIMAL STRESS ASSOCIATED WITH FESCUE TOXICOSIS

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Endophyte-infected tall fescue (**EI-TF**; *Festuca arundinacea* (Schreb), syn, *Lolium arundinaceum* (Schreb.) Darbysh) is a common pasture forage throughout the transition zone and one of the most persistent and productive forages in the world. The agronomically beneficial characteristics of EI-TF are a result, at least in part, of the presence of endophytic fungi (*Neotyphodium coenophialum*), which produces numerous ergot alkaloids (Bacon et al., 1977). It is estimated that approximately 70% of the more than 40 million acres of tall fescue grown in the southeastern U.S. is infected with these fungi (Shelby and Dalrymple, 1987). Ruminants grazing EI-TF generally exhibit a stressful multifaceted disease syndrome called fescue toxicosis (Hoveland et al., 1983; Paterson et al., 1995). Further, we have recently found that ruminants consuming EI-TF seed diets shed more *E. coli* O157:H7 in their feces (Looper et al., 2007). It is estimated that economic losses from animal consumption of EI-TF in the U.S. exceed $600 million annually (Allen and Segarra, 2001); consequently, U.S. beef producers need solutions for reducing animal stress resulting from the consumption EI-TF.

Management strategies to minimize or alleviate fescue toxicosis

The following considerations are by no means intended to be an exhaustive listing of all possible management considerations that minimize stress associated with fescue toxicosis. An excellent review of current research findings regarding fescue toxicosis can be found in the annual proceedings of the Southern Extension and Research Activities Information Exchange Group at http://animalscience.ag.utk.edu/SERA-IEG8/, as well as the book titled *Neotyphodium in Cool-Season Grasses* (2005; Roberts, West, and Spiers, Eds.; Blackwell Publishing).

Forage management. Several traditional options exist to minimize the physiological stress associated with EI-TF consumption including reseeding of EI-TF pastures with endophyte-free tall fescue, dilution of EI-TF pastures with legumes or other grasses, and(or) clipping EI-TF pastures to remove the more toxic seedheads.

Within the last 10 years, novel endophyte-infected ("animal friendly") tall fescue (**NE-TF**) varieties have been developed (West et al., 1998; Bouton et al., 2002) with endophytes that do not produce ergot-alkaloids and do not reduce animal performance. Researchers from Georgia (Parish et al., 2003; Watson et al., 2004) and Arkansas (Nihsen et al., 2004) found average daily gain and gain/acre were greater in cattle grazing NE-TF pastures than cattle grazing EI-TF. We (USDA-ARS, Booneville, AR) are completing a 3-year study investigating the influence of EI-TF and NE-TF on performance of pregnant heifers. Our preliminary data suggest cattle grazing NE-TF gain 0.6 lb/day more than EI-TF cattle. Further, cattle grazing EI-TF spend more time in the shade and around water tanks than heifers grazing NE-TF pastures.

The major issues with renovation of existing EI-TF pastures with improved forage varieties are the costs, both the input, as well as the opportunity costs of reseeding. Opportunity costs are those losses in profit due to not grazing newly renovated NE-TF pastures during the establishment time. Beck et al. (2006) recently estimated that it cost $232/acre to establish NE-TF pastures with almost $80 of that being opportunity costs. In comparison, cool-season annuals (ryegrass and winter wheat) cost an average of almost $115/acre. To minimize input costs to farmers, University of Arkansas researchers (K. Coffey), with assistance from USDA-ARS, Booneville, AR have initiated a study to determine the impact (both animal performance and economics) of renovating a portion (approximately 20%) of EI-TF pastures with NE-TF. Cattle will graze NE-TF during warmer months of the year instead of EI-TF pastures to minimize the stress associated with fescue toxicosis. A second major concern of incorporating NE-TF varieties is persistence of the stand. Several studies are ongoing to determine the persistence of NE-TF in comparison to EI-TF pastures.

There has been a renewed interest in stockpiling of EI-TF mainly due to a reduction in winter feed costs by approximately 60 to 75% when compared to conventional winter supplementation practices (Bishop-Hurley and Kallenbach, 2001; Jennings et al., 2004). Tall fescue provides sufficient forage growth and quality during winter months, and concentrations of ergovaline that induce fescue toxicosis are lower during the colder months (Kallenbach et al., 2003; Looper et al., 2005). In a 2-year supplementation study using market cows, research from USDA-ARS in Booneville, AR (Looper et al., 2005) showed nutritive content of stockpiled and spring-growth EI-TF exceeded the nutrient requirements of pregnant market cows, and as long as EI-TF forage was not limited, supplementation was not necessary to maintain body weight of cows. Further, concentrations of ergovaline did not exceed values that are associated with fescue toxicosis suggesting stress of EI-TF consumption may be reduced during the winter.

Animal management. Supplementation of either protein or energy to cattle grazing EI-TF causes a ‘substitution effect’ that may help in alleviating fescue toxicosis (Aiken et al., 1998). Adjusting stocking rate of cattle grazing EI-TF pastures also may help in minimizing fescue toxicosis. The decrease of EI-TF canopy height by either close grazing or clipping may decrease the toxicity of standing EI-TF pastures since a greater amount of ergot alkaloids are found in the seed. However, Aiken et al. (2006) reported serum prolactin (a physiological indicator of fescue toxicosis) decreased as stocking rate increased suggesting greater consumption of rapidly growing EI-TF in overstocked pastures may actually exacerbate fescue toxicosis. The limited availability of forages with heavy stocking rates also would affect animal performance.

Obviously one approach to reduce animal stress associated with EI-TF is to remove cattle from pastures with EI-TF. Extensive research has been conducted on removal of cattle for a certain amount of time (often referred to as recovery) to alleviate the effects of EI-TF during the warm summer months or before transport to the auction barn or feedyard. Aiken et al. (2001, 2006) reported that physiological indicators of fescue toxicosis (i.e., rectal temperatures and concentrations of prolactin) in steers consuming EI-TF returned to normal values after 3 to 4 days of a EI-TF-free diet for Brahman-influenced steers and 8-10 days of a EI-TF-free diet in British-influenced steers. For a more detailed report of research investigating recovery of cattle from the toxic effects of EI-TF, see Dr. Glen Aiken’s manuscript in these proceedings.

Numerous animal studies during the past 25 years have investigated the use of pharmacological compounds, such as anthelmintics and steroid implants that minimize stress related to consumption of EI-TF. The use of anthelmintics to reduce stress associated with fescue toxicosis has not been consistent. Bransby (1997) reported that steers grazing EI-TF had greater weight gain when administered ivermectin; however, others (Goetsch et al., 1988; Rosenkrans et al., 2001) reported no effect of ivermectin on weight gains of steers. Similarly, studies with steroid implants administered to cattle grazing EI-TF have had mixed results. Steroid implants increased average daily gain by 14% in steers grazing EI-TF (Coffey et al., 2001) but steroid implants did not impact recovery of steers after grazing EI-TF (Aiken et al., 2006). Type of implant, as well as forage quality and availability would affect animal performance and may explain differences in results among studies.

Novel approaches to an old problem

It is evident from the aforementioned research findings, development of plant and animal management strategies have made substantial progress in minimizing some of the stress associated with EI-TF consumption. However, there is still much we do not fully understand of the plant-animal interaction concerning EI-TF consumption. Novel approaches to this 'old' problem are needed and are currently being investigated, especially those that may be widely implemented by producers. Although not a comprehensive list, a few of the novel approaches that have interesting preliminary data are discussed here.

A majority of the research of how EI-TF consumption affects reproductive performance of cattle has focused on the female. Recognizing that the fertility of 1 bull may impact 20 to 25 cows, research efforts are now investigating the impact of EI-TF on the fertility of the bull. Bulls fed a pelleted EI-TF seed diet had smaller scrotal circumferences and tended to have decreased semen motility after 6 weeks exposure to EI-TF than non-EI-TF diets (Jones et al., 2004). Although semen motility and morphology did not differ between bulls fed control or ergotamine tartrate (alkaloid found in EI-TF) supplemented diets, development of embryos fertilized with semen from bulls fed ergotamine tartrate were decreased (Schuenemann et al., 2005). To confirm and expand these results, a study has been initiated at the USDA-ARS laboratory in Booneville, AR in collaboration with University of Arkansas researchers to assess how EI-TF and NE-TF impact bull performance and semen quality.

A considerable amount of research with horses has been conducted with the dopamine receptor blocker, domperidone (Cross et al., 1999). Domperidone was effective in alleviating a majority of the signs/symptoms of fescue toxicosis in pregnant mares. Work in cattle indicates that heifers consuming EI-TF seed diets and administered domperidone had similar daily weight gains as heifers consuming non-EI-TF seed diets (Jones et al., 2003). Further, domperidone may help in minimizing the toxic effects of EI-TF on reproduction in cattle. The USDA-ARS laboratory in Lexington, KY has ongoing studies to investigate the influence of domperidone on mammary development of heifers consuming EI-TF in their diets.

The implementation of doppler ultrasonography to determine blood flow in cattle consuming EI-TF shows extreme promise to further our understanding of the physiological mechanisms of fescue toxicosis. Research recently completed at the USDA-ARS laboratory in Lexington, KY (Aiken et al., 2007) reveals that short-term exposure to EI-TF will result in vasoconstriction of blood vessels in heifers consuming EI-TF.

For years, livestock producers have unintentionally or in some cases intentionally selected cattle that were more productive when grazing EI-TF. Cattle that did not maintain an annual calving cycle or that consistently produced a lighter calf at weaning were eventually culled from the cowherd. However, use of traditional selection techniques is slow, usually occurring over several years for individual animals. This process may be accelerated by the use of nontraditional methods such as physiological and(or) genetic markers. Understanding the animal response to the EI-TF stressors, particularly at the genetic and physiologic levels, is an area needing further exploration to develop new approaches to confront this problem. The liver is a detoxification organ involved in metabolism of toxins. Using DNA microarray techniques, University of Missouri researchers have shown that even short-term exposure to EI-TF diets down-regulated genes involved in cholesterol and lipid metabolism found in the liver of rodents (Bhusari et al., 2006; Settivari et al., 2006). Researchers at the University of Arkansas in collaboration with USDA-ARS, Booneville, AR have demonstrated that linking physiological changes to their genetic origins can be related to cow profitability traits. Current efforts focus on genetic and(or) physiological markers that can be useful in selecting cattle that are more productive on EI-TF. Specifically, how polymorphisms (specific genetic variations between individual animals) in the prolactin gene enhancer region and heat shock protein gene in cattle are related to productivity while grazing EI-TF is being investigated. Dr. Charles Rosenkrans' manuscript in these proceedings thoroughly discusses the genetic variations in cattle consuming EI-TF.

Endophyte-infected tall fescue is one of the most persistent and productive forages grown throughout the Southeast U.S. with one major disadvantage, a reduction in animal performance due to fescue toxicosis. Much progress has been made to help livestock producers minimize animal stress associated with consumption of EI-TF; however, additional work is still needed to alleviate this very economically costly problem. Currently, several innovative techniques and technologies seek alternative solutions to the endophyte problem. An increased understanding of animal responses to EI-TF forages will be the basis of new and(or) improved best management practices for cost-effective beef production in the U.S.

Literature Cited

Aiken, G. E., D. M. Ball, E. L. Piper, and C. P. West. 1998. Performance of steers fed a broiler litter-corn mixture on endophyte-infested and non-infested tall fescue. Prof. Anim. Sci. 14:51-55.

Aiken, G. E., B. H. Kirch, J. R. Strickland, L. P. Bush, M. L. Looper, and F. N. Schrick. 2007. Hemodynamic responses of the caudal artery to toxic tall fescue in beef heifers. J. Anim. Sci. (In press).

Aiken, G. E., M. L. Looper, S. F. Tabler, D. K. Brauer, J. R. Strickland, and F. N. Schrick. 2006. Influence of stocking rate and steroidal implants on growth rate of steers grazing toxic tall fescue and subsequent physiological responses. J. Anim. Sci. 84:1626-1632.

Aiken, G. E., E. L. Piper, and C. R. Miesner. 2001. Influence of protein supplementation and implant status on alleviating fescue toxicosis. J. Anim. Sci. 79:827-832.

Allen, V. G., and E. Segarra. 2001. Anti-quality components in forage; Overview, significance, and economic impact. J. Range Manag. 54:409-412.

Bacon, C. W. J. K. Porter, J. D. Robbins, and E. S. Luttrell. 1977. *Epichloe typhina* from toxic tall fescue grasses. App. Environ. Microbiol. 34:576-581.

Beck, P., S. Gunter, K. Lusby, C. West, B. Watkins, and D. Hubbell. 2006. Animal performance and economics of novel endophyte tall fescues. *In* Forage Management – from Basic to High Tech. Proc. AR For. Grassl. Coun. pp. 22-29. Ft. Smith, AR.

Bhusari, S., L. B. Hearne, D. E. Spiers, W. R. Lamberson, and E. Antoniou. 2006. Effect of fescue toxicosis on hepatic gene expression in mice. J. Anim. Sci. 84:1600-1612.

Bishop-Hurley, G. J., and R. L. Kallenbach. 2001. The economics of grazing beef cows during winter. Proc. Am. For. Grassl. Coun. p 274. Springdale, AR.

Bouton, J. H., G. C. M. Latch, N. S. Hill, C. S. Hoveland, M. A. McCann, R. H. Watson, J. A. Parish, L. L. Hawkins, and F. N. Thompson. 2002. Reinfection of tall fescue cultivars with nonergot alkaloid-producing endophytes. Agron. J. 94:567-574.

Bransby, D. I. 1997. Steer weight gain responses to ivermectin when grazing fescue. Large Anim. Pract. 18:16-19.

Coffey, K. P., W. K. Coblentz, J. B. Humphry, E. L. Piper, C. F. Rosenkrans, Jr., D. S. Hubbell, III, K. F. Harrison, T. M. Denard, F. W. Pohlman, D. H. Hellwig, L. B. Daniels, and L. J. McBeth. 2001. Growth performance and serum prolactin concentrations of stocker steers implanted with trenbolone acetate while grazing endophyte-infected fescue in the spring. Prof. Anim. Sci. 17:166-173.

Cross, D. L., K. Anas, W. C. Bridges, and J. H. Chappell. 1999. Clinical effects of domperidone on fescue toxicosis in pregnant mares. Proc. Am. Assoc. Equine Pract. 45:203-206.

Goetsch, A. L., K. L. Landis, G. E. Murphy, B. L. Morrison, Z. B. Johnson, E. L. Piper, A. C. Hardin, and K. L. Hall. 1988. Supplements, parasite treatments, and growth implants, for Brahman or English crossbred steers grazing endophyte-infected or noninfected fescue in the spring and fall. Prof. Anim. Sci. 4:32-38.

Hoveland, C. S., S. P. Schmidt, C. C. King, Jr., J. W. Odom, E. M. Clark, J. A. McGuire, L. A. Smith, H. W. Grimes, and J. L. Holiman. 1983. Steer performance and association of *Acremonium coenophialum* fungal endophyte on tall fescue pasture. Agron. J. 75:821-824.

Jennings, J. A., D. E. Kratz, M. S. Gadberry, and T. R. Troxel. 2004. Reducing winter feed costs with stockpiled forages – a farm-based demonstration program. Proc. Am. For. Grassl. Coun. 13:352. Roanoke, VA.

Jones, K. L., S. S. King, K. E. Griswold, D. Cazac, and D. L. Cross. 2003. Domperidone can ameliorate deleterious reproductive effects and reduced weight gain associated with fescue toxicosis in heifers. J. Anim. Sci. 81:2568-2574.

Jones, K. L., C. R. McCleary, S. S. King, G. A. Apgar, and K. E. Griswold. 2004. Case Study: Consumption of toxic fescue impairs bull reproductive parameters. Prof. Anim. Sci. 20:437-442.

Kallenbach, R. L., G. J. Bishop-Hurley, M. D. Massie, G. E. Rottinghaus, and C. P. West. 2003. Herbage mass, nutritive value, and ergovaline concentration of stockpiled tall fescue. Crop Sci. 43:1001-1005.

Looper, M. L., G. E. Aiken, R. Flores, and C. F. Rosenkrans, Jr. 2005. Influence of nutrient supplementation on body weight and condition, and pregnancy of market beef cows grazing stockpiled and spring-growth tall fescue. Prof. Anim. Sci. 21:225-231.

Looper, M. L., T. S. Edrington, R. Flores, J. M. Burke, T. R. Callaway, G. E. Aiken, F. N. Schrick, and C. F. Rosenkrans, Jr. 2007. Influence of dietary endophyte-infected (*Neotyphodium coenophialum*) tall fescue (*Festuca arundinacea*) seed on fecal shedding of antibiotic-resistance selected *Escherichia coli* O157:H7 in ewes. J. Anim. Sci. 85:1102-1108.

Nihsen, M. E., E. L. Piper, C. P. West, R. J. Crawford, Jr., T. M. Denard, Z. B. Johnson, C. A. Roberts, D. A. Spiers, and C. F. Rosenkrans, Jr. 2004. Growth rate and physiology of steers grazing tall fescue inoculated with novel endophytes. J. Anim. Sci. 82:878-883.

Parish, J. A., M. A. McCann, R. H. Watson, N. N. Paviva, C. S. Hoveland, A. H. Parks, B. L. Upchurch, N. S. Hill, and J. H. Bouton. 2003. Use of nonergot alkaloid-producing endophytes for alleviating tall fescue toxicosis in stocker cattle. J. Anim. Sci. 81:2856-2868.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889-898.

Rosenkrans, Jr., C., T. Bedingfield, and E. Piper. 2001. Physiological responses of steers to ingestion of endophyte-infected fescue hay, ivermectin treatment and immune challenge. pp. 255-260. *In* V. H. Paul and P. D. Dapprich (ed.), The Grassland Conference Proc. 4th Int. Neotyphodium/Grass Interactions Symp., Soest, Germany.

Schuenemann, G. M., J. L. Edwards, M. D. Davis, H. E. Blackmon, F. N. Scenna, N. R. Rohrbach, A. M. Saxton, H. S. Adair, F. M. Hopkins, J. C. Waller, and F. N. Schrick. 2005. Effects of administration of ergotamine tartrate on fertility of yearling beef bulls. Theriogenology 63:1407-1418.

Settivari, R. S., S. Bhusari, T. Evans, P. A. Eichen, L. B. Hearne, E. Antoniou, and D. E. Spiers. 2006. Genomic analysis of the impact of fescue toxicosis on hepatic function. J. Anim. Sci. 84:1279-1294.

Shelby, R. A., and L. W. Dalrymple. 1987. Incidence and distribution of the tall fescue endophyte in the United States. Plant Dis. 71:783-786.

Watson, R. H., M. A. McCann, J. A. Parish, C. S. Hoveland, F. N. Thompson, and J. H. Bouton. 2004. Productivity of cow-calf pairs grazing tall fescue pastures infected with either the wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542. J. Anim. Sci. 82:3388-3393

West, C. P., M. L. Marlett, M. E. McConnell, E. L. Piper, and T. J. King. 1998. Novel endophyte technology: Selection of the fungus. pp.105-115. *In* E. C. Brummer, N. S. Hill, and C. A. Roberts (ed.), Molecular and Cellular Technologies for Forage Improvement, Madison, WI: Crop Science Society of America.

Proceedings 61st *Southern Pasture & Forage Crop Improvement Conference, 2007*
Utilization Work Group

Management of Cattle to Reduce Vulnerability to Heat Stress Following Grazing of Toxic Tall Fescue

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Introduction

Tall fescue [Schedonorus *arundinaceus* (Schreb.) Dumort] is a cool-season perennial grass that covers approximately 15 million ha (Thompson et al., 2001) in a region referred to as the "fescue belt", which is between the temperate northeast and subtropical south. An endophytic fungus inhabits plants in greater than 90% of tall fescue pastures (Sleper and West, 1996) and produces alkaloid toxins that induce the fescue toxicosis malady. Toxicosis has symptoms in cattle that include poor weight gain, retention of rough hair coat, elevated body temperature, labored respiration, and decreased serum prolactin (Schmidt and Osborn, 1993). Ergot alkaloids bind biogenic amine receptors in peripheral vasculature (Oliver, 2005) and may reduce the animal's ability to dissipate body heat and cause severe heat stress at the onset of high ambient temperature (Hemken et al., 1981; Spiers et al., 2005).

Tall fescue is primarily utilized for cow-calf production because poor weight gain efficiency of calves exhibiting fescue toxicosis has prevented the wide use of tall fescue for stocker production (Hoveland, 1993). Most calves weaned on tall fescue pastures and not retained for herd replacement are typically sold and transported to other regions for pasture backgrounding while some are retained for shipment to feedyards. Fescue toxicosis exacerbates the stress from shipping and these combined stresses can increase morbidity and mortality, and the length of feedyard adjustment. Management strategies, such as preconditioning, could reduce stress levels of fescue cattle that are transported long distances. This paper reviews physiological changes in steers following the removal of steers from toxic tall fescue and placement on non-toxic diets.

Can Recovery from Fescue Toxicosis be Achieved in the Short Term?

To minimize toxiccosis, Aiken and Piper (1999) moved steers grazing endophyte-infected tall fescue in the spring to eastern gamagrass (Tripsacum dactyloides L.) pastures in Booneville, AR in the summer. Serum prolactin concentrations had increased from ~20 ng/mL to ~100 ng/mL by 28 d of being moved to eastern gamagrass. At the conclusion of summer grazing, 60% of the steers that remained on tall fescue had rough haircoats, but only 20% of the steers grazed on eastern gamagrass had rough haircoats. Severity of toxicosis had been substantially reduced by removing the steers from tall fescue at the onset of warm ambient temperatures; however, symptoms of toxicosis were seen in a few calves at the conclusion of grazing eastern gamagrass.

In another experiment, Stuedemann et al. (1998) reported that urinary alkaloid concentrations declined 67% in steers within 24 hr after being switched from endophyte-infected tall fescue to endophyte non-infected tall pastures. These experiments indicated there is short-term flushing of high concentrations of ergot alkaloids once cattle are removed from toxic tall fescue, but tight binding of alkaloids in certain animal tissues (i.e., vascular tissue, adipose, etc.) may cause some retention of alkaloids in vascular circulation.

Complete recovery from fescue toxicosis is not likely in the short term. However, there appears to be an easing of both vasoconstriction and dopinergic activities of ergot alkaloids shortly after fescue cattle are placed on non-toxic diets to improve health and stability, and reduce the vulnerability to heat stress.

Changes in Rectal Temperature and Prolactin Following Grazing of Toxic Tall Fescue

Aiken et al. (2002) grazed forty-five steers on toxic tall fescue for 66 d to evaluate effects of post-graze steroid hormone implantation and protein supplementation on temporal changes in rectal temperature and serum prolactin following placement on non-toxic diets. There was no effect of implantation or supplementation on changes in the responses. Mean rectal temperatures of 39.9°C at 10 h following removal from E+ fescue pastures declined to less than 39.2°C in 82 h. Although the monitoring was conducted in late June, ambient temperatures were below 25°C and likely contributed to the decline in rectal temperature. Initial serum prolactin was approximately 25 ng/ml, but increased and stabilized at 75 ng/ml serum in 58 hours following placement on non-toxic diets.

Aiken et al. (2006) compared changes in rectal temperatures and serum prolactin following grazing of toxic tall fescue in west-central Arkansas between steers that were implanted with progesterone and estrdiol or non-implanted. Steers were grazed on toxic tall fescue for 84 d from late March to late June and subsequently moved to bermudagrass pasture. Rectal temperatures of implanted steers were approximately 0.2°C higher those of non-implanted over the monitoring period. Rectal temperatures over both treatments averaged 40.4°C at the conclusion of grazing and declined to 39.7°C in 10 d (Fig. 2A). Ambient temperatures during monitoring were moderate, ranging from 22.8 to 26.1°C (Fig. 1) and may have contributed to higher rectal temperatures for the first 6 d. Based on the rate of decrease, rectal temperatures may have fallen to 39.2°C if temperatures had been monitored for an additional 2 days. There were no differences in serum prolactin concentrations between implant treatments. Serum prolactin concentrations increased curvillinearly as days on the non-toxic diet increased (Fig. 3A). Prolactin concentrations rose quickly between 0 and 3 d and the rate of increase slowed between 3 and 10 d. Similar to the rectal temperature response, serum prolactin did not reach a plateau concentration, which may indicate that the monitoring phase was not conducted for a long enough period of time.

Aiken and others (unpublished) in a 2-yr study compared changes in rectal temperatures and serum prolactin of unfed steers grazing toxic tall fescue in north-central Kentucky with steers that were fed soybean hulls (2.3 kg/steer/day). Steers were grazed from early June to middle September and subsequently moved to small pens and fed corn silage and a concentrate to represent a finishing phase. Ambient temperatures during the monitoring phase were below 25°C in both years (Fig. 1). Post-graze rectal temperatures of steers fed on pastures were approximately 0.1°C higher ($P < 0.01$) than those than those that were not fed. Rectal temperatures averaged over both years and treatments were 40.3°C at the conclusion of grazing and declined to 39.1°C in 9 to 10 d (Fig. 2B). There were no differences in serum prolactin concentrations between feeding treatments ($P > 0.10$), but serum prolactin increased ($P < 0.01$) rapidly and stabilized in approximately 20 d (Fig. 3B).

Aiken and others (unpublished) compared rectal temperatures and serum prolactin of pregnant heifers grazed on toxic (KY-31) with those grazed on non-toxic (MaxQ) tall fescue. In the first year of this 2-yr experiment, when mean ambient temperature was 26°C, initial post-graze rectal temperatures were higher ($P < 0.01$) in heifers on toxic (40.6°C) tall fescue than those on non-toxic (39.7°C) pastures (Fig. 4A). Rectal temperatures declined ($P < 0.01$) in heifers on both fescues and stabilized in 12 d at 39.4°C for heifers removed from toxic pastures and approximately 39.1°C for those removed from non-toxic pastures (Fig. 4B). Temperatures remained stable for the remainder of the 21-d monitoring period. Therefore, vasoconstriction in heifers grazed on toxic tall fescue was eased but not alleviated. Serum prolactin in pregnant heifers grazed on non-toxic tall fescue was initially high (~230 ng/mL) and in those grazed on toxic tall fescue was initially low (~90 ng/mL) (Fig. 5). Prolactin concentrations decreased ($P < 0.05$) in heifers grazed on non-toxic and increased ($P < 0.05$) in those grazed on toxic tall fescue, and both stabilized at similar concentrations ($P > 0.10$) in 6 d. Increased serum prolactin concentrations in those grazed on toxic tall fescue may indicate a reduction of dopinergic activity caused by ergot alkaloids. It is uncertain why serum prolactin concentrations decreased in heifers grazed on MaxQ.

Final Thoughts

Thus far, experiments have indicated that cattle can be removed from toxic tall fescue pastures to lower elevated body temperatures in 3 to 12 d. Number of days needed for rectal temperatures to decline to those of a healthy and stabile condition will depend on ambient temperatures. Longer recoveries from elevated body temperature appear to be required if ambient temperatures are above 25°C. Serum prolactin increases and stabilizes in 2 to 20 days after toxins are removed from the diet. Time for prolactin concentrations to increase and stabilize may also depend on ambient temperature. Other factors are the extent of time on toxic tall fescue pasture, pasture infection of stands, and alkaloid concentrations in grazed fescue. Changes in physiology of cattle as they switch from toxic to non-toxic diets appear associated with the excretion of alkaloids and the reduction of alkaloid concentrations in vascular circulation. High affinities of alkaloids at receptors likely slows their diffusion. More research is needed to determine possible storage and release of ergot alkaloids in organs and other tissues and evaluate long-term carryover effects of alkaloids on cattle physiology.

References

Aiken, G. E., M. L. Looper, S. F. Tabler, D. K. Brauer, J. R. Strickland, and F. N Schrick. 2006. Influence of stocking rate and steroidal implants on growth rate of steers grazing toxic tall fescue and subsequent physiological responses. J. Anim. Sci. 84:1626-1632.

Aiken, G. E., and E. L. Piper. 1999. Stocing rate effects on steer performance for two methods of alleviating fescue toxicosis. Prof. Anim. Sci. 15:245-252.

Aiken, G.E., Piper, E.L., and Meisner, C.R. 2001. Influence of protein supplementation and implant status on alleviation of fescue toxicosis. J. Anim. Sci. 79:818-823.

Hemken, R. W., J. A. Boling, and L. S. Bull, R. H. Hatton, R. C. Buckner, and L. P. Bush. 1981. Interaction of environmental temperature and anti-quality factors on the severity of summer fescue toxicosis. J. Anim. Sci. 52:710-714.
Hoveland, C.S. 1993. Importance and economic significance of the Acremonium endophytes to performance of animals and grass plant. Agric. Ecosys. Environ. 44:3-12.

Oliver, J. W. 2005. Pathophysiologic response to endophyte toxins. Pages 291-301 in Neotyphodium in Cool-Season Grasses. C. A. Roberts, C. P. West, and D. E. Spiers (Eds.). Blackwell Publishing, Ames, IA.
Schmidt, S. P., and T. G. Osborn. 1993. Effects of endophyte-infected tall fescue on animal performance. Agric. Ecosys. and Environ. 44:233-262.

Sleper, D.A., and C.P. West. 1996. Tall fescue. p. 471-502. *In* L.E. Moser et al. (ed.) Cool-Season Forage Grasses. Agron. Monogr. No. 34. ASA, CSSA, and SSSA, Madison, WI.

Spiers, D. E., T. J. Evans, and G. E. Rottinghaus. 2005. Interaction between thermal stress and fescue toxicosis: Animal models and new perspectives. Pages 243-270 in C.A. Roberts, C.P. West, and D.E. Spiers (Eds.). Neotyphodium in Cool-Season Grasses. Blackwell Publishing, Ames, IA.

Stuedemann, J. A., N. S. Hill, F. N. Thompson, R. A. Fayrer-Hosken, W. P. Hay, D. L. Dawe, D. H. Seman, and S. A. Martin. 1998. Urinary and biliary excretion of ergot alkaloids from steers that grazed endophyte-infected tall fescue. J. Anim. Sci. 76:2146-2154.

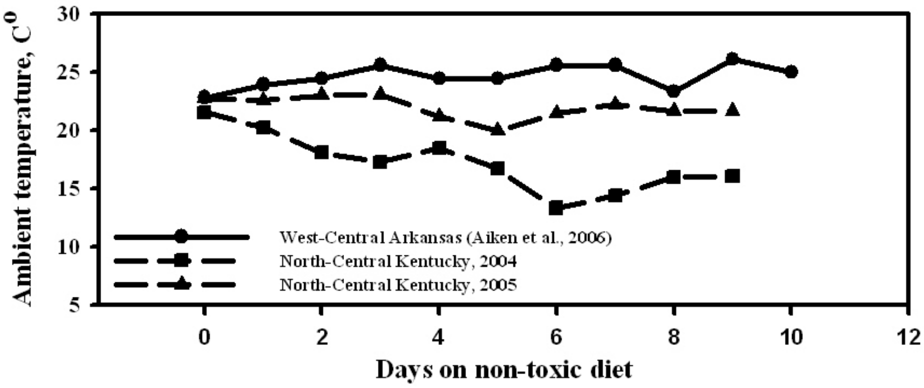

Figure 1. Ambient temparatures over monitoring periods following grazing of toxic tall fescue and placement on non-toxic diets in west-central Arkansas (Aiken et al., 2006) and north-central Kentucky (Aiken, unpublished).

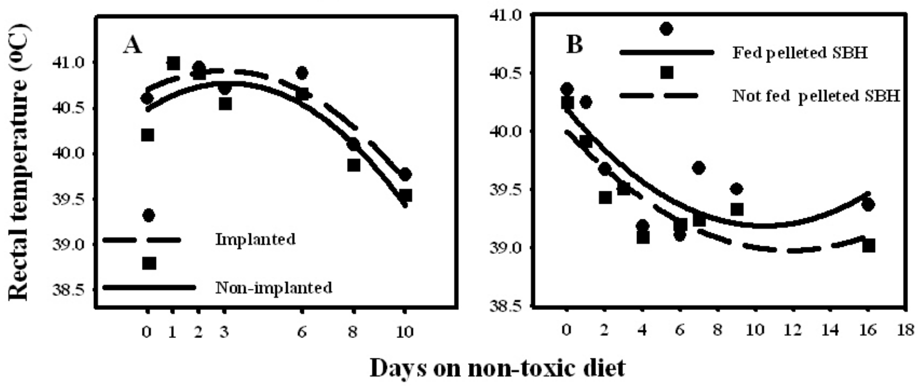

Figure 2. Rectal temparatures monitored following grazing of toxic tall fescue and placement on non-toxic diets for: A) implanted and non-implanted steers in west-central Arkansas (Aiken et al., 2006), and B) steers fed or not fed soybean hulls on pasture in north-central Kentucky (Aiken, unpublished).

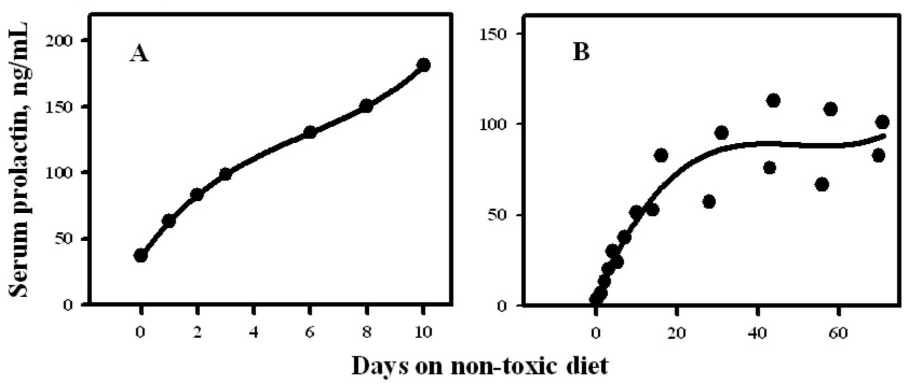

Figure 3. Serum prolactin concentrations monitored in steers following graazing of toxic tall fescue and placement on non-toxic diets for: A) implanted and non-implanted steers in west-central Arkansas (Aiken et al., 2006), and B) steers fed or not fed soybean hulls on pasture in north-central Kentucky (Aiken, unpublished)

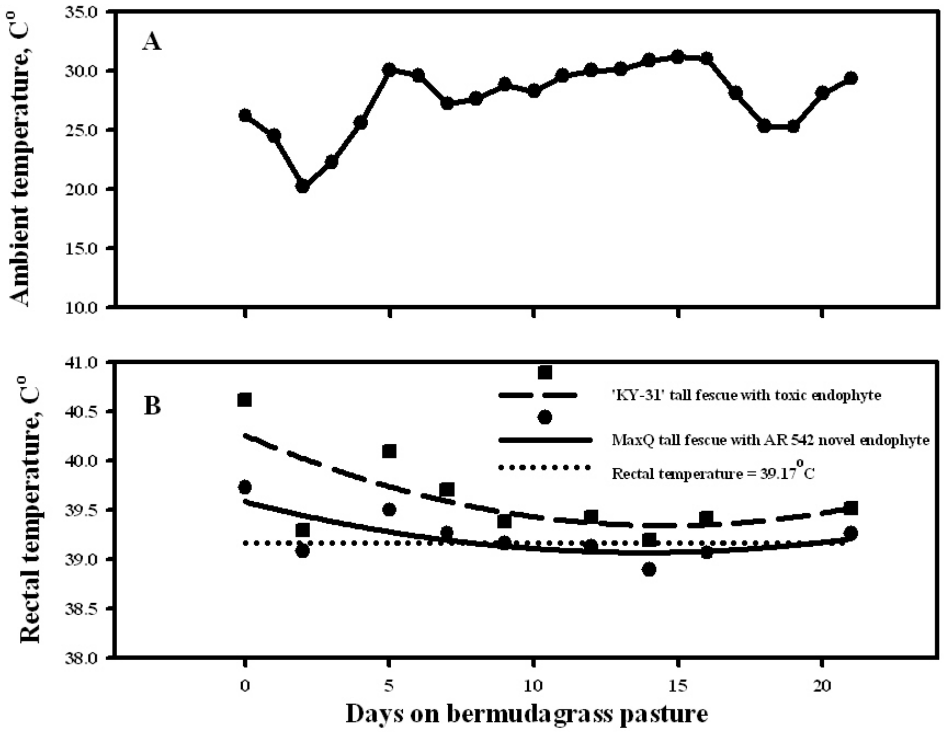

Figure 4. Ambient temparatures (A) and rectal temperatures (B) monitored for steers following grazing of Kentucky-31 with the toxic endophyte or MaxQ tall fescue with the non-toxic endophyte and placement on bermudagrass pastures (Aiken and Looper, unpublished).

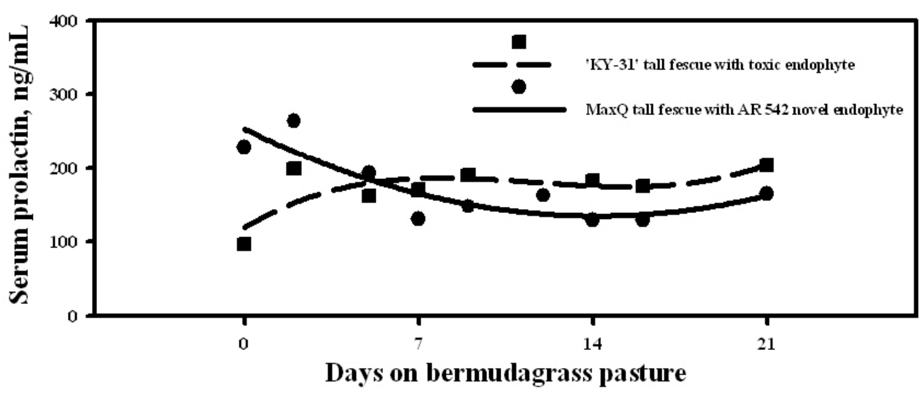

Figure 5. Serum prolactin concentrations monitored in steers following grazing of Kentucky-31 tall fescue with the toxic endophyte or MaxQ tall fescuewith the novel endophyte and placement on bermudagrass pastures (Aiken and Looper, unpublished).

Relationships Between Cattle Genetic Polymorphisms and Profitability Traits in Tall Fescue Forage Systems

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Introduction

Ergot alkaloid toxins produced by *Neotyphodium coenophialum* in association with tall fescue (*Festuca arundinacea*) have been shown to affect numerous physiological systems of livestock resulting in decreased profitability of those enterprises. One management technique that has been promoted to reduce the production losses in cattle is crossbreeding (Brown et al., 1997). In addition to crossbreeding *Bos indicus* (Brahman) and *Bos taurus* (Angus, Hereford, Senepol, etc.) cattle, one also can rotate cattle off of toxic fescue prior to the breeding season (Brown et al., 2000). While it was apparent that heterosis improved cattle productivity, specific genetic effects related to an animal's tolerance to ergot alkaloids is not known.

Heat shock proteins (HSPs), also known as stress proteins, are present in all cells of the body. The HSPs increase when an animal is subjected to stressors such as heat, cold, oxygen deprivation, and other conditions (for review see Lindquist and Craig, 1988). Although HSPs are present in high concentrations during cellular stress, they also are present at normal temperatures and play vital roles in normal cell function via protein chaperones, immune cell regulation, and steroid receptor function (Bresnick et al., 1989; Morishima et al., 2000; Smith et al., 1995).

Prolactin is a protein hormone secreted by the lactotropic cells of the anterior pituitary. The primary role of prolactin in mammals is the development of the mammary gland and lactation in the mature mammary gland during the last stage of pregnancy and following parturition (McCann, 1988; Bawden and Nicholas, 1999). Consumption of endophyte-infected tall fescue results in reduced feed intake, weight gains, blood flow to the periphery, pregnancy rates, as well as lower concentrations of serum prolactin and milk production (Nihsen et al., 2004; Browning, 2000; Samford-Grigsby et al., 1997).

In this report, the results of studies are presented that evaluated the relationships between cattle productivity and genomic polymorphisms in cattle. Specifically, the enhancer region of the prolactin gene and coding sequences of the HSP-70 gene in *Bos indicus* and *Bos taurus* cattle were genotyped and related to cattle productivity while grazing toxic tall fescue.

Materials and Methods

Animals

The cows were part of a long-term breeding program at the USDA-ARS Dale Bumpers Small Farms Research Center near Booneville, Arkansas. Blood samples were collected and the plasma was harvested. Buffy coats were then stored at -80°C to await genomic analysis. Genetic data was successfully collected on 157 cows. The breed composition of the cows and the number of each breed used were as follows: *Bos taurus* (Angus; n = 42), *Bos indicus*

(Brahman; n = 41), and *Bos taurus*/*Bos indicus* crosses (n = 74). The crossbred cows were distributed as follows: 38 Angus sired Brahman dams, 36 Brahman sired Angus dams.

Prolactin Genotyping

The prolactin enhancer sequence was predicted to be approximately 1.5 kb to 300 bp before the coding region, and sequences between positions 985 and 1124 were essential to enhancer activity (National Center for Biotechnology Information (NCBI) nucleotide sequence X16641; Wolf et al., 1990, 1992). Primers were designed to amplify a 501 bp fragment from positions 892 to 1392. Primer +PRL 892 (AAGTCCCCATAAGCACACTTGG) and primer –PRL 1392 (CTAACTTTAGGGAGTTCATACTG) were synthesized and supplied by Sigma–Genosys (Saint Louis, MO). The thermocycler conditions for PCR were 96°C 30 seconds denaturation, 50°C 30 seconds primer annealing, and 68°C 1 minute elongation for 36 cycles. The first 13 PCR products were gel purified using the Qiagen MiniElute gel purification kit according to the manufacturer's instructions (Qiagen Inc., Valencia, CA) and sequenced by the DNA Resource Center, University of Arkansas, using a Beckman CEQ 8000. The sequence was analyzed using DNAStar software. A single nucleotide polymorphism (SNP) was identified at base position 1286 (a cytosine to a thymine) and represents a distinct restriction enzyme site *Xba* I (T^CTAGA). The alleles that did not contain the SNP were 'cut' and coded as CC; whereas, those alleles that had the SNP were 'uncut' and labeled as TT.

Heat Shock Protein 70 Genotyping

Based on NCBI sequence accession number U09861 of *Bos taurus* HSP-70, three primers were designed for PCR amplification and sequencing. The primers were synthesized by Sigma-Genosys (Saint Louis, MO). Primers HSP1778F (CGCTGGAGTCGTACGCCTTC) and HSP2326R (CTTGGAAGTAAACAGAAACGGG) were used for amplification of a 548 base pair fragment from positions 1778 to 2326. After amplification, HSP1803F (GAAGAGCGCCGTGGAGGATG) and HSP2326R were used to sequence a 523 base pair fragment within the amplified region from positions 1803 to 2326. Specific DNA amplification occurred after 35 cycles of denaturation at 94°C for 2 minutes and then cycled at 94°C for 30 seconds, 55°C for one minute and 68°C for one minute.

Statistics

Distribution of cow genotype and breed were tested using Chi-square. Analysis of variance was used to determine genotype effects on the mean lifetime calving rate, milk quality and quantity (as reported by Brown et al., 1993), and calf weaning weight and height. Main effects included: genotype, forage type (tall fescue vs. bermudagrass), genotype x forage interaction. Age and sex of calf, month of sampling, and lactation number were used as covariates where appropriate. When F-tests were significant for main effects means were separated using multiple t-tests.

Results

Prolactin

The distribution of Xba SNP was affected ($P < 0.01$) by breed of cow (Table 1). Brahman cows had a greater proportion of TT genotype; whereas, Angus cows had a greater proportion of CC genotype. All breed groups had at least one cow in all three genotype possibilities. Table 2 presents the interactive means of forage type and prolactin genotype on cattle traits. Cows that were homozygous thymine and grazing tall fescue had lower ($P < 0.1$) lifetime calving rates when compared to cows grazing bermudagrass or other genotypes grazing tall fescue. Fat percent in milk was affected by an interaction ($P < 0.05$) of forage type and prolactin genotype. Homozygous cytosine cows grazing tall fescue had ($P < 0.05$) the least amount of butterfat in their milk when compared to all other groups, and tended ($P < 0.1$) to wean calves that were shorter than other genotypes.

Heat Shock Protein 70

The bovine HSP-70 gene was amplified from base 1778 to base 2326. By comparing the region of interest from our samples to the NCBI published sequence (accession number U09861), eight SNPs were identified with four of the eight resulting in an altered peptide sequence. The SNPs were identified at the following base positions on the HSP-70 gene: 1851, 1899, 1902, 1917, 1926, 2033, 2087, and 2098.

The frequency and breed composition of each of the eight SNPs are summarized in Table 3. The base change, location, and effect on amino acid profile are summarized in Table 4. The presence of SNP 2033 was not affected ($P > 0.5$) by breed. Brahman ancestry was related ($P < 0.11$) to the occurrence of SNPs at positions 1902, 1917, 1926, 2087, and 2098. Whereas, the presence of SNP 1851 was associated ($P < 0.11$) with Angus lineage.

Associations of HSP-70 SNPs and cattle traits are presented in Tables 5 and 6. Cows with genotypes inconsistent with NCBI sequence at bases 1902, 1917, and 1926 had milk with a greater ($P < 0.05$) percentage of butterfat and protein than other cows. Those same cows tended ($P < 0.1$) to have calves that were taller than calves from non-SNP cows (Table 5). Heterozygous (GC) cows at base 2033 had fewer ($P < 0.05$) somatic cells in their milk when compared with homozygous guanine cows. In addition, heterozygous cows grazing tall fescue had the lightest ($P < 0.1$) calves at weaning (Table 6).

Discussion

Fescue toxicosis has been shown to have varying effects on different breeds of cattle. In a study conducted by Criss (1986), Brahman and Angus cows were fed endophyte-infected tall fescue during the first 3 months of lactation; milk production by Brahman exceeded Angus. Brown et al. (1993, 1997) found that Angus cows were more susceptible to the ergot alkaloids when compared to Brahman. The percentage of milk fat was 0.68% greater in Brahman than Angus. They also found that crossbred cows (both Angus-Brahman and Brahman-Angus) were more resistant to the negative effects of fescue toxicosis than their purebred counterparts. Our study was aimed at identifying polymorphisms in the enhancer region of the prolactin gene in *Bos indicus* and *Bos taurus* that may account for the higher toxin tolerance of the Brahman. Our results suggest that prolactin promoter polymorphisms were associated with calving rate; however, that association was biased against Brahman on tall fescue.

The HSP-70 SNPs at positions 1902, 1917, 1926, and 2098 appeared to be linked, if a cow had one of the SNPs they had all four, and these SNPs appear to be driven by Brahman lineage. Somatic cell counts were associated with the SNP at position 2033 which was the most prevalent in the HSP-70 segment and was equally distributed over breed groups. In humans, a similar guanine to cytosine transition at position 2074, which is close to the G to C transition at 2033 in cattle, was associated with the risk of Parkinson’s disease (Wu et al., 2004).

Both the prolactin and HSP-70 sequences posted at NCBI were derived from Angus samples (*Bos taurus*); therefore, the SNPs associated with our *Bos indicus* samples may represent subtle species differences in genetic coding and possibly give rise to future advances in the understanding of the ability of one breed to perform better in stress situations than another breed within a genus.

Implications

These results suggest that single nucleotide polymorphisms associated with the prolactin and(or) heat shock protein 70 genes may server as genetic markers for production and reproductive traits related to cattle profitability. Genomic DNA evaluations will allow producers to evaluate the genetic potential of animals and, in the future, will increase the accuracies of selecting breeding stock that are less susceptible to ergot alkaloids.

Acknowledgements

This research was supported by USDA-ARS Dale Bumpers Small Farms Research Center Cooperative Agreement No. 58-6227-8-040, and Division of Agriculture, University of Arkansas. The author is appreciative of the collaborative efforts of Drs. H. Brown, Jr., M. Brown, Z. Johnson, M. Looper, R. Okimoto, and the technical assistance of Ms. S. Black, Ms. M. Lamb, Ms. B. Okimoto, and Ms. S. Reiter.

Literature Cited

Bawden, W.S. & Nicholas K.R. (1999) Molecular genetics of milk production. The genetics of cattle. Wallingford: CAB International. 539-576.

Bresnick,E.H., Dalman F.C., Sanchez E.R. & Pratt W.B. (1989) Evidence that the 90-kDa heat shock protein is necessary for the steroid binding conformation of the L cell glucocorticoid receptor. Journal of Biological Chemistry 264, 4992-4997.

Brown, M.A., Brown A.H. Jr., Jackson W.G. et al. (2000) Genotype x environment interactions in Angus, Brahman, and reciprocal-cross cows and their calves grazing common bermudagrass, endophyte-infected tall fescue pastures, or both forages. J. Anim. Sci. 2000. 78, 546–551.

Brown, M.A., Brown A.H. Jr., Jackson W.G. et al. (1997) Genotype x environment interactions in Angus, Brahman, and reciprocal cross cows and their calves grazing common bermudagrass and endophyte-infected tall fescue pastures. J. Anim. Sci. 75, 920–925.

Brown, M.A., Tharel L.M., Brown, A.H. Jr. et al. (1993) Milk production in Brahman and Angus cows on endophyte-infected fescue and common bermudagrass. J. Anim. Sci. 71, 1117-1122.

Browning, R. Jr. (2000) Physiological responses of Brahman and Hereford steers to an acute ergotamine challenge. J. Anim. Sci. 78, 124–130.

Criss, E.A. (1986) Milk production and composition, calf weaning weights and occurrence of subclinical mastitis in Angus, Brahman and Brahman x Angus beef cows. Ph.D. Dissertation. Mississippi State Univ., Starkville.

Lindquist, S. & Craig E.A. (1988) The heat shock proteins. Annual Review of Genetics 22, 631-677.

McCann, S.M. (1988) The anterior pituitary and hypothalamus. Textbook of endocrine physiology. New York: Oxford University Press. 70-99.

Morishima, Y., Murphy P.J., Li D.P., Sanchez E.R. & Pratt W.B. (2000) Stepwise assembly of a glucocorticoid receptor/hsp90 heterocomplex resolves two sequential ATP-dependent events involving first hsp70 and then hsp90 in opening of the steroid binding pocket. Journal of Biological Chemistry 275, 18054-18060.

Nihsen, M.E., Piper E.L., West C.P. et al. (2004) Growth rate and physiology of steers grazing tall fescue inoculated with novel endophytes. J. Anim Sci. 82, 878-883.

Paterson, J., Forcherio C., Larson B. et al. (1995) The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73, 889-898.

Porter, J.K., & Thompson, F.N. Jr. (1992) Effects of fescue toxicosis on reporoduction in livestock. J. Anim. Sci. 70, 1594-1603.

Samford-Grigsby, M.D., Larson B.T., Forcherio J.C. et al. (1997) Injection of dopamine Antagonist into Holstein steers to relieve symptoms of fescue toxicosis. J. Anim. Sci. 75, 1026-1031.

Smith, D.F., Whitesell L., Nair S.C., Chen S. et al. (1995) Progesterone receptor structure and function altered by geldanamycin, an hsp90-binding agent. Molecular and Cellular Biology 15, 6804-6812.

Wolf, J.B., David V.A., & Deutch A.H. (1990) Bovine DNA for prolactin 5'flanking regulatory region. NCBI Accession Number X16641.

Wolf, J.B., David V.A., & Deutch A.H. (1992) Identification of a distal regulatory element in the 5’ flanking region of the bovine prolactin gene. Nucleic Acids Research. 18, 4905-4912.

Wu, Y.R., Wang C.K., Chen C.M. et al. (2004) Analysis of heat-shock protein 70 gene polymorphisms and the risk of Parkinson's disease. Human Genetics 114, 236-241.

Table 1. Allele frequencies of *Xba* I restriction site by breed composition.

Breed[1]	CC[2]	CT	TT
AA	8	13	2
AB	1	19	1
BA	3	6	3
BB	1	8	8

[1] Breed designations are AA = purebred Angus; AB = sire was Angus, dam was Brahman; BA = sire was Brahman, dam was Angus; BB = purebred Brahman.
[2] Allele CC represents the samples that were homozygous for the restriction site allele (TCTAGA), WX represents the heterozygous cows, and TT allele represents the samples that were homozygous for the SNP (TTTAGA).

Table 2. Relationship between prolactin promoter restriction enzyme, *Xba*, digestion and milk composition, reproduction, and calf traits.

Item	Forage						SEM	Effects[1]
	Bermudagrass			Tall Fescue				
	Genotype							
	CC	CT	TT	CC	CT	TT		
Calvings, %	88	83	88	90	84	58	7	f*g
Prolactin, ng/ml	91	119	103	13	17	25	33	F
Milk								
Volume, kg/d	5.5	5.7	5.2	3.8	4.2	3.3	0.46	F
Butterfat, %	4.6	4.3	3.8	2.7	3.6	3.8	0.35	F, F*G
Protein, %	3.1	3.2	3.3	3.5	3.4	3.6	0.1	F
SCC, n	437	277	311	140	346	253	163	-
Calves								
Birth wt, kg	35.2	35.0	35.7	37.0	35.5	34.3	1.21	-
Weaning wt, kg	240	256	259	227	230	226	9.5	F, S, A
Weaning ht, cm	114	117	118	113	114	116	1.5	g, S, A

[1]Effects: for the statistical model main effects were forage (F, f), genotype (G, g), age at weaning (A, a), sex of the calf (S, s), and month (M, m) in the case of multiple dates of collection. Uppercase letters indicate that the main effect was significant at a probability of less than 0.05; whereas, lowercase letters indicates a significance below 0.1. Interactions between main effects are indicated with an asterisk using the same uppercase and lowercase designations.

Table 3. Effects of breed composition[1] on SNP occurrence in HSP-70 gene.

SNP	Sequence Position	Frequency[2]	Breed AA	AB	BA	BB
1	1851	0.045	2	0	5	0
2	1899	0.006	0	0	1	0
3	1902	0.038	0	1	1	4
4	1917	0.038	0	1	1	4
5	1926	0.038	0	1	1	4
6	2033	0.140	8	5	3	6
7	2087	0.064	0	2	2	6
8	2098	0.038	0	1	1	4

[1] The number of animals with the detected SNP by breed; AA-purebred Angus; AB-Angus sire; BA-Angus dam; BB-purebred Brahman
[2] Percentage of cows with that SNP in our population of 157 cows

Table 4. Relationship of HSP-70 SNP to potential codon position and translational products.

SNP	Base Change[1]	Codon Position[2]	Amino Acid Change[3]
1 (1851)	G to A	3	Ala (no change)
2 (1899)	G to A	3	Leu (no change)
3 (1902)	C to T	3	Asp (no change)
4 (1917)	G to T	3	Ala (no change)
5 (1926)	C to G	3	Asp to Glu
6 (2033)	G to C	2	Gly to Ala
7 (2087)	C to G	-	Post-translational
8 (2098)	T to A	-	Post-translational

[1] G-Guanine; A-Adenine; C-Cytosine; T-Thymine
[2] 1-first base in codon; 2-second base in codon; 3-third base in codon
[3] Ala-alanine; Asp-aspartic acid; Glu-glutamic acid; Gly-glycine; Leu-leucine

Table 5. Relationship between HSP-70 polymorphisms (c1902t, g1917t, and c1926g) and milk composition, reproduction, and calf traits.

	Forage					
	Bermudagrass		Tall Fescue			
	Genotype					
Item	**CGC**	**TTG**	**CGC**	**TTG**	**SEM**	**Effects[1]**
Calvings, %	84	83	80	89	9	-
Prolactin, ng/ml	87	83	23	11	28	F
Milk						
Volume, kg/d	5.7	6.2	4.0	5.1	0.67	f
Butterfat, %	3.9	5.4	3.2	4.1	0.54	G, F,
Protein, %	3.2	3.8	3.4	3.5	0.12	G, f*g
SCC, n	301	637	215	63	180	-
Calves						
Birth wt, kg	35.2	34.4	35.7	36.3	1.7	F*G*S
Weaning wt, kg	257	257	229	228	5	A
Weaning ht, cm	116.5	118.3	114.2	120.9	2.1	g, A

[1]Effects: for the statistical model main effects were forage (F, f), genotype (G, g), age at weaning (A, a), sex of the calf (S, s), and month (M, m) in the case of multiple dates of collection. Uppercase letters indicate that the main effect was significant at a probability of less than 0.05; whereas, lowercase letters indicates a significance below 0.1. Interactions between main effects are indicated with an asterisk using the same uppercase and lowercase designations.

Table 6. Relationship between HSP-70 polymorphisms (g2033c) and milk composition, reproduction, and calf traits.

	Forage					
	Bermudagrass		Tall Fescue			
	Genotype					
Item	**GC**	**GG**	**GC**	**GG**	**SEM**	**Effects**[1]
Calvings, %	85	83	72	82	5.1	-
Prolactin, ng/ml	60	91	16	23	17	F
Milk						
Volume, kg/d	5.9	5.7	3.7	4.2	0.38	F
Butterfat, %	4.1	3.9	2.9	3.3	0.24	F
Protein, %	3.2	3.3	3.5	3.4	0.07	F
SCC, n	175	350	47	259	103	G
Calves						
Birth wt, kg	34.6	35.3	36.4	35.6	0.9	s
Weaning wt, kg	253	258	220	231	7.5	F, S, f*g*s, A
Weaning ht, cm	115.6	116.7	114	114.6	1.1	f, S, A

[1]Effects: for the statistical model main effects were forage (F, f), genotype (G, g), age at weaning (A, a), sex of the calf (S, s), and month (M, m) in the case of multiple dates of collection. Uppercase letters indicate that the main effect was significant at a probability of less than 0.05; whereas, lowercase letters indicates a significance below 0.1. Interactions between main effects are indicated with an asterisk using the same uppercase and lowercase designations.