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STOCKER CATTLE PERFORMANCE AND CALCULATED PASTURE COSTS

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Most livestock producers know, or can easily determine, which forage species and varieties are suited for land they have available for pasture. However, before making planting decisions, it is critically important to understand the level of animal performance expected from those forages and the cost of that production. Given the recent volatility in production input prices, this is more important than ever.

Many grazing experiments have provided stocker cattle performance data on various forage species. However, because of the expense of conducting grazing research, it is rare to see animal performance comparisons on more than two or three species or species mixtures at a time. Thus, it is difficult for livestock producers to obtain an overall view of the relative productivity of various forages.
This article provides a comparison of stocker cattle performance criteria from several selected steer grazing experiments conducted in Alabama. It also provides pasture cost/acre and pasture cost/pound of gain information for the forage crops used in these tests, based on 2008 Auburn University enterprise budgets.

Studies Selected for Comparison

Auburn University scientists have conducted numerous steer grazing experiments that have involved various forage species. These studies have generally involved crossbred animals of similar breeding and weights, and they were conducted over multiple years. They provide a good basis for comparison of both the animal production potential and the production cost of various forage species commonly used in Alabama.

An early test at the Wiregrass Substation (WG) near Headland evaluated steer performance at four nitrogen levels on 'Coastal' bermudagrass and at three levels each on both 'Pensacola' bahiagrass and common bermudagrass. A later study at the Tennessee Valley Substation (TVS) near Belle Mina compared bermudagrass interseeded with either hairy vetch or 'Explorer' rye.

At the Black Belt Substation (BBS) near Marion Junction, the tall fescue varieties 'AU Triumph' (0 percent toxic fungal endophyte) and 'Kentucky 31' tall fescue (having approximately 1, 34, or 90 percent toxic endophyte) were compared. In another study, Kentucky 31 pastures having approximately 5 percent toxic endophyte and 94 percent toxic endophyte were tested. Also at that station, highly toxic endophyte-infected Kentucky 31 fescue and "AP-2," an experimental line of hardinggrass (*Phalaris*), were evaluated.

In addition, toxic endophyte-infected tall fescue was grazed in pure stands as well as with either ladino clover or birdsfoot trefoil at the Sand Mountain Substation (SMS) near Crossville. Steer gains on an orchardgrass-ladino clover mixture were obtained in a test at TVS. In another study at TVS, toxic endophyte Kentucky 31 tall fescue and common orchardgrass (both grown with and without 'Regal' white clover) were evaluated.

Continuously grazed 'AU Lotan' sericea lespedeza was tested against rotationally grazed AU Lotan sericea, 'Serala' sericea, and 'Cimarron' alfalfa at the Upper Coastal Plain Substation (UCP) near Winfield. At TVS, 'Funk's 78F' sorghum-sudan was evaluated. Various winter annual mixtures including rye, oats, ryegrass, and crimson clover were tested at the Lower Coastal Plain Substation (LCP) near Camden.

Procedure

To get a clearer view of the performance of stocker cattle on forages, performance criteria for stocker steers grazing the 37 different pasture treatments used in these Auburn University grazing studies were summarized from various research reports and articles. These experimental results provide a basis for comparison of animal performance among the treatments (Table 1). Subsequently, Auburn University 2008 budget estimates for the various forage species or species mixtures involved in these studies were used to determine both the approximate pasture costs/acre and the pasture costs/lb of gain. This information, also in table 1, provides a basis for economic comparison. The ranking (least to most expensive) of variable and total pasture cost of gain for each forage species is also provided.

Animal Performance Comparisons

As expected, the animal performance reported in these experiments varied greatly among the various pasture species or mixtures. The number of calendar grazing days ranged from a low of 77 for sorghum-sudan at TVS to a high of 238 for an orchardgrass-white clover mixture, also at TVS. The variation in calendar grazing days was greater among cool-season species and mixtures than among warm-season species. In comparisons of these studies, neither endophyte status nor presence of a legume companion species seemed to affect the number of grazing days obtained from pasture treatments involving tall fescue (although legumes can lengthen the grazing season in some situations).

High per-day gains (1.7 pounds or more) were obtained with alfalfa, continuously grazed 'AU Lotan' sericea lespedeza, tall fescue having low or medium endophyte infection, common orchardgrass, hardinggrass, orchardgrass with ladino clover, and tall fescue with ladino clover. In several cases in which ADG was high, a relatively short grazing season reduced gain per steer. In other cases, a lower ADG coupled with a long grazing season resulted in impressive gains per steer. Winter annuals often produce higher individual animal gains than were obtained in the experiments selected for this exercise.

The gain per acre was at least 475 pounds on ten of the pasture treatments. These were alfalfa, Coastal bermudagrass receiving at least 160 pounds of nitrogen per acre, Coastal bermudagrass overseeded with vetch or rye, endophyte-free AU Triumph tall fescue, endophyte-

infected tall fescue-white clover (SM), Hallmark orchardgrass,-white clover, and with two of the four winter annual mixtures. The lowest gain per acre (100 pounds) was obtained on common bermudagrass receiving no nitrogen fertilizer.

Table 1. Production and Economic Performance Data for Stocker Steers Using Various Forage Types and Varieties[a].

Description	Item No	Pasture	Line or Variety	Calendar Days Grazing	Average Grazing Dates	Years of Data	Location[b]
Warm-Season Perennial Grasses (WSPG)	1	Bermudagrass	Coastal	168	NS[g]	4	WG
	2	Bermudagrass	Coastal	168	NS	4	WG
	3	Bermudagrass	Coastal	168	NS	4	WG
	4	Bermudagrass	Coastal	168	NS	4	WG
	5	Bahiagrass	Pensacola	168	NS	3	WG
	6	Bahiagrass	Pensacola	168	NS	3	WG
	7	Bahiagrass	Pensacola	168	NS	3	WG
	8	Bermudagrass	Common	168	NS	3	WG
	9	Bermudagrass	Common	168	NS	3	WG
	10	Bermudagrass	Common	168	NS	3	WG
WSPG W/Winter Annuals	11	Bermudagrass w/Vetch	Coastal/Hairy	161	4/4 -9/27	8	TVS
	12	Bermudagrass w/Rye	Coastal/Explorer	161	3/19-9/27	8	TVS
Summer Annuals	13	Sorghum-Sudan	Funks 78-F	77	6/6-8/22	3	TVS
Perennial Legumes	14	Alfalfa[h]	Cimarron	163	3/30-9/8	3	UCP
	15	Sericea Lespedeza[h]	Serala	139	4/22-9/8	3	UCP
	16	Sericea Lespedeza[h]	AU Lotan	139	4/22-9/8	3	UCP
	17	Sericea Lespedeza	AU Lotan	139	4/22-9/8	3	UCP
Cool-Season Perennial Grasses	18	Tall Fescue[i]	AU Triumph	161	10/5-12/26 & 2/28-5/27	3	BB
	19	Tall Fescue	(0%)	161	10/5-12/26 & 2/28-5/27	3	BB
	20	Tall Fescue	KY 31 (1%)	161	10/5-12/26 & 2/28-5/27	3	BB
	21	Tall Fescue	KY 31 (34%)	161	10/5-12/26 & 2/28-5/27	3	BB
	22	Tall Fescue	KY 31 (90%)	172	10/23-12/24 & 2/26-6/16	4	BB
	23	Tall Fescue	KY 31(<5%)	172	10/23-12/24 & 2/26-6/16	4	BB
	24	Tall Fescue	KY 31 (94%)	150	3/18-7/9 & 9/25-11/22	8	TVS
	25	Orchardgrass	KY 31 (>90%)	139	3/23-7/9 & 9/25-11/11	8	TVS
	26	Tall Fescue	Common	177	10/17-12/26 & 3/7-5/19	3	BB
	27	Hardinggrass	KY 31 (0%)	177	10/17-12/26 & 3/7-6/19	3	BB
	28	Tall Fescue	AP-2 KY 31 (>90%)	206	10/15-1/15 & 3/15-7/19	2	SM
Cool-Season Perennial Grasses w/Legumes	29	Orchardgrass w/Ladino	Hallmark/Regal	238	9/5-12/5 & 4/1-8/27	2	TVS
	30	Tall Fescue W/Ladino	KY 31/Regal	143	3/18-7/9 & 9/25-11/15	8	TVS
	31	Orchardgrass w/Ladino	Common/Regal	143	3/23-7/9 & 9/25-11/15	8	TVS
	32	Tall Fescue w/Ladino	KY 31/Regal	205	10/15-1/15 & 3/15-7/19	2	SM
	33	Tall Fescue w/Birdsfoot	KY 31/Fergus	194	10/15-1/15 & 3/15-7/19	2	SM
Winter Annuals	34	Rye, Oats & Crm. Clover[j]	NS	121	10/18 – 5/2	2	TVS
	35	Rye & Ryegrass[k]	NS	153	10/24-5/15	7	TVS
	36	Rye, Ryegrass & Crm Clover	NS	177	10/6-5/2	6	BB
	37	Oats & Crm Clover	NS	201	10/29-5/18	2	BB

[a]Data complied from AAES reports (see references). Majority of steers were crossbred with an initial weight of approximately 500 pounds.
[b]WG = Wiregrass; TVS = Tennessee Valley Station; UCP = Upper Coastal Plains; BB = Black Belt; SM = Sand Mountain
[c]Put-and-take grazing was employed in most of these tests, which precludes calculation of figures in this column from other data presented. For example, if you multiply Gain Per Steer times the Stocking Rate, the number does not necessarily equal Total Gain, as it normally would.
[d]Variable costs (2008 estimates) include annual maintenance items such as fertilizer, mowing, etc. (excluding labor).
[e]Total costs (2008 estimates) include variable items plus fixed costs associated with establishment and ownership of machinery and equipment.

The ten lowest pasture costs/lb of gain are highlighted

Item No	Nitrogen Rate	Stocking Rate	Average Daily Gain[c]	Total Gain[c]	Gain Per Steer[c]	Variable Pasture Costs[d]	Total Pasture Costs[e]	Variable Pasture Cost $/lb	Ranking[f]	Total Pasture Cost $/lb	Ranking[f]
	Lb/A/Yr	Head/A	Lb/Head	Lb/A	Lb/Head	$/A	$/A	$/Lb		$/Lb	
1	0	1.40	NS	250	179	26.59	50.04	0.47	8	0.69	14
2	80	1.70	NS	340	200	50.22	75.32	0.54	14	0.71	17
3	160	2.60	NS	480	185	73.85	100.61	0.59	18	0.65	11
4	320	3.50	NS	620	177	121.11	151.18	0.60	19	0.73	18
5	0	1.20	NS	220	183	26.59	43.94	0.54	15	0.73	20
6	80	1.80	NS	290	161	50.22	69.22	0.63	22	0.80	24
7	160	2.00	NS	350	175	73.85	94.51	0.70	26	0.86	28
8	0	0.70	NS	100	143	26.59	43.83	1.18	35	1.33	35
9	80	1.40	NS	230	164	50.22	69.12	0.79	31	0.88	29
10	160	1.80	NS	300	167	73.85	94.40	0.82	32	0.90	30
11	0	2.26	1.29	493	218	47.46	73.05	0.35	5	0.47	4
12	150	2.45	1.30	530	216	94.89	123.81	0.49	9	0.62	9
13	100	2.80	1.10	210	84	78.96	93.89	1.18	36	1.35	36
14	0	1.30	2.16	475	352	51.49	131.51	0.51	10	0.91	31
15	0	1.30	1.39	248	193	21.49	37.54	0.42	7	0.60	7
16	0	1.20	1.65	276	229	21.49	37.54	0.37	6	0.54	6
17	0	1.20	1.87	306	260	21.49	37.54	0.34	4	0.49	5
18	200	1.54	2.09	519	336	89.85	112.01	0.55	17	0.65	12
19	200	1.32	2.16	462	348	89.85	112.01	0.61	21	0.73	19
20	200	1.40	1.76	397	283	89.85	111.44	0.71	28	0.85	26
21	200	1.77	1.41	370	227	89.85	111.44	0.77	30	0.91	32
22	200	1.32	1.82	426	323	89.85	112.01	0.67	25	0.79	23
23	200	1.73	1.00	301	174	89.85	111.44	0.94	34	1.12	34
24	150	2.13	1.31	268	126	75.08	95.64	0.91	33	1.11	33
25	150	1.27	1.77	200	157	75.08	97.00	1.22	37	1.49	37
26	200	1.40	1.78	434	310	89.85	112.01	0.65	23	0.78	21
27	200	1.26	1.73	347	275	89.85	112.86	0.70	27	0.85	27
28	150	1.76	1.06	374	218	75.08	95.64	0.65	24	0.79	22
29	0	1.97	1.62	576	292	38.83	58.85	0.22	2	0.30	2
30	0	1.81	1.46	244	135	38.83	57.49	0.52	12	0.71	16
31	0	1.46	1.83	244	167	38.83	58.85	0.52	12	0.71	15
32	0	1.63	1.53	582	314	38.83	57.49	0.22	1	0.30	1
33	0	1.24	1.51	398	293	57.43	77.40	0.32	3	0.44	3
34	130	2.00	1.37	544	272	97.07	111.50	0.59	18	0.65	10
35	130	1.86	1.36	528	278	91.71	105.77	0.54	16	0.60	8
36	100	1.31	1.57	364	278	94.85	109.13	0.76	29	0.85	25
37	100	1.38	1.60	443	321	86.04	99.70	0.61	20	0.68	13

[f]Ranking Based on lowest to highest; fractional differences not shown allowed separation of treatments rounded to the same cost/lb.
[g]NS = Not Specified.
[h]Rotationally grazed.
[i]Tall fescue varieties, where indicated, are identified by percentage of endophyte infestation.
[j]Average of 78 days of grazing; dates not specified.
[k]Average of 52 days of grazing; dates not specified

Notable Points Revealed

*The seven lowest total pasture costs/lb of gain and eight of the ten lowest total pasture costs/lb of gain involved legumes (Table 2).

*The seven lowest total pasture costs/lb of gain and eight of the ten lowest total pasture costs/lb of gain involved perennials.

Table 2. The Ten Lowest Calculated Pasture Costs/lb of Gain

Pasture Type	Line or Variety	Grazing Days	Grazing Dates	ADG	Pasture Cost/Ac	Pasture Cost/lb
Tall Fescue w/Ladino	KY 31/ Regal	205	10/15-1/15 & 3/15-7/19	1.53	$172.26	$0.30
Orchardgrass w/Ladino	Hallmark/ Regal	238	9/5-12/5 & 3/15-7/20	1.62	$172.08	$0.30
Tall Fescue w/Birdsfoot	KY 31/ Fergus	194	10/15-1/15 & 3/15-7/20	1.51	$173.28	$0.44
Bermudagrass w/Vetch	Coastal/ Hairy	161	4/4-9/27	1.29	$230.75	$0.47
Sericea Lespedeza	AU Lotan	139	4/22-9/8	1.87	$148.84	$0.49
Sericea Lespedeza	AU Lotan	139	4/22-9/8	1.65	$148.84	$0.54
Sericea Lespedeza	Serala	139	4/22-9/8	1.39	$148.84	$0.60
Rye & Ryegrass	NS*	153	10/24-5/15	1.36	$318.34	$0.60
Bermudagrass w/Rye	Coastal/ Explorer	161	3/19-9/27	1.30	$328.35	$0.62
Rye, Oats & Crim. Clover	NS*	121	10/18-5/2	1.37	$352.78	$0.65

*NS = None Stated

*The range of total pasture costs/lb of gain (lowest to highest) is much broader than it was in the early 1990s when a similar exercise (calculating pastures costs using this data) was conducted. This provides evidence that as input costs increase, producers need to be increasingly focused on costs and returns to guide their decisions.

*Forage yield is an important economic factor, as evidenced by the fact that in the Wiregrass test, total pasture costs/lb of gain for Coastal bermudagrass were less than for bahiagrass, and those for bahiagrass were less than for common bermudagrass. The forage quality of these three is similar, so the primary difference in pasture cost/lb of gain was production/acre. Data from this test also indicate that application of nitrogen is a more cost efficient practice (results in more dry matter production/lb of N applied) on some forages than on others.

*Coastal bermudagrass overseeded with vetch was a lower-cost treatment than any of the other warm- season perennial grass treatments, which suggests that overseeding a legume can be a cost effective practice.

*Use of a sorghum/sudangrass hybrid was a very expensive option. Both average daily gain and calendar days of grazing provided by this grass were low as compared to most other treatments.

*In general, the higher the percentage infection by toxic endophyte in tall fescue, the more costly the gains. For example, among treatments at the Black Belt the total pasture cost/lb of gain was almost double ($1.12/lb vs $0.65/lb) in the high- versus low-endophyte treatments.

*Adding legumes to either tall fescue or orchardgrass substantially lowered pasture cost/lb of gain. In fact, this management practice resulted in the lowest three pasture costs/lb of gain of the 37 forage alternatives evaluated.

*It appears that both improved forage quality and reduction of the amount of fertilizer nitrogen used were factors in substantially lowering total pasture cost/lb of gain when legumes were included in stocker cattle pastures. An important concept is that stocker cattle producers who are able to increase animal performance via providing higher quality pasture and/or who are able to lower fertilizer inputs (with legumes or by other means) can achieve lower pasture costs/acre and lower costs/lb of gain.

*Of the 37 forage treatments, only five had less than a $0.50 total cost/lb of gain. Careful assessment of performance and pasture cost/lb of gain are the crux of sound pasture decisions.

Other Factors to Consider

Various types and classes of livestock have different nutritional requirements. The data in this publication pertain to stocker-steer tests. Nonetheless, it has some relevance to other types of livestock operations, as it should facilitate obtaining a better understanding of the relative level and duration of nutrition provided by these forage species and mixtures. While valuable for the purpose of making general comparisons, various animal or plant factors can influence such results. Pasture cost values provided were **calculated** assuming the application of recommended management practices with commercially purchased inputs as reflected in 2008 Auburn University forage crop budgets. In addition, although pasture cost/lb of gain is an important measure of production efficiency, it does not take into consideration seasonal price fluctuations (buy-sell relationships) or other expenses associated with owning animals over time.

In addition, animal management and marketing costs should always be considered when evaluating forage and livestock systems. For example, the pasture costs/lb of gain for some of the warm-season perennial grass treatments are relatively low. However, few stocker cattle operations of this type exist in most years due to unfavorable buy-sell price margins during this time of year. In addition, greater production and marketing risks are associated with higher stocking rates and higher nitrogen fertilization levels required for high per-acre gains with warm-season perennial forage species. Also, the market for animals coming off warm-season species is usually poorer than for animals coming off cool season species. As a result, summer stocker programs are usually difficult to justify.

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"Site visits in the 21st Century"

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Overview

The full-time equivalent (FTE) of extension faculty effort devoted to forage and forage-based livestock systems has decreased by 28% in the past 10 years and is projected to decline at a similar rate for at least the next 10 years (Rouquette et al., 2009). In addition to additional time demands on remaining extension faculty, travel funding has become a major limiting resource for forage extension programs. In fact, one could argue that the term "site visit" may mean something totally different to extension faculty in the 21st century than it did in the 20th century (perhaps, it already does). At last year's SPFCIC, Ball (2008) summarized it well when he said there has been a fundamental shift during his career toward the "dissemination of forage information via non-face-to-face methods."

The use of a computer and a connection to the "information superhighway" has become nearly ubiquitous in our culture, including in the great majority of farm operations. Despite the stereotype that the average age of the American farmer precludes their use of the internet, producers are increasingly getting their information from the internet. Increasingly, Google™ is consulted before the "County Agent." Even if they do not have the facility or know how to do it, they often rely on a family member for help. Thus, it is critical to provide timely and detailed information to clientele via an easily accessed/navigable website.

Unfortunately, the regionalized nature and specificity of forage information does not lend itself well to incorporation into generic and/or larger, national extension efforts like www.eXtension.org. Though there are places where such a broad scope is complementary, such can potentially lead to confusion among our clientele (for example, reading an article on timothy hay and being unsuccessful in their attempt to grow it in Georgia or Texas). Many times, the need for information is specific to certain hardiness zones, physiographic regions, or even landscape position within a field. As such, it is easy for the stakeholder to become confused or misled.

It is at this stage where the local extension effort remains crucial. The combination of a well-designed website and a trained extension workforce can potentially bolster the prominence, performance, and, ultimately, the relevance of local extension agents/educators and the "county-delivery system." The prerequisite for this is, of course, well-trained extension agents/educators. Unfortunately, funding for agent-trainings suffers from the same malady as the aforementioned challenges to extension specialists (i.e., general lack of time and funding for travel). Therefore, there is a substantial niche for distance learning, either synchronous (i.e., in "real-time") or asynchronous (i.e., "whenever you have time").

Therefore, the objectives of this paper are to highlight methods being put in place in two states (Texas and Georgia) that 1) make web-based information easily available to the client, 2) makes it pertinent to his or her location, and 3) is buttressed with detailed trainings offered to extension agents/educators via both synchronous and asynchronous distance learning methods.

Building a Website Identity

One of the most difficult challenges when developing a website within the framework of the University is that the web address is usually long, not intuitive to the lay audience, and not easily remembered (e.g., http://www.caes.uga.edu/commodities/fieldcrops/forages/index.html). One way around this is to purchase a more memorable web address. While serving as Forage Extension Specialist at the University of Georgia, Dr. John Andrae bought the url address "www.georgiaforages.com." He purchased this address from Dotster.com, one of several companies that sell url addresses on the internet. Though all of the UGA forage information remains on UGA servers and it remains accessible at a UGA internet address (http://www.caes.uga.edu/commodities/fieldcrops/forages/index.html), the url address www.georgiaforages.com serves as a "url forwarding" address. In other words, when a client enters www.georgiaforages.com, the browser is automatically redirected to the UGA internet address.

A brief and memorable web address also allows a marketing plan to be developed around the address. For example, all forage programs performed by the Forage Extension Specialist or other members of the Forage Team at the University of Georgia end with a reminder that more information is available on www.georgiaforages.com. This is also easy to place on a business card or incorporate into an attractive and memorable logo (Fig. 1).

Fig. 1. A simple website is memorable and compact enough to use on a business card or with a logo.

County-Specific Information in Texas

Cultivar evaluations, soil fertility trials, germplasm evaluations, grazing trials, ecological studies and other experiments have been carried out with Texas forage and range plants for over 100 years. This data has been published in journal articles, field day reports, extension bulletins, experiment station progress reports, conference proceedings, and recently, on many different web sites. However, these websites are scattered, whether they stand alone or they are connected to the University. More often than not our clientele simply visit Google™ and type limiting keywords in search of information.

Data represents a large investment by Texas A&M University System, however, only a small fraction is easily available to our stakeholders or to the research and extension community. A system is needed to make this valuable data available in a manner that will allow stakeholders, researchers, extension specialists and county extension agents access to this data in a variety of applications. Cattlemen will be interested in animal performance on improved range management systems and new cultivars of forage crops. Hay producers need information related to forage cultivars, fertility management and new preservation techniques. A web-based information system will also benefit new landowners and novice ranchers by providing site

specific grazingland data to enhance their agricultural enterprise and to protect the natural resources of Texas.

The objective is to create a web-based information system for Texas forage information. A "go-to" information system for stakeholders and the research and extension community where all (or most) of their forage questions can be answered/addressed based on specific locations within the state. Specific objectives pertain to the development of a grazingland web-tool that allows stakeholders, new land owners, and scientists to more accurately predict pasture-rangeland production and make tactical and strategic management decisions which are compatible with conserving natural resources.

Texas has 10 different ecoregions creating a very diverse environment. The same stakeholder query in El Paso would require a different answer compared with a stakeholder in Beaumont. Therefore, the Texas web-based information system would be one website as a source for a majority of forage information taking into account county specifications (soil types and average rainfalls). A stakeholder would click on their corresponding county which would lead them to a site with county specific information. Information would be available on forages that can be successfully produced in that area, weed management, establishment methods, grazing information (stocking rates, etc.), fertilizer management/considerations, and publications of relevance. Active links will be available to connect to other valuable forage information whether it's within Texas or from other states. Contact information for specialists will be posted along with county extension office information.

Fig. 2. Texas Pastures is a repository for county-specific information about forage production.

This web-based tool for the vegetation regions and for each county in Texas will serve as an information system and a grazingland data repository. Users will include both novice and experienced stakeholders, students, scientists, policy makers, and anyone seeking site specific information on soils, climate, forages, rangeland, and animals for production management and/or natural resource conservation. Discovery and use of biological and economic decisions will enhance education of students and stakeholders. Primary impacts of this project include an enhanced awareness and use of grazingland data, a roadmap for future research directions, and the precursor to biological and economic modeling.

Providing Local Extension with Matching Training
The typical closing line to news articles, newsletters, and now web-materials that originate from the state Specialists is "See your local extension office for more details." Of course, this is predicated on the assumption that more details are in fact available at the local

extension office. For websites to bolster the prominence, performance, and, ultimately, the relevance of local extension programs, one must make agent training an equal priority to web-site development.

Distance learning technologies have greatly aided this effort. Distance learning allows the agent to receive additional training while at their office or even while traveling. The University of Georgia has been using HorizonWimba, and Texas A&M University has been using Saba Centra, internet-based classroom systems, as part of their teaching program. During the last three years, UGA Cooperative Extension has been using this system to provide extension agent training sessions. In 2008-09, the UGA Forage Extension program has used the Wimba classroom to perform 3 classes over 10 sessions (Fig. 3). Texas A&M University has been using Saba Centra since 2004 to provide educational programs and trainings to students, faculty, staff and county agents (Fig. 4). The Texas AgriLife Extension service has used the Centra classroom to perform agent trainings, individual county programs and multi-county programs. Neither the Specialist nor the Agent has had to travel to do these trainings. Furthermore, these Wimba and Centra-based trainings are available in "real-time" (synchronous) such that the participants can interact with the trainer (i.e., raise their virtual hand, type text message questions, or, if using a headset with a microphone, ask their question). This maintains the feel of a more interactive training.
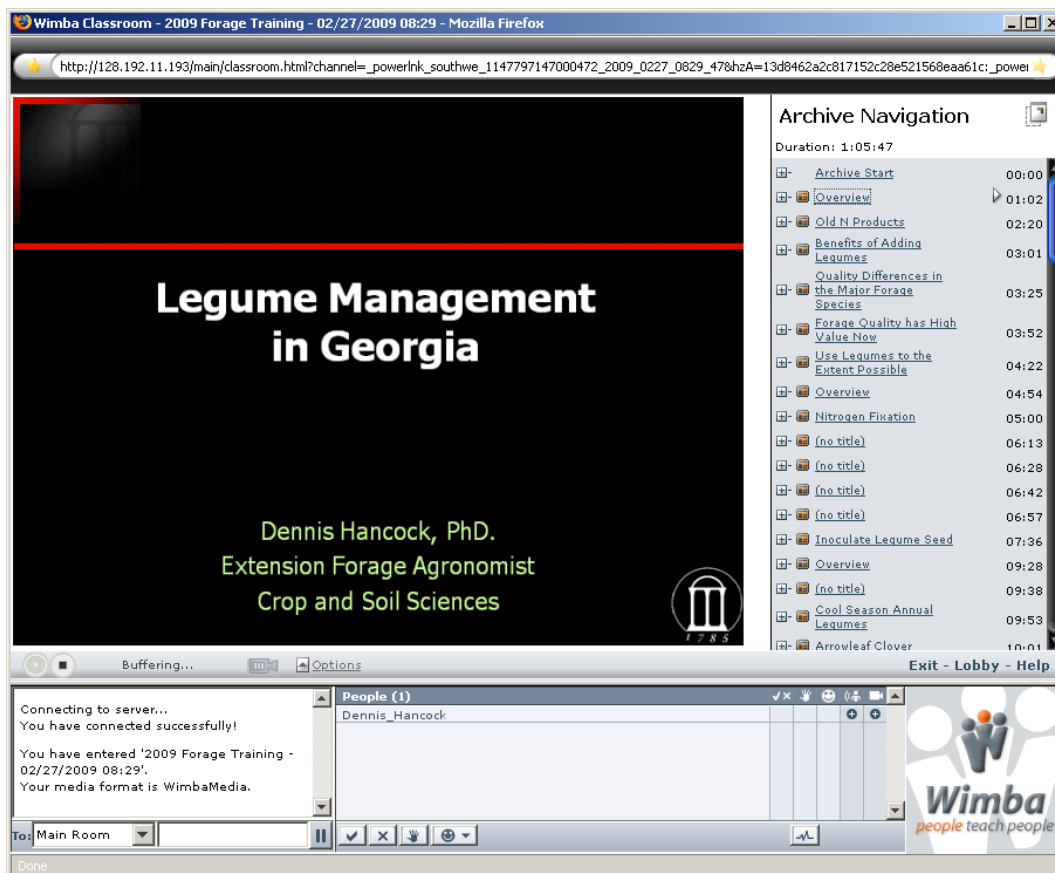

Fig. 3. An archived version of a HorizonWimba-based extension agent training session on legume management.
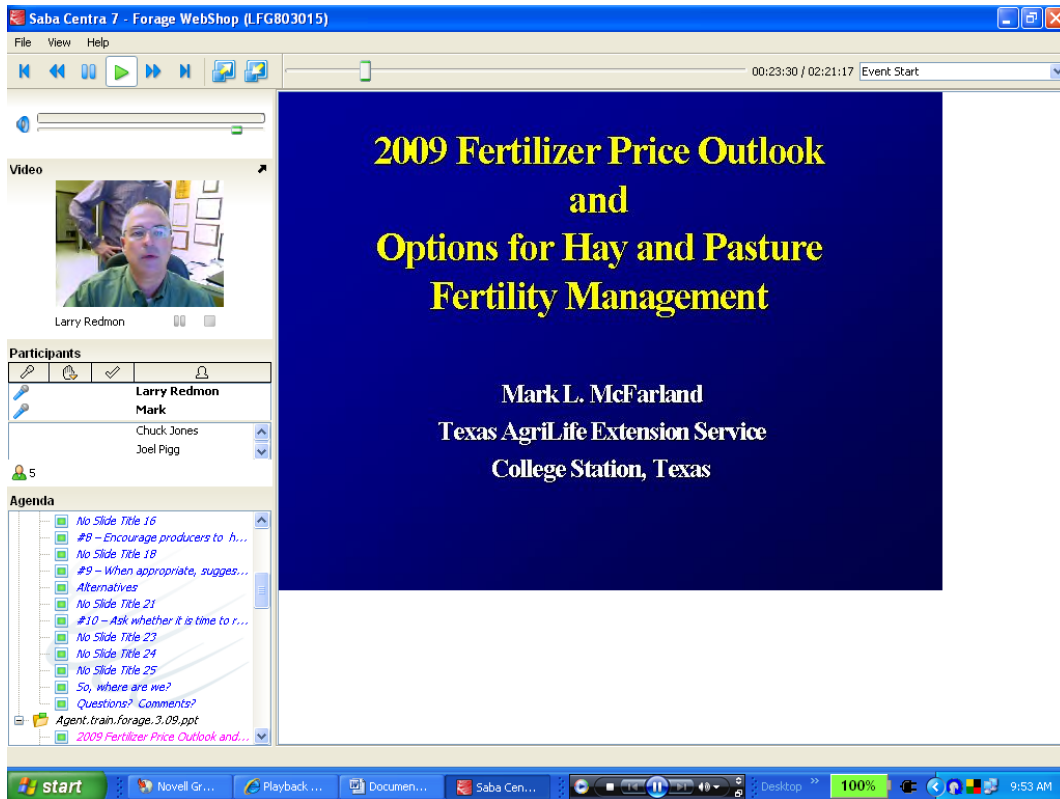
Fig. 4. An archived version of a Saba Centra-based extension agent training session on fertility management.

In addition, these Wimba and Centra-based trainings are archived so that the participant can attend the training whenever they may have time to do so. Such asynchronous training also allows the participant to skip over parts that are already well understood and to pick out parts that are new or unknown.

More recently, these distance learning techniques are becoming more mobile. The UGA Forage Extension program recently began recording their PowerPoint presentations using the Camtasia Studio software (http://www.techsmith.com/camtasia.asp) and a microphone. The software records these presentations as video files that can be posted to and viewed/downloaded from a website or used as a podcast. The Georgia Forages podcast is available by using any podcast "catcher" by subscribing to the RSS feed http://feeds.feedburner.com/GeorgiaForages. More conveniently, the interested user can subscribe to the podcast with iTunes (the interface software between a PC/Mac and the iPod available at http://www.apple.com/itunes/) by searching for keywords "Georgia Forages" or by clicking on the "Subscribe to our Podcast" icon at the bottom of www.georgiaforages.com.

Fig. 5. Visitors to www.georgiaforages.com can click on to this logo on the website and automatically be subscribed in iTunes to the Georgia Forages podcast.

Fig. 6. The Georgia Forages podcast description page on iTunes Store. This podcast is available for free and available in iTunes and to other podcast catchers.

Challenges to These Approaches

Unfortunately, the metric by which extension faculty are judged still does not give much (if any) credit for internet-based information development. Without an incentive for extension faculty to focus on the development of these approaches, these efforts risk stagnation and irrelevancy. If any organization's internet-based presence is stagnant or irrelevant in the current culture, the organization itself risks irrelevancy. Thus, the failure to recognize and give credit to extension faculty who develop internet-based information ultimate risks the relevance and future of the tripartite mission of the Land-Grant University system.

Extension administrators at the state and national level need to recognize the importance of state, regional, and local internet-based information. Further, they should strive to ensure that these efforts receive proper recognition and credit.

Summary

Despite the decline in extension faculty time and funding for forage management programming, a tremendous need for regionally- and/or county-specific information still exists. National efforts to provide broad-scale forage management information via the internet has its place, but it must be complemented with websites and internet-based media that is relevant to the local region and county. This can be done by 1) making web-based information easily available to the client by simplifying the url address and developing a marketing plan around the url address and website; 2) making the information available and pertinent to the client's location, and 3) complementing web-based information geared to the public with trainings for extension agents/educators that is convenient, inexpensive, and effective. Further, extension administrators at the state and national level need to ensure that proper recognition and credit is given to extension faculty who develop and implement the 21st century's version of a "site visit."

Strip-Seeding vs. Solid-Seeding for Establishing White Clover in Fescue Pastures

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Introduction: Nitrogen fertilizer costs have sharply increased making it difficult for producers to sustain adequate pasture productivity. Establishing clover in cool-season grass pastures helps reduce toxic endophyte infected fescue effects on livestock and helps reduce the need for expensive N fertilizer. Clover seed is typically broadcast or no-till planted in dormant grass sod across the entire pasture. In theory, planting clover over 100% of the pasture should result in an even distribution of clover over the field, but in practice, uniform stands of clover are seldom achieved. When clover is planted into an existing grass pasture, the resulting clover stand is considered good at 25% of the total pasture sward and is often distributed in patches.
When planting white clover at 1-3 lbs/acre, calibrating broadcast seeders is difficult and the recommended settings of no-till drills are often inaccurate. Because it is difficult to calibrate planters for low seeding rates and because clover planted at low rates often becomes established in only 25% of the pasture, it may be more cost-effective to plant clover at a higher seeding rate only in the areas of the field best suited for clover and let both vegetative growth and dispersal of seed by grazing animals spread clover into other areas of the pasture. In theory, 100% of the recommended clover seed for a field could be planted on only 25% of the area (4X rate), thus increasing the likelihood of establishing the same amount of clover as for planting the entire field. This would reduce time and calibration requirements while reducing labor and planting costs.
The objective of this study was to compare two strategies for establishing clover into dormant fescue sod: 1) 1x seeding rate (2 lbs/a) over the entire pasture and 2) 4x seeding rate (8 lbs/a) on 25% of the pasture.
Methods: White clover was no-till planted in tall fescue pastures of approximately 40 acres each in Cleburne County, Arkansas on February 20, 2007 and in Van Buren County, Arkansas on February 20, 2008. Both fields were closely grazed before planting. Two planting strategies were used: 1) no-till plant white clover at the recommended seeding rate of 2 lbs/acre (1X) rate over the entire pasture area and 2) no-till plant white clover at 8 lbs/acre (4X rate) in three strips totaling 25% of the pasture area. Each treatment was replicated twice with paddocks of approximately 10 acres each. Paddocks were separated by electric fence and were grazed during March and April to reduce grass competition until the clover began emerging. When the clover began to emerge, the two replicates of each treatment were rotationally grazed with separate groups of cattle to prevent potential seed dispersal by cattle among treatments. Stocking rate was approximately one animal unit per acre. Cattle remained on the paddocks throughout the season and were removed only as necessary based on field conditions. Clover establishment was assessed at approximately monthly intervals along transects in each paddock using a 5x5 wire grid frame with 5"x5" squares. Fifteen counts were made along three transects in each pasture. Presence of clover within the grid squares was used to calculate percent stand.
Results: Establishment of clover was good in both treatments, but in the strip-seeded treatment was more rapid and stands were visually thicker (Figure 1 and 2) than for the solid-seeded treatment. The average percent occupancy of clover in the squares (percent stand) was significantly higher for the strip-seeded treatment in both years in Cleburne County and for the seeding year in Van Buren County. Stands averaged 23% higher for the 4X seeding rate both

years in Cleburne County and 16% higher in Van Buren County. By the second growing season white clover began to spread to unplanted between the strips under rotational grazing management in Cleburne County. Clover stand counts indicated that the same total acreage of clover was established the first year for strip- or solid-seeding in year 1, but by the end of year 2 clover covered more total area for the strip-seeded treatment than for the solid-seeded treatment (Table 1). Results indicate that strip-seeding clover at higher than recommended rates reduces time needed for seeding, increases percent stand of clover where planted, and requires less precision for calibration with imprecise planting equipment.
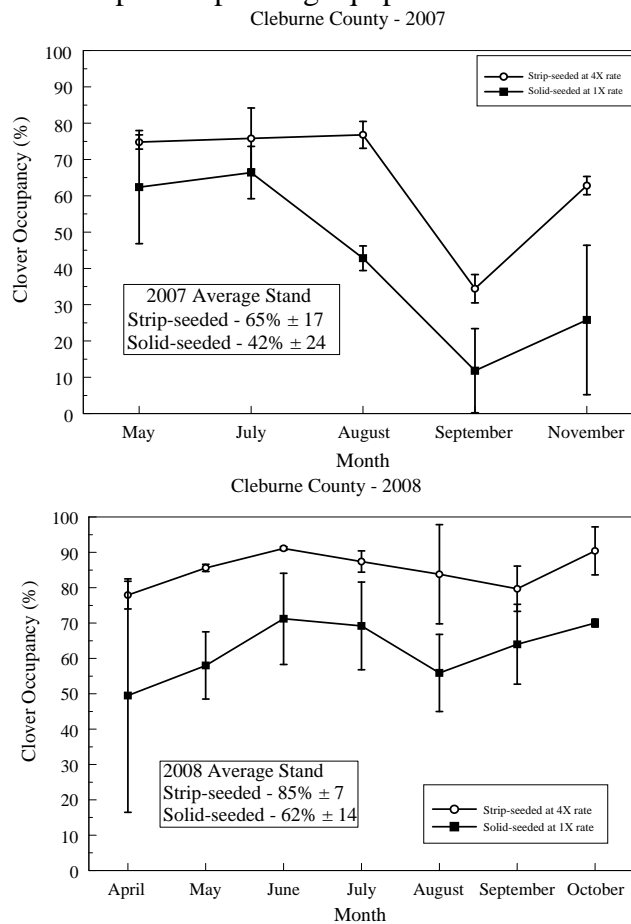

Figure 1. Clover occupancy percentage in 2007 and 2008 of white clover planted in fescue sod at a 4X rate on 25% of the field compared to a 1X rate planted on 100% of the field. Clover was no-till planted February/07.
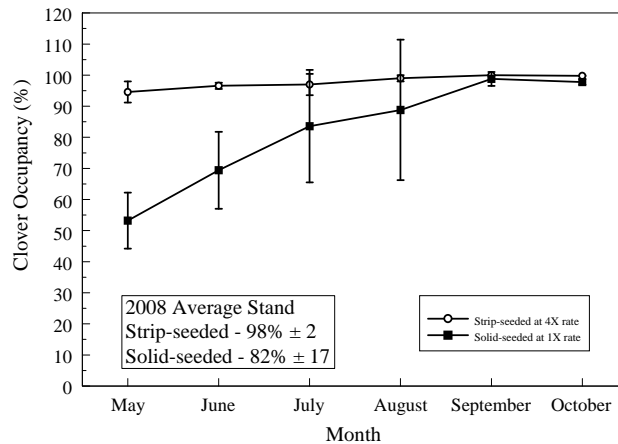
Van Buren County - 2008

Figure 2. Clover occupancy percentage in 2008 of white clover planted in fescue sod at a 4X rate on 25% of the field compared to a 1X rate planted on 100% of the field. Clover was no-till planted February/08.

Table 1. Cleburne County – 2007 & 2008. Total acreage containing white clover when clover was either strip-seeded in 25% of the pasture at 8 lbs/a or for clover solid-seeded in 100% of the pasture at 2 lbs/a in fescue. (The Middle area was unseeded and clover measured there volunteered from the strip-seeded area. Clover was planted in February, 2007)

	Strip-seeded + Middle Area		Solid-seeded	
	Acres including	Percent of field with	Acres including	Percent of field with
May 2007	5.4	33.8	10.0	62.5
July	6.0	37.5	10.6	66.3
August	5.0	31.3	6.9	43.1
September	1.7	10.6	1.9	11.9
November	**4.1**	**25.6**	**4.1**	**25.6**
April 2008	7	43.8	7.8	48.8
May	8.9	55.6	9.3	58.1
June	10.6	66.3	11.4	71.3
July	10	62.5	11.2	70
August	6.9	43.1	9	56.3
September	7.2	45	10.2	63.8
October	**14.6**	**91.3**	**11.2**	**70**
*The total acres in clover is the amount of area containing clover in a 5"x5" square. Data reflect the amount of clover out of a possible 16 acres for each treatment.				

Use of free-living bacteria in promotion of forage plants growth

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Achieving sustainable agriculture is a current challenge in modern agriculture in order to meet the increasing worldwide demands for food while minimizing the long-term impact on the environment. Since their introduction in farming practices in the early to mid 20th century, chemical fertilizers have been responsible for a constant increase in crop production. However, the low cost of these chemicals have led to their widespread excessive use leading to several adverse effects including persistence of recalcitrant pesticides in the soil, decreased soil biodiversity and groundwater pollution. In developed countries, the rising costs of petroleum-derived products together with the social demand for environmentally-friendly agricultural practices have stimulated research for alternative solutions.

Beneficial microorganisms (bacteria and fungi), that are natural soil inhabitants, have been used as biofertilizers for improving soil fertility and crop production. Plant-growth promoting rhizobacteria, so called PGPR, that form beneficial associations with the roots of a variety of crops represent such a promising alternative. The rhizosphere, which corresponds to a region in the soil in contact with the roots (and under the influence of the root exudates) harbors a very active community of microorganisms. Microorganisms present in this environment include some that have beneficial effects on plant growth via their activity on the roots.

Commonly used free-living bacteria in inoculants for forage crops include, but is not limited to, bacteria of the genus *Azospirillum, Azotobacter, Bacillus* or *Pseudomonas.* All of these bacteria are naturally present in soils and can form loose associations with the roots of plants via a combination of mechanisms that are not always clearly established. Nitrogen fixation, phosphate solubilization and plant hormones production (auxins, gibberellins etc.) by the free-living bacteria have been shown to contribute to the plant growth promoting effect of these microorganisms. Several environmental conditions related to soil properties and water availability were shown to affect the efficiency of the bio-inoculants and to lead to inconsistent results in the inoculation. The lack of clear understanding of how some of these bacteria-plant associations benefit plant health is a major challenge in the development of free-living bacteria containing-biofertilizers. In contrast to the *Rhizobium*-legumes symbiosis where a clear plant phenotype (root nodules formation) indicates successful inoculation, the successful association of most free-living bacteria with the roots of forage crops can only be inferred late in the growing season by detecting increased biomass production in inoculated crops.

Additional strategies have been implemented to increase the efficiency of free-living PGPR in bio-inoculants, for example, the use of mixed inoculants containing *Rhizobium* and free-living bacteria for the inoculation of forage legumes. Unfortunately, the issue of understanding how soil free-living bacteria become associated with their host plant has been poorly addressed in the United States while it has received more attention in South America, Europe and Asia. As a result, many bioinoculants used in forage crops and that take advantage of the plant-growth promoting properties of these organisms have been developed abroad.

The different steps involved in bio-inoculant production will be briefly presented with an emphasis of the most critical parameters that must be taken into account in developing and using free-living bacteria as bio-inoculants. For example, the observation of beneficial effects of strains

or mixture of strains on forage plant growth in greenhouse experiments may be confounded in the field. This apparent discrepancy is often linked to a lack of competitiveness of the inoculants used, an issue not systematically and directly addressed in the initial selection of the strains or mixture of strains that comprise the inoculants. Persistence and efficiency of the bio-inoculant strains applied to crops depends on the ability of the strains to compete with less efficient endogenous bacteria already present in the soil. Synergistic effects of mixtures of different PGPR in bio-inoculants have been repeatedly noticed. Other parameters to consider, which are common to all inoculants, are related to the shelf life of the inoculants, their production/processing at minimal cost for both the manufacturers and the farmers, their efficiency in combination of pesticides and simple use by the farmers. Innovative technologies are now being developed based on fundamental knowledge gained on the complex signaling between free-living microorganisms and plants. For example, some bio-inoculants are mixed with signal molecules that were shown to enhance the competitiveness of beneficial bacteria. However, these technologies are not yet widely available or reliable and additional long-term investments are needed to bring these to applications.

This presentation will review current literature on selected examples of the applications of bio-inoculants worldwide and in the United States. Current challenges and issues to be resolved in the field of bio-inoculant production will be discussed.

The quality of *Rhizobium* inoculants for forage pastures: An international perspective.

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Abstract
Nothing is more important for effective nodulation of legumes that the availability of sufficient numbers of an infective strain of rhizobia in the root zone of seedlings. In some cases, the soil will contain sufficient numbers of infective rhizobia but modern approaches to the use of genetically superior strains of rhizobia practically demands the use of some means of inoculation, thus raising the potential for effective N_2-fixing nodules being formed. The means by which inoculation is achieved varies both for legume species and by country. In Australia's recent past, peat cultures containing at least 10^9 rhizobial bacteria per g have been recommended for direct application to seed applied at a total rate of 10^{11}-10^{12} cells per ha were standard practice. This approach, coupled with a reliable means of certifying the quality (as viable cells of a specific nodulating strain) of the commercial cultures for a shelf life of at least 12 months in cool conditions proved very effective in Australia for the past 50 years since means of quality control were developed. Worldwide and in Australia other means of delivery of inoculants have been sometimes favoured. For example, liquid cultures in sealed flexible plastic containers with proprietary additives and a stated shelf life of one year have been favoured for field crops like soybeans. In other cases, the use of lyophilised (freeze-dried) cultures has been applied. Both of these techniques have the advantage of not requiring a good quality inert carrier but may raise questions regarding an effective certification procedure. Ideally, independent methods of quality assurance of inoculants will be available and in Australia the Australian Legume Inoculants Research Unit provides such a service. In the absence of such quality controls it is a recommended practice that users of commercial inoculants should conduct their own demonstration field trials by comparing the nodulation performance of at least one seeding run of un-inoculated forage legume with the inoculated plants at large.

Introduction
Inoculation of legumes with specific strains of rhizobia has now been practiced in the USA and the Americas, Europe and Australia for around 100 years. In Asia, inoculation was promoted more recently, by agencies such as NifTal based in Hawaii funded by USAID, the international agricultural research institutes (CGIARs) such as ICRISAT and ICARDA and the Australian Centre for International Agricultural Research (ACIAR). Early Australian experience was summarised by Brockwell (1977). The following review material is abstracted mainly from Deaker et al. (2004).

Australian practices
Legume seed has commonly inoculated in Australia in the past half-century with peat cultures of rhizobia. Their commercial production began in 1953 using finely milled peat as the bacterial carrier. Following widespread nodulation failures, the quality of inoculants was improved by the

amelioration of five main factors affecting survival in peat (Roughley and Vincent, 1967). Firstly, the origin of the peat was shown to be important. Survival of clover, lucerne and cowpea rhizobia varied according to the location and depth of the peat source. The peats tested varied according to their colour and texture but no explanation was given by the authors as to the cause of variation in survival. Secondly, pH was shown to be critical and acid peats could be amended with calcium or magnesium carbonate. Thirdly, peat sterilisation, preferably by gamma irradiation, was considered essential particularly for the growth and survival of slow-growing rhizobia presumably allowing them to outcompete faster-growing contaminants. Fourthly, when rhizobia were added to peat previously dried at 100°C, they survived poorly due to both the heat of wetting generated upon inoculation and the production of inhibitory substances originating from the heat treatment. Finally, moisture contents of 40–50% proved optimal for growth and survival of a range of rhizobial strains prepared as peat cultures. It was also essential that salinity not be excessive.

The implementation of these findings to inoculant production was a direct result of an initiative in inoculant quality control undertaken jointly by the University of Sydney and NSW Department of Agriculture Laboratory Service (UDALS). In 1971 this function passed to the Australia-wide Australian Inoculants Research and Control Service (AIRCS), since renamed in 2000 the Australian Legume Inoculants Research Unit (ALIRU) (Date, 1983; Roughley et al., 1984; Herridge et al., 2002). Inoculants must pass ALIRU standards based on the number of effective rhizobia in the peat that will result in a minimum number of cells per seed after application at the manufacturers recommended rate. These minimum standards are 500 for white clover, 10^3 for small-seeded legumes (e.g. alfalfa, subterranean clover), 10^4 for medium seeds (e.g. mungbean, pigeon pea) and 10^5 for large seeds (e.g. lupins and soybean).

These are widely accepted minimum standards although they may vary slightly in some countries (Lupwayi et al., 2000). There are also standards for the number of contaminants in commercial peat cultures. In Australia contaminants must number less than 10^7 cfu per gram of peat whilst in France there must to be no contamination throughout storage (Lupwayi et al., 2000; Catroux, 1991). However, overcrowding of plates at dilutions lower than 10^{-6} would make contaminants difficult to detect in such concentrated suspensions. Inoculant regulatory bodies may be supported by legislation such as in Canada, Brazil, France and Uruguay or have voluntary participation by manufacturers such as in Australia, South Africa and New Zealand. In the United Kingdom and United States product quality is at the discretion of the manufacturers (Gault, 1978; Lupwayi et al., 2000; Catroux et al., 2001).

The need for inoculation
The decision to inoculate is usually based on a demonstrated need from experimental plots. An investigation for inoculation of *Trifolium subterraneum*, grown in soils in New South Wales where nodulation failures had occurred, emphasised the difficulty in predicting the need to inoculate (Roughley and Walker, 1973). Of the 32 sites tested, 14 showed no response to inoculation because strains of effective rhizobia were found to occur naturally. Generally, lime-pelleting (addition of superfine limestone, Loneragan et al., 1955; Brockwell, 1962) produced more reliable results and was superior to slurry inoculation for acid soils where the pH was below 5.5.

Ireland and Vincent (1968) showed that high numbers of naturalised *R. leguminosarum* bv. trifolii, effective on white clover but not on subterranean clover, severely restricted nodulation of subterranean clover by an introduced effective strain. In a soil containing 10^5 ineffective rhizobia per g^{-1}, yield was doubled with a 10-fold increase in the inoculation rate of the introduced strain. Application of 10^6 rhizobia per seed was necessary to ensure 90% effective nodulation, a rate 1000 times higher than the rate recommended by the ALIRU. Furthermore, Thies et al. (1991a) reported a positive effect of inoculation on eight legume crops where the soil population of rhizobia was between 10 and 100 g^{-1} of soil. Elsewhere, they proposed a model to predict the response to inoculation and found that 59% of the variation-in-yield could be explained by the number of rhizobia present in soils at sowing (Thies et al., 1991b). Thus, high numbers of effective rhizobia out-compete populations of ineffective rhizobia in the soil or help build up more effective populations.

Inoculation techniques and death on seed
Table 1 summarises the techniques available. Full details of these and associated factoirs required for successful inoculation are reviewed in Deaker et al. (2004). While most techniques involve the application of rhizobial cells directly to seed, the use of inoculated granules has become more popular because of the convenience of application, for example used as a complement to seed applied directly in the seed box of planting equipment.

Table 1:   Legume inoculation techniques

Technique	Description
Seed inoculation	
Dusting	Peat inoculant is mixed with the seed without re-wetting
Slurry	Seed is mixed with a water solution of peat often with the addition of an adhesive
Lime or phosphate pelleting	Seed is treated with a slurry peat inoculant followed by a coating of calcium carbonate (superfine limestone) or rock phosphate
Vacuum impregnation	Rhizobia is introduced into or beneath the seed coat under vacuum
Soil inoculation	
Liquid inoculation	Peat culture mixed with water or liquid inoculant applied to the seedbed at the time of sowing (liquid inoculants may also be directly applied to seed as instructed)
Granular inoculation	Granules containing inoculum sown with seed in seedbed

Summarised from Brockwell, J., 1977; Bio-Care Technology Pty. Ltd.
Inoculant Brochure 1998; Thompson, J., 1988).

Death of all species of rhizobia on inoculated seed occurs rapidly, particularly when environmental conditions are unfavourable (Bowen and Kennedy, 1959; Marshall, 1964;

Diatloff, 1967; Brockwell et al., 1987). Early in the 20th century, researchers recognised the problem of poor survival of rhizobia on legume seed, and its partial amelioration through low temperature storage and the use of additives (Fred et al., 1932). Inoculation techniques were usually assessed in terms of resulting nodulation from 'grow-out' tests, and an increase in nodulation would often be attributed to improved survival.

It is clear that improved survival of the inoculant on seed would directly affect nodulation and subsequent yield of the plant. All these results call into question the current standards set for inoculants and that there should be an increase in the number of viable rhizobia applied per seed. In Australia, pre-inoculated seed is sometimes made available for farmers for pasture and forage species but tests by ALIRU have shown that these products are often sub-quality with insufficient numbers of rhizobia surviving from soon after manufacture.

Effects of additives and adhesives
In early studies on the freeze-drying of bacteria, the nature of the suspending media was identified as an important aid to survival (Heller, 1941; Annear, 1956, 1962; Vincent, 1958). Extensive research has been carried out on the use of bacterial nutrients as suspending agents for freeze-drying and storage of cells (Heller, 1941; Appleman and Sears, 1944; Annear, 1956, 1962; Redway and Lapage, 1974; Dye, 1982). Heller (1941) investigated the protective effects of crystalline compounds and colloids during desiccation of *Streptococcus pyogenes* C203 and *Escherichia coli* (communior). Sucrose proved to be a superior suspending agent to glucose, xylose, tryptophane, salicin, saline and water for both species. Heller concluded that survival was related to the assimilability and solubility of the compound. Furthermore, Vincent (1958) reported 24–44% of cells suspended in a 10% sucrose solution survived primary drying whereas only 0.1% survived when suspended in water. Sucrose was a superior suspending agent to sorbitol, mannitol, lysine, amino acid mixtures, milk and yeast mannitol broth.

The poor survival of rhizobia on seeds and beads was improved by the addition of sucrose. McLeod found that the incorporation of 10% sucrose into yeast mannitol broth improved the survival on glass beads compared with unamended broth (cited in Vincent (1958)). Elsewhere, Vincent et al. (1962) reported survival of broth cultures of *R. leguminosarum* bv. trifolii on glass beads was much higher after suspension in a solution of maltose than when suspended in other sugars, sorbitol and sodium chloride. The improved survival with maltose could not be attributed to concentration or properties previously suggested to have an effect, in particular, assimilability, presence or absence of a carbonyl group, osmotic pressure exerted, molecular size and solubility (Heller, 1941; Scott, 1960). Nor was the better performance of maltose attributable to a decrease in the rate of dehydration of the cells as improved survival over 48 h was not paralleled by a decrease in the rate of water loss (Vincent et al., 1962). They suggested the difference might rest in the particular molecular configuration of maltose affecting its interaction with biological surfaces. Addition of maltose to the suspending medium ameliorated poor survival at lower inoculation rates. It improved survival over a range of relative humidities and allowed cells to grow at 100% RH.

In Heller's (1941) investigation of the protective effect of colloids, S. pyogenes C203 survived best in peptone (1 and 10% w/v) followed by gastric mucin, gum tragacanth, starch and

aluminium hydroxide. Survival was positively correlated with solubility, hydrophilicity and gold number. The gold number relates to the protective effect one colloid has on another (colloidal gold in this case) against the precipitating action of salt. Improved survival results from colloidal stabilisation.

The adhesives used in current agricultural practice for the inoculation of legumes are essentially polymeric in nature (i.e. high molecular weight compounds). Examples include gum arabic, methylcellulose (MC), polyvinylpyrollidone (PVP), caseinate salts and polyvinylacetate (PVA). Much of the research on adhesives has focussed on their ability to maintain the viability of rhizobia on the legume seed (Scott, 1989). However, very little progress has been made in identifying the exact mechanism by which survival is improved by these polymers. Gum arabic is a complex carbohydrate extracted from Acacia. It enhances rhizobial survival and is widely used as an adhesive in inoculation of legume seeds. Vincent et al. (1962) found that gum arabic not only protected cells against desiccation on beads but resulted in better survival on seeds than maltose suggesting some protection against toxic seedcoat factors.

However, the difference in adhesion to seed of these two additives was not considered. Variable quality, availability, cost and the need for high concentrations (15–40% w/v) has limited the use of gum arabic as an inoculant adhesive. Methyl cellulose, a non-ionic water soluble cellulose ether, is a more widely used adhesive. It is readily available, its quality is relatively consistent as it is a semi-synthetic polymer and it is relatively low-cost due to the application of low concentrations (1.5% w/v) (Scott, 1989). However, there are variable reports on the protection of rhizobia by methyl cellulose when compared with gum arabic and it is generally considered to be less effective. Date (1968, 1970) found that the commercial methyl cellulose products did not provide the same degree of protection as gum Arabic on lime pelleted seed.

The realisation that the viability of bacteria is very susceptible to physical stresses as a result of rapid drying or re-wetting has led to the application of ameliorants applied together with inculants as measures to reduce the death rate on seed. This has been applied with variable success (Deaker et al., 2004) but the principles involved have been studied and recommendations regarding the potential for application of polyvinyl alcohol made (Deaker et al., 2006).

Conclusion
It is clear that current methods of inoculation limit the benefits of high quality legume inoculants. Research has identified factors that affect survival of rhizobia on legume seed and observed improvements in survival when various additives were used. The increasing demand for pre-inoculated seed requires a substantial increase in the number of viable rhizobia delivered to the rhizosphere on seed to improve yield.

As a result, there is a need to further clarify the factors affecting rhizobial survival on legume seed and to understand the physiological mechanisms of desiccation tolerance. Clear benefits to survival have also been demonstrated after selection of non-toxic seed cultivars. In terms of additives, a focus on specific properties of polymeric adhesives that improve survival would be advantageous. Polymers promoted to improve survival need to be selected carefully so that individual properties can be isolated and specific affects attributed to them. Desirable properties may then be optimised contributing to an overall positive effect on survival.

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CLOVER CONTRIBUTIONS TO A WARM-SEASON PERENNIAL GRASS IN THE SOUTHEASTERN US.

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INTRODUCTION

Introduced warm-season perennial grasses form the basis of pasture systems in the southeastern US because they are well adapted to the high temperatures, have good drought tolerance, and tolerate close continuous grazing. However they require N fertilizer and have lower nutritive value than cool-season grasses and legumes (Ellis and Lippke, 1972). Cool-season annual legumes, and perennials that act as reseeding annuals, are used in the southeastern US because cool-season perennial legumes will usually not persist through the hot and dry summers.

There are numerous published reports on the benefits of incorporating forage legumes in pasture systems. Grazing studies have shown animal performance is higher on legume-grass pastures than nitrogen-grass pastures because of the legumes higher nutritive value (Hoveland, 1986; Petritz, 1980). Small plot research has shown that forage legumes, when infected by the proper *Rhizobium* strain, do provide atmospheric nitrogen for companion grasses (Evers, 1985; Russelle, 1996). Evers (1983) reported that in small plot studies, cool-season annual clovers overseeded on warm-season perennial grasses provided spring weed control through plant competition. When overseeded on warm-season perennial grasses, clovers also provide earlier forage production than perennial grasses alone which reduces the winter feeding period (Evers, 1985). There have been no grazing studies in the southeastern US to document the combined economic value of these forage legume benefits in a pasture system.

The objective of this study was to compare forage production, animal performance, and economic return of three levels of pasture inputs: a high input N fertilizer-grass system, a medium input clover-grass system, and a no input pasture system on the Gulf Coast Prairie in southeast Texas.

MATERIALS AND METHODS

The grazing study was conducted in southeast Texas on Lake Charles clay (fine, montmorillonitic, thermic Typic Pelluderts) with a pH of 6.0 that was low in nitrogen (8 ppm) and phosphorus (2 ppm) and high in potassium (192 ppm). Grazing treatments were a high input 6 acre pasture, a medium input 6 acre pasture, and a no input 8.7 acre pasture. The high input pasture system was planted to common dallisgrass at 6 lb pure live seed/acre on a prepared seedbed in May of 1984. Annual management practices were 50 lb N and 60 lb P/acre in April with an additional 50 lb N/acre about June 1 and August 1. Grazon P+D [0.13 lb a.i. picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) and 0.5 lb a.i./acre 2,4-D (2,4-dichlorophenoxy

acetic acid)], was applied in April for broadleaf weed control. Stocking rate was 1 cow-calf pair/acre.

The medium input pasture system was planted to common dallisgrass in the same manner and time as the high input pasture. 'Louisiana S-1' white clover was broadcast at 4 lb/acre on the undisturbed dallisgrass sod in October 1984. The white clover seed was inoculated with the appropriate rhizobia inoculant immediately before planting. Annual management practices were 60 lb P/acre in the autumn and mowing one time in summer for weed control. Stocking rate was 1 cow-calf pair/1.5 acres. Poloxalene-molasses blocks (National Molasses Company, Willow Grove, PA) were available to the cattle to prevent bloat for 6 weeks in spring when white clover represented more than 75% of the available forage.

The no input pasture system was undisturbed grassland typical of the Gulf Coast Prairie consisting of native and naturalized species. Dominant grasses were common dallisgrass, common bermudagrass [*Cynodon dactylon* (L.) Pers.], and smutgrass [*Sporobolus indicus* (L.) R. Br.]. Dominant forb and shrub species were common ragweed (*Ambrosia artemisiifolia* L.), Seacoast sumpweed (*Iva annua* L.), and wild dewberry (*Rubus aboriginum* Rydb.). No fertilizer or weed control practices were used on the no input pasture system. Stocking rate was 1 cow-calf pair/2.9 acres.

Hereford-Brahman crossbred cows with Santa Gertrudis sired calves were used to evaluate the three pasture systems. In 1985, a year after dallisgrass and white clover were planted, all pastures were grazed at about half the planned stocking rate to allow the dallisgrass to become fully established. No pasture or animal data were collected in 1985. In 1986 and 1987, fall calving cows and their calves were used from the beginning of the grazing season in spring until early July. At that time they were replaced with spring calving cows and their calves until the end of the grazing season about November 1. In 1988 and 1989, one set of late winter calving cows were used for the entire grazing season. Cows and calves were fasted overnight (no water or feed) and weighed in the morning when placed on, or removed from, the pastures to determine animal weight gain. A 12% calcium-12% phosphorus mineral and salt were available during the grazing season on all pastures.

Eight 20 in. x 20 in. random samples were cut at a 2 in. height from each pasture the last week of each month during the grazing season. Samples were hand separated into clover, grass, and weeds and dried at 140°F for 48 hours to determine available forage and botanical composition. Pastures were the experimental unit and years were considered replications for statistical analysis using PC-SAS (SAS Institute, 1999). Fisher's Protected LSD at the 0.05 level of significance was used to detect differences among treatments.

The length of the winter feeding period was calculated by subtracting the 4-year grazing season average from 365 days. Winter hay and supplement costs were 2008-2009 averages for the region (Jason Banta, Texas Beef Cattle Specialist, personal communication). Fertilizer and herbicide costs were 2009 averages from area retail dealers. Costs for fertilizer and herbicide applications and mowing were taken from the most recent National Agriculture Statistics Services publication (USDA-NASS, 2005).

RESULTS

Annual rainfall was above average for 3 of the 4 years (Table 1). However, there were dry periods and months with excessive rainfall all 4 years. Rainfall exceeded 9 in./month in June, October, and November 1986, July 1987, April and July 1988, and January and June 1989.

Table 1. Monthly and annual precipitation during the 4-year grazing study.

Month	1986	1987	1988	1989	76-Year Average
	Precipitation (inches)				
January	1.72	4.21	1.98	11.63	3.77
February	1.23	6.08	2.39	1.43	3.45
March	1.45	0.51	6.05	4.63	3.21
April	1.36	0.49	9.09	1.75	3.16
May	5.61	6.56	1.54	4.00	4.49
June	9.42	6.63	1.02	17.77	4.94
July	0.25	9.30	12.50	6.18	5.18
August	2.01	2.64	1.67	6.17	4.79
September	7.38	5.83	6.07	3.49	5.86
October	14.27	0.88	0.65	1.19	4.07
November	11.31	6.98	0.20	3.06	4.06
December	6.77	5.67	2.24	0.62	4.38
Year	62.78	55.78	45.40	61.92	51.38

Forage production

Monthly available forage was influenced by rainfall. Due to above average rainfall in 3 of the 4 years, forage available for all systems was high in July (Table 1). Available forage on the high input system was generally between 700 and 900 lb dry matter/acre (Table 2). In the medium input system, available forage for February and March exceeded 1000 lb/acre because of the peak growing period of the white clover. Available forage on the no input system was usually lower than the other pastures systems because of no fertilizer and weed control inputs that limited forage production which made it more sensitive to low rainfall. This anticipated lower forage production was compensated for by the lower stocking rate of 2.7 acres/cow-calf vs. 1.5 and 1.0 were for the medium and high input pasture systems, respectively.

The botanical composition of the pastures was a reflection of management practices (Fig. 1). The high input N-grass system was essentially all grass with some cool-season annual weeds in March. The annual herbicide application in April controlled essentially all warm-season weeds. The presence of a small amount of weeds in August is due to about 350 lb/acre of weeds in 1 of the 4 years.

In the medium input clover-grass system, white clover accounted for over 70% of the available forage in February and March, and 50% in April. White clover is planted or volunteers in the autumn in the southeast US. However, it produces little growth until February in the Gulf Coast Region. White clover growth terminates sometime in June due to high temperatures. Seed

production during spring enables white clover to volunteer each autumn. Some weeds were present in the medium input system but accounted for only a small percentage of the available forage. When immature, most annual weeds will be eaten by livestock (Hoveland et al., 1986).

Table 2. Monthly available forage, ± standard deviation, averaged over four years for high, medium, and no input pasture systems.

Month	High input N + grass	Medium input clover + grass	No input grass
	------------------------yield (lb DM/acre) ± s.d.-----------------------		
February		1213 ± 618	
March	716 ± 252	1067 ± 651	519 ± 268
April	890 ± 309	731 ± 242	609 ± 173
May	777 ± 549	771 ± 349	461 ± 285
June	805 ± 442	617 ± 437	602 ± 293
July	1119 ± 547	964 ± 836	711 ± 405
August	874 ± 468	610 ± 252	434 ± 181
September	878 ± 427	874 ± 635	589 ± 344
October	747 ± 390	716 ± 293	364 ± 150

Weeds were abundant in the no input system. The amount of weeds in March was the same in the high and no input systems, before the April herbicide application in the high input system. Weeds as a percentage of the available forage increased through the grazing season and amounted to over half of the available forage from August to October. In the early part of the grazing season, some of the immature, tender weeds were consumed by the grazing livestock. Because of the lower stocking rate, the animals could pick and choose so that as weeds became more mature later in the grazing season the livestock ate more grass and fewer weeds.

Animal production
Grazing of the medium input pasture system with the white clover began 35 days earlier than the other two systems without clover (Table 3). Although the length of the grazing season was the same for the high input and no input pasture systems, the stocking rate was almost three times higher for the high input system than the no input system because of the higher forage production due to N fertilizer and chemical weed control.

Table 3. Length of grazing season of three pasture systems over four years.

Year	High input N + grass	Medium input clover + grass	No input
	Grazing season (days)		
1986	210	244	210
1987	227	268	227
1988	234	266	234
1989	226	258	226
Average	224 b†	259 a	224 b

†Values in a row followed by the same letter are significantly different at the 0.05 level, Fisher's Protected LSD.
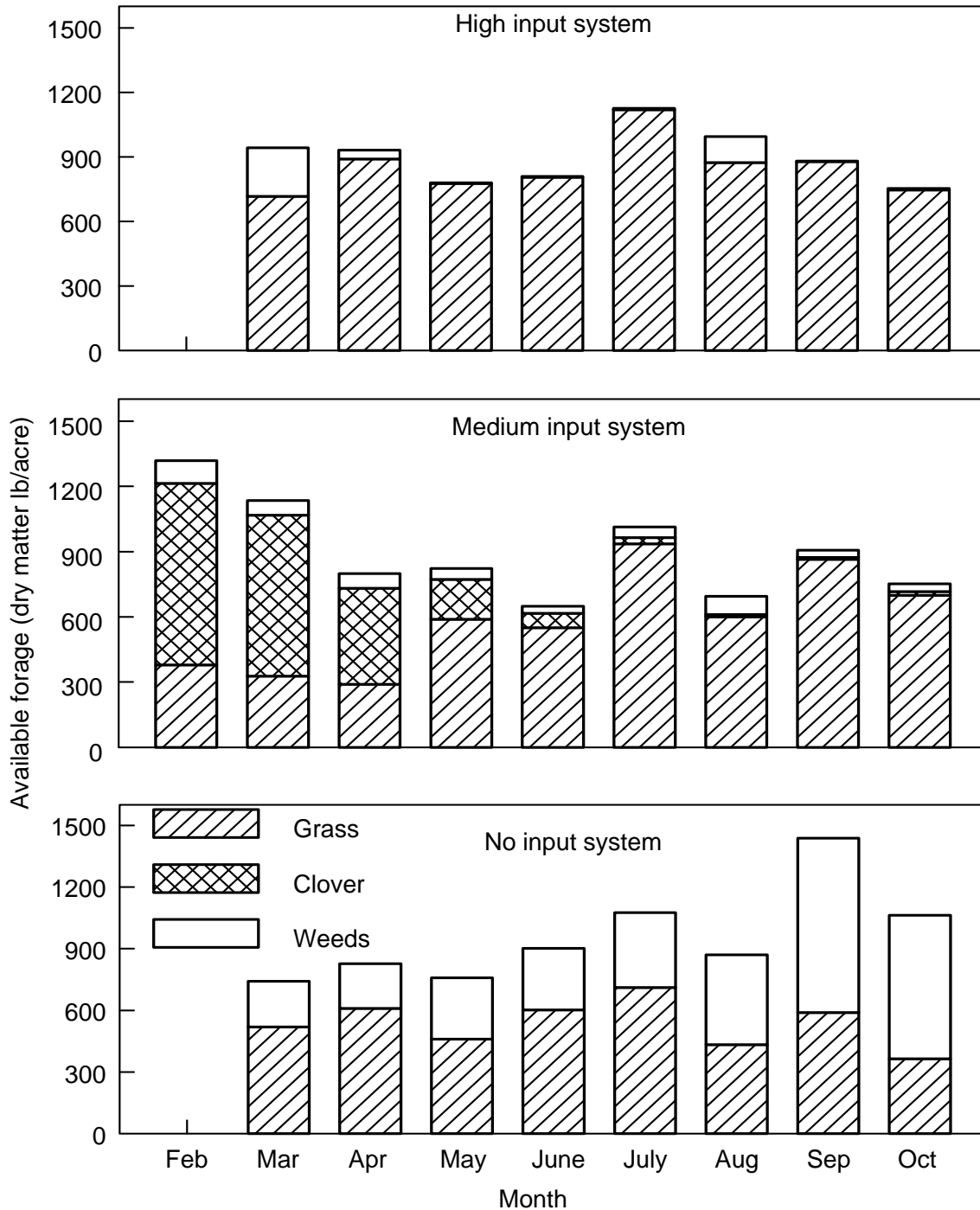
Figure 1. Monthly grass, clover, and weeds of high, medium, and no input pasture systems averaged over four years.

Cow weight gain per animal and per acre, and ADG was higher for the medium input, clover-grass system than the grass only systems (Table 4). The higher average daily gain reflects the higher nutritive value of the clover compared to the grass and higher gain per cow and per acre is due to the combination of the higher ADG and longer grazing season. There was no

difference in weight gain/cow and ADG between the high and no input systems. However, the gain/acre on the high input system was twice that of the no input system because of the higher stocking rate.

Table 4. Animal performance on three pasture systems average over four years.

	High input N + grass	Medium input clover + grass	No input
	------------------------------------lbs------------------------------------		
Cow			
Gain/cow	100 b†	255 a	117 b
Gain/acre	100 b	168 a	48 c
Avg. daily gain	0.45 b	0.98 a	0.52 b
Calf			
Gain/calf	340 b	470 a	369 b
Gain/acre	340 a	307 a	143 b
Avg. daily gain	1.57 b	1.82 a	1.66 ab

†Values in a row followed by the same letter are significantly different at the 0.05 level, Fisher's Protected LSD.

Weight gain/calf was also greater for the clover-grass system than the grass-only systems because of the higher nutritive value of the clover and longer grazing season (Table 4). There was no significant difference in calf gain/acre between the clover-grass and N-grass systems because of the lower stocking rate of the clover-grass system. The only significant difference for calf ADG was between the clover-grass and N-grass systems. When comparing weight gain/calf and ADG, there was no difference between the high and no input all grass systems.

Expenses
The high input N-grass system had the highest pasture input cost per acre of which 63% was nitrogen fertilizer (Table 5). Annual pasture expense for the medium input clover-grass system was $49.00/acre. In 2 of the 4 years, there were insufficient weeds to justify mowing in the clover-grass system, but the annual mowing cost is included. Land rent was the only expense for the no input system. Fencing and water costs were not included since it would be the same for all systems.

Table 5. Annual pasture expenses per acre for the high, medium, and no input pasture systems at 2007 costs.

	High input N + grass	Medium input clover + grass	No input
	------------------------------$/acre------------------------------------		
150 lb N/acre (60¢/lb)	90.00		
60 lb P/acre (35¢/lb)	21.00	21.00	
Herbicide + application	11.00		
Mowing		8.00	
Rent	20.00	20.00	20.00
	_____	_____	_____
Total	142.00	49.00	20.00

Annual cow expenses were the same for the high and no input systems (Table 6). However, the annual cow-calf expenses for the medium input clover-grass system were approximately $45.00 less than the grass only systems. The medium input clover-grass system had a 35 day shorter winter feeding period but had the additional cost of the Bloat-Guard blocks.

Table 6. Annual expenses/cow-calf for high, medium, and no input pasture systems.

	High input N + grass	Medium input clover + grass	No input
Winter feeding period (days)	141	106	141
Winter feed cost ($1.79/day) 30 lb hay ($50/1000 lb bale) 2 lb 20% protein supplement ($290/ton)	$252.39	$189.74	$252.39
Minerals 12% Ca – 12% P ($16.00/50 lb) Salt ($5.00/50 lb)	$15.00	$15.00	$15.00
Bloat Guard Block ($820/ton)		$17.22	
Vaccines (wormer, blackleg, etc.)	$12.00	$12.00	$12.00
Total cost	$279.39	$233.96	$279.39

In order to calculate the cost per pound of calf gain, pasture expenses per acre were converted to pasture cost per cow-calf by multiplying pasture cost/acre by acres per cow-calf pair (Table 7). Cost per pound of calf gain was lowest for the medium input clover-grass system because of the longer grazing season and higher nutritive value of the clover, moderate pasture expenses, and the highest calf gain. The high input N-grass system had the highest cost per pound of calf gain because of the high pasture costs. Cost of gain for the no input system was intermediate because calf gain was similar to the N-grass system but pasture cost was substantially lower. Reducing the stocking rate by allocating more acres per cow-calf (2.9 acres) compensated for the lower forage production in the no input pasture system.

DISCUSSION

A major portion of the annual expense of maintaining a beef cow is the winter feeding period. Combining a cool-season clover with a warm-season perennial grass extended the grazing season by 35 days, reducing annual cow expenses by approximately $60. This clover-grass system could be improved further by mixing annual ryegrass (*Lolium multiflorum* Lam.) with the clover. Annual ryegrass would provide grazing several weeks earlier than the clover which would further reduce the winter feeding period (Rouquette et al., 2002). The addition of annual ryegrass would also reduce the bloat potential from grazing a clover dominant sward in spring and eliminate the annual cost for Bloat Guard blocks.

Table 7. Cost per pound of calf gain.

	High input N + grass	Medium input clover + grass	No input
Pasture expenses/acre	142.00	49.00	20.00
Acres/cow-calf	1.0	1.5	2.9
Pasture expenses/cow-calf	142.00	73.50	58.00
Animal expenses/cow-calf	279.39	233.96	279.39
	_____	_____	_____
Total expenses/cow-calf	421.39	307.46	357.39
Calf gain (lb)	340	470	369
Cost/lb calf gain	1.24	0.65	0.97

Forage legumes have higher nutritive value than grasses which was reflected in increased animal performance in the present study (Ellis and Lippke, 1976). As a forage class, warm-season perennial grasses have the lowest nutritive value of any forage class which limits animal performance (weight gain, milk production, rebreeding percentage, etc.) (Ball et al., 2002). The higher nutritive value of the clover has a greater impact on animal performance with the low quality warm-season perennial grasses than the higher quality cool-season perennial grasses adapted to the northern US. Because clovers only provide forage during the spring, beef cows must calve in late winter so the cow's highest nutrient requirements after calving coincide with peak clover production.

Application of N fertilizer to warm-season perennial grasses increases yield and protein percentage, but has limited influence on the energy level (total digestible nutrients, digestible dry matter). As protein percentage increases, soluble carbohydrate percentages decrease (Ellis and Lippke, 1976). Application of 150 lb N/acre to the high input system in this study increased yield to support a higher stocking rate but gain per cow and calf and cost/lb calf gain were similar to the no input system.

The small pastures and low cow numbers per pasture prohibited the use of a bull in each pasture to document rebreeding of the cows in the three pasture systems. Based on beef cattle operations in the area, expected cow rebreeding percentages would be about 90% for the clover-grass system, 85% for the N-grass system, and 70% for the no input system (Jason Banta, Texas Beef Cattle Specialist, personal communication). Because of the difference in conception rates, the cost/lb calf gain would be higher for the no input system than the N fertilizer-grass system.

As the cost of commercial N fertilizer continues to increase, the N contribution from a forage legume will become more important. The main N transfer pathway from the legume plant to the soil is through grazing. From 65 to 90% of the N, P, and K in the forage consumed by cattle is returned to the soil in the urine and feces (Russelle, 1992). Reducing or eliminating N fertilizer also reduces the potential for nitrate leaching in the soil and in runoff to surface water.

Summer weed control from clover competition was as effective as the herbicide treatment in the N-grass system. The autumn seeded clover formed a solid canopy during the winter which shaded the soil and any emerging spring weed seedlings. Because clover leaves are phototropic and horizontal, a lower leaf area index is needed to shade the soil surface than grasses with long, narrow erect leaves (Kendall and Stringer, 1985).

This grazing study demonstrated the animal, agronomic, and economic benefits of adding a cool-season clover to a warm-season perennial grass for beef cattle production in the Gulf Coast area that resulted in the lowest cost per pound of calf gain. As the cost of feed, fuel, and fertilizer and other pasture production inputs increase in the future, the benefit of adding a cool-season clover to a warm-season perennial grass system will become even greater. The success of a legume-grass pasture system is based on using legume and grass species that are well adapted and compatible. Other forages than white clover and dallisgrass would be used in most of the southeastern US.

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Developing Relevant Research Data for Grazing Dairies in the Southern Coastal Plains

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Introduction

Over the past decade, there has been a trend in the dairy industry to shift from total confinement systems to managed intensive pasture systems (Kriegl and McNair, 2005). In Wisconsin, the percentage of diaries utilization intensive grazing management systems rose from 7% in 1993 to 23% in 2003 because of improved economic competitiveness and improved lifestyle (Johnson, 2002). Traditionally, improved economic competitiveness has been associated with increased farm output. But milk production in managed intensive grazing dairy systems decreases because of limited intake of nutrition available to grazers from pasture species (Dartt et al., 1999). Yet pasture based dairy systems have reduced costs by being more efficient at using machinery, housing, bedding, feed, and labor which offsets the cost of reduced productivity. Incorporating grazing into the farm operation results in a higher net return (Dartt et al., 1999). This intuitively suggests that as reliance on managed intensive grazing increases, farm efficiency would follow. If so, there would be a preponderance of dairy farms located in warmer climatic regimes in the US where climatic conditions permit longer grazing seasons. Yet, eight of the top ten dairy states in the US are located in the North where climatic conditions permit only limited grazing during summer months (Source: American Farm Bureau and USDA). Part of the reason for this demography is that feed crops used for total mixed rations in confinement systems can be easily grown in these states whereas feed grains grown in the southern US often contain high amounts of aflatoxin and fumonisins. Presence of mycotoxins renders grain which cannot be used for feeds in dairies.

Transitioning into grazing systems indicates a shift in the dairy production paradigm and may signal that areas suited to long grazing seasons are poised for growth by increasing the number of intensively managed grazed dairies. A review of literature found that as grazing days increased, the need for tilled acreage decreased, the total acreage needed decreased, and the net return (above expenses) per cow increased (Dartt et al., 1999; Johnson et al, 2002; Weil and Gilker, 2005; Hamilton et al., 2001) (Table 1). Therefore, the changing face of the dairy industry appears to be associated with sustainability and profitability rather than dependence on government subsidies.

Table 1. Cropped and grazed acreages necessary for one cow in dairies that have transitioned into managed intensive grazing systems.

State	----- Acres -----			Time grazed	Net Return	Source
	Crop	Graze	Total	Days	$/cow	
Michigan	3.00	2.90	5.90	135	262	Dartt et al., 1999
Wisconsin	3.00	2.70	5.70	142	316	Johnson, 2002
New York	2.55	1.57	4.12	142	310	Johnson, 2002
Maryland	--	1.5	1.5	--	614	Weil and Gilker, 2005
Missouri	0.10	1.44	1.54	231	867	Hamilton et al., 2001
Georgia	0.00	0.35	0.35	365	945	Hill, 2006

The 2005 US census indicates that the population of the southeastern US represents 32% of that of the Nation (http://www.census.gov/). Many of the states in the southeast are growing at a rate faster than the national average. Loss of manufacturing jobs to overseas competitors and economic expansion of the South has resulted in an efflux of population from northern states to the South and West. This efflux of population has been from states with the highest per capita milk production to states with the lowest per capita milk production. In fact, the southeastern US produces less than 8% of the national milk supply (Anon., 2004). These milk-deficient states rely on milk produced by conventional dairies from outside the geographic area.

Challenges to Conducting Relevant Forage Research for Grazing Dairies

Development of a grazing dairy industry is dependent upon a number of economic, environmental, and production variables. Having a good forage system is of paramount importance to grazing dairies, and development of a forage program for livestock operations appears to be a rather simple exercise. However, when one considers the number of forage species from which pastures can be planted, that their seasonality of production differs because some are cool- and other are warm-season species, that in-year or in-season transitioning from one forage species to another can be complicated by whether they are annuals or perennials, that grazing will differentially impact the regrowth potential of each, and that the quality of forage on offer is in a constant state of flux presents a complex matrix of forage traits from which a logical system must be developed. Development of forage systems is further complicated by the dynamic physiological condition of the cow and her changing nutritional needs, and the fact that forages have traditionally been tested under low-input dryland systems rather than the high-input irrigated scenario under which grazing dairies operate.

On-Farm Research

Generally, dairy research centers are ill-equipped to conduct grazing research because to the conventional confinement mindset of the dairy industry. The University of Georgia System is no different. We have opted to partner with producers to conduct research on-farm. The benefits of doing so are a direct transfer of technology to the producer and immediate credibility as to the relevance of the research effort and scientists involved. Our research focus is to 1) examine nitrogen cycling to a) document whether or not nutrient management under a grazing system is environmentally sustainable and b) to develop strategies from which efficient nutrient utilization might be developed if necessary; 2) develop a data based on forage production and quality from better forage systems can be produced based upon predicted milk performance based yield distributions and quality parameters. Our initial nitrogen cycling effort has focused on urea volatilization to ammonia and nitrate nitrogen leeching. We will also measure N_2O flux. Ammonia volatilization losses will be measured with the Integrated Horizontal Flux method described by Schjoerring et al. (1992). This method uses passive flux samplers consisting of two pairs of glass tubes with a coating of oxalic acid on their inner surfaces. As wind passes through the tubes, NH_3 is trapped by the oxalic acid and forms ammonium oxalate, which is soluble in water and can be determined colorimetrically (Mulvaney, 1996). The horizontal flux of NH_3 is then calculated based upon difference between between field and background ammonia levels in the tubes. Nitrate leaching is being measured by cup lysimeters installed to a depth of 90 cm in monitored fields. Water samples collected in the lysimeters are removed weekly and analyzed for nitrate by a colorimetric procedure (Mulvaney, 1996). Replicated forage plots have been planted

and are harvested at regular intervals for dry matter yield. Forage quality is estimated by NIR for nitrogen, fiber constituents, and net energy for lactation (NE_L [MJ kg^{-1}]). Predicted intake, milk yield per cow, carrying capacity, and milk yield per hectare are then calculated. Production curves are generated to illustrate seasonal distribution of nutrient supply (or milk output). Our goal is to develop "gaming" software by which producers can select forages, allocate each species to various acreages and match the herd needs by predicting needs based upon numbers of cows, calving date, and physiological state over time.

What We Have Learned Thus Far

1) Nitrogen losses from grazing dairies is minimal. Our data analysis is not yet complete, but we have data through the first year that has provided surprising results. Ammonia volatilization is minimal, even during summer months when urease activity is most active and release is greatest. Monthly means of ammonia volatilization range from 0.1 to 0.9 kg ha^{-1}. Ground water nitrate levels were generally low (1-3 ppm) but spiked (5-6 ppm) following fertilization events.

2) White clover is the only legume that persists under MIG grazing. All other legumes (both warm and cool season perennials) did not tolerate the frequency of grazing imposed by the dairy managers. While white clover expressed greatest persistence, it still requires several years to properly establish.

3) Early fall forage production is the biggest problem facing grazing dairies. There is a 60-day period from the end of summer grazing until initiation of late-fall or early winter grazing for which it is the most difficult to manage. Fall temperature has a large effect as to how well winter grazing establishes and grows. Novel approaches to late summer grazing need to be researched to established options to minimize this deficit period.

4) If it can go wrong on the farm, it can go wrong in your plots. Loss of electricity means cattle grazing plots when they are unwanted visitors, miscommunication with farm managers means delays in vital farm operations, and the distance from the office to the research means fewer observations which translates into minor mishaps that, if unchecked, could result in major dilemmas.

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Pasture-Based Nutrition Programs for Horses

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The soil and climate of the Central Kentucky region allow us to have productive pastures for much of the year. Pastures can be an economical source of nutrients for many horses including broodmares and growing horses. There are a few keys to maximizing the economic and nutritional benefits of pasture-based nutrition programs for horses. Pasture-based nutrition programs are commonly used for adult horses used for recreational purposes, broodmares and growing horses.

Understanding the Nutrient Value of Central Kentucky Pastures

The amount of pasture a horse consumes and the nutrient composition of that pasture determine the amount of nutrients consumed. We know that season of the year, as well as rainfall and fertilization practices will influence the amount of available pasture. Cool season grasses such as Kentucky bluegrass, tall fescue and orchardgrass, grow best in the spring and the fall. In the heat of summer, these grasses may grow more slowly and the amount of available pasture usually declines. Cool season grasses will be dormant during much of the winter. The nutrient composition of the pasture is also influenced by climate, fertilization and plant type.

In pasture-based feeding programs, the nutrients provided by the pasture form the basis of the daily diet and then other feeds are added as necessary to meet the nutrient requirements of each horse. The available nutrients in pasture are highest in the spring and fall and lowest in the summer and winter, so the need to supplement is usually lowest in the spring and fall and highest in the winter. There are three basic types of supplements that can be used to complement pasture: hay, concentrate and a mineral-vitamin supplement. Abundant pasture will meet the energy and protein needs of most non-breeding adult horses in Kentucky, but our pastures are often marginal in several minerals. Many feed companies sell a balancer pellet that is a concentrated source of minerals and vitamins. A small amount of a balancer pellet will balance the diet of many horses if pasture is abundant. When pasture availability wanes, horses may be given hay or hay and concentrate to maintain body weight. If horses are receiving a quality commercial concentrate and good quality hay, the balancer pellet can be removed from the feeding program because the concentrate already contains the mineral fortification. If the concentrate is a plain cereal grain (oats or corn), then a balancer pellet may still be necessary.

Horse owners often believe that grass hay (timothy or orchardgrass) is the best substitute for grass pasture, because they do not appreciate the difference in nutrient value between grass hay and grass pasture. Table 1 shows the nutrient analyses from some samples of hay and pasture that we have had analyzed in our research program. The values are shown on a 100% dry basis, to make comparisons easier. From the table below, it is apparent that spring and fall pasture grass can be very high in nutrient value. Although high quality legume hays often provide more nutrients than are needed by adult, non-breeding horses, their nutrient content closely resembles the nutrient content of good pasture. Good legume hays are often more economical than grass

hays. In addition to having more nutrients per pound, legume hays are often more palatable than more mature grass hays and horses will waste less.

Table 1: Nutrient Composition of Common Forages (100% dry matter basis)

	Digestible Energy	Acid Detergent Fiber	Crude Protein	Calcium	Phosphorus
Pasture – May	1.16 Mcal/lb	29.7%	19.0%	0.43%	0.51%
Pasture – July	0.95 Mcal/lb	40.4%	14.8%	0.58%	0.37%
Pasture – Oct	1.20 Mcal/lb	28.2%	19.3%	0.63%	0.31%
Alfalfa Hay - Leafy	1.15 Mcal/lb	30.8%	21.3%	1.18%	0.21%
Alfalfa Hay – Stemmy	0.98 Mcal/lb	37.8%	15.6%	1.39%	0.26%
Timothy - Soft, No Heads	1.00 Mcal/lb	33.5%	14.1%	0.51%	0.40%
Timothy- Coarse, Heads	0.85 Mcal/lb	39.0%	10.2%	0.61%	0.51

Pasture samples were taken from pastures with fall fertilization practices.

Lactating mares and growing horses have relatively high nutrient requirements and a grain-based, fortified concentrate is usually offered to these horses even when pasture is relatively abundant. However, the amount of concentrate should be adjusted pro-actively in respect to pasture availability. The management goal on a breeding farm should be maintain a desirable body condition in mares and a steady growth rate in the foals, weanlings and yearlings. Many Central Kentucky thoroughbred farms weigh foals and weanlings at least once a month to monitor weight gain in order to adjust the diet as necessary.

The Importance of Grazing Intensity

There is large farm-to-farm variation in the stocking rates used on Central Kentucky horse farms. In a survey we conducted several years ago, the average breeding farm had 3 to 4 acres of pasture per horse. However some farms reported having only 1 or 2 acres per horse and others had more than 10 acres per horse. Therefore, there is no "typical" horse farm and supplementation programs must be designed for horse farms on a relatively individual basis.

Almost all farms will have some paddocks or areas within a paddock that are overgrazed. Overgrazing is undesirable because plant health is affected and the long term productivity of a pasture is damaged. Overgrazed pastures are more susceptible to weeds and erosion. Horses in overgrazed pastures may have increased exposure to internal pastures. Undergrazing can also be undesirable. In undergrazed pastures, nutrients that could be consumed are left in the pasture, and/or resources (fuel, labor) are used to mow the pasture. An appropriate grazing intensity allows the pasture plants to remain healthy but minimizes the amount of forage that is wasted or that must be mowed. Some textbooks suggest that horse pastures should have a stocking rate of 2 to 3 acres per horse; so 5 mares would need a 10 or 15 acre pasture. But to make the most efficient use of pasture nutrients, the optimal stocking rate for any pasture should change during the growing season. When growing conditions are optimal one acre of high quality pasture can produce 30 to 60 lb of grass dry matter per day! So a 10-acre pasture will produce 300 to 600 lb of grass dry matter each day….the 5 mares that live in this pasture could never keep all of this forage harvested! Some of the forage will become overly mature unless the pasture is mowed regularly. In addition, the mares will graze selectively in the pasture, keeping some areas well grazed while others are untouched. The overgrazed areas will become less productive and the undergrazed areas will have more mature forage with less nutrient value.

During periods of rapid growth, many pastures will tolerate a stocking rate of 1 horse (or possibly 2 horses) per acre. By increasing the stocking rate, the horses will graze the pasture more evenly and less money will be spent on fuel and labor for mowing. In the middle of summer, pasture growth will slow (especially when we have drought) so the 10-acre pasture will be much less productive and may only produce 5 to 10 lb of dry matter per acre per day. In this case the 5 mares in the 10-acre pasture will probably need some supplementation unless the stocking rate is reduced.

Getting More from Pasture

Many farms keep horses in small groups (<6 horses), because it makes routine horse management tasks a little easier. There is also a perception that a small group size will reduce the incidence of injuries. Although it is beautiful to see a few horses grazing in large lush pasture, this practice does not make very good use of the pasture as a nutrient resource. In large pastures with only a few horses it is common to find areas that are grazed infrequently. Sometimes these unused areas will be those that are far from the water source or far from the preferred resting area. Moving the water source may encourage horses to graze more evenly. Uniform grazing can also be encouraged by dividing pastures into smaller units and then rotating horses from one paddock to another. If the 15 acre pasture described above was subdivided into three, 5-acre paddocks, the 5 mares could graze one paddock until the amount of available pasture decreased and then they could be moved to the next paddock. The length of each grazing period will vary with the growing conditions; horses should be moved before a significant amount of area is grazed to the ground. This plan results in each paddock getting several weeks of "rest" so that the plants in the selectively grazed areas can recover. There is always concern about close crowding of horses, but a stocking rate of 1 horse per acre is not very high.

If it is not possible to subdivide large pastures with permanent fencing, temporary fencing can be used to create the same system. The most common type of temporary fencing is an electric fence that uses plastic posts and wide, highly visible electric tape. Electric fence alone is not recommended as a perimeter fence for horses; and it may not be effective in keeping adjacent groups of horses separate. But, it is effective in keeping horses in a specific area of a pasture so that a rotational grazing system can be used. Temporary fencing is also flexible, so the size and layout of the subdivisions can be changed, and the fence can easily be removed to make pasture maintenance activities easier. Many horse owners are reluctant to use electric fencing because they are afraid that a horse will run through the fence, become tangled in the fence and get hurt. Horses are more likely to run through an electric fence if they are not familiar with it. When using electric fence to subdivide a pasture, it may be prudent to familiarize the horses with the pasture area before putting in the electric fence. The horses can be familiarized with the pasture for a few days before the electric fence is installed. Once the horses are quiet in the pasture, then the fence can be installed. The fence should be adjusted so that it provides a mild to moderate shock. Horses are curious and they are likely to approach the fence and touch it with their nose. If they receive a mild shock they will be startled enough to avoid the fence afterwards. A few horses may give the fence a very wide berth…therefore the water source should not be placed near the fence. The fence should be configured without any small corners where one horse could trap another. Young horses may be more likely to run through a fence than older horses.

There are other strategies that can be used to help smooth-out the pasture growth curve and provide a more consistent amount of forage all growing season. Spring fertilization will

favor spring growth which might be desirable under some conditions. However, it may also cause a surplus of spring pasture and increase the need for mowing. Fall fertilization may encourage some fall growth, but it will also enhance root development. Stronger roots will increase plant density which will help prevent weeds in pastures. Another consideration is plant selection. Central Kentucky horse pastures are composed mostly of cool season grasses; but not all cool season grasses have the same growing characteristics. Grasses that are more heat and drought tolerant may be suited for pastures that are grazed heavily in the summer, whereas grasses that prefer cooler temperatures may be ideal in paddocks that are used heavily in the early spring and fall. Warm season grasses such as Bermuda grass can be very productive in hot weather if water and fertilizer are adequate. However, in Central Kentucky the growing season for Bermuda grass is quite short, so paddocks containing Bermuda grass provide growing forage only in the summer.

Tall fescue is a common pasture plant in Central Kentucky, and most breeding farms are aware of the effects of endophyte infected tall fescue on late gestation mares. Observations from The University of Kentucky Pasture Evaluation Program suggest that many pastures on horse farms contain some endophyte infected tall fescue. The production of ergovaline by the endophyte is low in the winter and then increases during the late spring and early summer. Therefore, mares that foal in late April through June are at higher risk of problems from endophyte infected tall fescue than mares that foal in January, February and March. On commercial thoroughbred farms most mares foal before ergovaline concentrations increase in the tall fescue. However, many recreational horse owners have mares that foal later in the season. To minimize problems in pregnant mares, it is advisable to remove mares in late gestation from pastures containing endophyte infected tall fescue.

Tall fescue is a productive grass that is valued for its hardiness. Our research suggests that tall fescue may out-last other grasses in the same pasture because horses place more grazing pressure on other grasses in a mixed pasture. We have found that tall fescue varieties are almost always less preferred than timothy, orchardgrass, bluegrass and perennial ryegrass. In our grazing trials, the horses eventually consume the tall fescue but it is usually after they have reduced the availability of the other grasses (Watson, 2008). Therefore when other pasture plants are abundant, horses may avoid tall fescue. In agreement with these observations, Morrison (2008) found that the fecal material of horses contained less than 50% tall fescue even though the tall fescue was the primary grass in the pasture. Endophyte free tall fescue and tall fescue containing novel endophytes have been used safely with pregnant mares but horse owners may need to be educated about these varieties before they accept them. In our grazing trials we have not found that the absence of an endophyte influences the preference of the horses for tall fescue varieties.

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Switchgrass for Use as a Forage Crop and Biofuel Feedstock*

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Switchgrass is a perennial grass native to North America. It is a tall, sod forming species that is currently used mainly for hay, summer pasture, and erosion control in the Great Plains region. However, interest in this grass peaked recently when it was identified by the U.S. Department of Energy (DOE) as a primary target for development as a dedicated energy crop because of its potential for high fuel yields, hardiness, and ability to be grown in diverse areas. Switchgrass is relatively drought-tolerant, grows well on marginal cropland, and shouldn't require heavy fertilizing or intensive management practices.

Forage and Livestock Research at the Noble Foundation

"We believe that while at times we have felt the overshadowing presence of oil, we are living in an area that is essentially agricultural. This is easily realized when one takes the time to remember that the land must continue to provide for our food, clothing, and shelter, long after the oil is gone . . . ."
      Lloyd Noble

This quote from Lloyd Noble, founder of the Samuel Roberts Noble Foundation, is instructive indeed. First, it was made over 60 years ago, and second, it reinforces the Noble Foundation's current commitment to the founder's mission of assisting farmers and ranchers in the Southern Great Plains region (and beyond) to realize their personal economic goals in the context of good land stewardship and forage/livestock enterprise. Therefore, the switchgrass program at the Foundation, although driven by the interest in the grass as a biofuel feedstock, is also investigating its use as a forage crop. Please visit our website to see an overview of our overall research programs (http://www.noble.org/ForgBiot/index.html).

Switchgrass has very unique characteristics that make it useful as forage and pasture. First, it is the earliest warm season grass to break winter dormancy in the southern region; with growth beginning in early March in southern Oklahoma and reaching 4-6 tons by June 15 depending on rainfall. This growth is also very high in nutritional quality (60-70% TDN and 10-12% crude protein). During this period, we have found animal gains, depending of stocking rate, of 2.2 to 3.5 lbs per day and total gains of 100-200 lbs per acre. Therefore, the Foundation's current model for using switchgrass in a forage livestock system is to move stocker animals onto it after their removal from winter annual pastures if the goal is to add additional weight to the animals before selling them to the feed lots. Alternatively, waiting until late May or early June to make a hay harvest was also found to give high yields of good quality hay useful for feeding cows later in the year.

Noble's Biofuel Research

The initial DOE program to evaluate and develop switchgrass as a bio-energy crop was begun in the 1990s and was recently reviewed (McLaughlin and Kszos, 2005). The program sought to identify the best varieties and management practices to optimize productivity, while concurrently developing a research base for long-term improvement of switchgrass through breeding and sustainable production in conventional agro-ecosystems. Gains through plant breeding were found for switchgrass yield that exceeded that of corn. Significant carbon sequestration was projected for soils under switchgrass that should improve both soil productivity and nutrient cycling. Co-firing switchgrass with coal will reduce greenhouse gas reduction. Finally, collaborative research with industry included fuel production and handling in power production, herbicide testing and licensing, release of new cultivars, and genetic modifications for chemical co-product enhancement.

In June 2006, the Samuel Roberts Noble Foundation and Ceres, Inc., a California biotechnology company, announced a long-term relationship for the purpose of developing switchgrass as a feedstock for a growing bioenergy industry; especially that part of the industry dedicated to production of biofuels such as ethanol. As a consequence of this announcement, breeding and management research is currently underway at the Samuel Roberts Noble Foundation to make switchgrass a higher yielding and more chemically acceptable feedstock. In addition to producing higher biomass types, we are also looking commercialize some of our current experimental varieties and to develop new varieties that have less lignin deposition, better drought tolerance, and improved establishment characteristics. This should increase its economic value as a bio-energy crop especially in lands marginal for corn production.

New varieties
Two of our newest experimental varieties are to be sold under the brand name of Blade™ 1101 and 1102. Both have demonstrated substantial yield enhancement over the existing 'Alamo' and 'Kanlow" varieties. Commercial seed production has begun on these in partnership with Ceres and seed is currently available for purchase (also see
http://www.bladeenergy.com/switchproducts.aspx).

The same breeding approach used to develop Blade™ 1101 and 1102 will be employed to develop new experimental varieties. However, for this new project, we will also use more genetically diverse genetic material from outside the original breeding program including released cultivars, USDA plant introductions, and natural ecotypes from our own regional collections. This should greatly enhance our genetic base. The main trait of interest will continue to be biomass yield, although we plan also to begin examining specific value added traits such as better seedling establishment, seed yield, and forage composition.

Switchgrass is highly self-incompatible allowing hybridization from simple mutual or isolation crossing. Like corn, high heterosis is found when single cross hybrids were made from specific, clonally replicated switchgrass genotypes. Clonal replication using tissue culture is also possible for large scale production of the individual genotypes which should allow their use in a commercially viable F1 hybrid seed production program. These characteristics demonstrate the potential is high for developing high yielding single cross hybrids or F1 varieties of switchgrass.

Agronomic management research

There have always been problems establishing good stands of switchgrass. Even when plants emerge, their productivity during the initial year is very poor. The reason for this is not readily apparent, but could partially be due to the very hot and dry summers. Recent experiments continue to show a need for using a pre-plant and post-plant herbicide program, especially when using no-till methods, to give more productive stands. Management research to better establish switchgrass will need to continue in the future. A good management guide that includes some of our current findings and recommendations is now available online at http://www.bladeenergy.com/Bladepdf/Blade_Switchgrass_Crop_Guide_2009.pdf .

Biotech tools

Molecular markers are powerful tools for genetic mapping, genotype fingerprinting, population structure and genetic diversity studies. Simple sequence repeat (SSR) markers have become the marker class of choice because they are mostly co-dominant, abundant in genomes, highly reproducible, and some have high rates of transferability across species. Regular use of molecular markers for breeding and other applied research in a plant species depends on development of a large number of markers for the species of interest. However, a very limited number of molecular markers is currently available for switchgrass. As part of the research project with Ceres, a comprehensive molecular marker system will be generated for switchgrass and then used for selection of important traits.

Finally, researchers in the Foundation's Plant Biology Division have been very successful in manipulating lignin composition and levels in alfalfa and other forages to improve their digestibility. Cellulosic feedstocks are generally comprised of three components cellulose (~44%), hemicellulose (~30%) and lignin (~26%). The cellulose and hemicellulose provide a rich supply of carbohydrates that are ultimately used to produce ethanol.

The issue – and the bottleneck in supplying cheap ethanol from cellulosic feedstocks – is gaining ready access to the cellulose and hemicellulose. This is also true for ruminant animals to fully utilize the fiber in most forage crops. The obstacle is lignin. As lignin is responsible for a plant's structure, strength and rigidity, lignin naturally encompasses the plant's cellulose and hemicellulose. Because lignin is so effective serving its primary role – as the "scaffolding" within each plant – it has complicated and increased the cost for efficiently accessing cellulose and hemicellulose into ethanol. Lignin manipulation techniques created in the Plant Biology Division should allow development of plants capable of producing ethanol much more efficiently and cost effective.

Practical on-farm use

Farmers will choose to grow dedicated energy crops such as switchgrass based on simple economics. The on-farm value of these crops will be determined by a combination of variables including market demand, input requirements and costs, government support programs, and the alternative use of the land, for example, cattle production. Despite years of research and the development of improved biofuels feedstocks through government research programs, little has been done to definitively establish these economics.

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Therefore, the Foundation's work in bioenergy crops will continue to focus on using switchgrass as a dual purpose crop – forages and potential bioenergy. As shown in the figure below, we will continue to use research on breeding, management, and biotechnologies to increase the yield of the grass. At the end of the day, our switchgrass work, or really, any of our research with different forage crops, will be used to improve the lives of farmers and ranchers.

Achieving the Switchgrass Yield Goals via Breeding, Management, and Biotechnologies
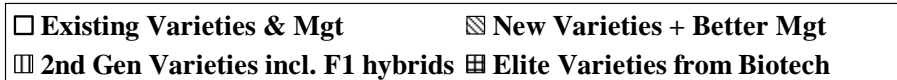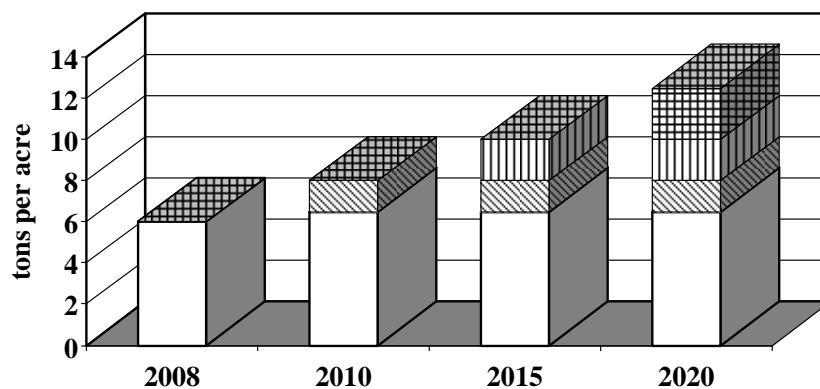
Forage Improvement Division

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Endophyte Alkaloids: Protecting The Home Turf
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Endophytes of tall fescue and perennial ryegrass

The epichloae (*Epichloë* and *Neotyphodium* species) are fungal symbionts of cool-season grasses (subfamily Pooideae), many of which produce alkaloids that protect their hosts from herbivory. Four alkaloid classes have been associated with these endophytes, the ergot alkaloids, indolediterpenes, lolines and peramine (Figure 1). All of these have anti-insect activities, but the ergot alkaloids and indolediterpenes also cause toxicoses and pose significant problems for livestock. Since the late 19th century (Freeman, 1904; Guérin, 1898), endophytes in the *Festuca / Lolium* complex of grasses have been suspected to be responsible for certain toxic syndromes suffered by grazing livestock. However, not until the 1980's did this relationship become widely accepted, particularly for tall fescue (*Lolium arundinaceum* = *Schedonorus arundinaceus*) and perennial ryegrass (*Lolium perenne*).

A comprehensive history of hexaploid tall fescue is reviewed by Buckner et al. (1979). In 1916, H. A. Schoth of the U.S. Department of Agriculture Agricultural Research Service (ARS, Corvallis, Oregon) observed in a nursery on the Max Heinricks farm, Pullman, Washington, plantings of a grass with unusual persistence under stress. Thus commenced a breeding program culminating in the 1940 release of cv. Alta. Also, in 1931, E.N. Fergus from the University of Kentucky identified a population of tall fescue on W.M. Suiter's farm in Menifee County, Kentucky. Plants from this farm were subjected to further breeding and selection, culminating in the release in 1943 of cv. Kentucky-31. With the releases of tall fescue cultivars, intense promotion of the plant by various entities, such as the U.S. Soil Conservation Service, resulted in its establishment over 14 Mha in the U.S. Most of this was 'Kentucky-31' and its derivatives, planted in Southeastern states. The area where tall fescue is considered best adapted extends from most of Missouri and Arkansas to the Eastern Carolinas, and from Kentucky and Southern Illinois, Indiana, Ohio and West Virginia, to central Mississippi, Alabama and Georgia (Burns and Chamblee, 1979). This is regarded as the transition zone, where dominance of cool season grasses (mainly subfamily Pooideae) gradually gives way to warm season grasses (mainly subfamilies Panicoideae and Chloridoideae). The adaptability of tall fescue to this zone is, in no small measure, due to its inconspicuous but profoundly important symbiont, the seed-transmitted endophyte, *Neotyphodium coenophialum*.

Despite the productivity and nutritional value of tall fescue, livestock performance on this forage was not as expected, and episodes of toxicosis became a concern (Bush et al., 1979). Symptoms of tall fescue toxicosis are reminiscent of ergot poisoning, associated with ergot alkaloids commonly found in the resting structures (sclerotia; ergots) of *Claviceps purpurea* that develop on grass ears and can contaminate the grain. The underlying reason for toxicosis was elucidated with the discovery by Bacon et al. (1977) of a seed-transmissible endophytic fungus, and subsequent demonstration that this "tall fescue endophyte" also produces ergot alkaloids (Lyons et al., 1986). Although the tall fescue endophyte is related to *C. purpurea* (Spatafora et al., 2007), its life history is dramatically different. The endophyte elicits no symptoms in the plant, produces no external signs of infection, and is transmitted vertically from infected mother plants to the seed progeny. Although it is not difficult to kill off this symbiont from seed lots, it has become evident that the robustness and persistence of the grass depends in large part on the symbiont (Malinowski and Belesky, 2000). Therefore, major efforts have been launched to

search for, or develop, "nontoxic endophyte" strains that do not produce ergot alkaloids, and incorporate these strains into tall fescue to replace the "common toxic endophytes" of existing tall fescue cultivars (Watson et al., 2004).
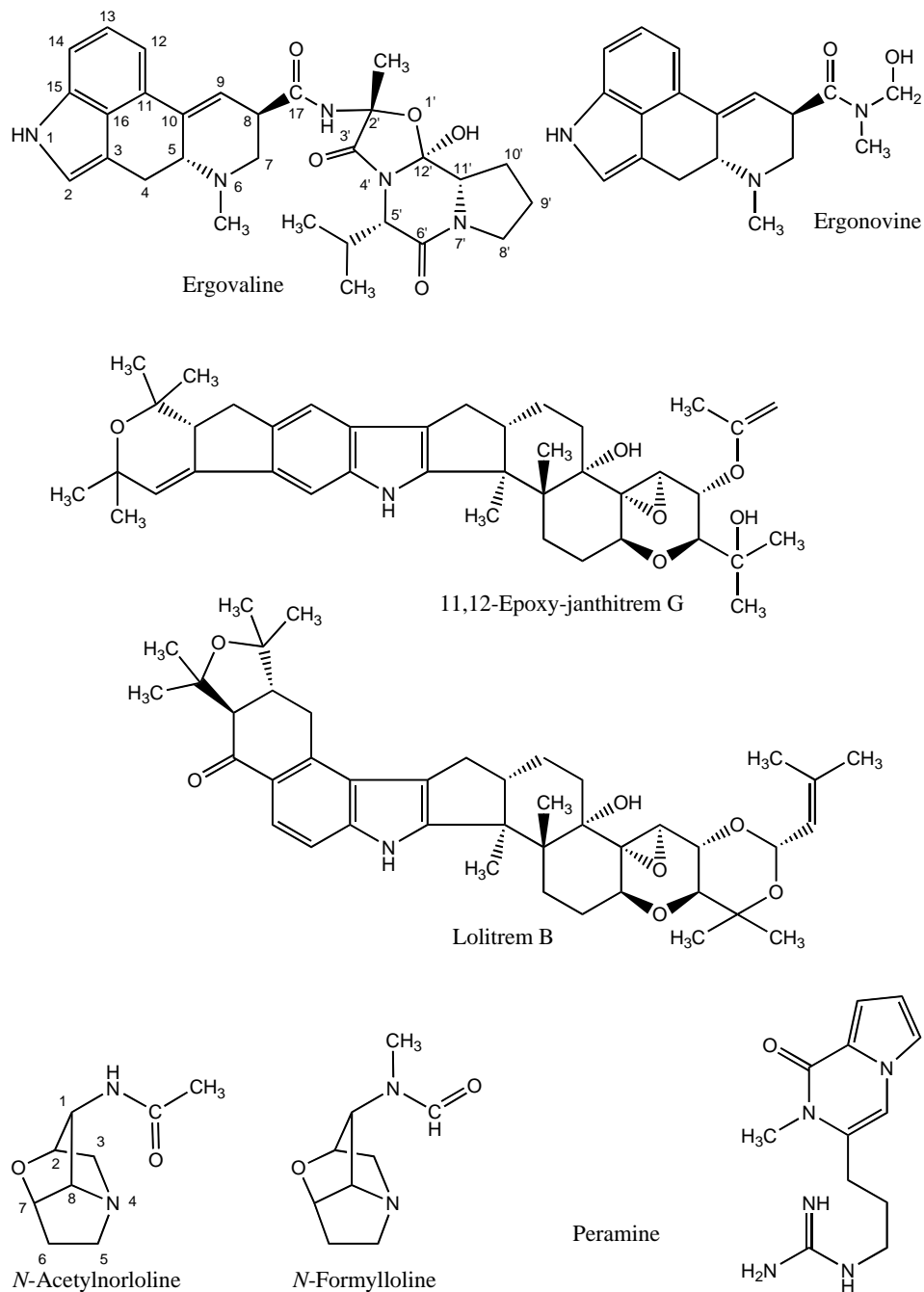

Figure 1: Representative alkaloids produced by epichloë endophytes of grasses. Shown are examples of ergot alkaloids (ergovaline and ergonovine), indolediterpenes (11,12-epoxy-janthitrem G and lolitrem B), lolines (*N*-acetylnorloline and *N*-formylloline), and peramine.

The endophyte of tall fescue was first taken to be the grass choke pathogen, *Epichloë typhina*, for which Anton De Bary had noted the "endophyte" stage in 1866 (reviewed in Ghimire and Hyde, 2004; Saikkonen et al., 2004). But, since then, the tall fescue endophyte has been named *Neotyphodium coenophialum* (Glenn et al., 1996), and numerous other *Neotyphodium* species also have been described (Schardl and Leuchtmann, 2005). Furthermore, the relationship to *E. typhina* and other *Epichloë* species has been well established (Moon et al., 2004), and *N. coenophialum* has been characterized as a complex hybrid with genomic contributions from three separate *Epichloë* species (Tsai et al., 1994). The ancestral genomes include one from *Epichloë festucae*, one from an *E. typhina* genotype related to those typically found inhabiting *Poa nemoralis*, and one from a so-far elusive *Epichloë* species related to *Epichloë baconii*. The *E. baconii*-related genome groups phylogenetically in the "*Lolium*-associated endophyte" clade of genomes found in hybrid endophytes of other *Lolium / Schedonorus* species, including *Neotyphodium occultans* in various annual ryegrasses, and FaTG-2 and FaTG-3 in a hexaploid grass that has been identified as tall fescue (Tsai et al., 1994), but may in fact be a different, so far undescribed, *Lolium* species (Schardl et al., 2008). The presence of a three-genome hybrid endophyte in hexaploid tall fescue seems especially interesting considering that the grass is, itself, a three-genome hybrid (Humphreys et al., 1995; Xu and Sleper, 1994).

The biology of two *N. coenophialum* ancestors, *E. festucae* and *E. typhina*, is fairly well established. Although *E. typhina* is a very damaging choke pathogen (preventing seed set) when it infects hosts such as orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*), and perennial ryegrass (*Lolium perenne*), it is less pathogenic and often seed transmitted in *Poa nemoralis* (Schardl and Leuchtmann, 2005) and *Puccinellia distans* (Olejniczak and Lembicz, 2007). Also, a surprisingly large number of nonpathogenic *Neotyphodium* species have genomes very closely related to those of *E. typhina* from *Poa nemoralis*. Examples are *Neotyphodium huerfanum* in *Festuca arizonica*, and *Neotyphodium typhinum* var. *canariense* in *Lolium edwardii*. Also, various interspecific hybrids in diverse pooid grasses throughout Europe, North America and South America (Gentile et al., 2005; Moon et al., 2004) have genomes related to this clade of *E. typhina* along with other genomes. Interestingly, *Neotyphodium uncinatum* is an *Epichloë bromicola* x *E. typhina* hybrid, and is symbiotic with *Lolium pratense*, one of the ancestors of hexaploid tall fescue (Humphreys et al., 1995; Xu and Sleper, 1994).

Epichloë festucae largely maintains an endophytic lifestyle and is transmitted in seeds of its host grasses (various *Festuca* and *Lolium* species), but can also produce choke disease on some hosts. Some strains of *E. festucae* produce ergot alkaloids, and some produce lolitrems (Figure 1), a class of alkaloids that causes staggers in mammals. In fact, the common endophyte of perennial ryegrass in New Zealand, *Neotyphodium lolii*, is essentially an asexual *E. festucae* lineage that produces lolitrems and causes ryegrass staggers (Pritchard and Lewis, 1995). It was the association of this endophyte with staggers that sparked interest in New Zealand, as well as Australia, in the grass-endophyte system (Gallagher et al., 1984; Rowan, 1993). As it turns out, endophytes of grasses native to temperate South America (Cabral et al., 1999; Gentile et al., 2005; Iannone and Cabral, 2006) can cause a related, but more severe and potentially fatal "*huecú*" or "*tembladera*" (trembling) toxicosis. Similar toxicoses have been problems of note in Africa (Meredith, 1955), China (Miles et al., 1996), and Japan (Miyazaki et al., 2004), further stimulating international interest in these fungi. The possibility that these other staggers-like syndromes are due to lolitrems or related alkaloids has not yet received much scrutiny, but the case of ryegrass staggers seems clear-cut (Tor-Agbidye et al., 2001).

Alkaloids that have been identified as endophyte-specific fall into four distinct classes: ergot alkaloids, indolediterpenes, lolines and peramine (a pyrrolopyrazine)(Figure 1). Because most endophytes are amenable to culture, it could be established soon after the endophytes were discovered that they were solely responsible for production of the ergot alkaloids (Porter et al., 1979), indolediterpenes (Gallagher et al., 1984; Penn and Mantle, 1994), and peramine (Rowan, 1993). But, the notable exception was the inability of *N. coenophialum* cultures to produce lolines. Eventually, the endophyte role was established by coaxing *N. uncinatum* to produce *N*-formylloline and *N*-acetylnorloline in culture (Blankenship et al., 2001). Hence, all four alkaloid classes are endophyte products.

Lolines

The loline alkaloids have been reviewed recently by Schardl et al. (2007). Early investigations of the causes of toxicity of meadow grasses to livestock focused on *Lolium temulentum*, with parallel searches for the biological principle and chemical principle involved. The biological search lead to discovery of the "seed fungus" (Guérin, 1898; Vogl, 1898), and exquisite elucidation of its joint life cycle with the host (Freeman, 1904). This endophyte, eventually named *Neotyphodium occultans* (Moon et al., 2000) is among the least tractable for research because it is nonculturable.

The chemical search led to the identification of alkaloids (Antze, 1891; Hofmeister, 1892), later called lolines (Yunusov and Akramov, 1955). Nearly two decades of study eventually yielded the exact loline structure, comprised of a pyrrolizidine ring system with an *exo*-1-amine (usually decorated with methyl, formyl, acetyl or acyl groups), and an oxygen atom bridging carbons 2 and 7 (Aasen and Culvenor, 1969; Bates and Morehead, 1972; Yates and Tookey, 1965) (Figure 1). The loline alkaloids are toxic to a broad range of insects, with potency comparable to nicotine (Riedell et al., 1991). Interestingly, there is little or no indication that lolines are toxic to mammals at physiological concentrations. In fact, of the four endophyte alkaloid classes, the *L. temulentum-N. occultans* symbiotum is reported to possess only lolines (TePaske et al., 1993). So the basis for toxicity of this grass to livestock remains a mystery.

Although most grass-epichloë symbiota lack them, the lolines are nevertheless distributed among a wide range of species. Levels of one-to-several mg/g dry weight are typical of tall fescue-*N. coenophialum* symbiota, and even higher levels have been found in meadow fescue with *N. uncinatum* or *N. siegelii* (Bush et al., 1997; Zhang et al., 2009). Lower levels typify *Lolium giganteum-E. festucae* (Siegel et al., 1990), *Glyceria striata-Epichloë glyceriae* (Gonthier et al., 2008), *Echinopogon ovatus-Neotyphodium aotearoae* (Miles et al., 1998), and *Agrostis perennans-Epichloë amarillans* (Spiering et al., 2008), whereas *Poa autumnalis-Neotyphodium* sp. has levels comparable to the tall fescue-*N. coenophialum* (Siegel et al., 1990).

The identification of culture conditions in which *N. uncinatum* produces lolines has allowed a series of studies to determine the biosynthetic precursors and certain key intermediates in the pathway (Blankenship et al., 2005; Faulkner et al., 2006; Spiering et al., 2008). Contrary to earlier speculation, the lolines are derived from amino acids, not polyamines. Specifically, L-proline and L-homoserine (or, more probably, *O*-acetylhomoserine) are the immediate precursors, and these are conjugated by a γ-substitution reaction to give *N*-(1-amino-3-carboxy)propyl proline. Then, a series of oxidation and internal cyclization reactions gives the core structure of lolines. The 1-amino group can be acetylated or methylated, and oxidation of an *N*-methyl group on the *N*-dimethylated form yields *N*-formylloline (Figure 1), which is the most abundant of the lolines in 'Kentucky-31' tall fescue.

Mendelian genetic analysis of *E. festucae* (Wilkinson et al., 2000), and gene expression analysis of *N. uncinatum* (Spiering et al., 2002), revealed the cluster of genes for loline biosynthesis (Kutil et al., 2007; Spiering et al., 2005). An RNA-interference (RNAi) experiment indicated a role for the *lolC* gene in the cluster (Spiering et al., 2005), and a gene knockout and complementation experiment revealed a role for *lolP* (Spiering et al., 2008).
It has been noted that lolines are induced to high levels by clipping (mock herbivory) of the plants (Craven et al., 2001). However, reports of concomitantly elevated *lolC* gene expression (Simons et al., 2009; Sullivan et al., 2007) are inconsistent or not of a magnitude that would suggest it as the primary basis for determining loline alkaloid levels. In experiments on meadow fescue symbiotic with *N. uncinatum* or *N. siegelii*, the clipping effect reflected the tendency for young tissue to have much higher loline alkaloid levels than older tissues (Zhang et al., 2009). Those tissues also tended to be high in precursor amino acids, but only in uninfected plants, whereas in the symbiota those amino acids were much reduced. Although some regulation of loline biosynthesis genes was evident in *N. uncinatum*, this was not true of *N. siegelii*. It appeared that, in both symbiota, concentrations of free amino acids in young tissues constituted the key regulatory mechanism governing loline levels. Interestingly, the overall effect was to ensure that younger tissues had high levels of lolines, in keeping with the optimal defense theory that plants should employ mainly chemical defenses in young vulnerable tissues (McKey, 1979).

Ergot alkaloids

The ergot alkaloids have recently been reviewed by Schardl et al. (2006). The role of ergot alkaloids in tall fescue toxicosis was suspected based on the relationships of symptoms to those of poisoning due to ingestion of *C. purpurea* ergots. Thus, it was established that *N. coenophialum* produces ergot alkaloids that can accumulate to toxic levels in tall fescue (Lyons et al., 1986). Symptoms of ergot poisoning in humans include hallucinations, tingling in extremities (St. Anthony's fire), dry gangrene of limbs, convulsions, and death. In livestock grazing tall fescue with toxic endophyte can show dry gangrene in extreme cases. But, the more common problems of tall fescue toxicosis are poor weight gain, agalactia, fat necrosis, and poor conception rates. Also, stillbirths may result when mares or cows in gestation are grazed on this grass.

The basic approach to eliminate the problem of tall fescue toxicosis is to identify or generate endophytes that do not produce ergot alkaloids, and incorporate them into cultivars. Natural variants of *N. coenophialum* have proven useful for this approach (Parish et al., 2003a; Parish et al., 2003b; Watson et al., 2004), and have been commercialized. There are some concerns about this approach, however, such as the whether long-term longevity of the stand or maintenance of the endophyte will be comparable to that of the 'Kentucky-31' endophyte. Also, these novel endophytes do not necessarily provide the same level of biological protection, for instance against nematodes (Timper et al., 2005).

An alternative approach is to modify the 'Kentucky-31' endophyte to eliminate its genetic capability to produce ergot alkaloids. Specifically, the *dmaW* gene for the first step in the ergot alkaloid pathway can be disrupted or knocked out by standard molecular approaches. This has been done in a perennial ryegrass endophyte (Wang et al., 2004), but is proving more difficult in *N. coenophialum* in part because this complex hybrid carries two functional *dmaW* genes. One of these genes has been knocked out, and work is underway to eliminate the second (Florea S, 2009). But, will knocking out ergot alkaloid production reduce the fitness benefit of the endophyte? When perennial ryegrass bearing a *dmaW*-knockout endophyte, wild-type

endophyte, or no endophyte was assessed for resistance to the migratory, ectoparasitic nematode, *Pratylenchus scribneri*, there was no significant difference (Panaccione et al., 2006b). So ergot alkaloids appear unnecessary for endophyte-derived resistance to this nematode. In contrast, a similar comparison with challenge by the *Agrotis ipsilon* (Lepidoptera: Noctuidae; sod webworm) indicated that ergot alkaloids have some effect against this insect (Potter et al., 2008). Considering that the endophyte in these experiments produces no loline alkaloids, it seems likely that ergot alkaloids are less important for insect resistance by tall fescue-*N. coenophialum*, which has abundant lolines. This possibility needs to be assessed experimentally, once the genetic knockouts are generated and incorporated into tall fescue.

A concern about a molecular genetic knockout of *dmaW* is that it requires the introduction of a marker gene, which is likely to raise public concerns and trigger onerous regulatory requirements. Therefore, we used the Cre-lox system to allow the removal of the marker, and in this way we have generated a *dmaW*2 knockout of *N. coenophialum* that now lacks foreign genes (Florea S, 2009). Application of the same technique to *dmaW*1 will generate a double-knockout strain that will be safe for field experiments and, if agronomically promising, release in tall fescue cultivars.

But, would a specific knockout of ergot alkaloid biosynthesis enhance the suitability of the grass for livestock? It is necessary to conduct larger scale experiments once knockouts of both *dmaW* genes have been completed. Nevertheless, results of preference tests with rabbits, using the ryegrass system, are intriguing (Panaccione et al., 2006a). Surprisingly, rabbits did not significantly prefer endophyte-free ryegrass over ryegrass with the ergot alkaloid-producing endophyte. However, they greatly preferred grass with the *dmaW*-knockout. Apparently the endophyte actually enhances the attractiveness of ryegrass unless that effect is counteracted by ergot alkaloids.

Meanwhile, tests with novel endophytes lacking ergot alkaloids, though not as strictly controlled for ergot alkaloid effects, yield results consistent with the hypothesis that these alkaloids are the major anti-nutritive factors produced by the 'Kentucky-31' endophyte (Watson et al., 2004). Replacement of tall fescue stands with new nontoxic endophytes appears attractive, but long-term studies of stand longevity with the novel endophytes are needed to accurately assess what circumstances on the farm make stand replacement economical (Zhuang et al., 2005).

Indolediterpenes

In the near-monocultures of *Lolium perenne* that constitute much of New Zealand's pastures, the indolediterpenes — also known as tremorgens — have proven to be a major problem. Strains of *N. lolii* inhabiting almost all perennial ryegrass throughout the islands produce types of indolediterpenes called lolitrems (Figure 1), which are implicated in ryegrass staggers suffered by sheep and other livestock grazed on these pastures.

The preponderance of *N. lolii* in New Zealand is in contrast to the situation in Northern Europe, where most perennial ryegrass plants do not bear endophyte (Lewis et al., 1997). Evidently, the reason for this disparity is intense insect pressure, particularly by the Argentine stem weevil on New Zealand pastures. Endophyte production of peramine is key to deterrence of the weevil and survival of the grass stands (Rowan and Gaynor, 1986). A survey of perennial ryegrass endophytes from Europe revealed considerable chemotypic variation, including some that produce peramine, but not lolitrems (Christensen et al., 1993). Therefore, a very successful effort has been underway to replace lolitrem producers with lolitrem-nonproducers in perennial

ryegrass cultivars (Bluett et al., 2005a; Bluett et al., 2005b). Interestingly, one of the *N. lolii* strains that lacks lolitrems produces a closely related janthitrem (Figure 1), and this strain also can cause staggers (Fletcher, 2005).

The indolediterpene biosynthetic pathway has been elucidated by isolation of apparent intermediates (Munday-Finch et al., 1998), and by genetic analysis of several fungi that produce these compounds (Saikia et al., 2007; Young et al., 2005; Young et al., 2001; Young et al., 2009; Zhang et al., 2004). In fact, there appears to be much more of a network, rather than linear pathway, at work for this group of alkaloids. This probably accounts for the considerable variety of indolediterpenes detected in perennial ryegrass-*N. lolii*. An intriguing aspect is the first step, proposed to be geranylgeranyl diphosphate (GGPP) synthesis by the action of the *ltmG* gene product (or *paxG* in *Penicillium paxilli*). GGPP is an essential compound, and a separate "housekeeping" gene is also present in these fungi, yet the housekeeping GGPP synthase does not substitute for the PaxG enzyme in the indolediterpene pathway (Young et al., 2001).

Peramine

The only natural pyrrolopyrazine alkaloid known is peramine (Figure 1), a metabolite produced by approximately half of the known epichloae (Bush et al., 1997; Siegel et al., 1990). Peramine has been characterized as an insect feeding deterrent. As such, it has been considered crucial for protection of perennial ryegrass from destruction by the Argentine stem weevil (Prestidge et al., 1985; Rowan et al., 1986). This role that was confirmed by experiments in which the *perA* gene of *E. festucae* was knocked out, and perennial ryegrass plants with the knockout and wild-type strains were challenged with the insect (Tanaka et al., 2005).

Like lolines, Peramine is likely to be derived from mainly from common amino acids or their precursors. The *perA* gene is predicted to encode a multimodular nonribosomal peptide synthetase with two peptide synthesis modules, a methylation module and a reduction module. Gene knockout and complementation demonstrates that *perA* is required for peramine biosynthesis, though it is not yet established that it is sufficient. Assuming that the PerA multimodular enzyme is sufficient, a biosynthetic scheme has been proposed whereby a dipeptide is formed between pyrroline-5-carboxylate (precursor of proline) and arginine, the arginine α-amine is methylated, and the molecule is reductively circularized. A final oxidation, perhaps spontaneously in air, would generate peramine (Tanaka et al., 2005).

There has been no indication of any negative effect of peramine on livestock, and *N. lolii* variants that produce peramine but no indolediterpenes or ergot alkaloids have proven useful for forage perennial ryegrass (Bluett et al., 2005a; Bluett et al., 2005b).

Conclusions

The grass-epichloë symbioses have been considered to be protective mutualists based on the abilities of many epichloae to produce anti-herbivore alkaloids (Clay, 1990), but two classes of epichloë alkaloids have been implicated in livestock toxicosis: the ergot alkaloids and the indolediterpenes. Indeed, endophytes lacking these two alkaloids, but expressing anti-insect loline alkaloids and peramine, have proven useful in commercial forage cultivars (Bluett et al., 2005a; Bluett et al., 2005b; Watson et al., 2004). Furthermore, the importance of lolines, peramine and ergot alkaloids in defense against insects has been established by genetic experiments employing gene knockouts or segregants (Potter et al., 2008; Tanaka et al., 2005; Wilkinson et al., 2000). Among the questions remaining to be systematically investigated are the roles of these alkaloids in natural ecosystems, such as effects on ecological succession (Clay and

Holah, 1999) and food web structures (Omacini et al., 2001), and the genetic and evolutionary reasons underlying the observed diversity of endophyte chemotypes (Leuchtmann et al., 2000).

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Conservation, Distribution, Utilization, and Security Backup of Forage Legume and Grass Genetic Resources

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Introduction

The Plant Genetic Resources Conservation Unit (PGRCU), Griffin, Georgia, conserves seed and/or clonal plants of 88,820 accessions of 253 genera and 1,509 species (USDA, ARS, 2009). The accessions conserved are those adapted to the climate of the southern U.S. and include a wide diversity of crops and wild species including sorghum, peanut, cowpea, pepper, mung bean, okra, watermelon, sesame, pearl millet, guar, kenaf, roselle, eggplant, sweetpotato, bamboo, and others. The accessions are distributed to research and educational users throughout the world. Over 7,600 of these accessions are warm-season grasses, forage legumes, and annual clovers commonly utilized for pasture and hay research. The objective of this paper is to document the conservation, distribution, utilization, and security backup of pasture and hay genetic resources from the PGRCU germplasm collection.

Conservation

The main forages conserved at Griffin are warm-season grasses, forage legumes, and annual clovers (Pederson et al., 2005). The large collection of sorghum of over 36,000 accessions maintained at Griffin is utilized for forage as well as grain research, but will not be included in this paper. A total of 4,259 warm-season grass accessions are maintained including big bluestem (*Andropogon gerardii*), cane bluestem (*Bothriochloa barbinodis*), Australian bluestem (*B. bladhii*), King ranch bluestem (*B. ischaemum*), bermudagrass (*Cynodon* spp.), fingergrass (*Digitaria* spp.), kleingrass (*Panicum coloratum*), switchgrass (*P. virgatum*), *Panicum* spp., dallisgrass (*Paspalum dilatatum*), bahiagrass (*Paspalum notatum*), *Paspalum* spp., and buffelgrass (*Pennisetum ciliare*). A total of 1,230 forage legume accessions are maintained including American jointvetch (*Aeschynomene americana*), hairy jointvetch (*Aeschynomene villosa*), alyce clover (*Alysicarpus vaginalis*), partridge pea (*Chamaecrista fasciculate*), Illinois bundleflower (*Desmanthus illinoensis*), *Desmodium* spp., striate lespedeza (*Kummerowia striata*), hyacinth bean (*Lablab purpureus*), sericea lespedeza (*Lespedeza cuneata*), siratro (*Macroptilium atropurpureum*), perennial soybean (*Neonotonia wightii*), *Ornithopus* spp., *Stylosanthes* spp., and other forage legumes. A total of 2,154 annual clover accessions are maintained including berseem clover (*Trifolium alexandrinum*), rabbit'sfoot clover (*T. arvense*), hop clover (*T. campestre*), rose clover (*T. hirtum*), crimson clover (*T. incarnatum*), ball clover (*T. nigrescens*), Persian clover (*T. resupinatum*), subterranean clover (*T. subterraneum*), arrowleaf clover (*T. vesiculosum*), and other *Trifolium* spp.

The bulk of all seed for the warm-season grass, forage legume, and annual clover accessions are maintained in sealed bags at -18 C to maximize seed longevity and interval required between regenerations. Small samples for distribution are maintained at 4 C and 25% relative humidity. Germination testing of the Griffin collection was initiated in 2002 and some crop collections have not yet been tested. Presently, about 20% of the warm-season grass collection, 76% of the forage legume collection, and 85% of the annual clover collection have been tested for germination.

Distribution

  Accessions are routinely regenerated to produce enough seed for distribution to users. All accessions are regenerated with adequate pollen control via caged increases or isolation by distance. Method of regeneration is dependent upon several factors including degree of cross and self pollination, wind or insect pollination, environmental requirements, etc. If seed quantity and/or seed quality is inadequate, then an accession is determined to be unavailable for distribution. Many of the wild species are very difficult to regenerate and often produce few seed or poor quality seed. Maintaining adequate quality seed for distribution is a constant process within a germplasm collection. Presently, about 88% of the warm-season grass collection, 80% of the forage legume collection, and 82% of the annual clover collection are available for distribution.

  Since 1988, more than 12,200 warm-season grasses, 4,000 forage legumes, and 10,800 annual clover samples have been distributed to researchers throughout the world. The warm-season grasses which were distributed most often during the last 20 years were switchgrass with about 3,400 samples distributed and buffelgrass with more than 2,250 samples distributed. The forage legumes distributed most often during the past 20 years were lablab with more than 1,660 samples distributed and lespedezas with about 700 samples distributed. The annual clovers distributed most often during the last 20 years were subterranean clover with about 2,700 samples distributed and berseem clover with more than 1,400 samples distributed.

Utilization

  Traditionally, plant genetic resources have been used for plant breeding and development of new crop cultivars. Forages are no exception, as the main use for these genetic resources is applied plant breeding, forage production, and management studies. However, the number of uses by researchers outside of traditional plant breeding has greatly increased in recent years (Pederson, 2008). Accessions of warm-season grasses, forage legumes, and annual clovers have been utilized for research in plant pathology (soybean rust alternate hosts, powdery mildew), entomology (fall armyworm, hessian fly resistance), plant physiology (protein, tannin, starch chemistry, phytoestrogen, photorespiration, photosynthetic metabolism) plant morphology (floral morphology), abiotic effects (shade tolerance, water stress, xylem anatomy, waterlogging tolerance, water use efficiency, salt, ozone tolerance), phytoremediation (arsenic, polycyclic aromatic hydrocarbons PAH remediation), molecular biology (transformation, tissue culture, DNA barcodes), phylogenetics (phylogenetic research, interspecific variation), education (weed and seed identification, 4-H, home school science projects), archaeology (identification of archaeological seeds), crop management (green manure, erosion prevention), symbiosis (nitrogen fixation, allelopathy, endophyte infection), alternative uses (biomass and biofuel production, anti-cancer drug research, ornamental grasses), and germplasm preservation (cryopreservation research) (Pederson, 2008).

Security Backup

  Plant genetic resources must be maintained at more than one location to serve as a security backup to prevent loss of accessions due to natural disaster, accidents, mechanical breakdown, terrorism, or other catastrophes. A total of 7,377 forage accessions or 96.5% of all forage accessions in the Griffin collection are backed up at a second germplasm site at the

National Center for Genetic Resources Preservation, Ft. Collins, CO. Seeds at Ft. Collins are maintained in secure storage vaults at -18 C.

Recently, a new global seed vault was built at Svalbard, Norway, for security backup of the world's plant genetic resources (Fowler, 2008). This remote location was chosen as the site for the seed vault because it is within the Arctic Circle (halfway between Norway and the North Pole); normal temperatures in the permafrost are -5 C; the relative humidity is low; and the political climate in Norway is stable. The storage site consists of a tunnel constructed 150m below surface into the mountain with three vault rooms (each 27m L x 9.5m W x 5m H). There is storage capacity for 4.5 million accessions in heat-sealed, moisture-proof, foil packages. Though the normal temperature is -5 C, the seed vaults are further cooled to -18 C. The first seeds were deposited in the vaults during February 2008 and included seed from several germplasm sites within the National Plant Germplasm System including the PGRCU collection at Griffin. Currently, 328 forage accessions from Griffin are backed up at both Ft. Collins and the Svalbard Global Seed Vault, Svalbard, Norway.

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**Direct Selection Responses in Annual Ryegrass (Lolium multiflorum Lam.)
Selected for Improved Winter Growth**

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Annual ryegrass (*Lolium multiflorum* Lam.) is a cool season annual bunchgrass possessing high palatability, excellent forage quality, good seedling vigor, persistence under close grazing and impressive dry matter yield. It has a high growth rate during the reproductive phase in spring but makes relatively little growth during winter. Availability of standing forage for grazing in the southeastern USA is limited during the cooler months and improved winter growth would be a great benefit to cattle producers.

The objective of this study was to evaluate the progress from selection for increased winter dry matter production in annual ryegrass resulting from two cycles of phenotypic recurrent selection. Intermating 50 plants from the six top performers in Alabama Annual Ryegrass Trials formed the base population for the selection experiment. Bulk-harvested seed from the first synthetic generation was intermated again to create a random mating population (C_0) for the selection experiment. A 1200-plant nursery was established in late October of each year at the Plant Breeding Unit of the E.V. Smith Research Center, Tallassee, AL with plants spaced 90 cm in all directions. The nursery was subdivided into 48 blocks of 25 plants each (5 x 5 arrangement). Plants were harvested and evaluated for dry matter determination 750 growing-degree-days (GDD) after transplanting. The best entries selected from each block were then intermated in isolation and bulk-harvested seed used for the next cycle. Seed for populations C_0, C_1, and C_2 was increased in isolation at the same location during the 2007/8 cropping season. In autumn 2008, seeded plots were established at five locations in Alabama (Belle Mina, Winfield, Tallassee, Headland, Fairhope) to assess changes in forage yield in response to selection. Populations C_0, C_1, and C_2 as well as check cultivars Gulf, Marshall, and Shiwasuaoba were established in a RCB (r = 4) at each location. Plots were fertilized with 50 lbs N acre^{-1} at seeding and after each harvest. The first harvest occurred 1000 growing-degree-days (GDD) post seeding, allowing 250 GDD for establishment and 750 GDD for dry matter accumulation. Thereafter, the target GDD was 750. A significant linear improvement over 2 cycles was obtained at three of the five locations, ranging from 262 lbs acre^{-1} cycle^{-1} at Belle Mina, AL to 972 acre^{-1} cycle^{-1} at the selection location in Tallassee, AL, and 751 lbs acre^{-1} cycle^{-1} at Headland, AL. No change in first-cut yield was observed at Fairhope, AL. The explanation for this non-response may be that average temperature at this location close to the Gulf of Mexico never dropped below 40 F and was in the 50-60 F range for most of the dry matter accumulation period prior to harvest 1 in early January 2009. The negative response (-242 lbs acre^{-1} cycle^{-1}) at Winfield correspondingly may be related to the extreme cool temperatures at that location indicated by the fact that it took > 5 month to accumulate 1000 GDD compared to 3 month at Tallassee and 2.5 month at Fairhope. The average yield at Winfield (790 lbs acre^{-1}) was < 50% of the yield at Bella Mina and < 30% of the yield at Tallassee, Headland, or Fairhope. Shiwasuaoba outyielded C_2 at all locations, ranging from 153 lbs acre^{-1} at Belle Mina to 1646 lbs acre^{-1} at Headland. Population C_2 yielded at least 1400 lbs acre^{-1} more than Marshall at Tallassee and Headland, whereas the differences at other locations were 162 lbs acre^{-1} or less in favor of Marshall. The trends for Gulf vs. C_2 were similar to Marshall. We can thus conclude that selection in annual ryegrass for improved winter productivity was successful.

Indirect Selection Response and Heritability of Forage Yield in Annual Ryegrass (*Lolium multiflorum* Lam.) Selected for Winter Growth

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Improving winter productivity in Alabama of annual ryegrass, a cool season bunch grass with 2n=2x=14 chromosomes, has been successful through agronomic means by adjusting seeding date and providing supplemental early-establishment irrigation. Plant breeding efforts towards the same goal have also been successful as two cycles of phenotypic recurrent selection (PRS) improved first-cut yields of annual ryegrass at three out of five testing locations. Selection for a given trait often is accompanied by correlated changes in other traits that were not the target of the selection effort. Unlike breeders of self-pollinated crops, those working with cross-pollinated crops often simply assume that genetic variation for the trait of interest exists and the proof is obtained through a positive selection response.

The first objective of our study thus was to determine the indirect effects of selection for improved winter productivity on reproductive maturity, plant growth habit, and disease response. The second objective was to evaluate the effect of selection for winter productivity on genetic covariance for yield and reproductive maturity in cycles C_0, C_1, and C_2 of the PRS program. For the first objective we established replicated (r = 4) seed increase nurseries of cycles C_0, C_1, and C_2 at the Plant Breeding Unit of the E.V. Smith Research Center, Tallassee, AL, where each seed increase block contained about 200 plants on 90-cm spacing in all directions. Individual plant observations for the abovementioned traits where taken during reproductive growth in the spring. Thus mean trait performance is based on approximately 800 plants per population. Seed was harvested from 24 random plants per isolation block for a total of 96 entries per population, where each selected plant represents a half-sib family. Each HS-family was threshed, cleaned and conditioned separately and serves as the basis for objective 2. The remainder of each increase block was harvested and processed in bulk for an evaluation of progress from selection in solid-seeded swards (see poster by Dhaliwal et al.). Half-sib families from populations C_0, C_1, and C_2 were seeded in short (90 cm) seeded rows on 30-cm spacing. There were actually three trials based on harvest scheme conducted in parallel; (1) harvest every 500 growing degree days, (2) harvest every 1000 GDD, and (3) harvest at heading plus end of season. The average spaced-plant heading date for C_2 was 8 d earlier than the base (C_0) population even though selection was done during the early vegetative phase of growth. Maturity of HS-families confirmed this earlier maturity, although the difference of 5 d was somewhat less than observed in spaced-plant nurseries. Selection also shifted the plants to a slightly more erect growth habit in C_2 compared to C_0. This is somewhat surprising because of the care taken during harvest; every tiller, even the very prostrate ones, was lifted off the ground and cut at a uniform predefined height. There was little effect of selection on overall frequency of plants showing disease symptoms. ANOVA among HS-families confirms the results from the solid-seeded sward studies that indicated progress from selection. Heritability estimates for the first cut of C_0= 0.54, C_1= 0.43, and C_2= 0.45 indicate that (1) narrow sense heritability is high enough to make progress, and (2) all three populations have similar heritability. Heritability for heading date ranged from 0.45 to 0.81, depending on the cycle; the base population (C_0) had the highest heritability. We conclude that the *a priori* assumption of sufficient genetic variation for winter productivity was fully warranted.

63rd SPFCIC

**Enhancing Winter Productivity of Annual Ryegrass (*Lolium multiflorum* Lam.)
Through Early Seeding and Supplemental Irrigation**

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There is generally low forage production in the South during the autumn and winter months forcing cattle producers to provide either stored or purchased feed to beef cattle. Stockpiling warm-season grasses during late summer can alleviate some of the shortfall in early autumn. Similarly, autumn-stockpiled tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.) can be used for the same purpose in early winter on some farms, yet there will still be a shortage of fresh forage during of autumn and winter in most situations. In the Southeast, annual ryegrass is commonly overseeded into established warm season perennial pastures or established on cropland as a winter cover and/or forage source. It produces high forage yield in early spring but is less productive during late fall and winter, particularly when seeded late. Late seeding often is associated with lack of rainfall. Additional growth during late autumn and winter would be beneficial to cattle producers. Any additional forage growth that could be achieved during these months would be more profitable to cattle producers than an equivalent amount of forage during mid-spring when forage is plentiful. There are agronomic or plant-breeding solutions to many plant production problems and the former are often easier and quicker to achieve than the latter. This study presents an agronomic solution.

The objective of this study was to determine how dry matter yield in annual ryegrass was affected by date of seeding and irrigation within the first 14-d post seeding period. Plots were established at two-week intervals at the E.V. Smith Research Center in Tallassee, AL, beginning in early September and ending in mid-November, 2008. Cultivars were Marshall, Gulf, Shiwasuaoba, and the experimental SWIPAR Cycle 2. For each seeding date the study design was a randomized complete block (r = 4) with a split-plot restriction on randomization, where irrigation levels (yes, no) were assigned to main plots and cultivars to subplots. Immediately after seeding, one acre-inch of water was delivered via drip-type irrigation. The amount of water applied for two weeks thereafter was based on evapotranspiration (ET) and gradually reduced to 65% of ET. The first harvest for the earliest two seeding dates was Nov. 11, 2008, whereas the last two seeding dates were first harvested March 24, 2009, a 2-month lag in harvestable dry matter production. By early February, the average forage yield penalty by seeding later into the fall was approximately 100 lbs day^{-1}. Early seeding thus was highly beneficial in terms of fall and winter forage production. By late March, cumulative forage yield indicated that Marshall, a late-maturing cultivar, was very sensitive to a delay in seeding date; its forage yield was 2400 and 5500 lbs acre^{-1} less than Gulf and Shiwasuaoba, respectively. Shiwasuaoba, a cultivar developed in Japan for early maturity ('Shiwasu' means December and 'aoba' green leaf in Japanese), or cultivars with similar early maturity may be an attractive alternative for emergency situations that force late seeding. Irrigation was significant only for the second seeding, as there was no precipitation recorded for the entire 2-wk post seeding period, with an average first cut yield in early November of 1988 lbs acre^{-1} compared with 422 lbs acre^{-1} for non-irrigated plots.

Breeding Tetraploid Bahiagrass for Southeastern USA

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University of Florida

Bahiagrass, *Paspalum notatum* Flüggé, is a perennial species extensively cultivated as forage and utility turf in southeastern USA. The tetraploid bahiagrass germplasm constitutes an underexploited source of genetic variation. This variation is locked in ecotypes introduced from South America that reproduce asexually by apomixis. The objectives were to create a segregating population by crossing induced sexual and apomictic ecotypes, and to evaluate the possibility of generating apomictic progeny with superior agronomic characteristics. Two cycles of hybridization were used to generate two populations (F_1 and F_2) by hybridizing sexual and apomictic tetraploid clones. Approximately 20% of the F_1 and F_2 were classified as apomictic. Eleven percent of the F_1 and only 3% of the F_2 were classified as highly apomictic (potential cultivars) indicating variable expressivity of apomixis between generations. Apomictic F_1 hybrids with superior vigor (individual plant characteristic) and previously introduced ecotypes (Argentine and Common) were cultivated in pure-stand plots in Gainesville, Live Oak, and Quincy in 2007 and 2008. Several F_1 hybrids (FL-3, FL-13, FL-14, and FL-93) yielded more above-ground biomass across locations during the cool-season compared with Common and Argentine. The results demonstrate that apomixis can be used to fixed superior genotypes in bahiagrass. Novel hybrids exhibiting superior cool-season growth will be further evaluated for persistence under defoliation stress.

'UF-Riata' Bahiagrass for the U.S. southern Coastal Plain.

A.R. Blount[1], C.L. Mackowiak[1], K.H. Quesenberry[2], T.R. Sinclair[2], and P. Mislevy[3]

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In the southern U.S., forage availability over the cool season is important when perennial summer grasses become dormant during the late fall. Livestock must rely on conserved forage and/or supplements during that period. UF-Riata is a novel diploid bahiagrass (*Paspalum notatum* Flügge) developed for greater fall and early spring forage production (Fig. 1). UF-Riata exhibits lower photoperiod sensitivity, improved leaf tissue cold tolerance, and increased forage production during the cool season, as compared to standard bahiagrass cultivars Argentine, Pensacola and Tifton 9. This new bahiagrass cultivar was released by the University of Florida Agricultural Experiment Station in 2007.

UF-Riata was developed from 'Pensacola' –derived (*P. notatum* Fluegge var. *saurae* Parodi, PI 422024) (USDA, ARS, National Genetic Resources Program, Germplasm Resources Information Network –GRIN, 2008; Finlayson, 1941; Burton, 1967) bahiagrass genotypes. Four cycles of recurrent restricted phenotypic selection were conducted on an annual basis with intercrossing of selected genotypes for photoperiod and cold response.

Fig. 1. UF-Riata breeder's seed increase, Jackson County, Florida.

UF-Riata was selected and tested at multi-locations for improved seedling vigor, late fall-season growth, and early spring-season re-growth, with tolerance to temperatures around -4^0 C. On average, UF-Riata seasonal forage yields have been 25% greater as compared with Argentine and Pensacola, and at least 8% to 10% greater as compared with Tifton 9.

UF-Riata may be sold by variety name only as a class of certified seed and is licensed exclusively to Ragan and Massey Inc., Ponchatoula, LA for marketing and promotion. U.S. plant variety protection is pending.

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Origin and History of Bahiagrass in Florida

Prepared by K. H. Quesenberry, C.A. Acuna, and A. R. Blount
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Bahiagrass is one of the most important pasture grasses in the southeastern USA. This is the 95 year history of the bahiagrass phenomenon in Florida.

Tetraploid Bahiagrass Introductions for Florida

1913-15
Common bahiagrass. Prostrate growth habit, cold sensitive, good spreading, persistent under grazing.

1940-45
Paraguay and **Paraguay 22** - Ecotypes from Paraguay, more upright than common, not used extensively in pastures.

Argentine – Ecotype from Argentina, highly productive, excellent spreading, lower seed head production, more cold tolerant than other tetraploid bahiagrass introductions.

Wilmington – Collected in coastal North Carolina, more narrow leaves than typical tetraploid bahiagrass introductions, darker green color, adapted to higher latitudes, turf potential.

Beef cattle grazing bahiagrass near Ocala, FL

2005
UF Experimental Hybrids – Developed by crosses of superior apomictic tetraploids on to sexual tetraploids produced at UF. Currently under evaluation at multiple locations in Florida. Selection for improved fall and spring yield and nutrient uptake

Diploid Bahiagrass Introductions for Florida

1943
Pensacola – Identified by Mr. E. H. Finlayson, Escambia County Agent in 1938. He collected and distributed seed of this bahiagrass and promoted it for pastures and conservation. Narrow leaves, good seed production, highly persistent under grazing, More cold tolerant than most tetraploid types, well adapted to most soil types in Florida and southeastern USA. Thought to trace to Sante Fe Province of Argentina, coming to Pensacola area of Florida as ballast in ships prior to 1926. Most bahiagrass pastures in southeastern USA today are Pensacola bahiagrass. About 70% of improved pastures and grazed cropland in Florida are planted to bahiagrass. Estimated to be planted on more than 3 million acres in Florida and 5 million acres in the SE USA.

1989
Tifton 9 – Developed at Georgia Coastal Plains Experiment Station by Dr. Glenn Burton. Individual plants selected from Pensacola having superior yields in early spring and late fall.

2008
UF-Riata – Developed by UF-IFAS. Individual plants selected from Pensacola, for further improvement in early spring and late fall production, improved frost tolerance, improved disease resistance.

County agent Ed Finlayson discovered a unique type of bahiagrass growing near the docks area in Pensacola, Florida in 1938-1939. He began evaluating and distributing seed of this grass to local farmers. This one grass is now the predominant grass across the SE Coastal Plains. From this population newer cultivars such as Tifton 9 have been developed. The release of UF-Riata bahiagrass continues the tradition begun by Mr. Finlayson of UF/IFAS selecting superior grasses to improve the well being of Florida livestock producers

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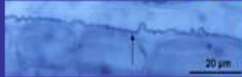
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also, soon after book release, at http://forages.oreegonstate.edu/tallfeascuemonograph

edited by Henry Fribourg, David Hannaway and Charles West

Stockpiling Capabilities of Elite Tall Fescue Cultivars

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Tall fescue is an important cool-season forage in the Central and Northern part of Mississippi and it allows producers to extend their grazing season. Producers are reluctant to utilize tall fescue in their pastures due to fescue toxicosis associated with the endophyte. Several novel endophyte lines have been evaluated in Mississippi for yield performance during the regular grazing season, but no data has been collected about their stockpiling potential and management for winter feeding. The objective of the study is to asses yield potential, changes in forage quality, and optimal fertilizer application and nitrogen use efficiency of different N sources when applied to tall fescue elite cultivars. A study was established in the fall of 2007 and 2008 to study the stockpiling potential, optimal N application date and rate, management, and forage quality of different novel endophyte lines. Six experimental Jesup tall fescue lines possessing different enphohytes were evaluated: EIWT (endophyte-infected wild type), EF (endophyte free), 502, 514, 542, and 584. The application dates were mid-September and mid-October of 2007 and 2008. Nitrogen treatment consisted of a control and two nitrogen sources (urea and ammonium nitrate) applied at two different rates (56 and 112 kg N ha^{-1}). The experimental design was Split-Split-Split Block replicated four times with dates and N rates randomized within each experimental line. The main plots were the experimental lines, the subplots were the application dates (September or October) and the sub-sub plots were the nitrogen rates. Small random grab samples will be collected from each plot every four weeks to determine changes in forage quality. Total yields were taken February of 2007 and January of 2008 to measure biomass potential using a flail-type harvester. No yield differences were observed in 2007 between experimental lines, but total yields were influenced by date, N source and application rate. Yield differences were observed in 2008 among the experimental lines. Ammonium nitrate was more efficient in increasing biomass yield than urea at both application rates. Forage quality is being analyzed and will be reported at a later time.

Assessment of Forage Production in Mississippi

Rocky Lemus and Jason Weirich

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Forage production, especially grazing systems, is an important component of the agricultural enterprise in Mississippi and provides the backbone to the economic viability of the livestock industry. In Mississippi, there are 22,560 milk cows, 521,517 beef cows, and 66,328 horses (USDA, 2007 Census). To maintain their operations, producers (cow-calf, beef stockers, dairy, and horses) are constantly striving to improve and balance both the productivity and economic efficiency of the available forage as source of animal nutrition. To illustrate forage production in Mississippi, a survey was conducted and data was collected in collaboration with MSU County Extension Offices and County Farm Service Agencies (USDA-FSA).   The purpose of this survey was to develop a knowledge base and guidelines for sustainable grazing-based livestock production systems. This survey will help producers and researchers to explore new ways to utilize and manage existing forages, and to develop and introduce new forages to the state.   Nearly 6.8% (2,043,974 acres) of the total land in Mississippi is in forage production with 72% in pasture production and 28% in hay production. Warm-season perennial pastures constitute approximately 1,218,793 acres with 54% pasture production being bahiagrass, 34.8% bermudagrass, and 11.2% dallisgrass. Perennial cool-season forage production is dominated by tall fescue (175,320 acres). There are 698,100 acres of cool-season annuals (annual ryegrass or mixed with small grains) planted in Mississippi for winter grazing. Most cool-season annual grasses are planted by over-seeding (sod-seeding) existing warm-season grasses or by planting in a prepared seed bed.   Ryegrass based stocker calf production is a very large proportion of that production. Approximately, 45 to 54% of those acres are grazed by 500,000 stocker calves annually in Mississippi (with greater concentration in the southern part of the state), with an economic value approaching $800/head. Mississippi agriculture is synonymous with forages and their production and use. Ultimately, a forage system must provide enough dry matter to carry a given set of animals for the year and also meet the desired quality standards of the livestock that will be grazing or consuming the forage.

Fertilization Effects on P Removal and Soil Aggregate Stability of Elite Tall Fescue Cultivars under Stockpiling

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Tall fescue is an important cool-season forage in Mississippi with an estimated 600,000 acres. It is most desirable to stockpile fall and winter forage. Stockpiled fescue not only extends the grazing season, but can also remove a large amount of P from high P soils and increase soil percent stable aggregates. Tall fescue plots were established in fall of 2007 at Mississippi State University South Farm on a Marietta loam soil (Fine-loamy, siliceous, active, thermic Fluvaquentic Eutrudepts). The objective was to study the stockpiling potential, P removal and soil aggregation for Jesup tall fescue infected with different endophyte strains, using various N application date, source and rate. The experimental design was Split-Split-Split Block replicated four times. Six cultivars of Jesup fescue lines containing different Endophytes were valuated: EIWT (endophyte-infected wild type), EF (endophyte free), 502, 514, 542, and 584. Nitrogen treatments consisted of a control and two nitrogen sources [urea and ammonium nitrate (NH_4NO_3)] applied at two different rates (56 and 112 kg N ha^{-1}) applied in mid-September and mid-October. Tall fescue yield and P removal was the same across cultivars, but was affected by N fertilizer and time of application. Tall fescue yielded 2210 and 1770 kg ha^{-1} and removed 6 and 5 kg ha^{-1} of P with 110 kg ha^{-1} of NH_4NO_3 and urea fertilizers. The earlier application date showed significantly higher yield and P removal. Dry matter yield and P removal for the September application date was 510 kg ha^{-1} and 0.63 kg P ha^{-1} higher than the October application date. Water stable aggregates (WSA_{250}) >250 µm diameters were similar for cultivars EF, E584, EIWT, and E514. Water stable aggregates (WSA_{125}) > 125 µm diameter was similar for cultivars EF, E584, E502 and EIWT. Nitrogen rate and source significantly affected WSA_{250}, but did not affect WSA_{125}. Water stable aggregates (WSA_{250}) were 3% higher with 56 kg ha^{-1} in comparison to 112 kg ha^{-1} NH_4NO_3 and were similar for the two rates of urea fertilizer. Application of nitrogen fertilizer in the form of NH_4NO_3 at rate of 56 kg ha^{-1} had a positive effect on WSA_{250}. Urea shows great promise as an alternative to NH_4NO_3 for stockpiling tall fescue with similar productivity, P removal and minimal impact on soil aggregation.

Global change factors interact with fungal endophyte symbiosis to determine tall fescue forage quality

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Background/Question/Methods:

Neotyphodium coenophialum is an endophytic fungus of tall fescue (*Schedonorus phoenix*) capable of producing alkaloids which can alter plant resource allocation, drought tolerance, resistance to herbivory, and forage quality. The objectives of this study were to: 1) evaluate whether global climate change factors affect the frequency of endophyte infection within tall fescue communities, and 2) determine the direct and interactive effects of global climate change and endophyte infection on tall fescue forage quality. Tall fescue tillers were collected from a (6 year) multi-factor manipulation experiment in a constructed "old field" community at the Oak Ridge National Laboratory in eastern Tennessee. The community, comprised of C3 and C4 grasses, forbs, and legumes, was exposed in open-top chambers to combinations of ambient or elevated $[CO_2]$, ambient or elevated air temperature, and high or low soil moisture.

Results/Conclusions:

Endophyte infection frequency of tall fescue was higher under elevated CO_2 compared to ambient (91% vs. 81% infected for elevated and ambient CO_2, respectively; $p<0.02$) but was not impacted by warming or moisture. Within endophyte infected tillers, elevated CO_2 decreased alkaloid concentrations, both ergovaline and loline, by ~30% ($P<0.05$). Warming had no effect on ergovaline concentrations, but increased loline concentrations 28% ($P<0.01$). In this study, uninfected tall fescue had higher %C than infected tall fescue ($P<0.01$); however there were no significant differences in %N, C:N, or acid-detergent fiber (ADF) between endophyte-infected and -free tall fescue tillers. Elevated CO_2 increased litter C:N compared to ambient CO_2 ($P=0.02$) , while warming and moisture had no effect on this parameter . ADF decreased 9% ($P<0.001$) under elevated CO_2 compared to ambient and increased 5% in wet relative to dry conditions ($P<0.02$). Warming had no effect on ADF. Taken together, these results suggest elevated CO_2 may interact with the plant-fungal symbiosis and lead to increased endophyte infection frequency and altered forage quality in tall fescue, more so than warming and changes in moisture. Understanding the ecological significance of these alterations in endophyte prevalence and forage quality will require further study.

Grazing and Eliminative Behavior of Horses Grazing Bermudagrass

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Abstract

Hummock patches of bermudagrass resulted from herbage growth stimulated by urinary N. Mares stopped grazing momentarily during urination, but defecated in motion, hence the spatial arrangement of hummocks reflected the pattern of grazing. Mares sought out and grazed down bermudagrass herbage growing over urine deposits in a classic patch grazing behavior, albeit the reciprocal of dogma. Grazing patterns indicate that mares used a strategy in line with foraging theory, i.e. they grazed hummocks because they could maximize energy intake with least expenditure of energy. The behavior of mares in the rotational grazing system refutes the concept that confinement and high stocking rates or stocking densities cause the "lawn and rough" landscape. In three years of grazing bermudagrass we never observed mares moving from areas of grazing to areas dedicated to urination and defecation, i.e. "latrine behavior". The amount of N and K excreted in as few as three urinary events per day over small area (each about 2 ft^2) was equivalent to broadcast applications of over 2.5 tons /A of urea fertilizer and 2 tons/A of KCL. Our data indicates that urination of grazing mares may contribute to nitrate and K in ground water in the absence of active pasture growth.

Profiling Sugars in Tall Fescue and Kentucky Bluegrass Extracts Assayed for Total Water- and Ethanol-Soluble Carbohydrates: Relationship of Chromatographic to Spectrophotometric Data.

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Abstract

Water-soluble carbohydrates (WSC) and ethanol-soluble carbohydrates (ESC) of herbage are often quantified by spectrophotometric assays. To determine if quantifying individual sugars from chromatograms could yield results comparable to those obtained by the assays, WSC and ESC were extracted from freeze-dried tall fescue (E+ and E-) and Kentucky bluegrass, profiled by high-performance liquid chromatography (HPLC), and quantified both from chromatograms and from standard spectrophotometric assays. The chromatograms demonstrated that ESC extracts contained mostly glucose and fructose. WSC extracts, before being hydrolyzed for the assay, contained glucose, fructose, and putative fructans. Hydrolysis removed the putative fructans and increased both glucose and fructose concentrations, indicating that glucans as well as fructans may have been present in the extracts. Quantifying WSC and ESC from peak areas on chromatograms yielded trends similar to those obtained by colorimetric assays.

Effects of feeding Soybean Hulls and Steroid Implants on Weight Gain and Physiology of Steers Grazed on Toxic Tall Fescue

Jessica Carter and Glen Aiken

Abstract

An endophyte (*Neotyphodium coenophialum*) that infests tall fescue (*Lolium arundinaceum*) produces ergot alkaloids that cause a malady collectively termed 'fescue toxicosis'. A two-yr grazing experiment was conducted with yearling steers grazed on toxic, endophyte-infected 'Kentucky-31' fescue to determine if feeding soybean hulls (SBH) can be combined with steroidal implantation to increase weight gain and mitigate the effects of toxicosis. Sixty-four steers were grazed from 7 May to 5 July in 2008 and sixty steers were grazed from 29 April to 24 June in 2009. Steers were assigned to six, 3.0-ha toxic fescue pastures. Treatments were assigned using a split-plot design, with the main plot treatment being with or without SBH, and the split-plot treatment being with or without ear implantation with steroid hormones (200 mg progesterone-20 mg estradiol), which were assigned to two subgroups within each pasture. Pelleted SBH were group-fed to provide daily consumption of 2.3 kg/steer (as fed). Unshrunk bodyweights were measured at initiation and termination of grazing. Jugular blood was collected on the final day of grazing for assaying serum prolactin. Hair coats also were rated on the final day as being rough, transitional, or sleek. Average daily gain was highest ($P < 0.05$) with the combining of SBH and implantation (1.23 kg/d), and was higher for SBH (0.95 kg/d) than for implantation (0.81 kg/d). Prolactin concentrations were not affected ($P > 0.10$) by steroid implants, but concentrations were greater ($P < 0.001$) with than without SBH. Similarly, there was no effect of implantation on hair coat ratings, but steers with SBH had a lower frequency of rough hair coat ratings (44%) than without SBH (61%). Results indicated that combining SBH with steroid implants can increase weight gain on toxic fescue, and that feeding SBH can reduce the severity of toxicosis.

Results of the 1st Year for a Grazing Evaluation of KYFA9302 Tall Fescue, With and Without the AR584 Novel Endophyte

Jennifer Johnson, G. Aiken, Tim Phillips, and Mike Barrett

Abstract

A wild-type endophyte (Neotyphodium coenophialum) that infests tall fescue (Lolium arundinaceum) imparts tolerances to environmental stresses, but also produces ergot alkaloids that adversely affect performance and physiology of cattle. Novel endophytes have been developed that do not produce toxic alkaloids. A 2-yr grazing experiment is being conducted to evaluate weight gain and physiology for yearling steers grazing a novel endophyte tall fescue, AR584-KYFA9301 (NE9301; not commercially released), in comparison with AR542-'Jesup' (MaxQ), endophyte-free KYFA9301 (EF9301), and wild-type 'Kentucky 31 (KY31) tall fescues. Entries were assigned to 1.0-ha pastures in a completely randomized design with three replications. Pastures were planted in September of 2006. Grazing with variable stocking (4 testers) was initiated in 2008 on May and terminated on July. Shrunk bodyweights were taken at the beginning and end of the grazing season. Rectal and skin temperatures were recorded on days 28, 56, and 77. Average daily gains were similar ($P < 0.05$) among MaxQ (0.87 kg/d), NE9301 (0.74 kg/d), and EF9301 (0.74 kg/d), which were greater ($P < 0.05$) than KY31 (0.57 kg/d). Rectal and skin temperatures among NE9301, EF 9301, and MaxQ were similar ($P > 0.10$), and these measures for the non-toxic entries were less ($P < 0.05$) than for KY31. Carrying capacities were similar ($P > 0.10$) among entries (431 ± 19 steer d/ha). Results in the first year indicated steer performance and body temperature responses for NE9301 and EF9301 were similar to those for MaxQ.