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Special Issue IGC 2013
Part 3

This issue of *Tropical Grasslands−Forrajes Tropicales* is the third "Special Issue IGC 2013" and comprises 58 selected poster papers on R&D topics, all related to the tropics and subtropics, that were presented at the 22nd International Grassland Congress, Sydney, 15-19 September 2013, in Congress sessions other than Session 1.2.1 ("Development and Impact of Sown Tropical Species").

It complements two previous Special Issues IGC 2013: The first, published in September 2013, is composed of all papers (2 keynote, 2 oral and 35 poster papers) presented in Session 1.2.1; and the second, published in December 2013, comprises 18 non-poster papers (1 plenary, 4 keynote and 13 oral papers) on R&D topics, again all related to the tropics and subtropics and selected from sessions other than 1.2.1.

This issue is also the result of an agreement with the International Grassland Congress Continuing Committee (www.internationalgrasslands.org), giving permission to co-publish the papers. The content of papers is essentially the same as that published in the Conference Proceedings. Any changes are the result of additional reviewing and adapting to the Journal's standards and style.

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Breeding strategies for *Brachiaria* spp. to improve productivity – an ongoing project

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Keywords: Apomixis, cultivar development, interspecific hybridization, signal grass.

Introduction

Two strategies have been used in the breeding of *Brachiaria* (syn. *Urochloa*) to produce new cultivars. The first involves exploring the natural variability existing in nature, which is the selection of ecotypes, mostly apomicts, from the diversity in germplasm banks. This strategy proved efficient originally and the cultivars in use in Brazil were derived in this way, but progress with this strategy is limited in the medium to long term.

The generation of novel variability through crossings is the alternative strategy to continue producing new improved varieties. This has been possible only through artificial chromosomal duplication of diploid and sexual *B. ruziziensis* and the fact that this species is cross-compatible with *B. brizantha* and *B. decumbens*, in Brazil the 2 most important species for tropical pastures.

Crossings between species have been carried out at Embrapa Beef Cattle, Campo Grande, MS, Brazil, since 1988 (Valle et al. 1993, 2001; Valle 1997; Resende et al. 2007). The initial success in obtaining interspecific hybrids in *Brachiaria* is indisputable and helped establish a practical methodology as well as allowed for the identification of apomictic parents with good combining ability. However, a comprehensive genetic improvement strategy to benefit from gains in quantitative characteristics associated with the majority of agronomic traits of economic interest in these species had not been started. Therefore, 3 methodologies are being used for this purpose: reciprocal recurrent selection; intra-population recurrent selection; and directed crosses between sexual and apomictic plants. The last 2 strategies are already underway and the strategies for agronomic evaluations are reported here.

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Methods

Intra-population recurrent selection

Twenty-one sexual progeny from agronomic evaluation of an experiment involving 1,000 individuals were recombined. Mode of reproduction was confirmed prior to planting to make sure all plants were sexual. The planting was done in December 2011, using previously prepared cuttings placed in an intercrossing area (Figure 1a) arranged in randomized blocks, with 8 replicates and square plots of 1 m x 1 m. This area was isolated physically and spatially to avoid external pollen contamination from apomictic plants. In addition, periodic maintenance of the crossing and surrounding areas was performed to eliminate possible compatible signal grasses, different from those that were being recombined.

Two harvests of seed were performed: second week of April, and first week of May 2012; and the half-sib progeny produced are now being evaluated in replicated plot experiments (Figure 1b). Dormancy of seed was broken and seeds were germinated in plastic tubes of 280 cm^3 in October 2012. For each progeny, 108 tubes were planted. After 75 days, 50 plantlets of each progeny were transplanted to the field in an experiment arranged in randomized blocks with 10 replicates; each plot contained 5 plants, spaced 1.5 m between rows and 1.5 m between plants within rows. In addition to the 21 progeny of half-sibs, 5 control varieties were used, resulting in 1,300 plants, which are being evaluated individually for leaf dry matter production, total dry matter production, leaf:stem ratio, regrowth capacity and nutritional value.

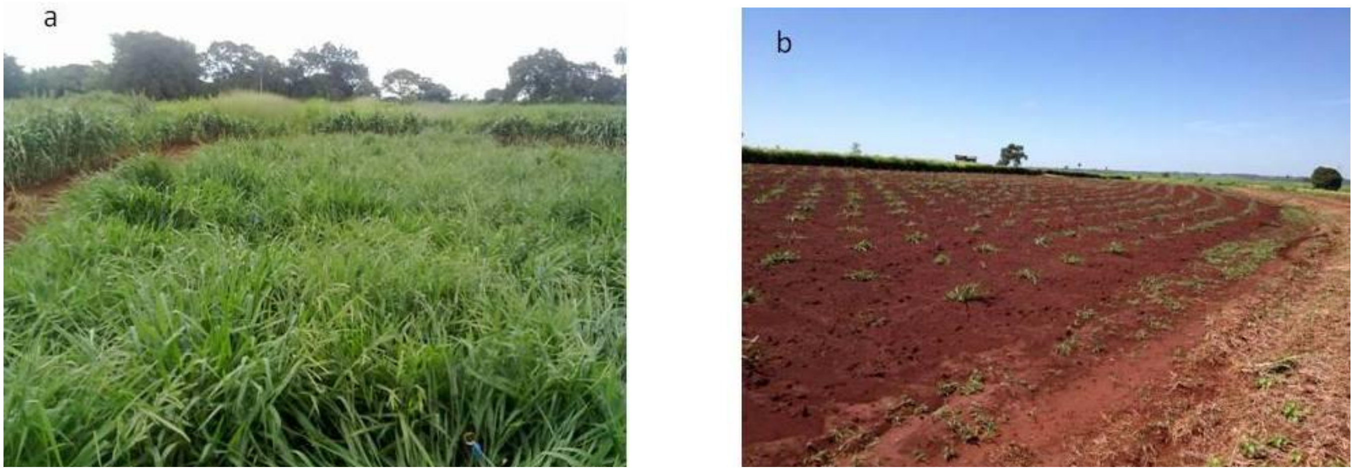

Figure 1. (a) Intra-population crossing block; (b) spaced plant half-sib progeny to evaluate individual plant performance.

Directed crosses between apomicts and sexuals

Crossings between 5 apomictic parents – *Brachiaria brizantha* (cvv. Marandu and Paiaguás, and B4), *B. decumbens* (cv. Basilisk) and the interspecific hybrid cv. Mulato II – and 4 sexual parents (BS09, BS15, HBGC336-T1 and HBGC336-T2) were made. These parents are divergent for characters of economic interest, such as: high productivity, resistance to spittlebugs, drought tolerance, tolerance of toxic aluminum levels and high nutritive value. The crossings were carried out both in the field and greenhouse, which resulted in successful production of all possible combinations. As for half-sibs, seed dormancy of these full-sib progeny was broken before seeds were germinated in tubes of 280 cm^3 at the beginning of October 2012. Again, 108 tubes per progeny were prepared. Seventy days after planting, the best 50 plantlets of each progeny were selected to be evaluated agronomically.

The experiment was arranged in randomized blocks with 10 replicates, each plot containing 5 plants, spaced 1.5 m between rows and 1.5 m between plants within rows. In addition to the 20 progeny of full-sibs, the 9 parents were planted as controls resulting in 1,450 plants, which are under evaluation for leaf dry matter production, total dry matter production, leaf:stem ratio, regrowth capacity and nutritional value.

The way forward

As the experiments were established between January 10 and January 16, 2013, only 2 harvests have been completed at the time of writing.

At least 7 harvests will be carried out (2 in the dry season and 5 in the rainy season) in order to select superior hybrids to continue breeding. It should be possible to estimate the number of half-sib progeny that are superior to the cultivars. In the case of full-sib progeny, in addition to the superiority in relation to parent material, estimates of heterosis and combining ability will be performed. In both groups of progeny, after selection for leaf dry matter production, total dry matter production, leaf:stem ratio, regrowth and nutritional value, the progeny will be subjected to selection for resistance to biotic (spittlebugs) and tolerance of abiotic (drought and flooding) stresses.

The sexual progeny selected by these strategies will be used to continue the intra-population recurrent selection program. Among the full-sibs, it is expected that half will be apomictic and the superior genotypes will be candidates for new cultivars.

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Herbage intake, methane emissions and animal performance of steers grazing dwarf elephant grass with or without access to *Arachis pintoi* pastures

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Keywords: Average daily gain, greenhouse gases, ingestive behavior, *Pennisetum purpureum.*

Introduction

The inclusion of legumes in diets based on grass has nutritional benefits due to ingestive and digestive interactions (Niderkorn and Baumont 2009). Moreover, it is speculated that tropical legumes can contribute to reducing the emission of greenhouse gases (GHG) compared with diets exclusively composed of grasses (Archimède et al. 2011). However, under grazing conditions, these advantages are not always possible to obtain. This occurs when the spatial distribution of sward grasses limits access to legumes by grazing animals (Solomon et al. 2011). This can be the case, for example, when legumes are overlapped by the leaves of a tufted tall grass like dwarf elephant grass (Crestani et al. 2013).

Considering that management strategies for increasing legume percentage in the diet of grazing animals should be investigated and data on enteric methane emitted by ruminants eating tropical forages are scarce, the aim of this work was to evaluate the effects on herbage intake, animal performance and enteric methane emissions of providing access to an exclusive area of forage peanut (*Arachis pintoi* cv. Amarillo) for cattle grazing dwarf elephant grass (*Pennisetum purpureum* cv. BRS Kurumi).

Methods

The experiment was conducted at Ituporanga, State of Santa Catarina, Brazil (approximate geographic coordinates 27°38' S, 49°60' W; 475 m asl). The assessments were conducted during 3 grazing cycles, from January to April 2012. The experimental treatments were: dwarf elephant grass heavily fertilized (150 kg N/ha as ammonium nitrate); and dwarf elephant grass intercropped with forage peanut plus an adjacent area of the legume which was allowed to be accessed by animals for 5 h/d, from 07.00 to 12.00 h. Each area was subdivided into 16 paddocks of approximately 400 m^2. Twelve Charolais steers, aged between 10 and 12 months and with an average weight of 213 ± 8.9 kg, were distributed in 4 groups, 2 per treatment. The animals were managed in a rotational grazing method with a herbage allowance of 6.0 kg of leaf DM/100 kg BW, and a fixed stocking rate, but a variable period of occupation.

Herbage intake was measured by the technique of n-alkanes (Mayes et al. 1986). To assess the average daily gain, animals were weighed before and after each grazing cycle, with previous fasting of solids and liquids for 12 hours. Grazing time was quantified by visual observations every 5 minutes from 07.00 to 19.00 h and every 10 minutes from 19.00 to 07.00 h. Whereas herbage intake and animal gain were measured in all 3 grazing cycles, enteric methane production was estimated by the technique of sulfur hexafluoride (SF6) (Johnson et al. 1994) in 2 grazing cycles only (February and March/April 2012).

Data were submitted to variance analysis using PROC MIXED (SAS 1996) considering repeated measures and using a model that included random effects of animals and the fixed effects of legume access, grazing cycle and the interaction between legume access and grazing cycle.

Results

There was no interaction between legume access and grazing cycle for any variable. Both average daily gain and

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herbage dry matter intake were higher (P<0.05), while time spent grazing in the morning and total grazing time were lower (P<0.001), for animals grazing legume pastures (Table 1). The daily methane emissions were higher (P<0.05) in animals grazing legume pastures, whereas methane emissions per kg DM intake and per kg LW gain were not affected by treatment.

Table 1. Herbage intake (during 3 grazing cycles), enteric methane production (during 2 grazing cycles) and animal performance of steers grazing dwarf elephant grass (*Pennisetum purpureum* cv. BRS Kurumi) with or without access to forage peanut (*Arachis pintoi* cv. Amarillo) pastures.

Parameter	Grass	Grass + peanut	RSD	P-value
Average daily gain/hd (kg)	0.70	0.97	0.174	<0.001
Herbage DM intake/hd				
(kg/d)	6.7	7.8	1.43	0.048
(% of body weight)	2.7	3.1	0.73	0.086
Methane production/hd				
(g/d)	146	180	23.5	0.009
(g/kg DM intake)	22.9	25.3	5.40	0.387
(g/kg LW gain)	254	230	64.2	0.415
Grazing time (min/d)				
Total	594	535	44.6	<0.001
Morning (6.00−12.00 h)	191	136	25.8	<0.001
Afternoon (12.00−18.00 h)	184	187	29.3	0.756
Evening (18.00−24.00 h)	151	155	13.4	0.372
Night (24.00−6.00 h)	68	57	12.3	0.025

Conclusion

Allowing steers grazing dwarf elephant grass access to forage peanut pastures can increase LW gains and grazing efficiency without increasing methane production per kg of DM intake or per kg of LW gain. Animals should reach slaughter weights at younger ages.

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Tropical Grasslands – Forrajes Tropicales (2014) Volume 2, 6−8

Developing methods to evaluate phenotypic variability in biological nitrification inhibition (BNI) capacity of *Brachiaria* grasses

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Keywords: Nitrous oxide emissions, ammonia mono-oxygenase (*amoA*), phenotyping, root exudates, brachialactone, *Brachiaria humidicola.*

Introduction

As part of the nitrogen (N) cycle in the soil, nitrification is an oxidation process mediated by microorganisms that transform the relatively immobile ammonium (NH_4^+) to the water soluble nitrate (NO_3^-), producing nitrous oxide (N_2O, a potent greenhouse gas) as a by-product (Canfield et al. 2010). Researchers at CIAT-Colombia, in collaboration with JIRCAS-Japan, reported that the tropical forage grass, *Brachiaria humidicola*, has the ability to inhibit the nitrification process by exuding chemical compounds from its roots to the soil. A major hydrophobic compound was discovered and named brachialactone (Subbarao et al. 2009). This capacity of *Brachiaria* grasses is known as biological nitrification inhibition (BNI) and could contribute to better N use efficiency in crop-livestock systems by improving recovery of applied N, while reducing NO_3^- leaching and N_2O emissions. The current methodologies for quantifying the BNI trait need enhancement to accelerate the process of identifying differences between genotypes.

In this paper, we aim to develop new (or improve the existing) phenotyping methods for this trait. Preliminary results were obtained using 3 different methods to quantify BNI: (1) a mass spectrometry method to quantify brachialactone; (2) a static chamber method to quantify N_2O emissions from soils under greenhouse conditions; and (3) an improved molecular method to quantify microbial populations by real-time PCR (polymerase chain reaction). Using these 3 methods we expect to apply scores to a bi-parental hybrid population (n=134) of 2 *B. humidicola* accessions differing in their BNI capacity, CIAT 26146 (medium to low BNI) x CIAT 16888 (high BNI), in an attempt to identify QTLs (quantitative trait loci) associated with the BNI trait.

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Methods

HPLC and GC-MS

For 24 hours, root exudates were collected from intact *Brachiaria* plants grown in a hydroponic system for 60 days after transplanting, using 0.5 L of aerated solutions of either NH_4Cl (1 mM) or distilled H_2O. BNI compounds were extracted by solvent partitioning using CH_2Cl_2. The organic fraction was collected and dried, while the residue was dissolved in CH_3OH and separated by HPLC (Agilent 1200 with DAD detector) using a Zorbax Eclipse XDB-C18 column (4.6 x 150 mm, 5 µ). Detection was performed at 230, 240 and 280 nm. The HPLC fraction from the sample collected in NH_4Cl at 35 min of retention time, was collected and mass spectra (MS) were recorded on a full scan mode using a GC (*AT* 6890 Series Plus), coupled to a MS (*AT* MSD5975 Inert XL).

Adaptation of a static chamber method for greenhouse gas (GHG) quantification

A method reported by Subbarao et al. (2009) for N_2O emissions was adapted, by completely covering the pots, where individual *Brachiaria* accessions were growing (Figure 2A), allowing the collection of N_2O gas manually with a syringe. For validation, 4 *Brachiaria* genotypes were evaluated for 5 weeks under greenhouse conditions with weekly measurements. In each measurement 4 gas samples were collected at 15 min intervals.

Improved molecular method to quantify microbial populations by real-time PCR

With the intention to diminish the error introduced by the differential soil DNA extraction efficiencies on individual samples for copy number quantification of *amoA* genes of ammonia-oxidizing bacteria and archaea through real-time PCR (Subbarao et al. 2009), a normalization method of soil DNA extraction reported by Park and Crowley (2005) was applied. Briefly, soil samples were spiked with known amounts of bacterial plasmid (pGEM-T easy® promega) as an internal standard, and DNA extraction was performed using the FastDNA SPIN for soil kit (MP Biomedicals).

Results

The results for the identification of brachialactone by HPLC and GC-MS are shown in Figure 1. Figure 2 illustrates the setup of the experimental procedure and presents the N_2O emissions, while Figure 3 shows the DNA quantification.

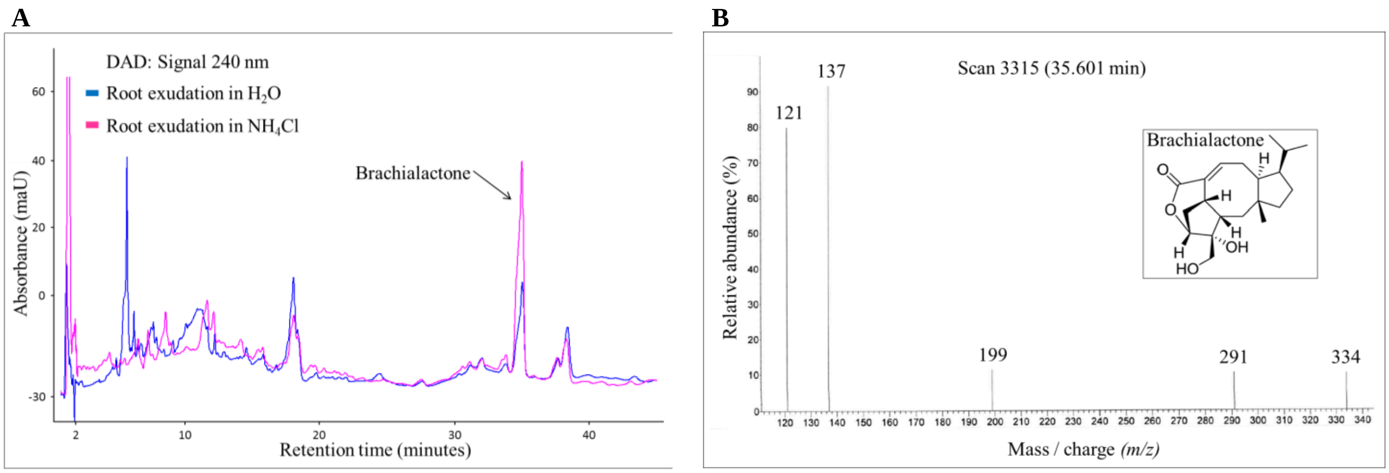

Figure 1. Identification of brachialactone from root exudates of *Brachiaria humidicola* by chromatography (HPLC) and mass spectrometry (GC-MS). A) Chromatogram of root exudates collected in aerated solutions of either NH_4Cl (1 mM) or distilled H_2O; putative brachialactone peak induced by NH_4Cl is indicated. B) Positive mass spectrum identification of brachialactone and its chemical structure.

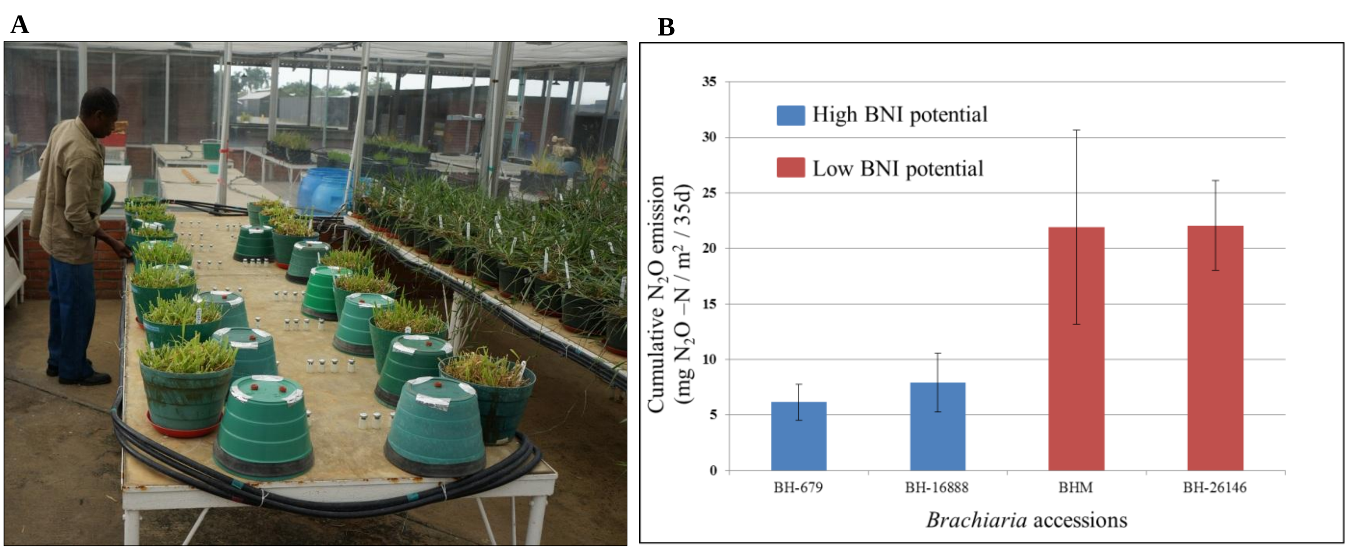

Figure 2. Static chamber method to quantify N_2O emissions from soil under greenhouse conditions: A) Setup of the experimental procedure with the caps used to hermetically seal pots containing *Brachiaria* plants; B) Cumulative N_2O emissions in 4 *Brachiaria* genotypes: BH-679 = *B. humidicola* CIAT 679 (standard cultivar Tully); BH-16888 = *B. humidicola* CIAT 16888 (a high-BNI capacity germplasm accession); BHM = *Brachiaria* hybrid cv. Mulato; and BH-26146 (a low-BNI capacity germplasm accession).

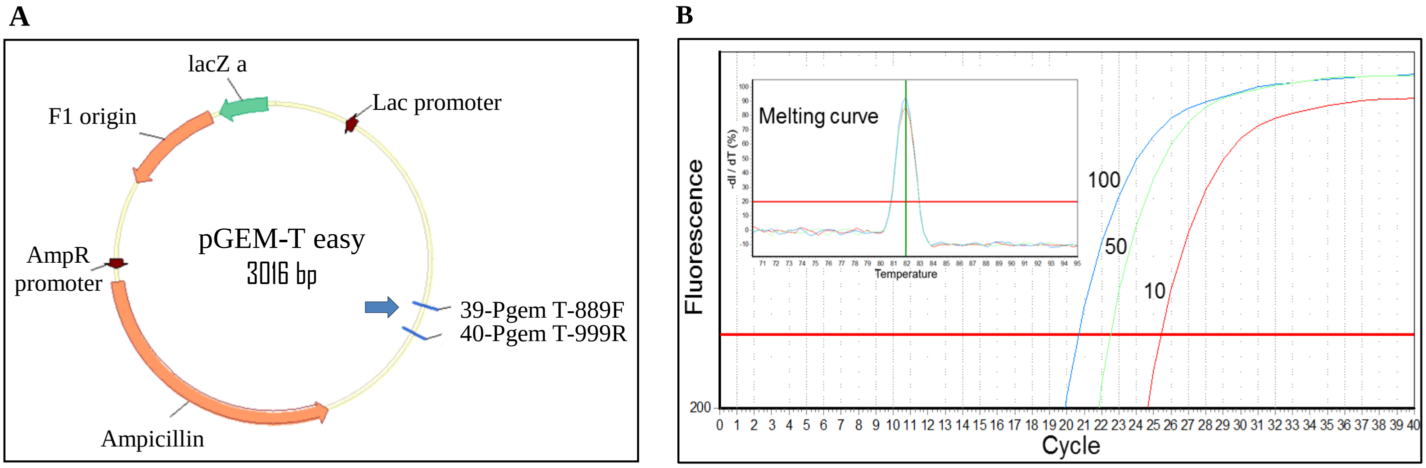

Figure 3. Normalization method for DNA extracted from soil to control different extraction efficiencies: A) pGEM-T easy map showing with the blue arrow the sequence used for normalization purposes; B) Quantification by real-time PCR of different amounts (100, 50 and 10 ng) of pGEM-T easy plasmid used as the internal standard in soil DNA extractions and the melting curve of the amplicons showing a specific amplification of a unique DNA sequence.

Discussion and Conclusions

The 3 phenotyping methods have shown distinct promise as a means of quantifying the BNI capacity of different species.

Positive identification of brachialactone (Figure 1) will allow rapid and precise estimation of the major BNI compound in *Brachiaria* grasses. Emissions of N_2O from *Brachiaria* genotypes under confined conditions (Figure 2) measured with the covered pot method, have been successfully validated using data reported in field experiments by Subbarao et al. (2009). This will streamline the examination of more plant accessions to determine how they influence N_2O emissions. Finally, the efficient normalization method (Figure 3) for quantification of DNA extracted from soil will overcome the problems associated with contaminants like humus, allowing more precise quantification of *amoA* genes in nitrifying microorganisms.

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Characterizing feeds and feed availability in Sud-Kivu province, DR Congo

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Keywords: Tropical forages, FEAST method, seasonality, livestock feeding.

Introduction

Animal husbandry in the Sud-Kivu province of the Democratic Republic of the Congo is gradually moving towards stall feeding, due to demographic pressure (Battistin et al. 2009) and scarcity of collectable forages (DSRP-RDC 2005). Therefore, lack of available feed is considered one of the main constraints faced by livestock production, especially in the dry season (Katunga et al. 2011; Maass et al. 2012). Unaffordable, fluctuating prices and scarcity of feed concentrates and the lack of improved forages adapted to marginal conditions, making them non-competitive with food crops, further exacerbate the livestock feeding situation. This study aimed to assess specific constraints and opportunities in the current feeding systems, as well as feed availability in this area.

Methods

Two main approaches have been followed to assess whether feed is one of the main limiting factors in livestock production and to arrive at possible solutions in a participatory manner. The first approach used the Feed Assessment Tool (FEAST) of Duncan et al. (2012) at 4 sites representing the agro-ecological conditions of Sud-Kivu. This tool consisted of 2 parts: (1) a Participatory Rural Appraisal (PRA) with 21−34 farmers per site, including all wealth categories, ages and gender of farmers; and (2) individual interviews to collect specific quantitative information from 9 households at each site.

The second approach involved 2 key informants per site, who showed the forage species usually fed to their animals. Morphological descriptions were conducted on these plants and their biotopes, before herbarium specimens were taken for identification.

Results

At all 4 sites, feed availability was strongly linked to rainfall pattern, with a great shortage during the dry season from May to September (Figure 1). Grazing (mostly by tethering) and collecting green forages from fields and roadsides were the dominant feeding systems. Only 37.1% of farmers cultivated forages on small areas, without further expansion because of lack of seeds and propagating material; cultivated forage contributed only 5.7% to the diet of animals.

Farmers gathered a wide variety of plants for feeding; overall, 93 different forage species belonging to 19 botanical families were identified. The most dominant families were Poaceae (41.8%) and Asteraceae (26.0%), essentially without improved forage species (Table 1).

PRA respondents proposed that their seasonal feed shortage problem may be overcome by identifying and adopting improved forages with high biomass yield and tolerance to drought stress. They also suggested that such forages could be planted on roadsides near the homestead, in banana plantations because of their microclimate, and on the edges of fields as contour bunds for additional erosion control. Planting adapted forages on sloping land, areas with low value for crop cultivation and otherwise degraded plots would substantially help to reduce fodder deficiency plus the collecting time (2 h/d), especially for women and youth who mostly carry out this activity.

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Table 1. Forage species by botanical families collected by farmers in Sud-Kivu.

Botanical family	Representation of forage species			
	Kalehe (No.)	Kabare (No.)	Walungu (No.)	General mean (%)
Poaceae	15	19	27	41.8
Asteraceae	8	11	19	26.0
Fabaceae	3	1	6	6.6
Convolvulaceae	1	2	2	3.4
Cyperaceae	3	1	0	2.7
Amaranthaceae	0	1	3	2.7
Musaceae	1	1	2	2.7
Others	6	5	9	14.1
Total	37	41	68	100.0

Unavailability of forage seeds or vegetative propagation materials was identified as a bottleneck to improving the feeding situation.

Conclusion

The identification of socio-ecological niches to increase fodder production, without compromising food crops, in the small farming areas operated by farmers of Sud-Kivu, who are traditionally agro-pastoralists, is considered of highest priority for future research.

Acknowledgments

We gratefully acknowledge the financial support by the Australian Agency for International Development (AusAID) under the Africa Food Security Initiative and through the partnership between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Biosciences eastern and central Africa (BecA) Hub at the International Livestock Research Institute (ILRI). All farmers of the study are appreciated for their unreserved participation and sharing their views.

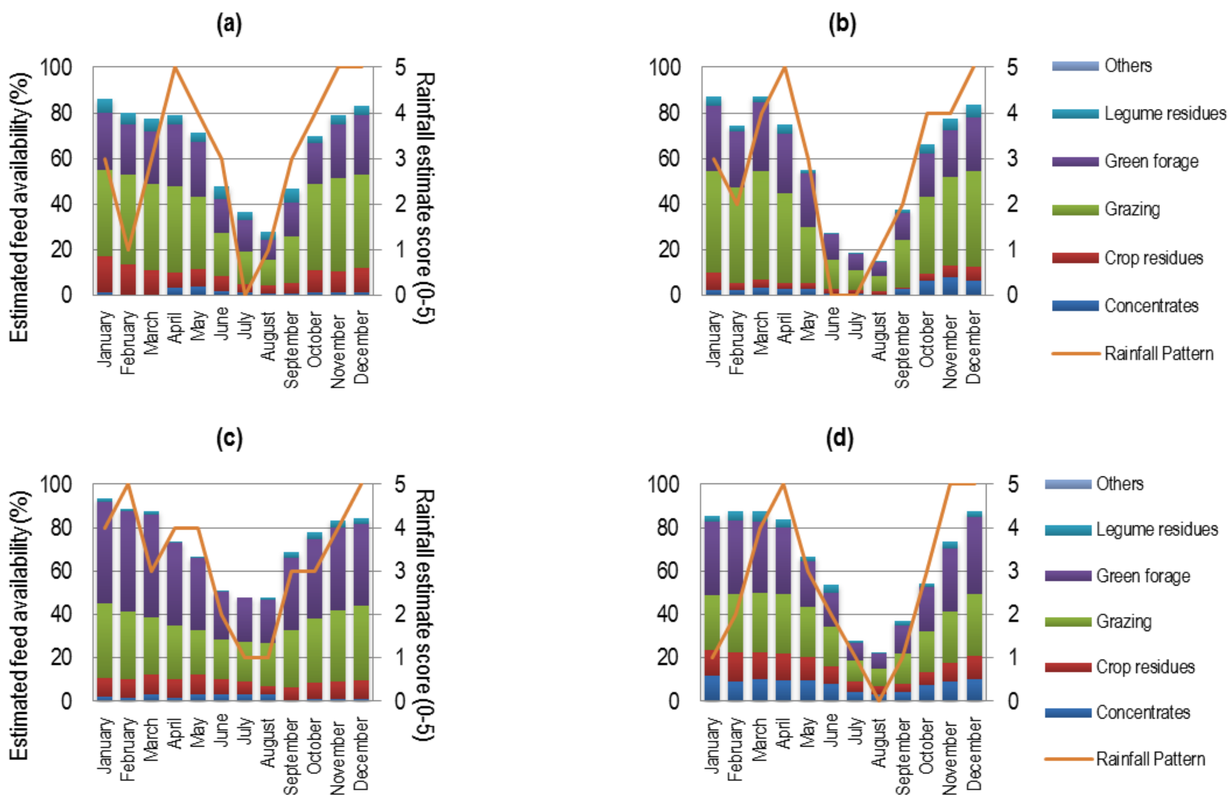

Figure 1. Feed resource availability throughout the year assessed by the FEAST method (Duncan et al. 2012) in: (a) Muhongoza – Kalehe territoire (02°04’ S, 28°53’ E; 1,585 m asl); (b) Cirunga – Kabare territoire (02°29’ S, 28°47’ E; 2,001 m asl); (c) Tubimbi – Walungu territoire (02°48 S, 28°35’ E; 1,073 m asl); and (d) Kamanyola – Walungu territoire (02°44’ S, 29°00’ E; 973 m asl).

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Phyllochron and leaf lifespan of four C4 forage grasses cultivated in association with trees

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Keywords: Morphogenesis, light interception, nitrogen, cutting frequency.

Introduction

Silvopastoral systems are emerging as an option for more sustainable land use. However, the challenge is to optimize pasture production and determine suitable management by understanding the growth and development of forages under tree canopies (Palma et al. 2007). In silvopastoral systems, trees change the environment under which forages grow, and can influence the development of plants and, consequently, sward dynamics. For instance, both light quantity (i.e. photon flux density) and quality (e.g. changes in red:far-red ratio) can be influenced by the tree canopy (Beaudet et al. 2011).

Phyllochron and leaf lifespan are morphogenic processes that control growth and development of plants by determining leaf area index and thus light interception by the sward (Lemaire and Chapman 1996). Both characteristics can be used as tools for pasture management and are influenced by management practices, like nitrogen fertilization. However, few studies have examined these characteristics for forages under a tree canopy (Paciullo et al. 2008), particularly when using light interception (LI) as a criterion for cutting frequency. Under full sun, rotational stocking using 95% canopy LI has been recommended for using C4 species to their fullest potential and to optimize ruminant weight gains on pastures (da Silva and Carvalho 2005).

The aim of our work was to determine the effects of shading (5-year-old plantation of *Eucalyptus dunnii*) and nitrogen availability on phyllochron and leaf lifespan of four C4 forage grasses in a subtropical environment, using the 95% light interception criterion to determine cutting frequency.

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Materials and Methods

The study was located at the Agronomic Institute of Paraná, Ponta Grossa, PR (25°07’22’’ S, 50°03’01’’ W). It examined 4 perennial C4 grasses (*Cynodon* hybrid Tifton 85, *Hemarthria altissima* cv. Florida, *Megathyrsus maximus* (syn. *Panicum maximum*) cv. Aruana and *Urochloa* (syn. *Brachiaria*) *brizantha* cv. Marandu) that are widely used in Brazilian cattle production, and are also recommended for use in silvopastoral systems (e.g. Soares et al. 2009).

The trees (*Eucalyptus dunnii*) were planted in 2007 in a double-row arrangement using 3 m between plants within rows and 4 m between rows, spaced 20 m apart (3 x 4 x 20 m) giving 155 trees/ha. The grasses were planted in pure stands in 2010 (4.5 m² in unshaded and 100 m² in the shaded area). Treatments were arranged in a split-split plot design, with 3 replicates. Shaded (i.e. system with trees) and unshaded conditions were the main plots, grass species were the subplots and 2 contrasting N levels (zero and 300 kg N/ha/yr; N0 and N300) were assigned to sub-subplots. The photon flux density was reduced on average by 34 ± 8.6% in the shaded area compared with the unshaded area. Forages were cut when light interception by the swards reached 95%. Rotational defoliation was simulated by mechanical cutting. Temperature was measured every 5 minutes during the experimental period (December 2011); in the shaded area, 3 thermometers, placed between the lines of trees, were used. Thermal time was calculated from the daily integration of air temperatures minus the base temperature (i.e. 10 ºC). To assess phyllochron and leaf lifespan, 4 measurements were done in 25 and 10 tillers per plot for shaded and unshaded areas, respectively, every 3-5 days, during 20 days in December 2011. The rate of leaf appearance was calculated by the linear regression between thermal-time (ºCd) and the number of visible leaves. Then phyllochron was calculated as the reciprocal of the rate of leaf appearance. The number of green mature leaves (GML) per tiller was recorded and the leaf life span was calculated by multiplying the number of GML per tiller by the phyllochron. Statistical analyses were performed using R software (www.r-project.org). The data were subjected to Analysis of Variance (ANOVA) and Tukey test for comparison of means.

Results and Discussion

Phyllochron for species growing under unshaded conditions (94.3 ± 36.23 ºCd) was lower than for species under trees (114.7 ± 33.87 ºCd). Therefore, shade reduced the rate of plant development, in contrast with the findings of Paciullo et al. (2008), who did not observe phyllochron changes in *Brachiaria decumbens* under *Eucalyptus grandis* canopy at 50% shade. Nitrogen fertilization reduced the phyllochron (114.9 ± 39.93 for N0 vs. 94.0 ± 29.22 for N300). Nitrogen is well known in the literature to accelerate plant growth and development (Paiva et al. 2012).

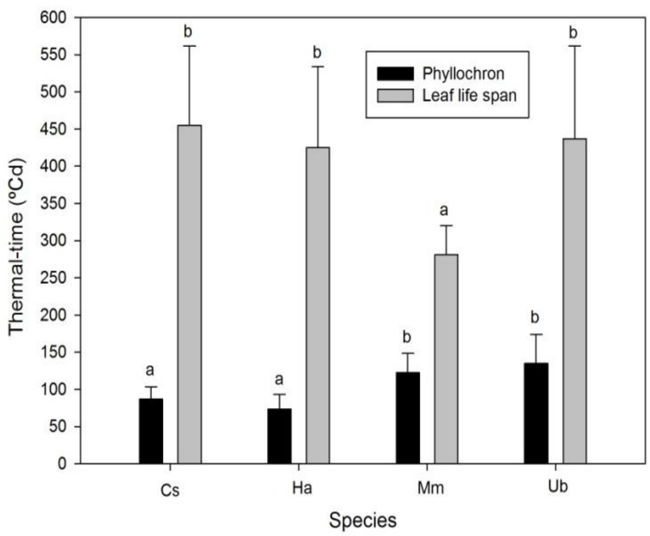

Figure 1. Phyllochron and leaf life span of four C4 grasses [*Cynodon* hybrid Tifton 85 (Cs), *Hemarthria altissima* cv. Florida (Ha), *Megathyrsus maximus* (syn. *Panicum maximum*) cv. Aruana (Mm) and *Urochloa* (syn. *Brachiaria*) *brizantha* cv. Marandu (Ub)]. Different letters indicate significant differences between species for phyllochron and leaf life span (P<0.05). Bars indicate the standard deviation.

Phyllochron differences between species were significant (Figure 1). Species with lower phyllochron, i.e. higher growth rate, showed higher numbers of green mature leaves (P<0.0001). However, no significant treatment x species interactions for phyllochron were observed (P>0.056).

Leaf lifespan for *M. maximus* (syn. *Panicum maximum*) cv. Aruana was shorter than for those of the other species (Figure 1). The mean daily temperature during the experimental period was 21 ºC, ranging from 12 to 32 ºC. On average, the leaf lifespan of all species was 352 ºCd. From this value and the mean daily temperature minus base temperature, an advisable cutting frequency of around 32 (days) was calculated for both unshaded and shaded conditions. Despite the same leaf lifespan and, consequently, a similar cutting frequency, the lower rate of development for species growing under shade could, however, affect the time for a sward to reach 95% light interception, commonly recommended as the indicator for a cutting or grazing decision.

Conclusions

Grass plants growing under tree canopy have a higher phyllochron than plants growing under full light, but this can be counteracted by application of N fertilizer. Differences in leaf lifespan between species would result in different optimal cutting frequencies, and this would be the same regardless of shading or N levels.

Acknowledgments

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Tropical Grasslands – Forrajes Tropicales (2014) Volume 2, 15−17

Morphological acclimation and canopy structure characteristics of *Arachis pintoi* under reduced light and in full sun

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Keywords: Forage legume, silvopastoral system, adaptation to shade, shade avoidance.

Introduction

Canopy structure is a key variable in determining the adaptive potential of forages and influences the radiation use efficiency (RUE) under different light conditions. The light extinction coefficient calculated from the Beer-Lambert formula (k) shows the canopy architecture and light interception patterns of plants and thus their potential ability to convert light energy (photosynthetically active radiation, PAR) into plant biomass (Hirose 2005). Under shade, forages may experience changes in plant morphology and canopy structure. Many authors have reported those changes and related them to modifications in light quantity and quality (Varella et al. 2011). The magnitude of these morphological changes may be a determinant in screening forages for shaded environments such as in silvopastoral systems.

The objective of this study was to determine the light interception patterns and extinction coefficients of *Arachis pintoi* under 2 artificial shading levels and to relate them to the adaptive potential of this legume for silvopastoral systems.

Materials and Methods

The experiment was conducted at Embrapa South Animal Husbandry and Sheep Research Centre located in Bagé, Rio Grande do Sul State, Southern Brazil from October 2009 to April 2011. It aimed to evaluate the light interception patterns and extinction coefficient (k) of *Arachis pintoi* (hybrid ecotype AGK12787 vs. NC1579 − Embrapa Cenargen) at 2 artificial shading levels (50 and 80% black shade cloth) and in full sun. The experimental design was a randomized block with 3 replicates. Additional methodological details were described by Barro et al. (2012). The leaf area index (LAI) was calculated from destructive samples collected in a 625 cm^2 quadrat. Each experimental unit grown with *A. pintoi* measured 2 m^2. The green herbage material was weighed and sub-sampled, followed by morphological separation into green leaf, stem and dead material. Total leaf area was measured using an optical planimeter (LI-3100, LICOR Inc.). The leaf area index was estimated using the equation: LAI = LA / S where: LA was the green leaf area of the sub-sample (cm^2) and S the soil sampled area (cm^2).

The photosynthetically active radiation (PAR) was measured with a ceptometer (Decagon model AccuPAR) prior to each cut. To determine both the incident PAR (PARi) and the transmitted PAR (PARt), ceptometer readings were made above and below the legume canopy, respectively. The PAR readings were taken between 11.00 and 13.00 h under clear sky conditions. The percentage of light interception (LI) was calculated as the amount of the intercepted PAR (PARi - PARt) divided by PARi and this result multiplied by 100. The light measurements were taken monthly over the experimental period.

The relationship between LAI and LI was fitted according to the model of light attenuation within the canopy, described by Monsi and Saeki (Hirose 2005). From the Beer-Lambert formula, k was determined using the regression model: $LI = LI\ max\ [1 - \exp(k \times LAI)]$ where: LI is the amount of PAR intercepted by the canopy, LI max is the asymptote of the curve for this exponential relationship and LAI is the leaf area index.

For the relationships between variables (LI and LAI), the data were submitted to a regression analysis at 5% probability level using the PROC REG feature of SAS (Statistical Analysis System, version 9.2).

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Results and Discussion

While growth under moderate shade (50%) was similar to that under full sunlight, 80% shading significantly ($P<0.05$) reduced total dry matter yield (DMY) of *A. pintoi* (Table 1). There was insufficient light energy under 80% shade to support high growth, as indicated by LAI and DMY data.

The relationship between LI and LAI was adjusted to different exponential models, according to shade levels, and results are shown in Figure 1. The light extinction coefficient (k) was determined from these regressions and based on the interpretation of their biological responses and by examining the confidence intervals generated. Whenever k (slope of equation) was in the same confidence interval, the relationships were expressed by a single regression for different shading levels. In this study, after reaching the critical LAI level (95% LI), *A. pintoi* leaf area continued increasing at constant-maximal levels of LI (Figure 1). Results indicated similar k values for plants grown under both 50% and 80% shading levels (Figure 1), showing that no structural changes occurred in the legume canopy. However, under 80% shading, LAI was the lowest of all treatments and this was probably related to lower forage yields associated with this intense level of shading (Barro et al. 2012).

Equal values of k (Figure 1) were obtained for 50 and 80% shading levels (k = 0.915), which indicated that structural changes occurred in the legume canopy in comparison with the full sun treatment where the k value was significantly lower (k = 0.536). This response confirmed that *A. pintoi* adapted well to shade by reducing leaf angle and by structuring a planophile canopy to intercept more light.

Conclusions

The light extinction coefficients under shade differed from those under full sunlight, showing adaptation of *A. pintoi* by decreasing canopy angle. While growth was strongly reduced under heavy shade (80% sunlight restriction), *A. pintoi* showed potential to grow under moderate shade. This has implications for use of this legume in different types of silvopastoral systems and at different stages of development of the trees.

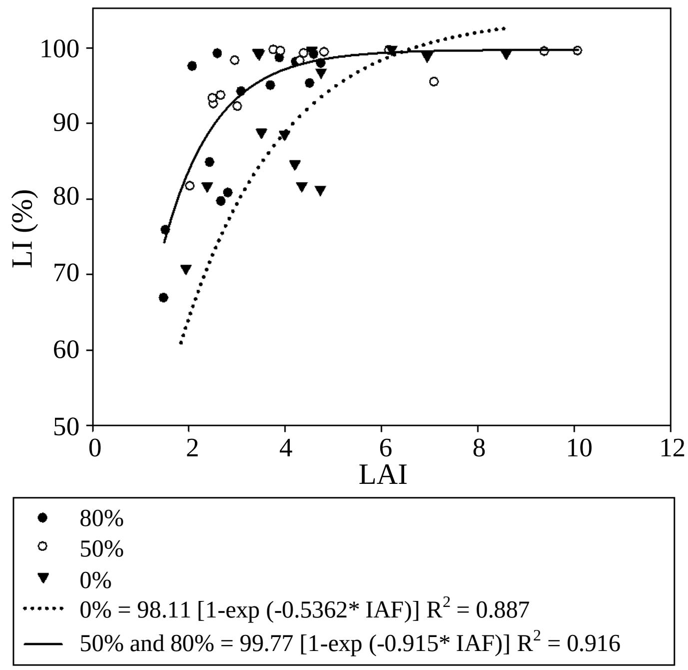

Figure 1. Relationship between leaf area index (LAI) and light interception (LI) of *Arachis pintoi* growing in full sun (▼) and under 50% shade (○) and 80% shade (●) in Bagé, RS.

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Table 1. Leaf area index (LAI), specific leaf area (SLA, cm^2/g), light interception (LI, %) and dry matter yield (DMY, g/m^2) of *Arachis pintoi* under heavy shade (80% shade cloth), moderate shade (50% shade cloth) and in full sunlight (0% shade). Data are averages of 10 evaluations conducted from November 2009 to April 2011.

Shading level	LAI	s.e.	SLA	s.e.	LI	s.e.	DMY	s.e.
0%	4.5 ab[1]	0.48	243.3 a	12.0	89 b	1.7	655.4 a	33.0
50%	5.3 a	0.48	255.4 a	12.0	96 a	1.7	613.0 a	33.3
80%	3.5 b	0.54	257.0 a	13.0	92 ab	1.7	394.6 b	33.0

[1]Values within columns followed by the same letters differ at P<0.05.

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Tropical Grasslands – Forrajes Tropicales (2014) Volume 2, 18−20

Dry matter yield of promising *Panicum maximum* genotypes in response to phosphorus and lime on Brazilian savanna

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Keywords: Cerrado, fertilizer, guinea grass, pasture, tropical grass.

Introduction

Soil fertility of the Brazilian savanna (Cerrado) is naturally poor. Extensive areas of pastures located in the central part of the territory are cultivated with *Brachiaria* grasses, which are less demanding for soil nutrients and lime than other species (Rao et al. 1998). On the other hand, *Panicum maximum* cultivars, such as the high yielding Mombaça grass recommended for intensive beef and dairy cattle systems (Euclides et al. 2008), must be seeded with a higher amount of fertilizer, especially phosphorus (P). Consequently, an effort is underway to select *P. maximum* genotypes with low P demand and high responsiveness. The objective of this study was to evaluate dry matter yields of genotypes of *P. maximum* in response to doses of P and lime in the Brazilian Cerrado.

Methods

The trial was conducted at Planaltina, Federal District, Brazil (15°35' S, 47°42' W; 1,007 m asl) from January 2012 to March 2013. Local annual rainfall averages 1,230 mm, concentrated between October and March. The soil of the area is classified as Oxisol with pH 4.2; P (Mehlich-I) 0.33 mg/dm^3; Ca 0.96 cmol$_c$/dm^3; Mg 0.54 cmol$_c$/dm^3; K 0.28 cmol$_c$/dm^3; base saturation 21%; and Al saturation 24%.

The promising *Panicum maximum* accessions PM32, PM34, PM39 and PM40 and cvv. Mombaça and Massai were evaluated with 3 rates of P (0, 25 and 175 kg/ha) and 2 levels of lime. The experimental design was completely randomized in a split-plot arrangement with 3 replications, with P allocated in the plots and genotypes in the subplots (2.5×3.5 m). The trial was replicated in 2 separate areas to evaluate 2 levels of dolomitic lime (1.6 and 3.2 t/ha), applied on 25 November 2011. Lime treatments were estimated to raise base saturation (BS) to 35% and 50%, respectively. Plots were fertilized with P (triple superphosphate) and seeded after tillage on 13 January 2012 in lines spaced 0.5 m apart.

Dry matter yield (DMY) was determined by cutting the forage at 20 cm from soil level. Harvests were done on 20 March 2012 (for 175 kg/ha P); 26 April 2012 (for 25 and 175 kg/ha P); and for all P levels on 11 July 2012; 03 December 2012; 30 January 2013; and 25 March 2013. On plots not harvested in March and April 2012, sward height did not exceed 20 cm. A total of 100 kg N and 83 kg K/ha were applied as 2 equal dressings on 20 March 2012 and 03 December 2012. DMY data were analyzed separately for the establishment (first 3 harvests) and maintenance (last 3 harvests) phases. Analysis of variance was performed using PROC GLM (SAS 1996) and comparison of genotype means using the Tukey test ($P<0.05$).

Results and Discussion

During the establishment period, DMY was affected by genotype and P for both lime rates ($P<0.05$; Table 1), with no significant interaction ($P>0.05$). No cultivar or accession produced viable yields in the absence of P fertilizer, as was also reported by Guedes et al. (2012). All accessions and cultivars responded well to P fertilizer at both BS levels. Cultivar Mombaça, PM32, PM34 and PM40 were the most productive genotypes during the establishment phase.

For the maintenance phase, there was a significant ($P<0.05$) genotype × P effect on DMY for BS 35% (Table 2). At all P levels, cv. Massai produced the highest yields but these were not always significantly greater than those of the other accessions. Obviously, cv. Massai has a low demand for P but responds well to P applica-

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tions. All accessions produced high yields at the highest P level (3,000–4,900 kg/ha). Only genotype (P<0.05) and P (P<0.05) effects were detected on DMY for BS 50%, which is the target usually recommended for *P. maximum*. During this phase, cv. Massai produced approximately 1,000 kg more forage than the other accessions.

Once established, all accessions produced useful DMYs in the absence of applied P, especially at BS 50% (Table 2). Although Mombaça, PM32, PM34 and PM40 were considered to be less P demanding than PM39 and cv. Massai in the establishment phase, all genotypes required P to achieve rapid regrowth. When pastures were established, all accessions required P to produce acceptable yields regardless of lime status. While PM39 was slow to establish, once established it produced high yields, as did PM32.

Table 1. Effects of P fertilizer level and base saturation (BS) on dry matter yields (kg/ha) of *P. maximum* genotypes during the establishment phase (first 3 harvests; January–July 2012).

P (kg/ha)	cv. Mombaça	PM32	PM34	PM39	PM40	cv. Massai	Mean
			BS 35% (1.6 t lime/ha)				
0	37	17	4	*	7	5	14C
25	2,575	2,306	2,258	1,025	1,694	765	1,919B
175	4,159	4,262	3,359	2,283	3,687	3,436	3,781A
Mean	2,257a[1]	2,195ab	1,874ab	-	1,796ab	1,402b	
CV = 7.3%							
			BS 50% (3.2 t lime/ha)				
0	312	83	60	23	133	40	109C
25	1,976	2,202	1,567	777	1,474	1,124	1,520B
175	4,050	3,469	3,120	2,696	3,685	3,072	3,349A
Mean	2,113a	1,918ab	1,582ab	1,165b	1,764ab	1,412b	
CV = 15.5%							

[1]Means followed by the same lower-case letter within rows and upper-case letter within columns did not differ by Tukey test (P>0.05). * No forage above 20 cm (not analyzed).

Table 2. Effects of P fertilizer level and base saturation (BS) on dry matter yields (kg/ha) of *P. maximum* genotypes during the maintenance phase of regrowth (last 3 harvests; July 2012–March 2013).

P (kg/ha)	cv. Mombaça	PM32	PM34	PM39	PM40	cv. Massai	Mean
			BS 35% (1.6 t lime/ha)				
0	826Bab[1]	597Bb	691Bb	218Bb	693Bb	1,805Ba	840
25	2,877Ab	3,384Aab	3,820Aab	3,426Aab	3,048Ab	4,382Aa	3,490
175	3,073Ac	4,233Aab	3,584Abc	4,074Aabc	3,554Abc	4,910Aa	3,905
Mean	2,259	2,738	2,699	2,867	2,432	3,699	
CV = 13.0%							
			BS 50% (3.2 t lime/ha)				
0	1,727	1,637	1,554	982	1,525	2,069	1,582C
25	2,507	3,413	3,316	3,379	2,990	4,494	3,350B
175	3,225	3,616	3,706	4,068	3,499	5,177	3,882A
Mean	2,486b	2,889b	2,859b	2,810b	2,671b	3,913a	
CV = 17.7%							

[1]Means followed by the same lower-case letter within rows and upper-case letter within columns did not differ by Tukey test (P>0.05).

Conclusion

All genotypes benefitted from P fertilizer during both the establishment and maintenance phases. They need adequate P to sustain high yields. Cultivar Massai could be considered both less demanding of and more responsive to P after the establishment phase.

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Adaptive responses of *Brachiaria* grasses to hypoxia stress

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Keywords: Aerenchyma, alcohol dehydrogenase, oxygen deficiency, tropical forage grasses.

Introduction

It is likely that oxygen shortage in waterlogged soils is the most limiting factor for plant growth, restricting root aerobic respiration and adenosine triphosphate (ATP) production (Vartapetian and Jackson 1997). When oxygen becomes limiting for oxidative phosphorylation, plant cells depend on alternative metabolic pathways to produce ATP (Rocha et al. 2010). The induction of fermentative metabolism is considered of adaptive value to maintain ATP production under oxygen-limited conditions. Ethanol is the main end product of fermentative metabolism in plants. Alcohol dehydrogenase (ADH) is a key enzyme in ethanolic fermentation. Roots can sustain aerobic respiration under oxygen deficiency if aerenchyma is present. Aerenchyma commonly refers to tissue containing air-filled spaces that provide oxygen under oxygen-limited conditions (Colmer and Voesenek 2009). The main objective of the present study was to determine morpho-physiological adaptive responses of 7 *Brachiaria* genotypes to hypoxia stress.

Materials and Methods

The material used in this study included 7 *Brachiaria* genotypes with different levels of known waterlogging tolerance: tolerant *B. humidicola* cvv. Tully and Llanero (accessions CIAT 679 and CIAT 6133, respectively); moderately tolerant *B. decumbens* cv. Basilisk (CIAT 606) and *B. brizantha* cv. Toledo (CIAT 26110); and sensitive *B. brizantha* cv. Marandu (CIAT 6294), *B. ruziziensis* (Br 44-02) and *Brachiaria* hybrid cv. Mulato II (CIAT 36087). Vegetative propagules were used for experiments. After 8 days of rooting in low ionic strength nutrient solution (Wenzl et al. 2003), 12 propagules of each genotype were selected for homogeneity and placed in 12 L plastic containers (6 plants of each genotype per container) with renewed nutrient solution and grown under aerated or hypoxic conditions. Hypoxia was achieved by previously flushing N_2 through the solution for 4 hours. Agar (1% w/v) was added to the hypoxic nutrient solution to simulate lack of gas convection in waterlogged soils (Wiengweera et al. 1997). Containers were arranged in a completely randomized design. Two harvests were made at 3 and 10 days of growth and roots were separated from shoots. To examine root ADH, root samples were collected from the first 4 cm from the root tip. The remaining root segments were placed in 50% ethanol solution for later use. ADH activity was measured according to Bergmeyer (1974). Roots conserved in ethanol solution were used for quantification of aerenchyma development. Three roots were randomly selected and cross-sections were taken at 1 cm from the root base. Cross-sections were viewed under a light microscope equipped with a digital camera (Nikon, Coolpix 4500, Osaka, Japan). The percentage of aerenchyma (expressed per unit cross-sectional area) in each digital picture was determined using ImageJ software (version 1.41, National Institutes of Health, Bethesda, USA).

Data were analyzed to generate mean values, standard deviation and analysis of variance (ANOVA) using R (v. 2.15.2). Log transformation was carried out to ensure normality of data. Differences between genotypes were analyzed with the least significant difference (LSD) at $\alpha=0.05$ and $\alpha=0.01$.

Results and Discussion

Plants grown under hypoxic conditions for 3 and 10 days had higher values of root ADH activity on average than plants grown under aerated conditions, but there were no significant differences among treatments or genotypes (Figure 1). Root ADH tended to decrease with time under hypoxic conditions. Growth under hypoxic conditions resulted in higher root aerenchyma formation than in aerated plants after 3 days ($P<0.05$) with further increases ($P<0.05$) by 10 days, and the extent was greater in tolerant genotypes (Figure 1). Lower values of root ADH after 10 days compared with 3 days of growth under hypoxic conditions suggest that O_2 diffusion in roots was presumably improved by increased formation of root aerenchyma.

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Conclusions

This study suggests that roots of *Brachiaria* grasses grown under hypoxic conditions experience an increase in ethanolic fermentation irrespective of known tolerance level to waterlogging. However, root ADH was not a good indicator of waterlogging tolerance in *Brachiaria* grasses and may not serve as a useful screening procedure for evaluating tolerance of hypoxia/waterlogging. Increased aerenchyma improves internal root aeration to sustain root aerobic respiration under oxygen-deficient conditions. The most waterlogging-tolerant genotypes (*B. humidicola* CIAT 679 and CIAT 6133) developed more aerenchyma in roots, but differences among less-tolerant genotypes could not be explained by this mechanism alone. Even with aerenchyma present, it is likely that root tips will experience some degree of O_2 deprivation (Colmer and Voesenek 2009). This suggests that the presence of both adaptive responses, namely increased root ADH and aerenchyma formation, may contribute to the fitness of *Brachiaria* grasses under oxygen-deficient conditions. Increased aerenchyma formation may contribute to longer-term tolerance of hypoxic conditions.

Acknowledgments

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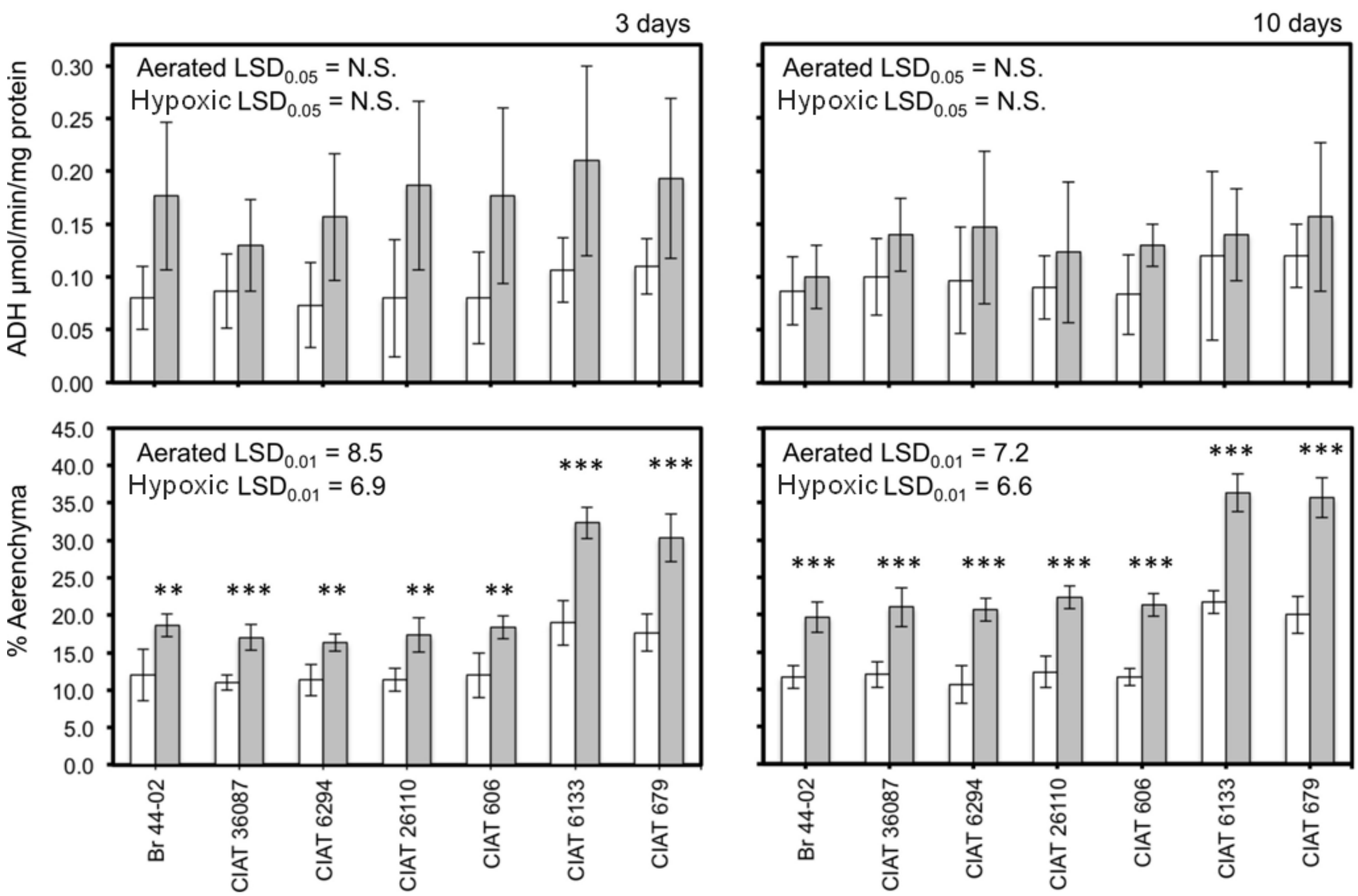

Figure 1. Differences in root ADH activity and aerenchyma formation among 7 *Brachiaria* genotypes grown under aerated (□) or hypoxic (■) conditions after 3 and 10 days of growth. Columns represent means, and error bars, their standard deviation. **, *** represent significant differences between treatments at $\alpha<0.05$ and 0.01, respectively; N.S., not significant.

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Forage yield and quality of *Leucaena leucocephala* and *Guazuma ulmifolia* in tropical silvopastoral systems

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Keywords: Forage trees, legumes, nutritive value, NDF, ADF.

Introduction

Low availability and quality of pastures during the dry season are common problems in tropical livestock production systems. However, several studies indicate that the use of trees and shrubs is a good alternative to overcome those problems (Ku-Vera et al. 1999), by producing foliage of higher nutritional value than that of forage grasses. In addition, their use could contribute to reforestation and restoration of degraded land (Casanova-Lugo et al. 2010).

While several recent reports have focused on the incorporation of *Leucaena leucocephala* in silvopastoral systems (Murgueitio et al. 2011), there is little information about other tropical tree species with high forage production potential, such as *Guazuma ulmifolia*, which is broadly used in Southeast Mexico. In addition, little is known about the effect of season on forage quality of these species under a particular management regime.

Therefore, the aim of this study was to evaluate the yield and forage quality of *L. leucocephala* and *G. ulmifolia* in the subhumid tropics during the dry and rainy seasons.

Methods

The experiment was undertaken at the Campus of Biological and Agricultural Sciences, University of Yucatán (UADY), in the Yucatán Peninsula, Mexico, from January to December 2009. Average annual rainfall is 953 mm and average annual temperature 26 °C. The area is located within a karst plateau characterized by a flat or gently rolling relief. Soils are shallow, heterogeneous, rocky (limestone) and clay-loam, with a pH of 7.5 to 7.8 (Bautista et al. 2005).

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In 2004, seedlings of *L. leucocephala* and *G. ulmifolia* were planted within 5 x 10 m plots (experimental unit), in rows 2.0 m apart and with 0.5 m between plants. A complete randomized block design with 3 replicates was used. Before starting the current experiment, a standardization pruning at 1 m height was performed. During the dry season, drip irrigation was applied for 3 hours in the mornings, twice per week. Ten plants of all species, within each experimental unit, were pruned to a height of 1.0 m at 3-month intervals (2 prunings per season). After each pruning, the biomass was collected and separated into edible and non-edible material. Three samples were taken from the edible portion (leaves and tender stems) of both species, approximately 1 kg each, and were dried at 60 °C in a forced-air oven until constant weight. Dry forage subsamples (leaves and tender stems) were ground and analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) using an ANKOM (Macedon, NY) A200 fiber analyzer. Crude protein (CP) was estimated using a Leco CN 2000 elemental analyzer (N × 6.25). Dry matter digestibility (DMD) was estimated based on ADF concentration, according to Ayala-Burgos et al. (2006).

Forage yield data were analyzed with a one-way ANOVA to examine the effect of season. For chemical composition, a multivariate analysis of variance (MANOVA) was used, with a PROC GLM (SAS Institute). Where significant differences were found, means were compared using Tukey's statistic ($P \leq 0.05$).

Results and Discussion

Forage yield, CP concentration and DMD of *L. leucocephala* showed no significant changes over the 2 seasons, with average values of 3.45 t DM/ha, 22.8% and 66.7%, respectively. However, the concentrations of NDF and ADF were greater during the rainy season (Table 1). In contrast, forage yield and NDF of *G. ulmifolia* were higher in the rainy season than in the dry season, while the reverse occurred with ADF (Table 1). However, CP concentration of *G. ulmifolia* (14.5% on average) and DMD (65.9%) were not influenced by season.

Table 1. Edible forage yield and quality of *L. leucocephala* and *G. ulmifolia* during the dry and rainy seasons in Yucatan, Mexico.

Season	Yield (t DM/ha)	CP (%)	NDF (%)	ADF (%)	DMD (%)
			Leucaena leucocephala		
Dry	3.5	22.2	41.3 b[1]	23.8 b	70.2
Rainy	3.4	23.4	49.0 a	32.8 a	63.2
s.e.	0.55	5.65	3.75	8.50	7.23
			Guazuma ulmifolia		
Dry	3.7 b	15.0	44.0 b	33.6 a	62.4
Rainy	5.3 a	14.0	47.2 a	24.8 b	69.4
s.e.	0.65	3.2	3.23	5.42	4.30

[1]Means within columns and species followed by different letters are significantly different (Tukey's statistic).

Woody species have different capability to take advantage of good conditions in the wet and to combat dry conditions; some show high biomass production in the dry in spite of the water limitations, as was the case for *L. leucocephala*, while others show a decline in production, as suggested by Tamayo-Chim et al. (2012). A reduction in photoperiod and air temperature coincides with the end of the rainy season, which reduces growth despite the availability of adequate soil moisture. *G. ulmifolia* seemed capable of utilizing the favorable conditions in the rainy season to produce high DM yields, but showed lower growth in the dry season, while *L. leucocephala* maintained a similar level of growth throughout. Some rain was recorded in the dry season, although erratic and of short duration; this was sufficient to promote plant growth as temperature and photoperiod were appropriate for a response to available soil moisture.

These two facts, the ability of *L. leucocephala* to search for limited soil-water and some rainfall events during the dry season, could explain the fact that this legume had similar behavior in both seasons. Moreover, important nutritional parameters, such as CP and DMD, were not affected by season, possibly due to the ability to maintain high reserves of C in the tissues (Lizárraga et al. 2001). However, *L. leucocephala* fiber (NDF and ADF) concentrations during the rainy season (almost 19% higher than in the dry season) could be due to the high and rapid regrowth ability of this legume, and the long pruning interval (3 months) used in this study. In contrast, *G. ulmifolia* developed more slowly than *L. leucocephala* and, therefore, the pruning interval could have been more appropriate for this species than for *L. leucocephala*. As a consequence, fiber content was less affected by season than in the case of *L. leucocephala*.

Conclusions

Both *L. leucocephala* and *G. ulmifolia* showed potential for production of high quality forage in Mexico. While *L. leucocephala* can maintain good forage yield throughout the year, growth of *G. ulmifolia* declines during the dry season. However, total DM production favored *G. ulmifolia,* although the crude protein concentration of *L. leucocephala* forage was higher in both seasons. Further research is needed to determine the appropriate interval between prunings for the individual species.

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Tropical Grasslands – Forrajes Tropicales (2014) Volume 2, 27−28

Accumulation of dry matter and morphological composition of irrigated Mombaça grass with and without nitrogen fertilizer under grazing

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Keywords: Leaf blade, fertilization, forage, *Panicum maximum*.

Introduction

Brazil has the largest commercial cattle herd in the world and is the world's leading exporter of fresh and processed meat. Beef production is based on pastures and the production system is influenced by the absence of fertilization and the seasonality of forage production during the year, caused mainly by variation in temperature, rainfall and sunlight hours. Nitrogen (N) is the most important element for the development and growth of grasses, since it accelerates the formation and growth of new leaves, and improves regrowth vigor, resulting in greater production and carrying capacity of pastures (Cecato et al. 2011). The present study aimed to quantify the accumulation of dry matter and percentage of leaf blade of irrigated Mombaça grass (*Panicum maximum* cv. Mombaça) at 4 N fertilizer levels, under intermittent grazing.

Methods

The work was conducted in the northwest of Paraná, Brazil (22°50'16" S, 51°58'22" W; 410 m asl). The soil is classified as Oxisol of sandy texture (Embrapa 2006). A split-plot design with blocks of Mombaça grass (*Panicum maximum* cv. Mombaça) with 4 replications was used. As main plot, 4 levels of N fertilizer were imposed: 0 (control), 200, 400 and 800 kg N/ha/yr; the seasons of the year were the subplots. The nitrogen was applied after grazing in split applications according to the number of grazings per treatment, with 4, 7, 9 and 10 grazing cycles, respectively, for 0, 200, 400 and 800 kg N/ha/yr. The pasture was irrigated with 80 mm per month. A rotational stocking method with crossbred dairy cows was used, with animals entering when the pasture reached 95% light interception and being removed when the pasture's residue was 40 cm high. To determine dry matter (DM) production, 6 samples of 1 m^2 per paddock were cut to ground level before grazing commenced. The harvested forage was dried and herbage accumulation calculated as the difference in available DM before and after grazing. The percentage of leaf blade was determined by separation of the morphological components into leaf, stem and dead material. Results were expressed on a seasonal basis (spring, summer, autumn and winter). The data were analyzed by the statistical analysis system (SAS 2002).

Results and Discussion

Accumulation of DM was highest in summer at all N levels, with the other seasons generally following in order spring, autumn and winter (Table 1). In general, DM accumulation increased linearly as N fertilizer level increased; this was also reported by Freitas et al. (2005), Moreira et al. (2005) and Fagundes et al. (2006).

In all seasons, fertilizing with N increased the average Lf % (percentage of leaf blade). However, overall Lf % was higher in summer, spring and autumn than in winter, independently of N fertilization. The lowest Lf % occurred in non-fertilized plants, independently of the season, and in winter, independently of the dose of N. This result shows the importance of using N at times with appropriate weather conditions to influence the number of leaves and the rate of elongation, and consequently the production of pasture DM (Cecato et al. 2011).

Conclusions

Application of N fertilizer is a useful management tool to increase both available dry matter and the percentage of leaf in the available forage. Manipulation of fertilizer usage to suit particular seasons is a valuable way to obtain optimum responses.

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Table 1. Accumulation of dry matter and percentage leaf blade (± SD) of irrigated Mombaça grass with and without N fertilizer under grazing, for the various seasons of the year.

Season	Nitrogen (kg/ha/yr)				Mean
	0	200	400	800	
		Accumulation of dry matter (t DM/ha)			
Spring	2.89±0.22 Db[1]	6.53±0.29 Cb	10.17±0.18 Bb	17.45±0.59 Ab	9.25±5.60
Summer	4.23±0.26 Da	8.11±0.23 Ca	11.99±0.17 Ba	19.75±0.48 Aa	11.05±5.98
Autumn	2.51±0.48 Cb	4.45±0.32 Bc	6.46±0.30 Ac	6.79±0.80 Ac	5.05±1.62
Winter	1.58±0.35 Db	2.51±0.14 Cd	3.52±0.25 Bd	5.11±0.81 Ad	3.21±1.42
		Percentage of leaf blade (%)			
Spring	65.2±0.55 Ca[1]	76.0±1.79 Aa	73.5±2.40 Ba	72.4±0.88 Bb	71.9±4.41
Summer	60.5±1.97 Ca	71.9±1.10 Ba	75.5±2.96 Aa	76.4±2.33Aa	71.1±6.81
Autumn	63.3±3.26 Ba	74.2±2.46 Aa	73.3±2.69 Aa	73.3±1.26Ab	71.5±5.51
Winter	48.8±4.23 Bb	66.5±1.22 Ab	66.8±2.73 Ab	71.3±1.51Ab	63.3±9.16

[1]Values within parameters followed by the same letters do not differ by Tukey's test ($P<0.05$); upper-case letters compare N rates within seasons, while lower-case letters compare seasons at the same N rate.

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Animal performance on Tanzânia grass pasture intercropped with Estilozantes Campo Grande or fertilized with nitrogen

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Keywords: Nitrogen fertilization, grass-legume pasture, pasture quality, *Panicum maximum*, *Stylosanthes*.

Introduction

Nitrogen (N) is the most important nutrient for growth and development of pastures, giving the plant a faster growth rate and greater production (Roma et al. 2012). Despite its proven effectiveness, use of N fertilizer by farmers is limited due to high cost. On the other hand, the legume mixture Estilozantes Campo Grande (80% *Stylosanthes capitata* + 20% *S. macrocephala*), capable of fixing atmospheric nitrogen, has become a promising forage plant (Embrapa 2010; Ribeiro et al. 2011). However, there is still a lack of information about its use in association with grasses for animal production.

This study aims to measure the performance of livestock grazing Tanzânia grass (*Panicum maximum* cv. Tanzânia-1) fertilized with nitrogen or grown with Estilozantes Campo Grande (Estilozantes CG).

Methods

The work was conducted in the northwest of Paraná, Brazil (22°50'16" S, 51°58'22" W; 410 m asl) on an Oxisol soil (Embrapa 1999). The experimental design was blocks with split plots and 3 replications, the main plots being: Tanzânia + Estilozantes CG; Tanzânia + 75 kg N/ha; Tanzânia + 150 kg N/ha; and Tanzânia + 225 kg N/ha; and the subplots the seasons of the year: spring, summer and autumn. The swards were grazed continuously at variable stocking rates aiming to maintain the pasture at a height between 40 and 45 cm (residue). The animals used were Nellore (Zebu) with an initial average body weight of 230 kg. Each paddock contained 3 test animals plus additional regulator animals that were added or removed depending on the height of the pasture, using the "put and take" method (Mott and Lucas 1952). Animal performance was assessed by average daily gain (ADG), estimated by the difference in weight of test animals at the beginning and end of the experiment, divided by the number of days in the pasture, with weighing every 28 days. Stocking rate (SR) was calculated from the average weight of the regulator animals, multiplied by the number of days they remained in the pasture and divided by the number of days in the period, plus the weight of the tester animals, converted to animal units/ha [450 kg of LW = 1 animal unit (AU)]. Analysis of variance was performed with the aid of the Statistical Analysis System and Genetic/SAEG and the averages were submitted to Tukey test at 5% probability.

Results and Discussion

The average production of dry matter (DM) of forage throughout the experimental period for Tanzânia grass intercropped with Estilozantes (CG) or fertilized with 75, 150 and 225 kg of N was 3.35, 3.55, 3.73 and 4.16 t/ha, respectively. In spring, summer and autumn average production was 3.89, 3.66 and 3.55 t DM/ha, respectively. The pasture presented 13% of Estilozantes CG, in the total herbage mass. There was no interaction between treatments and seasons for average daily gain (ADG) or stocking rate (SR), with a significant difference between seasons (Table 1). Overall, ADGs on all treatments were similar with a mean value of 0.74 kg/hd/d. On all treatments, peak weight gains per head occurred in spring with progressive declines to summer and autumn (Table 1).

Stocking rates (carrying capacity) varied with season and treatment. In general, the number of grazing animals was highest in spring and lowest in autumn but differences between summer and autumn were often small. According to Almeida (2001), an increase in SR results in a decrease in consumption of the leafy fraction of the grass, due to increased competition for the more

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Table 1. Animal performance (± SD) on Tanzânia grass pasture intercropped with Estilozantes Campo Grande or fertilized with nitrogen, during the various seasons.

Season	Treatments				Mean
	Estilozantes CG	75 kg N	150 kg N	225 kg N	
			Average daily gain (kg/hd/d)		
Spring	1.07±0.11	0.99±0.08	0.96±0.08	1.03±0.03	1.01±0.08 A[1]
Summer	0.64±0.03	0.62±0.08	0.84±0.09	0.76±0.22	0.72±0.14 B
Autumn	0.46±0.12	0.44±0.16	0.48±0.09	0.52±0.05	0.48±0.10 C
Mean	0.72±0.28 a	0.69±0.26 a	0.76±0.23 a	0.77±0.25 a	
			Stocking rate (AU/ha)[2]		
Spring	2.31±0.11	3.45±1.01	3.75±0.81	4.62±0.18	3.5±1.03 A
Summer	1.78±0.12	2.07±0.05	2.95±0.37	4.43±0.85	2.8±1.15 B
Autumn	1.66±0.06	2.26±0.29	2.78±0.31	3.16±0.07	2.5±0.62 B
Mean	1.92±0.31 c	2.59±0.84 b	3.16±0.65 b	4.07±0.82 a	

[1]Means within columns and parameters, followed by the same upper-case letters and in rows followed by the same lower-case letters, do not differ by Tukey test ($P<0.05$).
[2]Animal units per hectare.

nutritious forage, which decreases the chance for selection of leaf. As a result, pastures fertilized with higher doses of N supported greater SRs due to increased forage production (Roma et al. 2012), but this did not affect ADG. The presence of Estilozantes CG, which produces forage of good nutritional value, allowed this treatment to produce similar ADGs to the N-fertilized treatments but at a lower SR.

Conclusions

This study has shown that irrigated Tanzânia pastures can support excellent weight gains at high stocking rates in the presence of adequate levels of N fertilizer. Intercropping with Estilozantes Campo Grande can produce similar gains per head but at the cost of lower carrying capacity. The choice of which system to adopt will depend on relative costs of fertilizer, water and seed and the grazing time lost to establish the legume.

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Canopy height and its relationship with leaf area index and light interception in tropical grasses

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Keywords: Forage measurements, morphology, correlation, radiation penetration, warm-season grasses.

Introduction

Photosynthetically active tissues, mainly green leaves, are the major component of forage growth and development. The amount of these tissues in a forage plant is influenced directly by cutting management, i.e. cutting frequency and stubble height. The normal recommendation is to cut (or graze) forage whenever it reaches a given stubble height. Brougham (1956) stated that the critical leaf area index (LAI) is reached when the forage canopy is intercepting 95% of the photosynthetically active radiation, and the forage is near its maximum growth rate without shading itself. Alternatively, the optimum LAI occurs when the forage reaches the maximum point of mass accumulation, indicating the time to start grazing or cutting. Generally, the critical and optimum LAI values are quite similar, but not necessarily the same (Brown and Blaser 1968). This trial evaluated the relationships among canopy height, LAI and light interception in 10 tropical grasses.

Methods

The experiment was carried out at the Animal Science Department of the Universidade Federal Rural de Pernambuco. The evaluated species were: *Brachiaria decumbens*, *Brachiaria* hybrid cv. Mulato II, *Brachiaria brizantha* cv. Xaraés, *Brachiaria brizantha* cv. Marandu, *Panicum maximum* cv. Tanzânia, *Panicum* hybrid cv. Massai, *Sorghum vulgare*, *Sorghum bicolor*, *Pennisetum purpureum* "Common" and *P. purpureum* cv. Roxo. Light interception, LAI and mean leaf angle (MLA) were measured using a Plant Canopy Imager CI-120 from CID Bio-science®, simultaneously with canopy height, at 1-week intervals over 2 months, in experimental plots measuring 2.8 x 1.8 m. Measurements were replicated 4 times per plot in every weekly evaluation. Correlation analyses were performed using Sigmaplot 12.0, and the correlation magnitude was based on Franzblau (1958).

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Results and Discussion

Correlation analyses between canopy height and light interception (Table 1) were non-significant ($P>0.05$) for the following species: *Brachiaria brizantha* cv. Xaraés, *Brachiaria brizantha* cv. Marandu, *Brachiaria* hybrid cv. Mulato II, *Panicum maximum* cv. Tanzânia, *Pennisetum purpureum* cv. Roxo and *Sorghum vulgare*. Positive linear correlations were shown for *Brachiaria decumbens* and *Panicum* hybrid cv. Massai ($P<0.05$; $r = 0.44$ and 0.47, respectively) and *Sorghum bicolor* and *Pennisetum purpureum* "Common" ($P<0.01$; $r = 0.65$). Correlation between canopy height and leaf area index showed that, only in the case of *Brachiaria decumbens*, there was a moderate correlation ($r = 0.59$), with the coefficient of determination (r^2) = 0.35. LAI and light interception were significantly correlated for all species except *Brachiaria brizantha* cv. Xaraés, *Brachiaria brizantha* cv. Marandu and *Brachiaria* hybrid cv. Mulato II.

In contrast with our findings, Galzerano et al. (2010) found, for *Panicum maximum* cv. Áries and *Cynodon nlemfuensis*, very strong correlation between canopy height and LAI, with coefficients of determination of 0.76 and 0.88, respectively. Engel et al. (1987), studying a cool season grass, *Bromus inermis*, found that LAI and light interception were strongly correlated with season of the year and fertilization level. They also found that forage mass per unit area correlated well with light interception of 95%. In the same study, the authors reported that, during the reproductive phase of *B. inermis*, tillers became elongated and the canopy became more erect and open, requiring higher values of LAI to intercept the same radiation as absorbed by a smaller and denser canopy.

Table 1. Correlations between canopy height, light interception, leaf area index and mean leaf angle of 10 tropical forage grasses (T-test, with linear correlation).

Species	Canopy height x Light interception	Canopy height x Leaf area index	Light interception x Leaf area index	Light interception x Mean leaf angle	Leaf area index x Mean leaf angle
Brachiaria decumbens	0.4372 *	0.5883 **	0.6589 **	0.2579 ns	0.8452 **
Brachiaria brizantha cv. Xaraés	0.0332 ns	-0.1521 ns	0.2352 ns	-0.2236 ns	0.8598 **
Brachiaria brizantha cv. Marandu	-0.2947 ns	0.1203 ns	0.2795 ns	-0.6464 **	0.4364 ns
Brachiaria hybrid cv. Mulato II	-0.3287 ns	-0.2558 ns	0.2959 ns	-0.4922 *	0.5366 *
Panicum maximum cv. Tanzânia	0.0835 ns	0.0625 ns	0.6936 **	-0.1863 ns	0.5411 *
Panicum hybrid cv. Massai	0.4728 *	0.4157 ns	0.4631*	-0.1328 ns	0.5941**
Pennisetum purpureum "Common"	0.6478 **	0.2989 ns	0.8166 **	-0.6258 *	-0.3064 ns
Pennisetum purpureum cv. Roxo	0.4176 ns	0.3726 ns	0.8886 **	0.0774 ns	0.3358 ns
Sorghum vulgare	0.1099 ns	0.0866 ns	0.5244 *	0.1275 ns	0.2405 ns
Sorghum bicolor	0.6534 **	0.4639 ns	0.7207 **	-0.2698 ns	0.1608 ns

Falster and Westoby (2003) reported that small values for mean leaf angle are directly related to higher indices of light interception. In our study, LAI and mean leaf angle correlated positively (P<0.05) and affected *Brachiaria* hybrid cv. Mulato II, *Panicum maximum* cv. Tanzânia, *Panicum* hybrid cv. Massai, *Brachiaria decumbens* and *Brachiaria brizantha* cv. Xaraés. Mean leaf angle affected negatively (P<0.05) light interception for only 3 species: *Brachiaria brizantha* cv. Marandu, *Brachiaria* hybrid cv. Mulato II and *Pennisetum purpureum* "Common".

Conclusions

Canopy height seldom correlated well with light interception and leaf area index across a range of tropical grasses. Other measurements on the canopy, either directly as herbage mass or indirectly as disk settling height (Santillan et al. 1979), could be alternative measurements to correlate with light interception in tropical grasses.

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Recent development of pasture plants in Queensland

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Keywords: Plant evaluation, plant collection, cultivar release, germplasm storage, private-public collaboration.

Why continue to develop new pasture plants in Queensland?

The beef (AU$3,280 M), dairy (AU$230 M) and sheep (AU$197 M) industries contribute significantly to the Queensland economy (Queensland Government 2011). Introduced tropical grasses and legumes, used in permanent or temporary pastures, are the primary feed base for dairy and beef-finishing operations. Sown legumes are also used to increase the productivity of extensive native grasslands, particularly for beef breeding and sheep production. By the mid-1990s, the net present value of sown pastures to the beef industry alone was estimated at AU$712 M with an annual gross benefit of AU$80 M (Walker et al. 1997).

There is continued impetus to develop new pasture plants. Key reasons in the last 10 years include: increasing productivity (biomass and feed quality) of pastures to maintain business profitability (*Brachiaria* and *Arachis* spp. for beef finishing and dairy); imparting tolerance to diseases (*Stylosanthes guianensis* and *Macroptilium atropurpureum*) and insect pests (*Leucaena leucocephala*); developing new agricultural systems (*Clitoria ternatea* and *Macroptilium bracteatum* in crop/graze systems); and developing summer-active grasses in temperate areas and filling production niches where few plants exist (*Desmanthus virgatus* and *Stylosanthes seabrana* for beef production on vertisols). Current emphasis in Queensland is placed on legumes to enhance the productivity of sown and native beef pastures in moderate rainfall zones.

Historical approaches to pasture plant development and release

Tropical pasture development began in earnest in Queensland during the 1960s, with the development of well-resourced federal and state government programs. By 1997, 72 tropical grass and 65 tropical legume cultivars had been released in Australia, mostly in Queensland (Hacker 1997). Co-funding arrangements between grazing industry development corporations and government agencies saw systematic evaluation programs, in which a wide range of accessions were introduced to Australia, assessed under a range of environments and promising types progressed towards commercial release (Clem and Jones 1996; Pengelly and Staples 1996; Bishop and Hilder 2005). (Mostly) public cultivars were released by government agencies once vetted by a committee comprising government agencies, universities and seed companies.

The Australian Tropical Forages Collection (ATFC), a seed-bank comprising tropical grasses and legumes collected over some 40 years, has been the key resource for developing new tropical pasture varieties in Queensland (Hacker 1997). Following significant downsizing, it now contains ~10,000 (614 species) warm-season grasses and ~2,700 (255) legumes targeting cultivar development in Australia (Cox et al. 2009). However, difficult access to plant description and field performance data (where known) and declining quality and volume of stocks compromise its future use.

Despite the best intentions of plant evaluation teams, the introduction of new pasture plants, even palatable types, can result in the naturalization of plants deemed undesirable by the broader community. Notable examples in Australia include *Andropogon gayanus* and *Hymenachne amplexicaulis*. At present, the beef industry and Queensland Government are co-funding the control of certain unpalatable legumes before they spread from plant evaluation sites and become widespread contaminants of grasslands (Cox 2006). Clearly, the development of new cultivars should include protocols which minimize the risk of releasing a new weed.

Recent approaches to pasture plant development and release

Government agencies have significantly reduced investment in sown pastures over the last 20 years and private sector involvement in developing new pasture cultivars has

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Table 1. Some recent approaches to the development of new pasture varieties grown at the Queensland Government seed production facility in north Queensland.

	Method	Organization(s)	Genera (no. of species)
1	Importing elite overseas varieties[1]	Queensland government, seed companies	*Brachiaria* (*Urochloa*) (2), *Cenchrus* (1), *Chloris* (1), *Dichanthium* (1), *Panicum* (3), *Stylosanthes* (1)
2	Identifying useful accessions in ATFGRC[1]	Queensland government, seed companies, university	*Arachis* (2), *Bothriochloa* (1), *Chloris* (1) *Digitaria* (1), *Lablab* (1), *Macroptilium* (2), *Urochloa* (1)
3	Re-selecting plants from old evaluation sites	Queensland government, university	*Desmanthus* (2), *Stylosanthes* (2)
4	Plant breeding and selection program	Queensland government, seed companies, university	*Chloris* (1), *Macroptilium* (1)
5	Plant collection and selection (Australia)	Queensland government	*Dichanthium* (1), *Heteropogon* (1), *Setaria* (1), *Themeda* (1)

[1]Often using the knowledge of retired government research workers.

increased. A range of methods have been employed to maintain momentum in pasture cultivar development, including rapidly progressing imported material or accessions of known merit from the ATFC, re-selecting accessions from old plant evaluation sites and, in a few recent instances, undertaking plant breeding programs (Table 1). Most involve collaboration between government and seed companies and universities, if only to produce seed at the Queensland Government facility to support breeding, evaluation and commercial adoption. Recent releases include public and proprietary cultivars, including some with international intellectual property rights. The release process is less structured than in the past, following the disbanding of the advisory committee.

The current approach of using government, university and private facilities has been effective for quickly and inexpensively developing and releasing new pasture plant varieties. However, the identification of promising accessions and cultivars is heavily reliant on the infrastructure (ATFC, evaluation sites and government research facilities) and personal knowledge developed over 40 years of research, often targeting different goals from those we seek today. Whereas there have been some within-organization assessments of plant performance, there has been no coordinated or systematic approach for comparing new public or private varieties in grazing operations, including assessment for weediness. As a result, graziers often rely on incomplete or outdated recommendations for their businesses.

Conclusions

In the absence of well-resourced sown pasture programs, processes used to develop new pasture cultivars in Queensland have recently focused on progressing 'best-bets' as efficiently as possible, and the performance of many of these cultivars has not been rigorously tested under a range of grazing management systems. On-farm demonstration and independent promotion of new pasture plants is urgently required. Given the increasing development of varieties by private enterprises, this can best be achieved through public-private sector collaboration, preferably adhering to the priorities of the grazing industries. In the longer term, as previous knowledge becomes less useful for emerging needs, a greater focus on the plants entering evaluation programs will be needed. Assuming the ATFC remains a key source of useful pasture plants, the grow-out, describing and publishing of data on carefully selected genera/species, prioritized by industry needs, will benefit both private and public plant development programs.

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Copper status of free ranging cattle: what's hidden behind? A pilot study at the Gilgel Gibe catchment, Ethiopia

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Keywords: Mineral deficiency, soil, humid tropics, zebu.

Introduction

Copper (Cu) deficiency is known to be a major risk for cattle health and production and is diagnosed through low liver copper reserves and low plasma copper levels. The widespread problem is due to low Cu concentrations in the natural diet, the presence of dietary Cu antagonists, such as S, Mo and Fe, and low absorption rates in the rumen (Suttle 2010). Cattle in the tropics are even more prone to shortage of this mineral, since animals are often grazed extensively and largely dependent on natural pasture (McDowell and Arthington 2005). In Ethiopia, Cu deficiency has been described in zebu (*Bos indicus*) cattle by several authors (e.g. Dermauw et al. 2013). Similar to other minerals, Cu is part of the soil-plant-animal chain, with many factors influencing Cu concentrations at every level. In our study, the overall goal was to investigate the possible influence of certain environmental and management factors on dietary concentrations of Cu and antagonists and plasma Cu levels in free-ranging cattle.

Methods

This study was conducted in the Gilgel Gibe catchment, southwestern Ethiopia. In 3 elevation zones (1 = 1,700 −1,800 m asl, 2 = 1,800−2,000 m asl, 3 = 2,200 m asl), 19 herds (<10 to >70 animals per herd) of free-ranging zebu (*Bos indicus*) cattle were randomly selected within a radius of 35 km around the town of Jimma, and observed during one day. One lactating cow per herd was closely observed, the body condition score (BCS) was recorded and a blood sample was obtained. The soil type [Nitisols, Acrisols and Ferralsols (soil association NAF) or Planosols and Vertisols (soil association PV) according to Van Ranst et al. (2011)] was identified based upon landscape position and visual inspection of the soil. Management practices were evaluated based upon grazing strategy (communal vs. individual), supplementation with crop residues (as % of dietary observations) and the total herding distance covered (during one grazing day). The dietary plant composition was estimated through observation of ingested plant species every 10 minutes. One ingested plant per observation was equal to 1 point, several ingested species per observation were allocated 1 point divided by the number recorded. A sample of all ingested plants was collected.

To estimate the dietary mineral concentrations, the ingested proportions of each plant were multiplied by mineral content and summed. If no sample could be obtained due to small plant size, the mineral concentration of the known percentage of ingested plants was extrapolated to 100%. Finally, the number of ingested plant species (NIPS) was recorded. Plasma was obtained through centrifugation at 1,500 × G for 10 min. Plant samples were oven-dried at 65 °C for 72 h. All samples were digested using microwave destruction with 10 mL HNO_3 (plasma: open; plants: closed vessels) followed by filtration and mineral analysis through inductively coupled plasma optical emission spectrometry and mass spectrometry (ICP-OES & -MS) (Vista MPX radial, Varian, Palo Alto, CA, USA and Elan DRC-e, Perkin Elmer, Sunnyvale, CA, USA, respectively).

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Statistical analysis was performed using SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA). To determine the association between categorical variables, a Fisher's Exact test was used. To determine the effect of the physical environment and management on mineral concentrations in ingested diet and status, a fixed effects model with one categorical or one continuous covariate at a time was fitted to the different response variables. Hypotheses were tested using the F-test at the 5% significance level.

Results

Of the 19 observed animals, 12 were severely Cu deficient [mean: 0.48 ± 0.19 (SD) mg/L], while estimated dietary Cu concentrations were below requirements for all herds (5.8 ± 1.4 mg/kg DM). Soil type and elevation were significantly associated ($P<0.001$), with the typical occurrence of Planosol/Vertisol associations (PV) at lower elevation. Soil type did not affect the amount of crop residues offered by the farmers ($P>0.05$), but significantly influenced herd type (more communal grazing for longer distances on PV soils). Focusing on the impact of soil type on diet, NIPS [10.7 vs. 17.2 ± 1.3 (s.e.m.)], dietary concentrations of Cu (4.7 vs. 6.4 ± 0.3 mg/kg DM) and Fe (765 vs. 1672 ± 183 mg/kg DM) were lower on PV soils, whereas concentrations of Mo (1.47 vs. 0.96 ± 0.10 mg/kg DM) were higher than on NAF soils (all $P<0.05$). Dietary concentrations of S tended to be lower on PV soils (0.15 vs. 0.19 ± 0.01 % DM, $P=0.082$). Animal Cu status, however, was not affected by soil type.

Concerning the impact of management practices on diet and status, dietary Mo concentrations were higher in communal grazing herds (1.4 vs. 1.0 ± 0.1 mg/kg DM), whereas the Cu:Mo ratio was higher in individual grazing herds (6.8 vs. 4.0 ± 1.0) (both $P<0.050$), but Cu status was not affected ($P>0.050$). The amounts of crop residues offered to grazing animals had a significant negative effect on dietary Zn concentrations ($P=0.033$) and tended to negatively affect dietary Mo and S concentrations ($P=0.064$; $P=0.063$, respectively). Animal mineral status was not affected by this, but BCS was positively affected ($P=0.010$). Herding distance tended to negatively affect Cu:Mo ratio ($P=0.082$), but did not affect Cu status or level of Cu antagonists.

Conclusion

Zebu cattle grazing in the study area were under high risk for Cu deficiency, potentially aggravated due to Fe, Mo and S overload. Lower dietary Cu concentrations were ingested on PV soils, which coincided with higher dietary Mo and lower Fe concentrations. Herd type, crop residue supplementation and herding distance had or tended to have an effect on dietary concentrations of Cu antagonists. Despite the unaffected Cu status, these results accentuate the impact of both environment and management on dietary concentrations of Cu and antagonists. The impact of these factors may encourage farmers to take informed choices, which might improve the copper status of their animals.

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Climate-smart *Brachiaria* grasses for improving livestock production in East Africa

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Keywords: Endophytes, greenhouse gas emissions, smallholder crop-livestock farmers, tropical grasses.

Introduction

Climate change is a global phenomenon with severe negative impacts on poor people in developing countries (Morton 2007). Across many parts of Africa, rural poor communities rely for their survival on agriculture and livestock, which are amongst the most climate-sensitive economic sectors. Climate-smart agriculture helps farmers to increase food production, become more resilient to climate change and reduce greenhouse gas (GHG) emissions. The main anthropogenic GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); they are critically important for regulating the Earth's surface temperature. Inadequate quantity and quality of feed are major constraints to livestock production, particularly during the dry seasons across Africa.

The overall objective of this interinstitutional program is to increase feed availability in action areas of the target countries in East Africa (e.g. Kenya, Rwanda) by use of climate-smart *Brachiaria* forage grasses (Rao et al. 2011) for increased animal productivity and for generation of extra income by smallholder farmers. An innovative programmed approach will be used to reintroduce to Africa high quality, persistent and productive *Brachiaria* genotypes, that were selected and improved in Latin America (Miles et al. 2004). These forage grasses will help alleviate feed shortages, increase income of resource-poor farmers, improve soil fertility, adapt to and mitigate climate change, increase milk and beef production, and as a result improve livelihoods and protect the environment.

The program uses trans-disciplinary research by integrating modern tools and technologies to identify and disseminate *Brachiaria* cultivars that are adapted to climate change through endophytes (biological protection agents), that improve adaptation to drought stress and also have the potential to mitigate climate change through carbon sequestration in soil and reduction of emissions of both methane and nitrous oxide.

Methods

The program is focused on 4 major outputs:

- The role of endophytes in improving adaptation of *Brachiaria* grasses to climate change (drought) determined and novel methods to detect endophytes developed;
- The contribution to mitigation of climate change by *Brachiaria* grasses adapted to drought and low soil fertility quantified;
- Improved *Brachiaria* grasses integrated into mixed smallholder crop-livestock systems, their role in improving milk and meat production in grazing and cut-and-carry forage systems determined and their impact in reducing land degradation assessed; and
- Systems for the creation of forage seed production and marketing enterprises for poor farmers, mainly females, established.

At each step of the program, implementation, monitoring and evaluation will be applied to ensure that generated technologies are delivered to end users.

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Results

Output 1: Role of endophytes

The role of endophytes in improving adaptation of *Brachiaria* grasses is being investigated at the BecA-ILRI Hub, CIAT and Grasslanz Technology Ltd. The preliminary results from isolation and determination of endophyte metabolites in culture and in planta will be presented. This will be followed by the development of an efficient inoculation process to test the impact of endophytes on biological nitrification inhibition (BNI) and nitrous oxide (N_2O) emissions from *Brachiaria* grasses under greenhouse conditions and to identify the most promising lines for testing under field conditions. The impacts of endophyte infection on forage yield and forage quality of promising *Brachiaria* grasses during drought stress under field conditions will also be investigated.

Output 2: Mitigation of climate change

Ten cultivars and 80 germplasm accessions of different *Brachiaria* species have been sent from Colombia to New Zealand, Kenya and Rwanda for agronomic evaluation based on abitioc (drought and low soil fertility) and biotic stress conditions to quantify their adaptation to and mitigation of climate change.

Output 3: Role in improving milk and meat production

Selected *Brachiaria* grasses are being integrated into mixed smallholder crop-livestock systems in Rwanda and Kenya. *Brachiaria*-based rations are fed to dairy cows and beef cattle in communal feedlots using cut-and-carry forage systems and milk and meat production plus environmental benefits are being recorded.

Output 4: Forage seed production enterprises

After evaluation of *Brachiaria* genotypes with farmer participation, a farmer cooperative to produce and market *Brachiaria* seed will be established in Rwanda and Kenya, where female farmers will also be involved.

Conclusions

This research for development program is being implemented by 5 institutions, namely ILRI (the BecA-ILRI Hub) in Kenya, CIAT in Colombia, KARI in Kenya, RAB in Rwanda, and Grasslanz Technology Ltd in New Zealand. If the research is successful, novel methods for detecting endophytes to improve adaptation of *Brachiaria* grasses to climate change, especially drought stress, will be developed. Adoption of this technology will improve feed availability for smallholders in Kenya and Rwanda, while mitigating climate change through improved carbon sequestration and reduced emissions of methane and nitrous oxide.

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Isolation of root endophytic bacteria in elephant grass (*Pennisetum purpureum*) cultivars

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Keywords: Biological N fixation, endophyte, forage, nutrient, pasture.

Introduction

Elephant grass (*Pennisetum purpureum*) is one of the most productive warm-season grasses. Farmers utilize elephant grass in different forms, such as cut-and-carry, grazing, conserved forage (silage, hay), and as an energy source (Lira et al. 2010). Nitrogen (N) is an essential element for plant growth and development and is usually a limiting factor for forage production in the tropics (Boddey et al. 2004). Biological N fixation (BNF) may occur in warm-season grasses by their association with diazotrophic bacteria. These bacteria colonize different niches in the host plant: Endophytic bacteria form colonies inside the plant tissue, whereas epiphytic bacteria colonize external surfaces of plants (Compant et al. 2010). Both types of bacteria may benefit host plants (Badri et al. 2009). This study evaluated endophytic diazotrophic bacteria density associated with the roots of different elephant grass cultivars using 2 N-free growth media, at different times after inoculation.

Materials and Methods

Root samples from 3 elephant grass cultivars (cvv. Elefante B, Venezuela and Pioneiro) were collected in October 2012. These cultivars had been growing for 3 years under cutting management without N fertilization, at the Agronomic Research Institute of Pernambuco (IPA), Itambé, Pernambuco, Brazil. Root endophytic bacteria were isolated following the methodology of Döbereiner et al. (1995) and Kuklinsky-Sobral et al. (2004). Inoculations were performed using a serial dilution method (10^{-3}, 10^{-4} and 10^{-5}) in a saline-phosphate buffering solution. Subsequent inoculation was replicated 5 times using the semi-solid media, NFb and JMV (Baldani et al. 2000), adding to each sample 50 μg/mL of Thiophanate Methyl, a commercial fungicide (Cercobin 700®). The semi-solid N-free media, NFb (neutral pH) and JMV (acid pH), are commonly used for enrichment and isolation of bacteria (Döbereiner et al. 1995; Videira et al. 2007). Samples were incubated thereafter at 28 °C. Bacterial growth inside the media was evaluated 5, 8, 10 and 12 days after inoculation. The most probable number (MPN) of diazotrophic bacteria per gram of sample was determined using the McCrady table as described by Döbereiner et al. (1995). Bacterial population densities were expressed at the $\log_{10}$ basis and submitted to ANOVA using the statistical software package SISVAR 5.3®; means were compared by Tukey test ($P<0.05$).

Results and Discussion

For the JMV medium, MPN of microbial cells per gram of fresh vegetal tissue (FVT), regardless of time since inoculation, ranged from 5.50×10^4 to 1.57×10^5; from 3.23×10^4 to 4.5×10^4; and from 6.17×10^5 to 7.00×10^5 for Elefante B, Venezuela and Pioneiro, respectively. For the NFb medium, MPN per gram of FVT ranged from 4.70×10^4 to 6.60×10^4; from 7.00×10^3 to 2.53×10^4; and from 5.76×10^5 to 6.46×10^5 for Elefante B, Venezuela and Pioneiro, respectively. No significant difference was observed ($P>0.05$) for MPN per gram of fresh vegetal tissue between media (Table 1).

Time after inoculation (5, 8, 10 and 12 days), cultivar and isolation medium had no effect on microbial density.

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Table 1. Root endophytic diazotrophic bacteria density (log MPN cells/g FVT) in elephant grass (*Pennisetum purpureum*) cultivars in 2 N-free media (JMV and NFb) and at varying times since inoculation.

Elephant grass cultivars	Isolation medium	Reading days after inoculation			
		Day 5	Day 8	Day 10	Day 12
Elefante B	JMV	4.63 Aa[1]	4.96 Aa	5.19 Aa	4.71 Aa
	NFb	4.43 Aa	4.47 Aa	4.75 Aa	4.50 Aa
Venezuela	JMV	4.47 Aa	4.45 Aa	4.59 Aa	4.44 Aa
	NFb	3.89 Aa	4.00 Aa	4.15 Aa	3.83 Ab
Pioneiro	JMV	5.00 Aa	5.00 Aa	5.45 Aa	5.45 Aa
	NFb	5.04 Aa	5.14 Aa	5.18 Aa	5.18 Aa

[1]Means followed by the same letter, upper case within rows and lower case within columns, do not differ (P>0.05) by Tukey test.

Conclusions

High numbers of root endophytic diazotrophic bacteria are associated with elephant grass, with no differences between cultivars. The benefit of this association to the plants is the subject of other studies.

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Decomposition of cattle dung on mixed grass-legume pastures

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Keywords: Nitrogen fertilization, nutrient cycling, fecal breakdown, organic matter, mineralization, immobilization.

Introduction

Animal excreta contribute positively to nutrient cycling and can improve the quality of soil (Dubeux Jr. et al. 2009; Carvalho et al. 2010). Cattle excrement, when evenly distributed over a pasture, can help to maintain plant nutrition without the application of fertilizers. The introduction of legumes intercropped with grasses benefits the soil by means of nitrogen fixation. When ruminant animals eat legumes, the feces produced may have lower C:N, C:P, lignin:N and lignin:P ratios, promoting better nutrient return to the soil than when cattle eat only grass. Given the importance of nutrient return from and decomposition time of cattle feces on pastures, the objective of this study was to quantify the decomposition of feces of heifers managed in mixed grass-shrubby legume pastures and grass-only pastures.

Materials and Methods

The research was performed at the experimental research station of Itambé, run by the Instituto Agronômico de Pernambuco (IPA). Average precipitation during the experiment was 727 mm. The experiment examined the decomposition of feces of heifers grazing signal grass (*Brachiaria decumbens*) pastures or signal grass plus shrubby legumes. Treatments were: Signal grass in pure stand and not fertilized; signal grass in pure stand + 60 kg N/ha/yr; signal grass intercropped with *Mimosa caesalpiniifolia*; signal grass intercropped with *Leucaena leucocephala*; signal grass intercropped with *Bauhinia cheilantha*; and signal grass intercropped with *Gliricidia sepium*. The pastures were planted in July 2008; legumes were planted in double rows spaced 10 m x 1.0 m x 0.5 m. Paddocks (plots) measured 660 m^2 and were individually fenced. Fecal samples were collected from cattle grazing/browsing the different pasture combinations, and dried at 65 ºC for 72 hours. Samples were then exposed in nylon bags under field conditions (Dubeux Jr. et al. 2006) for 7 time periods (4, 8, 16, 32, 64, 128 and 256 days) with 3 replicates per exposure time, from 23 June 2010 to 26 February 2011. Losses of organic matter, nitrogen (N), phosphorus (P) and potassium (K) were assessed at each stage. The means were analyzed using the PROC MIXED procedure of SAS (SAS Institute 1996). A single exponential model (Wagner and Wolf 1999) was used for percentage loss of organic matter.

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Results and Discussion

The *Brachiaria decumbens* + 60 kg N treatment had the highest rate of fecal biomass loss (k=0.0031 g/g/d), with 55% loss of organic matter over the 256-day exposure period. The lowest rate of loss was seen for the grass-*Mimosa caesalpiniifolia* treatment (k=0.0018 g/g/d), with 37% of the material decomposing over the same period. Loss rates for the grass-*Gliricidia sepium* and *B. decumbens* treatments were 0.0025 and 0.0027 g/g/d, respectively, while the grass-*Leucaena leucocephala* decomposition rate was close to that of the *B. decumbens* + 60 kg N treatment (Table 1). Losses of N, P and K were similar on the various treatments with marked losses over time (Figure 1). Loss of N over 256 days (16%) was much lower than that of phosphorus (60%) and potassium (99.6%).

Table 1. Percentage of organic biomass of heifer feces from grass-legume pastures and grass-only pastures remaining after different exposure times in the field.

Treatment	Days of exposure (%)								Exponential model
	0	4	8	16	32	64	128	256	
Brachiaria decumbens	90.2	89.2	88.3	86.4	82.7	75.9	63.8	45.2	$Y = 90.2^{-0.0027t}$
B. decumbens + 60 kg N/ha	87.3	86.2	85.2	83.0	78.9	71.4	58.4	39.1	$Y = 87.3^{-0.0031t}$
B. dec. + *Gliricidia sepium*	88.9	87.9	87.0	85.3	81.9	75.5	64.2	46.4	$Y = 88.8^{-0.0025t}$
B. dec. + *Leucaena leucocephala*	90.2	89.2	88.1	86.1	82.1	74.7	61.8	42.3	$Y = 90.2^{-0.0029t}$
B. dec. + *Bauhinia cheilantha*	88.6	87.8	87.0	85.58	82.4	76.7	66.3	49.7	$Y = 86.6^{-0.0023t}$
B. dec. + *Mimosa caesalpiniifolia*	90.5	89.6	89.2	87.9	85.4	80.6	71.8	57.9	$Y = 90.5^{-0.0018t}$

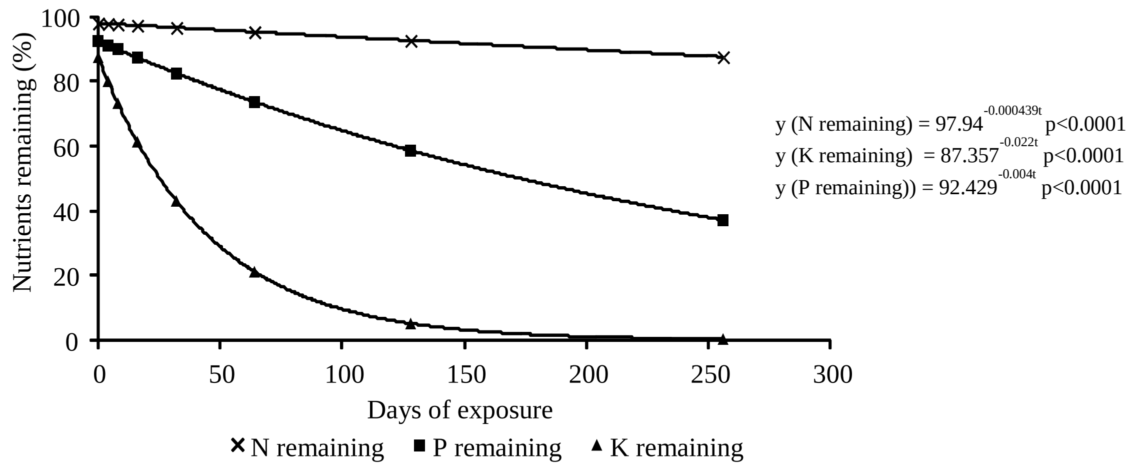

Figure 1. Percentage of nitrogen, phosphorus and potassium in heifer feces from grass-legume and grass-only pastures remaining after different exposure times in the field.

Conclusions

Dung decomposition from cattle grazing on the *B. decumbens* - *M. caesalpiniifolia* system was lower than for dung in other grass-legume combinations. Secondary compounds in *Mimosa* may partially explain this pattern. While organic biomass loss from feces in nylon bags in mixed grass-legume and grass-only pastures was quite significant during the season, after 256 days, 45−73% of the organic matter remained on the various treatments. How these figures relate to natural conditions is open to debate, e.g. dung beetles etc. were excluded. It was significant that only a small proportion of N was lost from the dung during this period but most P and virtually all of the K had disappeared. These findings are significant for nutrient cycling and nutrient use efficiency.

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Decomposition of cattle feces from *Pennisetum purpureum* pastures managed under different post-grazing stubble heights

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Keywords: C:P ratio, C:N ratio, lignin, nutrient cycling, elephant grass, fecal breakdown.

Introduction

Pasture management can affect cattle diets. Post-grazing stubble height is a structural characteristic intrinsically linked to forage quantity and quality. Stubble height also indicates forage utilization rate, and as a result, affects nutrient return pathways (excreta or litter) and, ultimately, nutrient cycling. While deposition of cattle excreta affects soil chemical and physical characteristics (Carran and Theobald 2000), slow release of nutrients from cattle dung delays nutrient bioavailability for subsequent forage growth (Haynes and Williams 1993). This study evaluated how different post-grazing stubble heights on elephant grass (*Pennisetum purpureum*) pastures may affect cattle dung decomposition and nutrient release.

Materials and Methods

Three post-grazing stubble heights (40, 80 and 120 cm) were tested on elephant grass pastures, in a complete randomized block design, with 3 replications. Cattle fecal samples were collected directly from the animals' rectums, dried at 65 °C, and subsequently exposed in nylon bags measuring 15 x 30 cm and 75 µm mesh size. Bags were placed in a forced-air oven drier for 72 h at 65 °C and weighed thereafter. Samples of dried feces (11.25 g) were placed in bags to achieve a ratio of 25 mg of feces per cm^2 of bag surface. Incubated fecal samples were not ground in order to preserve original surface exposed to microbial attack. Bags were sealed, placed on the ground, covered with a thin soil layer and left for different periods: 0, 4, 8, 16, 32, 64, 128 and 256 days during 2007 and 2008. After the relevant periods, bags were retrieved, brushed, placed in the forced-air oven drier for 72 h at 65 °C and weighed. Analyses of the remaining material included DM, OM, N, P, K, Ca, Mg, ADFN (Silva and Queiroz 2006), carbon (Bezerra Neto and Barreto 2004) and lignin (Van Soest et al. 1991). Data were analyzed using Proc Mixed from SAS (SAS 1996). When exposure period was significant, non-linear models were tested and the single exponential negative decay model was used to fit the data, using SAS Proc Nlin.

Results and Discussion

Post-grazing stubble height affected both the composition of cattle dung (Table 1) and the remaining fecal biomass ($P<0.05$), with a decline in fecal decomposition rate as post-grazing stubble height increased (Table 2). After 256 days of exposure, final remaining fecal biomass was 52, 64 and 70% for 40, 80 and 120 cm post-grazing stubble heights, respectively.

Post-grazing stubble height did not affect nutrient release ($P>0.05$), which was influenced only by the exposure period; data followed the single negative decay model ($P<0.001$). Decay of the various nutrients over the 256 days varied greatly, ranging from only 30% loss of N to 83% of K (Table 3). Losses of P, Ca, Mg and Na were intermediate. Fecal C:N ratio decreased with increasing exposure period (Table 1).

After exposure, all treatments presented C:N ratios <20, with averages of 19, 12 and 9 for 120, 80 and 40 cm, respectively (Table 1). Post-grazing stubble height

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Table 1. Lignin (LIG) and acid detergent fiber N (ADFN) concentrations, and C:N, C:P, LIG:N, ADFN:N and LIG:ADFN ratios on an organic matter (OM) basis for feces of cattle grazing on elephant grass pastures managed under different post-grazing stubble heights (PGSH), before (0 day) and after (256 days) soil exposure.

PGSH (cm)	LIG (g/kg)		ADFN (g/kg)		C:N		C:P		LIG:N		ADFN:N		LIG:ADFN	
	0 d	256 d	0 d	256 d	0 d	256 d	0 d	256 d	0 d	256 d	0 d	256 d	0 d	256 d
40	70.1a[1]	121b	9.5a	12.2a	13.3c	9.2c	32.8b	73.4a	2.7b	4.4b	4.5b	4.3b	7.4a	10b
80	67.7a	139b	7.9b	9.2a	20.2b	12.2b	58.4a	63.6a	3.4b	6.4b	4.2b	4.4b	8.6a	14a
120	79.3a	182a	6.7c	11.1a	27.4a	19.1a	60.2a	102.8a	4.9a	11.3a	6.5a	6.3a	11.8a	17a
s.e.	6.9	6.9	0.1	0.1	0.4	0.3	7.8	9.3	0.3	0.7	0.6	0.8	0.8	0.8
P	0.236	0.002	0.001	0.213	0.002	0.001	0.048	0.06	0.009	0.001	0.002	0.003	0.096	0.003

[1]Means followed by the same letter within columns are not different by Tukey (P>0.05).

Table 2. Percentage of fecal biomass from cattle grazing *Pennisetum purpureum* pastures managed at different post-grazing stubble heights remaining after varying exposure periods.

Post-grazing stubble height (cm)	Days of exposure								
	0	4	8	16	32	64	128	256	
40	100.0	99.5	98.0	96.5	92.6	85.4	72.6	52.4	$y\ 40=100^{-0.00254t}$
80	98.0	97.3	96.7	95.4	92.9	88.1	79.1	63.9	$y\ 80=97.9^{-0.00167t}$
120	98.8	98.1	97.8	96.7	94.7	90.7	83.2	69.9	$y\ 120=98.8^{-0.00135t}$

Table 3. Percentage of fecal nutrients from cattle grazing *Pennisetum purpureum* pastures managed at different post-grazing stubble heights remaining after varying exposure periods.

Nutrient	Days of exposure								
	0	4	8	16	32	64	128	256	
N	95.4	94.9	94.5	93.6	91.8	88.3	81.8	70.11	$y\ N=95.4^{-0.00095t}$
P	92.0	90.5	89.1	86.3	80.9	71.1	54.9	32.7	$y\ P=92^{-0.00389t}$
K	99.6	96.9	94.2	89.1	79.6	63.7	40.7	16.6	$y\ K=99.6^{-0.00654t}$
Ca	98.5	97.3	96.3	94.2	90.1	82.4	68.9	48.3	$y\ Ca=98.5^{-0.00268t}$
Mg	96.5	95.2	93.9	91.4	86.6	77.7	62.6	40.7	$y\ Mg=96.5^{-0.00312t}$
Na	82.5	81.6	80.7	79.0	75.6	69.2	58.1	40.9	$y\ Na=82.5^{-0.00315t}$

also affected (P=0.048) fecal C:P ratio, with samples from the 40-cm treatment presenting the least initial C:P ratio (32.8). Lignin:N ratio also varied with treatment, with highest initial (4.9) and final values (11.3) for the 120-cm treatment (Table 1).

Conclusions

Increasing post-grazing stubble height increased fecal C:N, C:P, LIG:N and ADFN:N ratios and slowed fecal decomposition. This is an additional factor to consider when determining grazing strategies, as decomposition of feces has implications for nutrient recycling. Even after 256 days, 50–70% of the OM in dung was still in place, indicating the length of time taken for material to be incorporated back into the soil.

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Alternatives for intensification of beef production under grazing

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Keywords: Cattle breeds, genetic group, feed supplementation, savanna, *Brachiaria*, *Panicum*.

Introduction

Sustainable technological alternatives, which will maintain a constant uniform beef supply year round, are needed, if Brazil is to maintain its position, as one of the most important players in the world beef market. One approach is to more intensively use the alternatives available for pasture management and feed supplementation. However, the responses obtained could be enhanced by using animals with superior genetic makeup, to make better use of the resources provided. Thus, a grazing experiment was designed to evaluate combinations of pasture grasses (*Brachiaria* and *Panicum*), pasture management (feed supplementation and rotational grazing) and animal genetic groups.

Methods

This trial was carried out on an Oxisol at Embrapa Beef Cattle, Campo Grande, MS, Brazil, from May 2006 to October 2007. Sixteen weaned calves of each of the following genetic groups: F1 Nellore-Angus (AN); ½ Braford - ¼ Angus - ¼ Nellore (BfAN); ½ Brahman - ¼ Angus - ¼ Nellore (BhAN); and ⅝ Charolais - ⅜ Nellore (Canchim) were evaluated.

The pastures utilized during both dry periods were 8 *Brachiaria brizantha* cv. Marandu (palisade grass) paddocks (3 ha each). These paddocks were fertilized with 50 kg N/ha in February and were continuously stocked during the dry periods. In May 2006, 64 calves, approximately 8 months of age and with an average initial weight of 220 kg, were distributed in the 8 paddocks as follows: two from each of the 4 genetic groups in each paddock, allocated on weight basis within each genetic group. During the first dry period (FDP, May–September 2006), animals in each paddock were supplemented with 1 of the following 2 mixtures: a concentrate mix (CS) with 43% corn, 40% soybean, 11% urea, 4% mineral mixture and 3% calcium carbonate (4 paddocks); and a multiple mineral mixture (MM) with 33% corn, 35% soybean hulls, 12% urea, 15% NaCl and 5% of other essential minerals (4 paddocks). These supplements were provided in quantities representing 0.8% and 0.2% of live weight, respectively, for 142 days.

During the subsequent rainy period (RP, October 2006−April 2007) all animals were transferred to *Panicum maximum* cv. Tanzânia (guinea grass) pastures. The total area (13.5 ha) was divided into 8 modules of 6 paddocks for rotational stocking. Two animals of each genetic group were allocated to each module: one animal that was supplemented with MM and the other with SC. The grazing process was monitored carefully to achieve the targets for post-grazing sward height of 40 cm and pre-grazing height of 90 cm, corresponding to 95% light interception by the canopy (Barbosa et al. 2007; Difante et al. 2010). The pastures were fertilized in October 2007 with (kg/ha): 80 P_2O_5, 80 K_2O and 200 N; the latter was split in 3 applications, namely, October, December and February.

During the second dry period (SDP, May−September 2007) animals were allocated, according to supplementation type and genetic group, to the same 8 *Brachiaria* paddocks used in the previous dry season and pasture management was the same as described above. All steers had their diet supplemented with CS at 0.8% of LW. The animals were weighed each 28 days and checked with respect to the end point (minimal 3 mm of fat cover). Animals considered finished were slaughtered. Palisade grass samples were taken at 28-day intervals, and guinea grass samples pre- and post-grazing. Data were grouped according to periods (FDP, RP and SDP) and subjected to analysis of variance using SAS Mixed Procedure. The applied model included the random effect of the blocks, the fixed effects of the supplement and genetic group, and the interactions between them. The means were compared with a Tukey test at the 5% significance level.

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Results and Discussion

The herbage mass of the deferred *B. brizantha* pastures was sufficient to support the animals during both dry periods. Despite low percentage of leaf, CP and IVOMD (Table 1), as shown previously by Euclides et al. (2007), with the aid of supplementation, animals were able to make weight gains of at least 0.5 kg/d. The correct management of *P. maximum* pastures in the rainy season resulted in greater herbage mass of high quality (Table 1), producing ADGs in excess of 0.6 kg/d.

No genetic group x feed supplement interaction (P>0.05) was detected for any variable studied (Table 2). However, independently of genetic group, animals receiving CS feed supplementation in the first dry period gained more weight than those receiving MM diet supplementation (Table 2) and could be slaughtered at a younger age than those receiving MM during the dry period, in spite of gaining a little less during the rainy period (Table 2). During the rainy period, animals receiving MM during the dry season displayed compensatory growth and gained more weight than those receiving CS. However, at the end of the rainy season, the animals supplemented with CS were still heavier (P=0.0001, 447 vs. 413 kg). On the other hand, during the second dry period ADGs were similar for all groups. Slaughter age was affected by supplementation during the first dry period (Table 2).

As far as genetic groups were concerned, AN gained more weight and reached slaughter condition at a younger age than all other groups. This result might be a consequence of the combined effects of heterosis and breed, since Angus is an early fattening/maturing breed.

Conclusion

The amount and type of concentrate used as a supplement for calves grazing pasture following weaning is important in increasing growth rates of animals. Use of genetic groups, which are early maturing, provides a mechanism for capitalizing on the diet improvement provided by supplementation and integrated pasture management systems by further reducing time to slaughter.

Table 1. Means for herbage mass, percentage of leaf lamina, crude protein (CP) concentration and in vitro organic matter digestibility (IVOMD) of *Brachiaria brizantha* pastures utilized during first and second (FDP and SDP) dry seasons, and *Panicum maximum* utilized during the rainy period (RP)**.**

	Brachiaria brizantha FDP	*Panicum maximum* RP	*Brachiaria brizantha* SDP
Herbage mass (t DM/ha)	3.8	4.6	3.0
Leaf lamina (%)	23.6	70.4	17.9
CP (%)	7.2	14.5	6.1
IVOMD (%)	49.4	66.2	46.1

Table 2. Means for average daily gain (ADG; kg/hd/d) for the first and second dry periods and for the rainy period, live weight (LW) at slaughter, carcass weight, fat cover and slaughter age, according to genetic groups and type of supplement in the first dry season. Means followed by the same letter in the same row do not differ (P>0.05).

	Genetic group effect					Supplement effect		
	AN	Canchim	BfAN	BhAN	P	MM	CS	P
ADG (first dry period)	0.65 a	0.61 a	0.50 b	0.52 b	0.0001	0.40	0.75	0.0001
ADG (rainy period)	0.73 a	0.63 b	0.69 ab	0.67 ab	0.0470	0.72	0.65	0.0058
ADG (second dry period)	0.62 a	0.49 b	0.57 a	0.55 ab	0.0277	0.57	0.55	0.5366
LW at slaughter (kg)	475	495	493	490	0.0002	487	492	0.0050
Fat cover (mm)	4.1	3.6	3.9	3.8	0.3895	3.7	4.0	0.2516
Carcass weight (kg)	256b	265a	263a	255b	0.0001	259	261	0.1753
Slaughter age (no. of months)	19.2 c	23.3 a	22.2 b	22.7 ab	0.0001	23	21	0.0001

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Intake rate and nutritive value of elephant grass cv. Napier subjected to strategies of rotational stocking management

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Keywords: *Pennisetum purpureum*, herbage intake, sward structure, grazing management.

Introduction

Several research papers on tropical forage grasses have demonstrated that grazing management modifies sward structure that, in turn, alters patterns of ingestive and foraging behavior of the grazing animal. For that reason it has been used to explain adjustments in intake characteristics like bite mass, bite rate, intake rate and nutritive value of the consumed herbage (Fonseca et al. 2012). Tall tussock plants like elephant grass (*Pennisetum purpureum*) cv. Napier display stem elongation during the vegetative state (da Silva and Carvalho 2005), causing swards to become too tall and out of reach for grazing animals, making efficient grazing management difficult, particularly when long regrowth periods are used. In that context, an increase in defoliation frequency can improve herbage intake and nutritive value (Palhano et al. 2007), by favoring leaf elongation as opposed to stem elongation and senescent material accumulation throughout successive grazing cycles.

Against that background, the objective of this experiment was to evaluate the components of short-term herbage intake (intake rate, bite mass and bite rate) and nutritive value of the consumed herbage from elephant grass cv. Napier subjected to rotational stocking management defined in terms of pre- and post-grazing management targets.

Methods

The experiment was carried out at E.S.A. “Luiz de Queiroz” (ESALQ), University of São Paulo, Piracicaba, SP, Brazil (22°43’ S, 47°25’ W; 554 m asl), from October 2011 to April 2012 (mid-spring and summer). Treatments corresponded with combinations of 2 post-grazing conditions (post-grazing heights of 35 and 45 cm) and 2 pre-grazing conditions (95% and maximum canopy light interception during regrowth – $LI_{95\%}$ and LI_{Max}), and were allocated to experimental units (850 m^2 paddocks) according to a 2 x 2 factorial arrangement and a randomized complete block design, with 4 replications. Canopy light interception was monitored using a canopy analyzer LAI 2000 (LI-COR, Lincoln, NE, USA).

An oeso-phageal-fistulated Nelore heifer was used to harvest extrusa samples and measure time spent to execute 20 bites during 8-minute sampling periods for each grazing at the pre-grazing condition. Extrusa samples were freeze dried (lyophilized), weighed and ground. Data were used to calculate bite rate (bites/min), bite mass (g DM) and intake rate (g DM/min). Ground samples were used to determine concentrations of neutral (NDF) and acid (ADF) detergent fiber (Van Soest et al. 1991) and crude protein (CP) (Leco Corporation, St. Joseph, MI, USA), as well as in vitro dry matter digestibility (IVDMD) (Tilley and Terry 1963; adapted by Van Soest et al. 1991). Analysis of variance was carried out using SAS® (Statistical Analysis System), version 8.2 for Windows®, on average data for the entire experimental period. When appropriate, treatment means were calculated using the “LSMEANS” statement and comparisons made with the Student test at 5% probability.

Results

Resulting sward structures were different between LI pre-grazing treatments, with pre-grazing heights of 85 and 130 cm for the $LI_{95\%}$ and LI_{Max} targets, respectively. While bite mass at $LI_{95\%}$ target was smaller (P=0.0009) than at LI_{Max}, a higher bite rate (P<0.0001) on this treatment meant that intake rate (g/min) was not influenced by LI pre-grazing (P>0.05) (Table 1). There were no

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treatment differences in NDF, ADF and IVDMD ($P>0.05$), but CP was higher on swards managed with the $LI_{95\%}$ target relative to those managed with the LI_{Max} target ($P=0.0025$).

Conclusion

Increasing grazing frequency on elephant grass pasture had no marked effects on forage intake as the grazing animal adjusted its grazing behavior, in terms of smaller bite mass and higher bite rate to maintain the same intake as with less frequent grazing. Higher CP with the more frequent grazing could impact on animal performance. Responses in DM production, utilization levels, liveweight gains or milk production would need to be studied to measure any benefits from altering the grazing frequency.

Table 1. Bite rate, bite mass, intake rate and chemical composition of extrusa samples of elephant grass cv. Napier subjected to rotational stocking management with pre-grazing targets of 95% and maximum canopy light interception from October 2011 to April 2012.

Light interception	Intake components			Chemical composition			
	Bite rate (no. bites/min)	Bite mass (g DM/bite)	Intake rate (g/min)	NDF (%)	ADF (%)	IVDMD (%)	CP (%)
$LI_{95\%}$	25.4 a[1]	1.20 b	30.0	53.0	27.2	71.1	17.4 a
LI_{Max}	17.6 b	1.53 a	26.0	54.0	26.0	71.2	15.5 b
s.e.m.	1.18	0.070	2.93	0.70	0.52	0.86	0.39

[1]Values in columns followed by different letters differ ($P<0.05$).

Acknowledgments

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Production of Aruana guinea grass subjected to different cutting severities and nitrogen fertilization

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Keywords: Cutting height, *Panicum maximum*, morphological composition, forage accumulation.

Introduction

Aruana guinea grass (*Panicum maximum* cv. Aruana) is widely used as pasture for sheep, which are extremely susceptible to infestation by larvae of gastrointestinal parasites in tropical pasture-based systems (Zanini et al. 2012). One way to mitigate this problem, and consequently reduce the need for use of anthelmintics, is to manage pastures with post-grazing height low enough to ensure sunlight reaches the base of tussocks. This will aid in killing larvae and controlling their development, without jeopardizing canopy regrowth and persistence. The pre-grazing sward height recommended for Aruana guinea grass is 30 cm, when the canopy intercepts 95% of the incident light, with post-grazing height at 15 cm (Zanini et al. 2012). As cutting severity and nitrogen (N) fertilization cause morphological and physiological adaptations in individual plants − altering the production of forage grasses − the objective of this study was to evaluate the accumulation of morphological components of Aruana guinea grass subjected to different cutting severities and N fertilization.

Methods

Cylinders (15 cm diameter x 20 cm deep) of undisturbed soil + plant samples (Mattos and Monteiro 2003) were collected from an Aruana guinea grass pasture established in 2001 and used for sheep grazing. The material (soil + plant) collected was stored in ceramic pots and placed in a greenhouse. Treatments corresponded to 4 nitrogen (N) rates (50, 100, 150 and 200 mg/dm^3) combined with 2 defoliation severities (10 and 15 cm height), in a complete randomized block design with 4 replications in a 4 x 2 factorial arrangement. The experiment was conducted from November 2012 to March 2013. After a 20-day adjustment period, the first cut at 10 and 15 cm height and application of N were carried out. Further cuts at 10 or 15 cm were made when the pastures reached 30 cm height. After each cut, the collected material was separated into leaves (leaf laminae), stems (stems + leaf sheaths) and dead material, then dried in a forced-draught oven at 65 ^{o}C until reaching constant mass before weighing. The results were used to calculate the accumulation of each component above the cutting heights (10 and 15 cm) on each occasion and to determine total production of each morphological component during the period evaluated. Data were subjected to analysis of variance using the GLM procedure of the statistical package SAS® (Statistical Analysis System, version 9.3), using a 5% significance level. The F test was used to compare means of cutting heights, and for the N rates regression analysis (linear and quadratic effects) was used. For analysis of leaf accumulation and leaf:stem ratio, data were log-transformed and for stem accumulation, data were square root-transformed.

Results and Discussion

Dry matter accumulation per pot of leaf, stem and dead material of Aruana guinea grass varied according to cutting height and N rate (Figure 1). Accumulation of leaf material increased significantly as the level of applied N increased, but there was no consistent effect of cutting height on leaf yield. The regression analysis showed a linear response to N rate for accumulation of leaf material ($Y = -0.9250 + 0.08695N$; $R^2 = 0.99$) across the cutting heights. Both stem and dead matter accumulation were higher at 10 cm cutting height than at 15 cm for all N rates. Leaf:stem ratio varied between cutting heights for all except the 200 mg/dm^3 treatment. With regard to stem accumulation per pot, regression

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analysis showed a quadratic effect in the average of cutting heights ($Y = 0.84375 - 0.0127N + 0.00013 N^2$, $R^2 = 0.98$); the smallest forage accumulation was observed with 50 mg/dm^3 of N. No effect of N rate on dead material accumulation was observed.

According to Zanini et al. (2012), managing Aruana guinea grass swards with grazing at 95% incident light interception (30 cm high) and having it grazed to 15 cm post-grazing height, ensures greater rates of dry mass accumulation and better control of stem elongation. However, our results showed that there seems to be no difference between 10 cm and 15 cm cutting height in terms of leaf accumulation per pot. Cutting to 10 cm height can have an additional advantage of allowing sunlight to penetrate to the base of tussocks, restricting the development of gastrointestinal larvae.

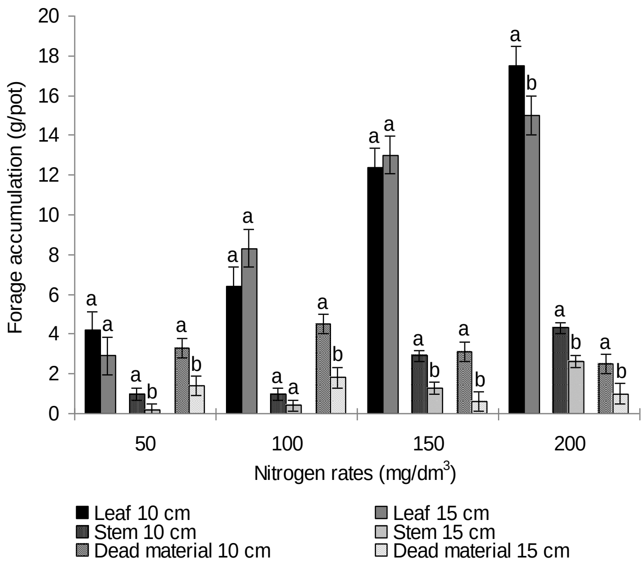

Figure 1. Accumulation of morphological components in Aruana guinea grass subjected to 2 cutting heights and 4 nitrogen rates. Different letters on columns indicate significant differences ($P<0.05$) between morphological component means within nitrogen rates. Vertical bars correspond to standard error of the mean.

At all fertilizer levels, the accumulation of both stem and dead material was higher at the 10 cm cutting height. Therefore, when using N fertilizer to increase productivity, it is important to adjust the frequency and severity of cuts. For the N application to be most effective, leaves should be harvested before they become senescent, and stem elongation should be prevented, which is common in tropical grasses from the point when the canopy intercepts more than 95% of incident light.

Conclusion

The use of 10 cm cutting height together with a regrowth interval that allows the canopy to reach 30 cm height can be used as a target in the management of Aruana guinea grass, in particular if N provided is adequate.

Acknowledgments

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Tiller population stability of Aruana guinea grass subjected to different cutting severities and fertilized with nitrogen

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Keywords: Cutting height, *Panicum maximum*, stability index, tiller persistence.

Introduction

Tiller appearance, death and survival rates determine the persistence of each grass species and its herbage accumulation. The balance between these factors may vary with frequency and intensity of grazing and nitrogen (N) fertilization. Separate analysis of data on tiller appearance and survival or death may not indicate if tiller population is stable over a given time, that is, if sufficient tillers appear to replace those which die, keeping tiller population stable. Rather, an integrated analysis of tiller appearance and death is available, the tiller population stability index (SI), as defined by Bahmani et al. (2003). If SI values are lower than 1, population stability is compromised, as tiller appearance is lower than tiller death and population density tends to decrease; the opposite happens if SI values are higher than 1. This index can be an indicator of the persistence of a pasture, as the reduction in tiller number indicates pasture degradation.

Aruana guinea grass (*Panicum maximum* cv. Aruana) is widely used as pasture for sheep, which are extremely susceptible to infestation by larvae of gastrointestinal parasites in tropical pasture-based systems. One way to mitigate this problem, reducing the need for the use of anthelmintics, is by managing pastures with a post-grazing height low enough to allow sunlight to reach the base of tussocks, possibly killing larvae and controlling larval development, without jeopardizing canopy regrowth and persistence. Sward targets for grazing Aruana guinea grass correspond to a pre-grazing height of 30 cm, equivalent to 95% canopy light interception during regrowth, and a post-grazing height of 15 cm (Zanini et al. 2012). Lowering the post-grazing height would help with parasite control. The objective of this experiment was to evaluate tiller population stability of Aruana guinea grass subjected to 2 cutting severities and N fertilization, using the stability index.

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Methods

Cylinders (15 cm diameter x 20 cm deep) of undisturbed soil and plant samples (Mattos and Monteiro 2003) were collected from an Aruana guinea grass pasture established in 2001 and used for sheep grazing. The soil + plant material was placed in ceramic pots in a greenhouse. Treatments corresponded to 4 nitrogen (N) rates (50, 100, 150 and 200 mg/dm^3) combined with 2 defoliation severities (10 and 15 cm height), in a complete randomized block design with 4 replications in a 4 x 2 factorial arrangement. After a 20-day adjustment period, the first cuts at 10 and 15 cm and application of N were carried out. Further cuts at 10 or 15 cm were made as the plants reached ~30 cm high.

Response variables were the rates of tiller appearance, death and survival, which were used to calculate the tiller population stability index (SI) using the equation P_1/P_0 = TSR (1 + TAR), where: P_1/P_0 stability index was the ratio of tiller populations in month 1 and month 0; TSR was the tiller survival rate in month 1; and TAR was the tiller appearance rate in month 1 (Bahmani et al. 2003). Data were subjected to analysis of variance using SAS® (Statistical Analysis System, version 9.3) statistical package and a 5% significance level. For the N rates, regression analysis (linear and quadratic effects) was used.

Results and Discussion

Tiller population stability indexes varied according to N rates and there was interaction between cutting height and N rate (Figure 1). SI values increased as N rates increased (Y = 0.708 – 0.003N, R^2 = 0.76), demonstrating that N supply had a positive and linear effect on SI.

This clearly shows the importance of N fertilization in promoting tillering in plants and highlights the importance of ensuring adequate nutrition of the herbage and the potential benefits of management practices like N fertilization. The SI is dependent on both cutting height and N rate. At a cutting height of 10 cm, SI was higher than 1 only with the highest N level (200 mg/dm^3). On the other hand, the 15 cm cutting height showed SI higher than 1 with both 150 and 200 mg/dm^3 of N (Figure 1). These results indicate that, with 15 cm cutting height, a lower N application is required to maintain the stability of the tiller population than with cuts at 10 cm height. However, cuts at 10 cm height are interesting as they can assist in the control of gastrointestinal larvae development, by allowing higher incidence of solar radiation at the base of tussocks. As long as nutritional requirements are met (as in this experiment) and in the absence of environmental stresses (e.g. water deficit, diseases), our results suggest that 10 cm cutting severity with N fertilization at optimal rates will maintain Aruana guinea grass tiller populations stable. This result indicates opportunities for developing management practices for grazing and N fertilizer usage to maintain the tiller population of plants, without jeopardizing production system sustainability.

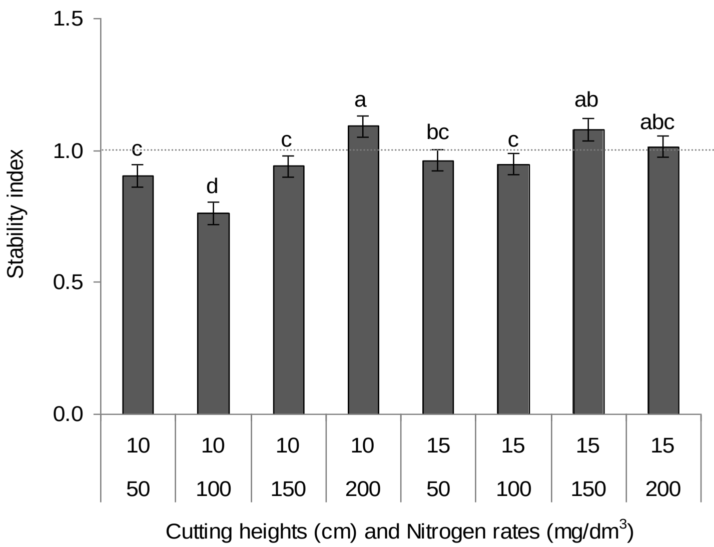

Figure 1. SI of Aruana guinea grass subjected to 2 cutting heights and 4 N rates. Lower-case letters compare SI means between treatments. Vertical bars correspond to standard error of the mean.

Conclusion

A cutting height of 10 or 15 cm, together with the regrowth period required for the canopy to reach 30 cm height, can be used as management targets to maintain plant tiller populations, as long as N supply is adequate for Aruana guinea grass. With 10 cm cutting height more attention to the supply of N is needed.

Acknowledgments

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The growth response of tropical and subtropical forage species to increasing salinity

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Keywords**:** *Chloris gayana*, *Medicago sativa*, *Leucaena leucocephala*, NaCl, $CaSO_4$.

Introduction

There is currently a growing coal seam gas (CSG) industry in Queensland, Australia. The industry requires beneficial-use strategies to consume the significant volumes of water released during CSG extraction. Irrigation of tropical and subtropical forage species for beef production is one option; however, quality of coal seam (CS) water varies due to moderate–high salinity and alkalinity. The application of chemically amended CS water over time could potentially increase soil salinity, which is known to reduce plant biomass production (Shabala and Munns 2012). While the salinity tolerance of many tropical and subtropical forage species has been investigated over the last 30 years (Russell 1976; Keating et al. 1986; Kitamura 1986; Hansen and Munns 1988; Deifel et al. 2006), there is a need to examine the tolerance of more recently released species and cultivars, which are suitable for planting in the Queensland CSG area.

Methods

A flood and drain hydroponic system was used to study the dry matter (DM) response of several tropical and subtropical forage species: 2 cultivars of Rhodes grass, *Chloris gayana*; 4 cultivars of alfalfa, *Medicago sativa*; and 1 cultivar of leucaena, *Leucaena leucocephala* (Table 2) to increasing salinity in a semi-controlled environment at Cleveland, Australia from December 2011 to June 2012. Three hundred and thirty-six pots (180 mm deep, 90 mm wide) were arranged as a split-plot incomplete block design with 7 salinity treatments (Table 1). There were 3 duplicates of each treatment and 2 replications. Within each of the 7 salinity treatments, species were segregated based on growth rate and habit to prevent shading. Otherwise species and cultivars were randomized.

Salinity treatments were established based on increasing rates of NaCl and $CaSO_4 \cdot 2H_2O$ to prevent sodium-induced calcium deficiency. The calcium activity ratio (CAR) of the bulk solution was maintained at ≥0.03 (Deifel et al. 2006). The electrical conductivity (EC) of the control solution was ~1.1 dS/m and comprised 5.1 g 'Flowfeed EX7', 10.2 g KNO_3, 13 g $MgSO_4$ and 51.1 g CaH_3NHNO_3 in 92 L of water. Plants were grown for 10 weeks before salinity treatments were increased incrementally (by a maximum of 1.5 dS/m/day) until the desired level was attained. The pH of the solutions was adjusted to 6 every second day and the solutions replaced every 7 days. To prevent an overestimation of salinity tolerance, salinity estimates were based on total accumulated regrowth (DM) over 100 days at the maximum salinity treatment (Deifel et al. 2006). Four intermittent harvests occurred during this period.

Table 1. Concentrations of NaCl and Ca (as $CaSO_4 \cdot 2H_2O$) used to achieve the respective solution electrical conductivities (ECs) (approximate) and maintain a CAR ≥0.03.

Soil solution EC (dS/m)	1.1	2.4	4.8	11.5	14.4	17.3	20.1
NaCl (mM)	2.6	18.5	46.6	97.7	124.4	151.1	177.7
[1]Ca^{2+} (mM)	2.6	2.6	2.6	8.4	10.1	11.7	12.6

[1]Includes 2.6 mM Ca^{2+} from the basal nutrient solution.

Results and Discussion

The relationship between salinity and DM yield was non-linear for all species as observed by Steppuhn et al. (2005) and Kopittke et al. (2009). DM yield response with

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increasing salinity was modeled as DM yield = A(ln(salinity))+B. EC_{75} and EC_{50} thresholds were calculated (Table 2) for each species to demonstrate the salinity level that reduced growth by 25% and 50%, respectively, relative to the control. As anticipated, *Chloris gayana* was the most salt-tolerant species. The maximum salinity treatment failed to cause an EC_{50} in *C. gayana* cv. Finecut, with a maximum biomass reduction of 44% at the highest salinity treatment of 20.1 dS/m. The EC_{50} of *C. gayana* cv. Toro (19 dS/m) was lower than the published threshold for *C. gayana* cv. Pioneer (Table 3). The EC_{50} of between 6.4 and 5.2 dS/m observed in *Medicago sativa* cultivars was significantly lower than the published threshold of 10.2 dS/m for *M. sativa* cv. Hunter River grown in soil media. There was no significant difference in DM yield among the cultivars of *M. sativa* (P=0.168) or *C. gayana* (P=0.241). *Leucaena leucocephala* had an EC_{50} of 4.9 dS/m, consistent with findings of Hansen and Munns (1988) in similar experimental conditions.

Differences in salinity thresholds between studies may be attributed to a number of factors: (1) methodology (it is suggested that the effect of salinity may be exacerbated in solution culture due to the absence of matric potential and cation exchange capacity present in soil-based systems); (2) failure to account for sodium-induced calcium deficiency; (3) differences in evapotranspiration demand (ETD) (low ETD results in reduced salt uptake and an increased ability to grow at a given salinity); (4) duration of exposure (short-term studies may not wholly reflect the effect of specific ion toxicity); (5) choice of model to explain results; and (6) intraspecific variation (Deifel et al. 2006; Kopittke et al. 2009; Tavakkoli et al. 2010).

Conclusions

Rhodes grass (*Chloris gayana*) was the most salt-tolerant species tested, followed by alfalfa (*Medicago sativa*) and then leucaena. Intraspecific variation was not evident within cultivars of *C. gayana* and *M. sativa*. The lower EC_{50} thresholds obtained for *C. gayana* and *M. sativa* in comparison with those published by Russell (1976) may be due to the different cultivars tested and also to differences in the experimental system and ETD.

On-going analysis of specific ion uptake will provide further understanding of the response of the forage species to increasing salinity. Further work is also needed to identify improved salinity tolerance within alfalfa and leucaena cultivars.

Acknowledgments

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Table 2. Estimated salinity levels (dS/m) in solutions when growth of several tropical and subtropical forage species was reduced by 25% (EC_{75}) and 50% (EC_{50}) relative to the control.

Species	EC_{75}	EC_{50}	Variance explained by model
Chloris gayana cv. Finecut	5.8	*	0.87
Chloris gayana cv. Toro	4.6	19.0	0.73
Medicago sativa cv. Multileaf	2.6	6.4	0.99
Medicago sativa cv. Titan 9	2.5	5.7	0.95
Medicago sativa cv. L91	2.5	5.7	0.95
Medicago sativa cv. Force 10	2.4	5.2	0.94
Leucaena leucocephala cv. Tarramba	2.3	4.9	0.96

*DM yield reduction <50% at 20.1 dS/m.

Table 3. Published salinity tolerance thresholds (dS/m) based on 50% yield reduction relative to the control.

Species	EC_{50}	Experimental system	Reference
Chloris gayana cv. Pioneer	23.2	Small pots − soil media	(Russell 1976)
Medicago sativa cv. Hunter River	10.2	Small pots − soil media	(Russell 1976)
Leucaena leucocephala cv. K8	~5	Sand culture	(Hansen and Munns 1988)

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Planet at risk from grazing animals?

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Keywords: Climate change, global warming, methane, greenhouse gases, biodiversity, grass-fed beef.

Introduction

The famous FAO report "Livestock's Long Shadow" (Steinfeld et al. 2006) and hundreds of subsequent publications blamed domestic livestock, in general, and grassland-based production systems in the (sub) tropics, in particular, of causing serious environmental hazards such as climate change, claiming that 18% of anthropogenic greenhouse gas (GHG) emissions are from livestock, more than from the transport sector. Few reviews challenged this claim, and those that did received little attention from the media. Pitseky et al. (2009) revealed the double standard applied by the FAO in this matter: Whereas for livestock products a full life cycle assessment for GHG emissions was applied, for the transport sector only fuel consumption was taken into account. This striking weakness of the FAO report alone considerably disadvantages livestock husbandry due to a scientifically questionable comparison.

Approach

In this review the most widely spread claims of alleged negative environmental impacts produced by livestock are discussed, partly in the light of lesser known publications, as well as empirical facts and data determined on a global scale, and partly with specific reference to the grazing systems in the Paraguayan Chaco.

Results and Discussion

Critique: "Livestock contributes to climate change"

The basic assumption for human-caused climate change is a noticeable climate sensitivity to anthropogenic GHG emissions, which is supported by the conclusions of the latest IPCC Assessment-Report AR4 (IPCC 2007). There is, however, quite a bit of empirical evidence which casts doubt on these conclusions:

- In Table 2.11of that report, 16 variables are identified as global warming-forcing agents and the level of understanding for 11 of them is specified as 'very low to low'. Yet the IPCC comes up with a 90 to 99% certainty in the results of its models, a conclusion which is logically unacceptable and scientifically indefensible.
- Mean global temperature has not increased in the past 15 years in spite of steadily increasing CO_2 levels in the atmosphere, an observed reality contrary to all model projections published by the IPCC.
- A large number of recently published peer-reviewed papers, such as Kobashi et al. (2011), Esper et al. (2012), Markonis and Koutsoyiannis (2012) and Axford et al. (2013), present evidence of the existence of various eras during the Holocene (since the end of the latest ice age about 12,000 years ago), which were warmer than or at least as warm as the present age (in spite of the pre-industrial atmospheric CO_2 levels in those times).

Even if we ignore these objections and keep assuming a measurable climate sensitivity to anthropogenic GHG emissions, many inconsistencies between the reality and the popular claim "meat = heat" still remain. CO_2 emitted by livestock respiration, forage digestion and the consumption of meat and milk, does not increase atmospheric CO_2 levels, as it is part of the natural carbon cycle. Not a single livestock-born CO_2 molecule is added *additionally* to the atmosphere, as it has previously been captured through photosynthesis. The amount of CO_2 released annually by livestock is offset by re-growing CO_2 assimilating forage. The only sources of *additional* CO_2 emissions caused by livestock husbandry beyond the natural carbon cycle are: (1) fossil fuel consumption during the production process, which is particularly low in grazing systems; and (2) deforestation for pasture establishment, which is partly offset by carbon captured by deep-rooted tropical grasses (Fisher et al. 1994), by persistent charcoal residues from burned wood (Mannetje 2007) and by bush encroachment and for-

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age hedgerow establishment. Deforestation causes a unique "carbon debt", which has to be shared out over the animal products generated during the total utilization period of the pasture, which replaced the forests, which may easily be hundreds of years (as in the case of European grasslands). However, for life cycle assessments of livestock products, this carbon debt is either neglected or charged entirely to the year of its appearance.

Just like CO_2, methane emissions also form part of a natural cycle with a relatively short atmospheric lifetime of 8.7 ± 1.3 years (IPCC 2007). Therefore, constant emissions from ruminant enteric fermentation cannot change atmospheric methane concentration, as they are counteracted by a constant or oscillating rate of breakdown. To my knowledge, not a single relevant publication takes this consideration into account, as livestock-born methane emissions are consistently interpreted at a 100% level as an *additional* anthropogenic GHG source, just like fossil fuel-born CO_2. Methane baseline scenario considerations over time and space are virtually absent in literature.

Between 1990 and 2007, the global cattle and buffalo population rose by more than 125 million head, or by 9% (FAO: http://faostat.fao.org/site/291/default.aspx), while the growth rate of atmospheric methane fell to zero (NOAA: www.esrl.noaa.gov/gmd/aggi). These empirical observations are hardly consistent with a domestic livestock contribution to anthropogenic methane emissions of 35–40% as claimed by Steinfeld et al. (2006). Quirk (2010) showed that historical increases of atmospheric methane concentrations are best explained by human fossil fuel consumption. The stabilization of methane emissions in the 1990s is very likely to be associated with the adoption of modern technology in fossil fuel production and use, particularly the replacement of leaking pipelines in the former Soviet Union. Since 2008, methane is slightly rising again, which Quirk (2010) attributes to natural atmospheric changes modulated by El Niño. The idea of a considerable livestock contribution to global methane emissions relies on theoretical bottom-up calculations. However, there is no discernible relationship between mean atmospheric methane concentrations, as measured by the ENVISAT satellite (http://goo.gl/OVkUJ3) over 3 full years (2003−2005) and global livestock distribution (Steinfeld et al. 2006, Map 20, p. 344).

Critique: "Livestock affects groundwater recharge and ineffectively uses huge amounts of water"

In the Chaco, groundwater recharge is less under bushland than under grassland (Glatzle et al. 2008). A great part of the beef industry in the semi-arid Chaco relies entirely and sustainably on locally harvested rainwater.

Critique: "Livestock causes loss of biodiversity through deforestation and grazing land development"

Paraguayan regulations on land clearing strictly prohibit pasture establishment on more than half of each cattle ranch's area, bringing about a diversification of habitats (pronounced bush-border effects, savanna-like grasslands, and rain water collection basins that provide water for wild game throughout the year as well). This causes an increase in the diversity of native vertebrate species by about 50% as compared with the closed pristine dry forest (Glatzle 2012).

Critique: "Grazing livestock 'consumes' a lot of land and ruminant food energy conversion is very poor"

Enteric cellulolytic bacteria enable ruminants (unique among vertebrates) to convert the most abundant substance in the biosphere, cellulose, into high value food, such as meat and milk. Therefore, grazing makes efficient use of marginal lands with highly fibrous feed, which comprise up to half the global terrestrial surface. Hence grass-fed beef is a complementary and not competing food for humans, thereby contributing considerably to global food security.

Conclusion

The contribution of domestic livestock and particularly grazing animals to climate change, as has been claimed in some published reports, has never been proved. Careful land development and appropriate management practices can assure full compatibility of grazing systems with the environment.

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Detection of toxicity in ruminants consuming leucaena (*Leucaena leucocephala*) using a urine colorimetric test

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Keywords: Leucaena toxicity, mimosine, DHP.

Introduction

Leucaena *(Leucaena leucocephala)*, a productive leguminous shrub for feeding ruminant livestock, contains the toxic amino acid, mimosine, which post ingestion is converted to 3,4-DHP and 2,3-DHP, isomers of dihydroxy-pyridone. While DHP generally does not produce acute toxic symptoms in animals, it has been suggested that it is an appetite suppressant that reduces liveweight gain (Jones 1994). With no observable symptoms, subclinical toxicity is difficult to detect (Phaikaew et al. 2012). In 1982, the DHP-degrading rumen bacterium named *Synergistes jonesii* was introduced into Australia as a potential solution to DHP toxicity, as it spreads easily throughout cattle herds grazing leucaena (Jones 1994). However, toxicity events reported since the 2003 drought suggest that the toxicity status of herds, previously understood as being protected, may have changed. This may be the result of loss of effective *S. jonesii* bacteria from the rumen. Widespread subclinical leucaena toxicity has since been confirmed, representing a significant economic threat to the beef industry (Dalzell et al. 2012).

At present, testing for toxicity requires a sophisticated chemical analysis of urine samples using high performance liquid chromatography (HPLC). Producers, however, require a robust and reliable means to routinely test for toxicity in their herds. A colorimetric urine test protocol is available, based on the color reaction of mimosine and DHP with $FeCl_3$ solution (Jones 1997). When this simpler colorimetric test was used under a wide range of conditions, false negatives were obtained. The aim of this study was to improve the reliability of the $FeCl_3$ urine color test.

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Materials and Methods

Urine samples collected from 5 herds grazing leucaena pastures in central Queensland were preserved (19 mL urine + 1 mL 10 N HCl). An acid titration was used to determine urine alkalinity. Urine hydrolysis and clean-up methods (filtering & chromatography) were optimized to reduce interference of background compounds. Color reaction matrix conditions were optimized for the detection of mimosine and 2,3-DHP by adjusting $FeCl_3$ concentration (Figure 1) and acid (HCl) strength (Figure 2). Final ratios of urine:$FeCl_3$ reagent were studied to optimize sensitivity of the test. HPLC analysis (Dalzell et al. 2012) was performed on urine samples to determine toxin concentrations and validate the color responses of the test kit.

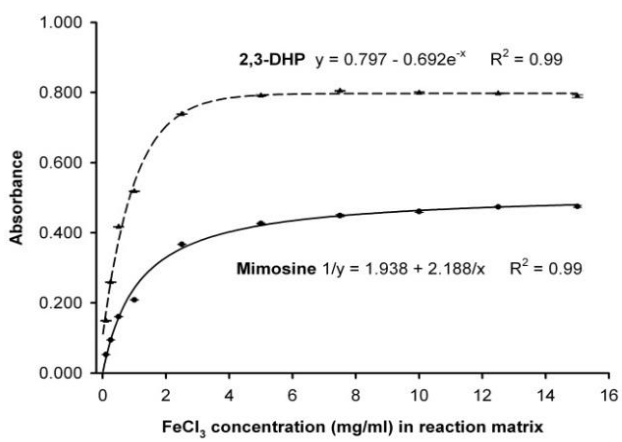

Figure 1. Color development (absorbance) for 200 µg/mL mimosine (λ = 535 nm) and 2,3-DHP (λ = 590 nm) at different $FeCl_3$ concentrations in 0.35 N HCl.

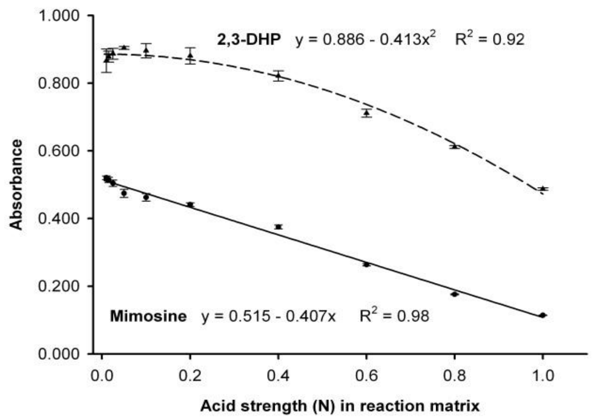

Figure 2. Color development (absorbance) for 200 µg/mL mimosine (λ = 535 nm) and 2,3-DHP (λ = 590 nm) at different acid strengths (HCl) with 10 mg/mL $FeCl_3 \cdot 6H_2O$.

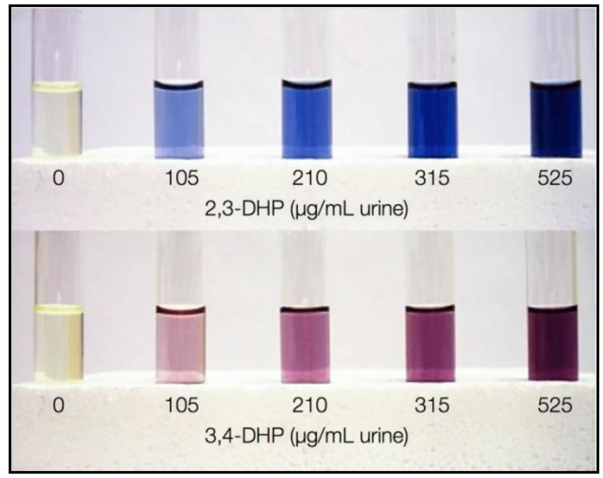

Plate 1. Test response to a range of standards equivalent to µg/mL toxin in urine (1:2 reagent reaction ratio).

Results and Discussion

The urine of cattle grazing leucaena was found to be very alkaline (pH=9). Preserving 9.5 mL urine by adding 0.5 mL 10 N HCl gave a residual acid strength of 0.35 N. Hydrolysis of the preserved urine by heating in boiling water for 1 h was required to release toxins that are typically conjugated to sugars prior to colorimetric analysis. Hydrolyzed samples were then cleaned prior to testing by filtering (0.45 µm) and chromatography (Maxi-Clean 300 mg C-18 columns) to remove background color. Optimal color development for both isomers of DHP occurred at $FeCl_3 \cdot 6H_2O$ concentrations >5 mg/mL and were most consistent at acid strengths of 0.2−0.4 N (Figures 1 and 2). Color development for 3,4-DHP was the same as for mimosine (G. Kerven, unpublished data). A reaction ratio of 1 urine:2 $FeCl_3$ reagent developed good color without being too sensitive. Samples from commercial cattle herds tested using this procedure developed pink/red color for mimosine/3,4-DHP and blue for 2,3-DHP (Plate 1). These results were confirmed by HPLC analysis. The color test proved to be robust with replicated sample results having a coefficient of variation <15%.

When Graham et al. (2013) applied this test in the field they found a high level of variability in urinary toxin concentrations among animals within a herd grazing the same leucaena pasture. They recommended that for herds consuming high dietary percentages of leucaena, urine samples from at least 10 cattle would be required to reliably assess herd protection status.

The recommended test protocol is: dilute urine samples 19:1 with 10 N HCl; hydrolyze for 1 h in boiling water; filter (0.45 µm) and pass through a C-18 column; dilute treated urine samples 1:2 with 10 mg/mL $FeCl_3 \cdot 6H_2O$ in 0.35 N HCl and then compare with standard toxin solutions. If mean herd urinary DHP concentrations >100 µg/mL are detected, the herd may be suffering from leucaena toxicity (Dalzell et al. 2012).

Conclusions

This semi-quantitative test kit will enable routine testing of herds for presence of toxins to determine their protection status at relatively low cost. While the urine samples can be collected by farmers, it is likely that the test will be carried out by appropriately trained service providers.

Acknowledgments

Dr. Olena Kravchuk provided statistical advice. The participation of graziers in the study is greatly appreciated.

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Rehabilitating degraded frontage soils in tropical north Queensland

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Keywords: Rehabilitation, degraded pastures, water quality, mechanical disturbance, Great Barrier Reef.

Introduction

The extensive tropical grasslands of north Queensland are grazed by beef cattle and provide a significant proportion of the water flowing into the Great Barrier Reef (GBR) lagoon. Soil sediments and nutrients eroding from the grazing lands of the Burdekin and Fitzroy catchments in north-east Queensland contribute to reduced water quality in the GBR lagoon. Degraded and eroded D-condition bare areas and eroding gullies in grazing lands provide a disproportionate amount of soil and nutrient losses from predominantly native pasture grasslands used for cattle grazing. Rehabilitating these degraded areas will help improve water quality flowing onto the reef.

Rehabilitation methods were evaluated on 3 soil types on a degraded creek frontage in the Burdekin River catchment of north Queensland over the 2011/12 summer. These bare patches occur widely across the 2 catchments and consistently degraded sites have been identified by 24 years of satellite imagery. The objectives of this study were to identify mechanical methods and management practices for regenerating pasture on these bare patches. This will assist landholders in returning unproductive land to useful grazing pastures and will provide benefits to the wider community by improving quality of water from grazing lands that enters the GBR lagoon.

Methods

Site

Long-term, bare D-condition areas were identified by the Bare Ground Index from satellite imagery over 1988−2011, and surveyed by ground-truthing to locate a 10 ha research site in the mid-Burdekin catchment of tropical north Queensland. The site was a periodically inundated creek flat with up to 50 cm of topsoil eroded, in undulating narrow leaved ironbark (*Eucalyptus crebra*) and Reid River grey box (*E. brownii*) flats west of the Burdekin River (GPS 19.337^{o} S, 145.814^{o} E). There were 3 soil types: a deep grey sodosol (Dy3.13); a crusty deep black vertosol (Ug5.15); and a sodic brown dermosol (Uf6.41).

Treatments and measurements

Four unreplicated mechanical soil disturbance treatments of 1−2 ha size: chisel plowing to 20 cm deep at 20 cm tyne spacing; deep ripping to 50 cm deep at 1 m spacing; crocodile seeder (a rotating seed-containing large drum with shovel-like tools attached); and grass hay mulch to 20 cm deep after surface disturbance and levelling with a grader blade, were compared with an undisturbed control. The mechanical treatments were applied to dry soil in October 2011, and a seed mix of tropical pasture grass and legume was broadcast over all treatments, including the control. This was followed by 100 mm of rainfall within a week in mid-October 2011 and a total of 775 mm in an above average rainfall wet season. Pasture measurements were: establishment, species yield and ground cover, which were monitored after the first summer season in April 2012. Cattle grazing was excluded.

Results and Discussion

The rainfall following seeding produced germination of pasture seed over the trial site, and all seedlings died during one month of heat-wave conditions to 40 °C, eliminating some soft-seeded species. These false germination starts are a threat to pasture rehabilitation in spring in this area. There was a second germination event in mid-December 2011, following 96 mm of rainfall. This germination was predominantly Indian bluegrass (*Bothriochloa pertusa*), butterfly pea cv. Milgarra (*Clitoria ternatea*) and desmanthus cv. Progardes (*Desmanthus* spp.). Establishment success varied with soil type. Cover (to 90%) and yields (>3,400 kg/ha) were highest on the vertosol and sodosol soil

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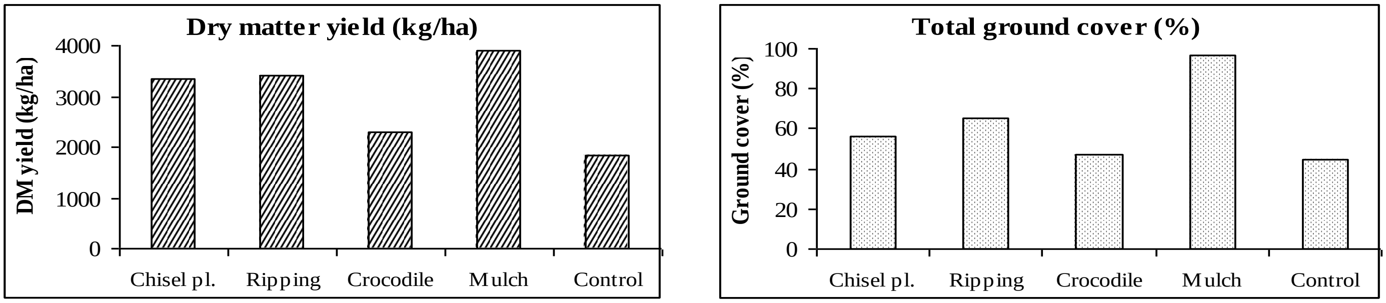

Figure 1. Pasture dry matter yield and cover for various mechanical treatments (April 2012).

types and lowest on the sodic dermosol soil (cover <20% from annual native *Sporobolus* and *Portulaca* spp.).

The hay mulch cover treatment produced the highest total dry matter yield (3,910 kg/ha), including 55% Rhodes grass (*Chloris gayana*), and cover (97%), while results were similar from the deep ripping and chisel plowing treatments (3,400 kg DM/ha and 60% cover) over the first growing season (Figure 1). Crocodile seeding produced a lower yield than other disturbance methods, only marginally higher than the control, and cover similar to the control (mean all soil types 45%). Pasture basal area was highest in the deep ripping and chisel plowing treatments (1.8%) and lowest in the control (1%).

Dry matter yields of pasture species groups (Table 1) showed the hay mulch layer produced the highest yields of both perennial (predominantly Rhodes grass) and annual grasses. Chisel plowing and deep ripping treatments produced similar yields (predominantly Indian bluegrass), and the highest legume yields. The crocodile seeder treatment was inferior to the more intensive surface disturbance treatments and only marginally superior to the undisturbed control.

Table 1. Mean pasture dry matter yield in rehabilitation treatments over the first summer.

Plant group	Pasture yield (kg/ha)				
	Chisel plow	Ripping	Crocodile	Hay mulch	Control
Perennial grasses	2,110	1,820	2,060	3,040	1,420
Annual grasses	190	100	60	460	210
Legumes	1,030	1,430	170	300	200
Forbs	30	70	20	110	30
Total DM yield	3,360	3,420	2,310	3,910	1,860

Conclusions

Mechanical rehabilitation on degraded D-condition bare areas in tropical north Queensland in spring, when the following rainfall conditions over summer are favorable for pasture establishment, can produce sufficient pasture cover to limit erosion within the first year. Selecting suitable soil types and the most adapted pasture species offers the greatest chance of success. False germination events could lead to failure in the first year, as the two 100 mm rainfall germination events in early summer in this study were not an annual occurrence in this environment. In an above average rainfall summer, soil type had the most influence on establishment success, production and cover in the first year.

While pasture seeding with grass hay mulch cover on disturbed vertosol and sodosol soils produced the highest herbage yields and ground cover in the first season, deep ripping and chisel plowing are much more practical options and produced a greater legume percentage in the pasture. These methods are recommended for pasture establishment on these soils. The resulting pasture is sufficient to limit soil sediment and nutrient losses from bare areas in these grasslands.

Pasture survival and cover levels in following years will determine if these methods of rehabilitation of D-condition bare areas provide a permanent solution to improving land productivity and reducing sediment and nutrient losses from these grasslands. Additional research is needed to identify appropriate methods for developing sustainable pasture cover on the sodic dermosol soils.

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The efficacy of in vitro *Synergistes jonesii* inoculum in preventing DHP toxicity in steers fed leucaena-grass diets

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Keywords: *Leucaena leucocephala*, mimosine, dihydroxypyridine, urine.

Introduction

Leucaena leucocephala (leucaena) is a valuable forage tree legume for tropical animal production, which contains the toxin mimosine. The breakdown products of mimosine in ruminants (3,4-DHP and 2,3-DHP) can adversely affect their health and limit weight gains (Jones and Hegarty 1984). The rumen bacterium *Synergistes jonesii*, introduced into Australia in 1983, was shown to completely and rapidly degrade these toxins to safe levels (Jones and Megarrity 1986). Since 1996, an inoculum has been produced in vitro and made commercially available to Australian graziers (Klieve et al. 2002). Accordingly, the issue of leucaena toxicity in Australia was thought to be resolved. However, extensive testing in 2004 found that up to 50% of Queensland cattle herds consuming leucaena were excreting high levels of urinary DHP, suggesting subclinical toxicity remained an issue for graziers (Dalzell et al. 2012). Some of these herds had previously been inoculated with in vitro *S. jonesii*, suggesting the inoculum may not be able to either persist within a herd, or remain effective in degrading DHP.

The aim of this study was to assess the capability of the in vitro *S. jonesii* inoculum to efficiently break down DHP in a controlled feeding trial environment.

Methods

Sixteen mixed breed stall-housed steers, previously naïve to leucaena and S. jonesii and weighing 200−300 kg, were fed 3 different leucaena-grass diets (25, 50 and 100% leucaena) offered at 2.5 kg dry matter (DM)/ 100 kg live weight over a 6-week period to establish subclinical toxicity (pre-inoculation). Animals were then inoculated with the in vitro *S. jonesii* inoculum and continued to consume the same leucaena-grass diet for another 4 weeks (post-inoculation). At inoculation, a control treatment was imposed on half of the animals consuming 50% leucaena, where lucerne (*Medicago sativa*) replaced leucaena. Animal toxicity status was determined by analysis of urinary DHP levels; each animal spent 24 hours in a metabolism crate once per week, where a bulk urine sample was collected. Concentrations of DHP were measured by HPLC (Graham et al. 2013), and urine volume was recorded, allowing total DHP excreted to be expressed in mg/hd/d. Dalzell et al. (2012) adopted a mean herd DHP excretion level above 100 mg/L in urine as indicative of subclinical toxicity. Accordingly, an excretion level of 100 mg/L was used as a mean treatment threshold for toxicity. Mean urine volume was approximately 3.5 L/hd/d, thus a mean DHP excretion greater than 350 mg/hd/d was regarded as indicative of subclinical toxicity.

Results and Discussion

During the 6 weeks prior to inoculation, total DHP excretion increased with amount of leucaena consumed (Figure 1). However, total DHP had peaked at 3 weeks and was already declining at 6 weeks, when animals were first inoculated (Figure 2). This was associated with a decline in the isomer 3,4-DHP, while the isomer 2,3-DHP, which first appeared at week 2, remained static until after inoculation (data not presented).

During the 4 weeks post-inoculation, the rate of total DHP excretion continued to decrease (Figures 1 and 2) to low levels, albeit still above the threshold level of 350 mg/hd/d at higher levels of leucaena feeding. There was, however, a sharp decrease in 2,3-DHP to very low

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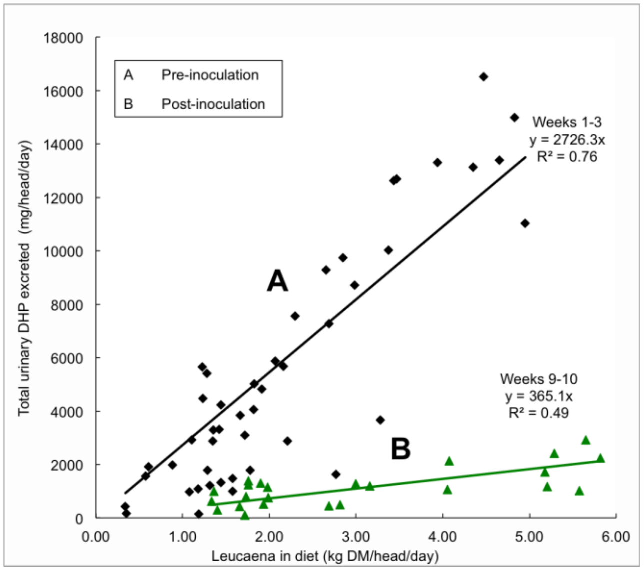

Figure 1. Relationship of total DHP excreted per day (mg/hd/d) with amount of leucaena in diet (kg DM/hd/d).

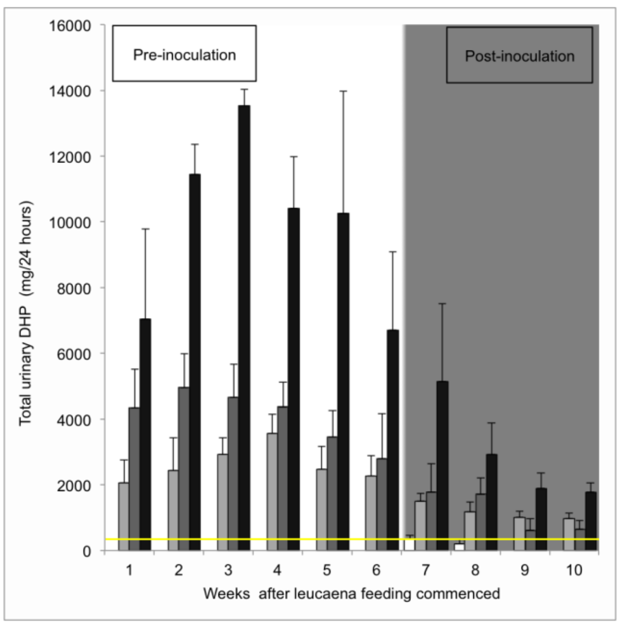

Figure 2. Mean total daily urinary DHP excreted (mg/hd/d) over the 10-week period (+ s.e.) for: ▢ 25%, ▢ 50%, ■ 100%, and ☐ Control treatments. Yellow line denotes safe threshold level of 350 mg/hd/d.

levels, while 3,4-DHP remained unchanged from week 6 through to week 10. The control animals ceased excreting DHP within 2 weeks of the change from leucaena to lucerne.

The degradation of 3,4-DHP prior to inoculation was presumably due to existing microorganisms capable of degrading 3,4-DHP but not effective at degrading 2,3-DHP. Since these cattle had never previously consumed leucaena or been inoculated with *S. jonesii*, it appears that organisms that can degrade 3,4-DHP to 2,3-DHP may be more widespread than previously thought.

Conclusions

Since previous work demonstrated that in-vivo sources of *S. jonesii* almost completely eliminated urinary DHP excretion within 7-10 days of inoculation (Jones and Lowry 1984), this work has shown that the current in vitro *S. jonesii* inoculum may not be as effective, especially in animals consuming high leucaena diets. The in vitro inoculum appeared to augment degradation of 2,3-DHP by the resident microbial populations more capable of, albeit incomplete, 3,4-DHP degradation. Further research is warranted to seek a more efficient in vitro inoculum, which can be readily produced, stored and administered.

Acknowledgments

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Prevalence of DHP toxicity and detection of *Synergistes jonesii* in ruminants consuming *Leucaena leucocephala* in eastern Indonesia

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Keywords: Dihydroxypyridine, mimosine, urine, rumen fluid, PCR.

Introduction

Leucaena leucocephala (leucaena) is a productive forage tree legume widely used in eastern Indonesia. While highly nutritious, it contains the toxin mimosine, which adversely affects animal production. In ruminants, mimosine is readily converted to the 2 isomers of dihydroxypyridine (3,4-DHP and 2,3-DHP) known to cause goitre, suppress appetite and cause severe mineral deficiencies. These adverse symptoms may be partially responsible for the reluctance of some farmers to feed leucaena.

A bacterium capable of complete degradation of DHP, *Synergistes jonesii*, originally discovered in Hawaii in goats consuming leucaena (Jones and Megarrity 1986), was later found in Indonesia, which led to the assumption that all Indonesian ruminants were protected from leucaena toxicity even on 100% leucaena diets.

The objective of this study, conducted during October-November 2011, was to test this hypothesis via an extensive survey of the toxicity status of ruminants consuming leucaena in eastern Indonesia.

Methods

Cattle, goats and buffalos from 5 villages in each of the islands of Lombok, Sumbawa, Sumba and Timor were selected from existing leucaena-based fattening systems (Table 1). Urine samples were collected from up to 10 animals within each village; discussion with farmers revealed that leucaena ranged between 30 and 100% of the diet. Urine samples were preserved and analyzed for DHP by HPLC, using the method described in Graham et al. (2013). Rumen fluid was collected from 3 animals in each village for PCR detection of *S. jonesii* at CSIRO Animal, Food & Health Sciences laboratory in Brisbane, Australia, using a modified method described in Graham et al. (2013). No rumen samples were collected in Sumbawa.

Results and Discussion

On Lombok island (Table 1), where leucaena is often fed to goats, animals in villages less than 40 km apart (in some cases <1 km) differed completely in their toxicity status; mean DHP excretion by goats in the village of Bayan approached 1000 mg/L, whereas goats in the village of Pemenang excreted no urinary DHP on the same diet of leucaena. PCR analysis of rumen fluid confirmed the presence of *S. jonesii* in Pemenang, but not in Bayan.

On the isolated island of Sumba, farmers have often reported that cattle are reluctant to eat leucaena (Jacob Nulik, unpublished data). However, goats and buffalos were located consuming high leucaena diets without adverse effects. Ten buffalos consuming up to 100% leucaena from 3 districts were sampled; all were excreting low levels (<150 mg/L) of DHP. *Synergistes jonesii*, identical to the type strain (strain 78-1, ATCC 49833), was detected in 5 of 7 samples of rumen fluid.

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Table 1. Urinary total DHP (3,4-DHP + 2,3-DHP) excretion ranges and detection of *S. jonesii* in ruminants in villages in eastern Indonesia.

Island	Village	Animal (#)	Mean urinary DHP (mg/L) (±s.e.)	Urinary DHP range (mg/L)	*S. jonesii* detected
Lombok	Bayan	goats (10) & cattle (9)	420 (±142)	0−2,000	N
	Pemenang	goats (8)	5 (±1)	0−10	Y
	Pringgabaya	goats (9)	481 (±143)	0−1,200	Y
	Sekotong	goats (9) & cattle (9)	276 (±124)	0-2,000	Y
	Rambitan	goats (7)	105 (±67)	0−400	Y
Sumbawa	Poto Tano	cattle (7)	811 (±383)	0−2,000	N/A
	Baturea	cattle (6)	765 (±352)	0−2,000	N/A
	Rhee Jatisari	cattle (9)	421 (±125)	0−1,000	N/A
	Penyenger	cattle (9)	818 (±359)	0−2,800	N/A
	Labangka I	cattle (8)	816 (±247)	0−1,500	N/A
Sumba	Kamalaputi	goats (6)	4 (±2)	0−10	Y
	Kambaniru	goats (5)	22 (±15)	0−100	Y
	Melolo	buffalo (4)	82 (±21)	0−150	Y
	Wanga	buffalo (1)	25 (-)	25	Y
	Kakaha	cattle (2) & buffalo (2)	45 (±32)	0−150	Y
Timor	Ponain, Amarasi	cattle (6)	216 (±138)	0−700	Y
	Tesbatan II, Amarasi	cattle (5)	227 (±117)	0−500	Y
	Oelbeba	cattle (4)	532 (±149)	100−900	N
	Lili	cattle (5)	27 (±9)	0−60	Y
	Sumlili	goats (4) & cattle (4)	830 (±276)	0−2,000	Y

Animals in the 5 villages sampled in Sumbawa showed high variability, both between and within villages. In the village of Rhee Jatisari, which had a highly productive leucaena-based cattle fattening system, farmers regularly bought in new bulls naïve to leucaena. Data showed a high variability between old and new (<5−6 weeks on leucaena) animals, which showed low and high urinary DHP, respectively. This was expected as it can take up to 5 weeks to acquire *S. jonesii* from nearby stock (Jones et al. 1985).

Ruminants consuming leucaena on the island of Timor also showed high variability in DHP excretion; DHP excretion rates in villages in Amarasi (Jones 1983) ranged between 0 and >1,000 mg/L DHP. Regular stock movement from cattle trading and purchases is likely to be the cause of the variability, and like Sumbawa, both areas are productive leucaena-based cattle fattening regions.

Conclusions

In summary, PCR results indicate that *S. jonesii* is widespread throughout ruminants sampled in villages in Lombok, Sumba and Timor, where leucaena diets have been employed for long periods. Contrary to the initial hypothesis, capacity to degrade DHP does not appear throughout the entire region, and is often isolated within certain farms or certain villages; significant numbers of animals were found to be excreting high levels of urinary DHP, suggesting animals were experiencing subclinical DHP toxicity. *Synergistes jonesii* was detected in many of these animals; however, different strains of the bacterium may have different DHP-degrading capacity. Animals not fully protected will be underperforming and subject to adverse health concerns from untreated DHP toxicity. As such, it is important to educate local extension officers about methods to detect and manage DHP toxicity, including improved inoculation protocols, to overcome a possible barrier to the further adoption of leucaena.

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Germination of tropical forage seeds stored in ambient and controlled temperature and humidity conditions

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Keywords: Seed viability, seed storage, embryo dormancy, humid tropics.

Introduction

Correct storage of tropical forage seeds in the humid tropics is critical in order to safeguard germination. Storing Mulato hybrid brachiaria (*Brachiaria ruziziensis* x *B. brizantha*) seed under ambient conditions could be safely done for 8−12 months in Thailand, but rapid deterioration in viability occurred with longer storage, with seed being totally non-viable after 20 months storage (Hare et al. 2008). However, Mulato seeds kept in cold storage (10 °C and 40% RH) for 3 years still maintained 80% germination. Similar results were found in northern Australia (Hopkinson and English 2005), where loss of viability of *Panicum maximum, Brachiaria decumbens, Brachiaria humidicola, Setaria sphacelata* and *Chloris gayana* seeds was rapid under ambient conditions with total death at 3 years. Under cold storage, maximum seed viability was still maintained after 6 years of storage.

Embryo dormancy is reduced with age (length of storage) and is usually short-lived (i.e. several months) in many *Brachiaria* species. Hare et al. (2008) found that dormancy was quickly lost in Mulato seed stored at ambient temperatures but still persisted strongly after 3 years in cold storage. Hopkinson and English (2005) found that dormancy persisted longer under cool storage than under ambient storage.

Forage seeds produced by Ubon Forage Seeds at Ubon Ratchathani University (Hare et al. 2013) are stored in a large commercial cool room (18−20 °C and 50% RH), but there are no data on how long seeds can be safely stored in this room. The objectives of this trial were to study: the effects of ambient storage and cool-room storage on germination of our range of tropical forage seeds; and the persistence of embryo dormancy with storage.

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Materials and Methods

This study is an ongoing trial conducted at the Faculty of Agriculture, Ubon Ratchathani University, Thailand. It commenced in January 2011 and will continue for as long as seeds continue to germinate. This paper reports on the germination results for the first 2 years (January 2011−January 2013). Seeds of Mulato II (*Bracharia ruziziensis* x *B. decumbens* x *B. brizantha*), Mombasa guinea (*Panicum maximum*), Tanzania guinea (*P. maximum*), Ubon paspalum (*Paspalum atratum)* and Ubon stylo (*Stylosanthes guianensis*) were studied. Two lots of Mulato II seed were available (harvested from ground-sweeping the seed; and harvested by knocking the seed from seedheads), and half of each lot was scarified in sulphuric acid for 10 minutes and half left untreated. Ubon stylo seeds were either scarified with sulphuric acid or left untreated. Each lot consisted of 3 kg of seed placed into commercial polyethylene bags.

Seeds were placed in 2 storage rooms (ordinary ambient conditions and a cool room). The ambient seed room was a seed storage shed at Ubon Ratchathani University and average monthly temperatures in this room varied from 22 °C (January) to 34 °C (July) and average daily RH from 80% (January) to 95% (August/September). The cool room was at the Ubon Rice seed station and was maintained at 18−20 °C and 50% RH throughout the study.

Seed samples were drawn in August and January of each year. Three lots of 100 seeds for each cultivar test were placed on petri dishes on top of filter paper wet with a 0.2% potassium nitrate solution and placed in a germination cabinet at 25 °C with 16 h dark and 35 °C with 8 h light. Germination counts were taken at 7 and 14 days.

Results

Seed germination of all cultivars, except Ubon stylo, deteriorated rapidly under ambient conditions with almost total death after 1 year of storage (Table 1). After 2 years storage in the cool room, seed germination of Mulato II and

Ubon stylo was maintained but germination of Mombasa, Tanzania and Ubon paspalum seeds was starting to decline. Under ambient storage, only seed of Ubon stylo that was not acid-scarified still produced high germination (94%) after 2 years (Table 1).

Seeds of Mombasa and Tanzania guinea grasses showed improved germination following 8 months cool-room storage (Table 1). Seeds of Mulato II and Ubon stylo not scarified in acid and stored in the cool room, maintained very low germination (0−23%) but once scarified with acid, germinations increased to 73−88% for Mulato II and 99−100% for Ubon stylo (Table 1).

Discussion and Conclusions

This study indicates that:

- under ambient storage conditions, seeds of Mulato II, Mombasa guinea, Tanzania guinea and Ubon paspalum cannot be safely stored, even for short periods (8−12 months), with seeds almost totally non-viable after 12 months;
- seeds of Mulato II and Ubon stylo can be safely stored in controlled cool-room conditions for 2 years;
- seeds of Ubon paspalum and Mombasa and Tanzania guinea grasses can be safely stored in a cool room for up to 20 months, after which germination starts to decline;
- embryo dormancy in Mulato II and hardseededness in Ubon stylo could not be broken by storage and persisted strongly after 2 years storage in a cool room; and
- embryo dormancy in Mombasa and Tanzania guinea grasses was quickly broken by cool-room storage.

The study will continue to determine when, under cool-room conditions, the viability of the guinea grasses and Ubon paspalum reaches zero and for how long treated Mulato II and Ubon stylo seed will maintain its viability and untreated seed will retain its dormancy/hard-seededness.

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Table 1. Effect of seed storage room conditions on 14 day seed germination (%) of 5 tropical forage cultivars.

Cultivar	January 2011	August 2011		January 2012		August 2012		January 2013	
		Cool[1]	Ambient[2]	Cool	Ambient	Cool	Ambient	Cool	Ambient
Mulato II ground sweep, acid	84	91	34	90	3	89	0	87	0
Mulato II ground sweep, non-acid	5	9	17	7	1	17	0	7	0
Mulato II ground sweep, non-acid then acid with test	84	78	51	75	3	88	0	81	0
Mulato II hand knocked, acid	51	80	17	81	0	90	0	84	0
Mulato II hand knocked, non-acid	0	2	5	1	0	3	0	1	0
Mulato II hand knocked, non-acid then acid with test	51	83	26	75	0	84	0	73	0
Mombasa guinea	35	72	10	68	0	65	0	49	0
Tanzania guinea	43	58	15	45	1	58	0	29	0
Ubon paspalum	73	81	16	79	0	83	0	60	0
Ubon stylo acid	92	99	94	94	0	99	0	97	0
Ubon stylo non-acid	16	16	17	19	2	23	0	5	1
Ubon stylo non-acid then acid with test	92	100	96	99	87	99	93	99	94

[1]18−20 °C and 50% RH; [2]Range of mean monthly temperature: 22−34 °C; range of mean monthly RH: 80−95%.

Herbage accumulation and animal performance on Xaraés palisade grass subjected to intensities of continuous stocking management

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Keywords: Herbage mass, liveweight gain, grazing management, *Brachiaria brizantha*.

Introduction

Most grass species used in Brazil belong to the genera *Brachiaria* and *Panicum*, with Marandu palisade grass (*Brachiaria brizantha* cv. Marandu) being the main cultivated forage grass (Santos Filho 1996). *B. brizantha* cv. Xaraés was released as an option for diversifying forage species; it has high herbage yield and fast re-growth, favoring high stocking rates and animal productivity (Euclides et al. 2008; 2009). The objective of this study was to evaluate herbage accumulation and animal performance of beef steers grazing continuously stocked Xaraés palisade grass managed at 15, 30 and 45 cm sward height.

Methods

The experiment was carried out at Embrapa Gado de Corte, Campo Grande, MS, Brazil (20º27' S, 54º37' W; 530 m asl). According to Köppen classification (Kottek et al. 2006), the climate corresponds to a transition from Cfa to Aw humid tropical with dry winters. Average annual rainfall is 1,560 mm, with a dry period from May to September (30% of annual rainfall). *B. brizantha* cv. Xaraés (Xaraés palisade grass) was studied from December 2008 to December 2009. Treatments were 3 sward surface heights (SSH, 15, 30 and 45 cm), generated by continuous stocking and maintained on target using variable stocking rates, and were allocated to a complete randomized block design, with 2 replications; paddock size was 0.67 ha. Herbage mass was sampled every 28 days using fifteen 1.0 m^2 quadrats per paddock with cuts made at ground level. All herbage within quadrats was harvested and separated into 2 subsamples. One was dried in a forced-draught oven at 55 °C for 72 hours and then weighed. The other one was hand-separated into the morphological components leaf (leaf lamina), stem (stem + leaf sheath) and dead material. These were also dried in a forced-draught oven, similarly to the total-herbage mass samples, and dry weights used to calculate morphological composition as percentage of total herbage mass. Three test animals per paddock were weighed regularly to determine weight gains, with extra steers used to adjust stocking rate according to the need to maintain treatment specifications.

Results

Plant responses

Herbage mass varied with SSH (P<0.05) and corresponded to 1,410, 3,610 and 5,180 ± 66 kg DM/ha on swards managed at 15, 30 and 45 cm, respectively, equivalent to herbage bulk density values of 89, 115 and 115 kg DM/ha/cm. In general, morphological composition of sward herbage mass (percentage of leaf, stem and dead material, and leaf:stem and leaf:non-leaf ratios) was affected by SSH, season of the year and SSH x season of the year interaction (P<0.05). The percentage

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of leaf normally decreased with SSH, except during autumn, when there was no difference among treatments.

Animal responses

Animal daily liveweight gain (ALWG) varied with SSH and season of the year (P<0.05) (Table 1). Recorded values were larger on swards managed at 30 cm than on swards managed at 15 and 45 cm (0.50, 0.77 and 0.60 ± 0.04 kg/hd/d for 15, 30 and 45 cm, respectively). There was a clear contrast between rainy and dry seasons, with larger values recorded during late spring, summer and autumn and lower during winter and early spring (0.74, 0.80, 0.45, 0.40 and 0.73 ± 0.04 kg/hd/d for summer, autumn, winter, early and late spring, respectively).

Daily gain per hectare (Table 2) was affected by SSH, season of the year and SSH x season of the year interaction (P<0.05). Treatment differences were small but cumulative, resulting in larger gain per hectare on swards managed at 30 cm at the end of the experiment. For swards managed at 15 and 45 cm, larger values were obtained during summer, lower values during early spring and intermediate values during autumn, winter and late spring. Values were relatively stable throughout the experiment on swards managed at 30 cm. Variations in total weight gain per hectare between treatments were similar to those of ALWG, with values on swards managed at 30 cm being 14 and 26% larger than those recorded on swards managed at 15 and 45 cm, respectively. With the exception of swards managed at 30 cm, weight gain per hectare was largest during summer and lowest during early spring; the difference between these 2 seasons was particularly large on swards managed at 15 cm. This can be explained by variations in changes in ingestive behavior characteristics, particularly intake rate, since under continuous stocking with fixed sward targets, as used in this experiment, animals exploit the top third of the sward canopy, which is comprised almost exclusively of leaf lamina. In this context, variations in chemical composition are not large enough to explain differences in animal performance, indicating that differences are mainly due to variations in intake (Da Silva and Nascimento Jr. 2007).

Conclusion

It is concluded that under continuous stocking management with growing steers, the optimum sward target was 30 cm.

Table 1. Seasonal changes in animal daily liveweight gain (kg/hd/d) on Xaraés palisade grass swards subjected to intensities of continuous stocking throughout the year.

Season of the year	Sward surface height (cm)			Mean
	15	30	45	
Summer	0.74 (0.07)[2]	0.79 (0.07)	0.68 (0.07)	0.74 a[1] (0.04)
Autumn	0.54 (0.11)	1.04 (0.11)	0.82 (0.11)	0.80 a (0.06)
Winter	0.41 (0.07)	0.49 (0.07)	0.44 (0.07)	0.45 b (0.04)
Early spring	0.15 (0.11)	0.55 (0.11)	0.49 (0.11)	0.40 b (0.06)
Late spring	0.66 (0.07)	0.95 (0.07)	0.47 (0.07)	0.73 a (0.04)
Mean	0.50 B (0.04)	0.77 A (0.04)	0.60 B (0.04)	

[1]Overall means followed by the same letters (lower case for seasons and upper-case for sward heights) are not different (P>0.05). [2]Values in parentheses correspond to standard error of the mean (s.e.).

Table 2. Daily weight gains per hectare (kg/ha/d) on Xaraés palisade grass swards subjected to intensities of continuous stocking throughout the year.

Season of the year	Sward surface height (cm)			Mean
	15	30	45	
Summer	4.90 (0.44)[2]	4.20 (0.44)	4.80 (0.44)	4.63 a[1] (0.25)
Autumn	2.32 (0.62)	3.63 (0.62)	2.68 (0.62)	2.88 bc (0.36)
Winter	2.81 (0.44)	2.74 (0.44)	2.17 (0.44)	2.57 bc (0.25)
Early spring	0.86 (0.62)	2.59 (0.62)	1.73 (0.62)	1.73 c (0.36)
Late spring	3.25 (0.44)	4.56 (0.44)	1.92 (0.44)	3.24 b (0.25)
Mean	2.83 AB (0.23)	3.54 A (0.23)	2.66 B (0.23)	
Total for the experiment (kg/ha)	1026 B (15)	1173 A (15)	930 B (15)	

[1]Overall means followed by the same letters (upper case for sward heights and lower case for seasons) are not different (P>0.05). [2]Numbers in parentheses correspond to standard error of the mean (s.e.).

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Barriers to and opportunities for the use of forage tree legumes in smallholder cattle fattening systems in Eastern Indonesia

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Keywords: *Leucaena leucocephala*, *Sesbania grandiflora*, situation analysis, outreach strategy.

Introduction

Forage tree legumes (FTL) have existed in the Eastern Indonesian landscape since colonial traders introduced several species in the late 1800s. A specific effort was made to establish leucaena (*Leucaena leucocephala*) and sesbania (*Sesbania grandiflora*) for use as forage for cattle fattening at Amarasi in East Nusa Tenggara Province and Central Lombok in West Nusa Tenggara, in the 1970s (Yuksel et al. 1999; Dahlanuddin and Shelton 2005). Their spread within these provinces as potential forage to intensify cattle fattening systems, however, has been slow, if not stagnant. In preparation for intensified efforts to encourage farmers in East and West Nusa Tenggara to grow and use FTLs for cattle fattening, we asked the question why successful FTL feeding practices by some communities had not spread widely to adjacent areas within the provinces. A situation analysis study was conducted in 2011/12 in East and West Nusa Tenggara Provinces; it aimed at identifying the barriers to and opportunities for FTL use in smallholder cattle fattening systems. This paper describes the methodology of this study, its main findings and the implications for follow-up expansion of FTL innovations.

Methodology

The study sites were selected based on a set of criteria, including cattle population, ownership and management system, land ownership by farmers, current use or potential of FTLs, and suitability and accessibility of the villages for follow-up activities. The study looked at locations where leucaena and sesbania were already being intensively used for cattle fattening but where farmer practices can be improved, and where FTL use is limited. A total of 34 hamlets in 12 sub-districts in 6 districts across the 2 provinces were visited by study teams for 3 days each, during which a range of data collection methods were conducted. These included a transect walk with participatory mapping, observations and informal interviews (Figure 1), focus groups with male and female farmers (Figure 2), and

Figure 1. Informal interview during transect walks

Figure 2. Focus group discussion.

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household interviews with 9−10 selected farmers per hamlet (Figure 3). The study provided detailed profiles of each of the locations, and a general understanding of farmers' current cattle management practices and their perceptions on the use of FTLs as cattle feed.

Figure 3. In-depth household interview

Results and Discussion

Barriers to adoption of forage tree legume innovations that were identified included the following:

Leucaena systems (West Timor, Sumba, Sumbawa)

- Where large areas of communal grazing lands are available, farmers do not see a need to allocate resources and labor to tether or pen cattle and feed by cut-and-carry methods. Families that own cattle and have the capacity to fatten tend to have a relatively large number of animals and prefer grazing over a cut-and-carry system, for which they do not have sufficient labor.
- In some areas, especially West Timor, farmers consider it is safer to let cattle graze on communal land than to tether or pen them, as theft tends to happen in built-up areas.
- There is a perception that newly established forage plots will be damaged by free-grazing animals, if the whole community does not participate in penning or tethering practices.
- Previously introduced varieties of leucaena are prone to psyllid infestation.

Sesbania systems (Lombok)

- Farmers do not have enough land to plant (more) sesbania trees. Where sesbania trees are planted on the paddy bunds, farmers feel they cannot increase their density, as there are already many trees and other fodder crops on the bunds.
- Many farmers believe that the sesbania trees on the bunds disrupt the development of the main crop in the paddy field by shading. In areas in Lombok with very narrow bunds, farmers fear (and have experienced) that sesbania roots can damage the bunds or cause water leakage.

Both systems

- FTL trees are not always available in the area, or not in sufficient amounts for intensive feeding, while other fodders such as grass are in abundance.
- Farmers lack knowledge and skills regarding tree establishment and have no access to FTL seed sources. Farmers tend to have limited knowledge on the feeding/nutritional requirements of cattle and how to match these with the nutritional value of different forages. There are many misconceptions among farmers about the nutritional value of FTLs and their side effects on cattle and feed preferences.
- In many cases, the price received for cattle at sale is not determined by the actual live weight but on an estimation by the trader. The limited bargaining power of the farmers provides a negative incentive for achieving maximum live weight of the animals. Many farmers tend to sell their cattle below the optimum sale weight due to lack of capital. This situation is unfavorable to the adoption of good feeding practices.

Opportunities identified for the introduction and intensified use of FTLs

- There is ample land available that can be allocated to FTLs, especially in areas where forage production systems are underdeveloped (Timor, Sumba and Sumbawa). Farmers have shown a willingness to make use of available land to integrate FTLs into their cropping and cattle feeding systems.
- A psyllid-tolerant variety of leucaena (cv. Tarramba) is now available in Eastern Indonesia and seems to be thriving under local conditions. Some farmers produce and sell FTL seed, while others market FTL foliage as forage to other farmers and perceive this to be a lucrative business.
- Areas where FTL plots were established have attracted participation from Department of Livestock cattle distribution schemes for farmers. Local village governments expressed a willingness to introduce village regulations to limit free grazing of animals and hence provide more favorable conditions for FTL plots to establish.

Conclusions

While initial barriers to and opportunities for the adoption of leucaena and sesbania innovations were identified and formed the design of an outreach strategy, continuing follow-up assessment is needed in order to understand how increased knowledge of and access to FTL innovations influence farmers' perceptions and practices.

To overcome barriers to the implementation of FTL innovations and capitalize on existing opportunities, an effective outreach strategy would need to address perceptions, access and regulations. Perceptions can be influenced by providing information and experiences to farmers that alter their attitudes and improve their knowledge, skills and practices. This can be in the form of exchange visits, demonstration trials, information media, practice-based training and dialogue. Access relates to agricultural inputs, such as high quality FTL seed, advisory and credit services and land availability. Regulations may be required in some locations to support collective action. Such an outreach strategy is comprehensive and long-term, involves multiple stakeholders, and requires all elements to be aligned to overcome the diverse set of barriers and utilize existing assets.

Acknowledgments

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Tithonia diversifolia for ruminant nutrition

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Keywords: Methane, in vitro, forage, nutritive value.

Introduction

According to FAO (2006), Brazil is the highest emitter of methane from cattle, followed by India and the USA (9.6, 8.6 and 5.1 Mt CH_4/yr, respectively). In livestock, CH_4, formed from enteric fermentation of carbohydrates, is primarily responsible for the emissions by the agricultural sector. Regarding livestock methane emission, Delgado et al. (2012) evaluated 20 tree and shrub species using in vitro techniques and demonstrated lower methane production from *Tithonia diversifolia*, a member of the Asteraceae family, than from grasses, for example, *Cynodon nlemfuensis*. *T. diversifolia* can be very useful, not only in animal nutrition, e.g. in silvopastoral arrangements (Plate 1), by increasing the protein content of animal diets at low cost (Murgueitio et al. 2010), but also in the recovery of degraded soils, for it grows in areas with low levels of fertility. Furthermore, it has a high phosphorus uptake ability, even if P is unavailable to other forage species (Kwabiah et al. 2003). The objective of this study was to assess the nutritional quality, including quantification of enteric methane generated during in vitro ruminal fermentation, of *T. diversifolia* as a forage for ruminant nutrition in the tropics.

Methods

T. diversifolia (tithonia) forage was evaluated at 2 developmental stages (booting and pre-flowering) and 5 levels of inclusion with *Brachiaria brizantha* cv. Marandu (brachiaria) (0, 25, 50, 75 and 100% of tithonia in the mixture; DM basis). Brachiaria was cut using the square method (1 m^2) in a paddock managed for milking cows. The forage was sampled when it reached a height of 40 cm, leaving a stubble residue of 20 cm, with fixed cutting intervals of 30 days during the rainy season. Whole tithonia plants were harvested using the square method (1 m^2) as follows: during the booting stage, when plants reached 80 cm (leaves plus stem); and 40 days later at the pre-flowering stage (leaves plus stem and flowers). The harvested forage was milled, dried and mixed according to the

Plate 1. *Tithonia diversifolia* in a silvopastoral arrangement (with *Cynodon nlemfuensis*) and at booting and pre-flowering.

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treatment ratios and later analyzed for: neutral detergent fiber, NDF; acid detergent fiber, ADF; hemicelluloses; and crude protein, CP, according to AOAC (1990); in vitro fermentation kinetics parameters (Mauricio et al. 1999); and volatile fatty acid (VFA) and methane production at 6 and 12 h by gas chromatography. The experimental design was randomized and statistical procedures were performed using the Tukey test at 5% probability.

Results and Discussion

Crude protein was the only chemical parameter for tithonia which was affected by stage of growth, with the value at booting exceeding (P<0.05) that at pre-flowering (166.1 vs. 117.2 g/kg DM) (Table 1). Brachiaria used as a control (0% tithonia) had 126.6 g CP/kg DM and 286.3 g hemicelluloses/kg DM. IVDMD decreased progressively (P<0.05) as the level of tithonia in the mixtures increased. Comparing both forages, we observed lower IVDMD, NDF and hemicelluloses and higher CP at booting (166.1 g/kg DM) in tithonia. Regarding VFA and methane production, overall there were minimal effects of ration composition on these parameters. The absence of differences in methane emissions from pure tithonia and pure brachiaria is at variance with the findings of Delgado et al. (2012), that tithonia produced less methane than grasses. There were indications that acetate/propionate ratio and methane emissions were lowest for the 50:50 mixture of tithonia and brachiaria, but differences were not always significant.

Conclusion

It appears unlikely that including *T. diversifolia* in sowings with *Brachiaria brizantha* cv. Marandu will have any positive effects on animal performance, as digestibility of the mixed rations was lower than for pure grass pasture. Similarly, including *T. diversifolia* had little consistent impact on methane emissions during in vitro digestion studies, so there appears a limited possibility that grazing animals would emit less methane. Regarding the latter, the inclusion of 50% of *T. diversifolia* with *Brachiaria brizantha* cv. Marandu, however, could hold some promise.

Table 1. Concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicelluloses (HEM) and crude protein (CP), in vitro dry matter digestibility (IVDMD), volatile fatty acid (acetate/propionate) ratio and methane production (mg/g degraded DM) of mixtures of *Tithonia diversifolia* (2 stages: booting and pre-flowering) and *Brachiaria brizantha* cv. Marandu. Means followed by different letters in rows (lower case; inclusion levels) and columns (upper case; stages) differ statistically by Tukey test at 5% probability.

Parameter	Stage	Inclusion level (%) of *Tithonia diversifolia*					s.e.d.
		100	75	50	25	0 (= brachiaria control)	
NDF (g/kg DM)	Booting	450.1 eA	498.5 dA	546.9 cA	595.4 bA	643.6 aA	17.7
	Pre-flowering	446.5 eA	495.9 dA	545.2 cA	594.5 bA	643.6 aA	
ADF (g/kg DM)	Booting	386.3 aA	379.2 aA	372.0 aA	364.8 aA	357.9 aA	12.7
	Pre-flowering	383.5 aA	377.0 aA	370.5 aA	364.1 aA	357.9 aA	
HEM (g/kg DM)	Booting	63.8 eA	119.4 dA	174.9 cA	230.6 bA	286.3 aA	10
	Pre-flowering	63.1 eA	118.8 dA	174.6 cA	230.4 bA	286.3 aA	
CP (g/kg DM)	Booting	166.1 aA	156.3 abA	146.5 abcA	136.7 bcA	126.6 cA	9.9
	Pre-flowering	117.2 aB	119.7 aB	122.1 aB	124.5 aA	126.6 aA	
IVDMD (%)	Booting	46.5 cA	56.4 bA	57.8 abA	61.6 abA	64.6 aA	2.8
	Pre-flowering	48.9 bA	54.2 bA	58.6 abA	61.6 aA	64.0 aA	
Ac/Pr ratio 6h	Booting	3.1 aA	3.0 aA	2.8 aA	3.1 aA	2.9 aA	0.5
	Pre-flowering	3.6 aA	3.6 aA	2.6 aA	3.4 aA	2.9 aA	
Ac/Pr ratio 12h	Booting	4.6 aA	4.0 abA	2.8 bA	3.3 abA	3.5 abA	0.5
	Pre-flowering	4.2 aA	4.2 abA	2.8 bA	3.3 abA	3.5 abA	
Methane 6h (mg/g DM degraded)	Booting	6.1 aA	8.1 aA	3.2 aA	5.4 aA	6.9 aA	2
	Pre-flowering	7.0 aA	4.3 aA	5.2 aA	6.4 aA	6.9 aA	
Methane 12h (mg/g DM degraded)	Booting	5.0 abA	6.4 abA	3.0 bA	8.6 aA	8.2 abA	2
	Pre-flowering	9.8 aA	7.6 aA	6.8 aA	7.6 aA	8.2 aA	

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Pasture characteristics and animal performance in a silvopastoral system with *Brachiaria decumbens*, *Gliricidia sepium* and *Mimosa caesalpiniifolia*

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Keywords: Leguminous trees, stocking rate variability, average daily gain.

Introduction

Grasslands are the major source of feed for ruminants (Zanine 2005). Seasonality of production, however, is a constraint in forage-based systems. Silvopastoral systems combine different components (animals, trees and forages) into an integrated system and may improve forage distribution across seasons. Resource use is usually more efficient both spatially and temporally, increasing land use efficiency (Nair 1993). Tree legumes present potential for silvopastoral systems because they can fix N from the atmosphere, improve cattle diets and lead to a faster N cycle. In addition, trees provide shade and may reduce heat stress for grazing animals in tropical and subtropical grasslands. Leguminous trees are commonly found in these climates and present potential for use in silvopastoral systems.

This research studied the pasture characteristics and animal performance of signal grass (*Brachiaria decumbens*) in a pure stand or in silvopastoral systems with *Gliricidia sepium* or *Mimosa caesalpiniifolia*.

Materials and Methods

The grazing experiment was carried out at the IPA Itambé Research Station located in the coastal region of Pernambuco State, Brazil. Treatments were: (1) *B. decumbens* (signal grass) + *M. caesalpiniifolia* (sabiá); (2) *B. decumbens* + *G. sepium* (gliricídia); and (3) *B. decumbens* in pure stand. Experimental plots were 1-ha paddocks. The experimental design was randomized blocks, with 3 replications. Leguminous trees were planted in double rows (15.0 m x 1.0 m x 0.5 m) and tree population was 2,500 trees/ha. Signal grass was planted between the double rows. Crossbred Holstein x zebu steers with an average initial weight of 175 kg were used as experimental animals. Cattle were weighed every 28 days after a 16-h fast. Herbage mass of signal grass was determined every 28 days using the double sampling technique described by Haydock and Shaw (1975). Herbage components were fractionated into green herbage and dead/senescent material. Herbage accumulation rate was determined using exclusion cages moved every 14 days (Sollenberger and Cherney 1995). Continuous stocking with a variable stocking rate, adjusted according to herbage allowance (HA), occurred over 12 grazing cycles of 28 days, totaling 336 experimental days (February 2012–January 2013). Two animal testers were allocated to each paddock. A target HA of 3 kg of green-herbage dry matter per kg of live weight (LW) was used. Data were analyzed using SAS (SAS 2003) and means compared by Tukey at 5% probability level.

Results and Discussion

Accumulation rate of signal grass herbage varied among cycles and ranged from 19.7 to 48.5 kg DM/ha/d ($P>0.05$) (Figure 1). Green herbage mass varied between grazing cycles and treatments ($P<0.05$), but HA was affected only by grazing cycle, ranging from 0.74 kg (May 2012) to 4.16 kg green DM/kg LW (October 2012) (Table 1). Average green herbage mass ranged from 321 kg/ha in May 2012 to 3,923 kg/ha in August 2012. Stocking rate followed a similar pattern to green herbage mass, with an interaction between grazing cycles and treatments. Stocking rate within each grazing cycle

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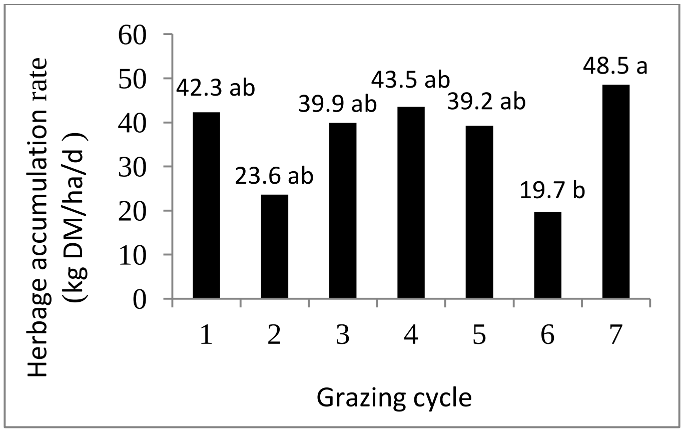

Figure 1. Herbage accumulation rate (kg DM/ha/d) of *Brachiaria decumbens* for different grazing cycles; average of 3 blocks.

Table 1. Green herbage mass of *Brachiaria decumbens* and herbage allowance in different grazing cycles; average of 3 blocks.

Grazing cycle (date)	Green herbage mass (kg DM/ha)			Herbage allowance (kg green DM/kg LW)
	Signal grass	Signal grass + gliricídia	Signal grass +sabiá	
1 (Feb 2012)	2,994 aB[1]	2,805 aB	2,957 aAB	3.05 B
2 (Mar 2012)	1,874 aBC	1,914 aBC	1,900 aB	2.95 BC
3 (Apr 2012)	1,682 aC	1,627 aBC	1,682 aB	3.03 B
4 (May 2012)	327 aD	316 aC	319 aC	0.74 D
5 (Jun 2012)	991 aCD	978 aC	957 aBC	2.18 BC
6 (Jul 2012)	2,193 aBC	2,093 aBC	1,903 aB	2.89 BC
7 (Aug 2012)	4,249 aA	4,080 aA	3,441 aA	3.40 AB
8 (Sep 2012)	1,145 aCD	1,146 aC	1,099 aBC	2.06 C
9 (Oct 2012)	2,511 aBC	2,504 aB	2,283 aAB	4.16 A
10 (Nov 2012)	1,962 aBC	2,010 aBC	1,941 aB	2.94 BC
11 (Dec 2012)	867 aCD	890 aC	892 aBC	2.47 BC
12 (Jan 2013)	1,338 aCD	1,147 aC	1,204 aBC	2.77 BC
s.e.			477	0.41

[1]Means followed by the same letter, lower case within rows and upper case within columns, do not differ by Tukey test (P>0.05).

did not vary among treatments, but differences occurred among cycles (Table 2). Animal performance (gain per animal and gain per unit area) was not affected by treatment, but varied among cycles. Average daily gain (ADG) ranged from 0.21 to 0.86 kg/hd/d.

Conclusion

Animal performance and pasture characteristics were similar for signal grass in pure stand and in silvopastoral systems with *Gliricidia sepium* or *Mimosa caesalpiniifolia*. Timber production, particularly in the case of *Mimosa*, is considered a major benefit of planting leguminous trees in pastures. Pastures with *Mimosa* had similar animal performance to the others but have a timber stock with the potential to double the net profit for the cattle producer. Soil organic matter build-up and long-term improvement of pasture productivity are also expected to occur in silvopastoral systems with leguminous trees. Potential environmental and economic benefits from the tree component must be analyzed. Long-term results are also important in order to make a conclusive decision regarding the benefit of each system.

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Table 2. Stocking rate, average daily gain per head (ADG) and gain per unit area (GPA) in the different grazing cycles; average of 3 blocks.

Grazing cycle (date)	Stocking rate (AU[1]/ha)			ADG (kg/d)	GPA (kg/ha)
	Signal grass	Signal grass + gliricídia	Signal grass + sabiá		
1 (Feb 2012)	2.99 aA[2]	2.81 aA	2.64 aAB	0.69 AB	56.25 AB
2 (Mar 2012)	1.75 aBC	1.77 aB	1.77 aBC	0.60 AB	29.82 ABC
3 (Apr 2012)	1.53 aBC	1.51 aBC	1.45 aBC	0.43 B	17.98 BC
4 (May 2012)	1.19 aC	1.21 aBC	1.06 aC	0.54 B	17.49 C
5 (Jun 2012)	1.24 aC	1.26 aBC	1.09 aC	0.21 B	7.27 C
6 (Jul 2012)	1.95 aB	1.81 aB	1.97 aB	0.60 AB	33.01 ABC
7 (Aug 2012)	3.51 aA	3.14 aA	2.65 aA	0.72 AB	63.82 A
8 (Sep 2012)	1.36 aBC	1.51 aBC	1.33 aBC	0.86 A	34.93 ABC
9 (Oct 2012)	1.48 aBC	1.52 aBC	1.36 aBC	0.26 B	9.38 C
10 (Nov 2012)	1.67 aBC	1.72 aBC	1.68 aBC	0.71 AB	36.26 ABC
11 (Dec 2012)	0.97 aC	1.04 aC	0.97 aC	0.33 B	9.65 C
12 (Jan 2013)	1.33 aBC	1.09 aC	1.11 aC	0.31 B	8.90 C
s.e.		0.24		0.11	7.44

[1]AU = 450 kg.
[2]Means followed by the same letter, lower case within rows and upper case within columns, do not differ by Tukey test (P>0.05).

Biological nitrification inhibition (BNI) in *Brachiaria* pastures: A novel strategy to improve eco-efficiency of crop-livestock systems and to mitigate climate change

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Keywords: Ammonium-oxidizing microorganisms, nitrous oxide emissions, nitrogen use efficiency, genetic variation.

Introduction

Up to 70% of the nitrogen (N) fertilizers applied to agricultural systems is lost due to nitrification and denitrification. Nitrification is a microbiological process that generates nitrate (NO_3^-) and promotes the loss of N fertilizers by leaching and denitrification. Nitrification and denitrification are the only known biological processes that generate nitrous oxide (N_2O), a powerful greenhouse gas contributing to global warming. There is an urgent need to suppress nitrification processes in soil to improve N recovery and N use efficiency (NUE) of agricultural systems and to mitigate climate change (Subbarao et al. 2012). Certain *Brachiaria* grasses (*B. humidicola*) can suppress soil nitrification by releasing biological nitrification inhibitors (BNIs) from roots, thereby reducing N_2O emissions. This phenomenon, termed biological nitrification inhibition (BNI), has been the subject of recent research to characterize and validate the concept under field conditions (Subbarao et al. 2009).

Advances on 3 aspects of BNI research are reported here: (1) gene quantification of soil nitrifying microorganisms to determine BNI activity in *B. humidicola*; (2) screening of *B. humidicola* breeding materials to identify hybrids with contrasting levels of BNI; and (3) quantification of the BNI residual effect from *B. humidicola* on N recovery and agronomic NUE of a subsequent maize crop.

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Methods

Gene quantification of soil nitrifying microorganisms to determine BNI activity in B. humidicola

A proof of concept work was designed to monitor the dynamics of nitrification in soils as influenced by *Brachiaria* spp. with differential BNI capacities (Subbarao et al. 2009). A soybean crop and bare soil, which lack such BNI capacity, were used as controls. Ammonium sulfate was applied to each plot. Copy numbers of *amoA* genes of ammonia-oxidizing bacteria (AOB) and archaea (AOA) were determined through Real-Time PCR to quantify the impact of inhibitory effects from *B. humidicola* under field conditions at 1 day after the ammonium sulfate application.

Screening of B. humidicola *breeding materials to identify hybrids with contrasting levels of BNI*

A set of apomictic *B. humidicola* hybrids were screened by determining nitrification rates in soil samples taken from unreplicated field plots established for seed production. Four CIAT accessions were used as controls for BNI activity.

Quantification of the BNI residual effect from B. humidicola *on N recovery and NUE of a subsequent maize crop*

A 1-ha field was selected from each of 3 contrasting land uses: a 15-year-old pasture of *B. humidicola* CIAT 679 (cv. Tully) with accumulated inhibitory effect in soil (i.e. high BNIs in soil); a nearby agricultural field (in which a crop rotation of maize and soybean was practiced for 4 years) with low BNIs in soil; and a native savanna field with moderate level of BNIs in soil. Hybrid maize (Pioneer 30K73) was sown on 17 July 2012 at all 3 field sites. Nitrogen fertilizer was applied at 3 rates (60, 120 and 240 kg N/ha) at each site. Grain yield and agronomic NUE were determined to assess the BNI residual effect on subsequent maize cultivation.

Results

Molecular data confirmed that *B. humidicola* accession CIAT 16888 has the capacity to inhibit soil nitrification (BNI activity). Rhizosphere soil from *B. humidicola* CIAT 16888 plots exhibited a lower gene copy number of AOB and AOA *amoA* genes than the controls (soybean and bare soil) and the other tropical grasses (Figure 1). Different values of nitrification rates observed in field plots of *B. humidicola* breeding materials suggested genetic variation for BNI and contributed to identification of hybrids with contrasting BNI capacities (Figure 2). The higher grain yields of maize observed from *B. humidicola* pasture land use were associated with greater values of agronomic NUE, particularly at lower rates of N applied (60 kg/ha). This observation indicates the importance of accumulated BNIs from this pasture over time in improving the agronomic NUE of maize crop (Figure 3).

Conclusion

BNI activity in *Brachiaria humidicola* plots was confirmed by observing a lower copy number of *amoA* genes from bacterial and archaeal populations compared with soybean and bare soil plots. The wide variation of nitrification rates observed in a set of apomictic *B. humidicola* hybrids contributed to the identification of hybrids with contrasting BNI capacity. Accumulation of BNIs in soil of a long-term *B. humidicola* pasture improved grain yield and agronomic NUE of the subsequent maize crop.

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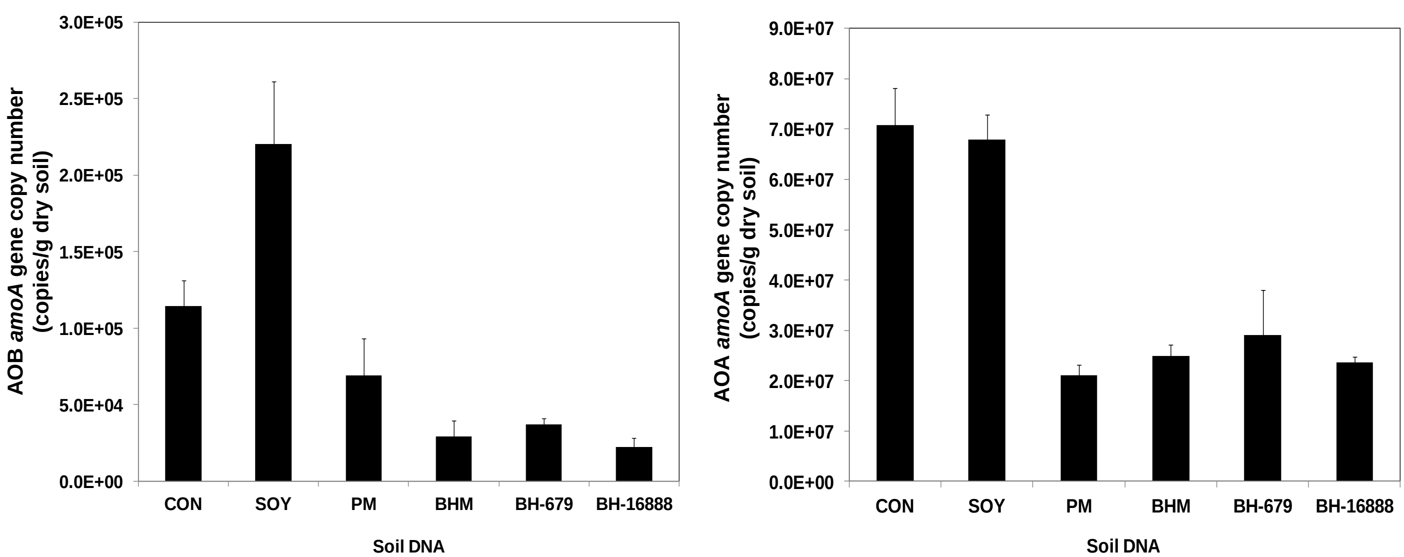

Figure 1. Gene copy numbers of ammonia-oxidizing bacteria (AOB) *amoA* gene (left), and ammonia-oxidizing archaea (AOA) *amoA* gene (right) at 1 day after ammonium sulfate application. CON = control (bare soil); SOY = soybean; PM = *Panicum maximum*; BHM = *Brachiaria* hybrid cv. Mulato; BH-679 = *B. humidicola* CIAT 679 (standard cv. Tully); BH-16888 = *B. humidicola* CIAT 16888 (a high-BNI capacity germplasm accession). Gene copy number was expressed as copy number per g of dry soil. Values are mean ± s.e. from 3 replications.

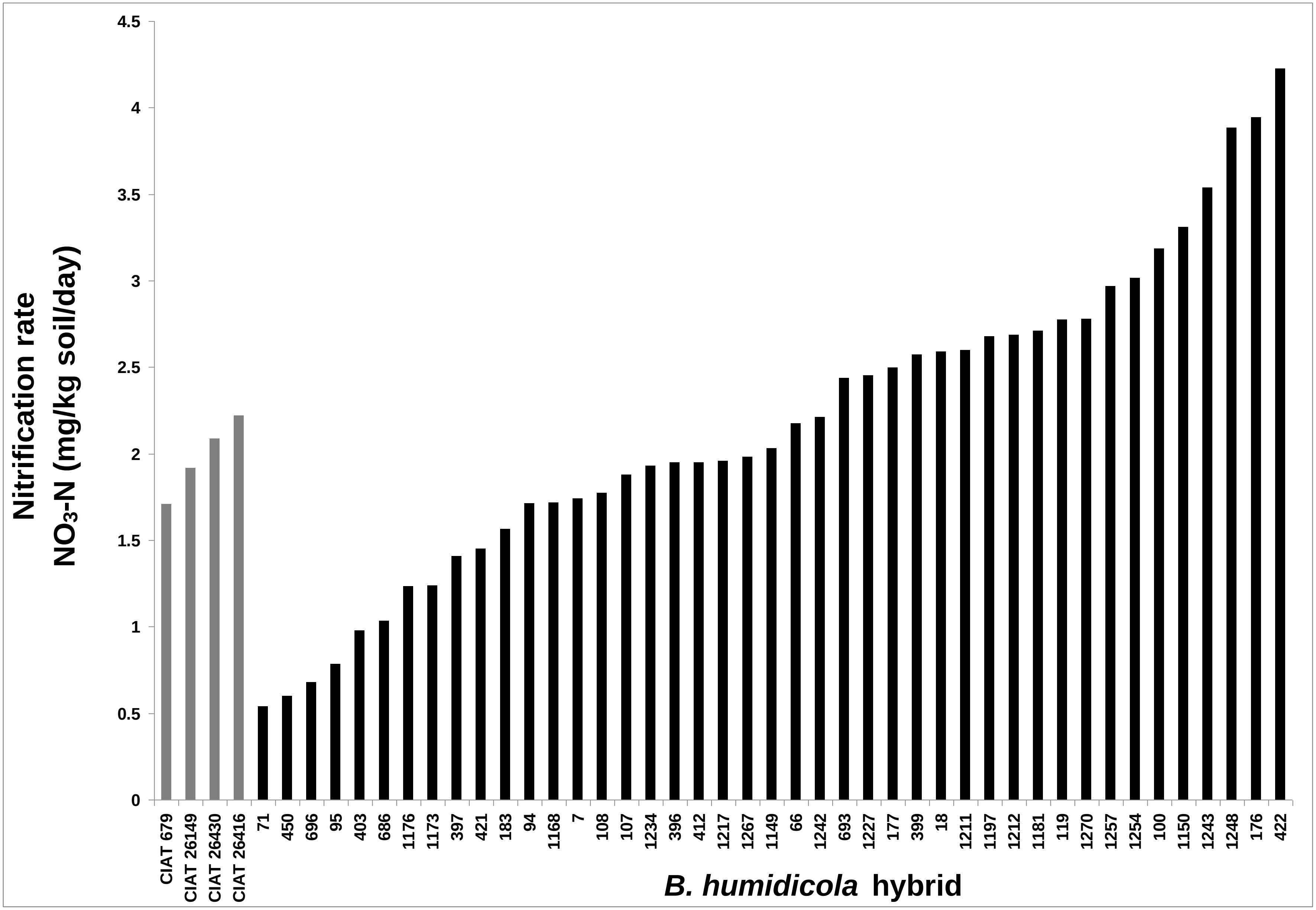

Figure 2. Genotypic differences in nitrification rates – expressed as NO_3-N (mg/kg soil/d) in field plots of *B. humidicola* hybrids. Gray bars represent *B. humidicola* CIAT accessions used as controls.

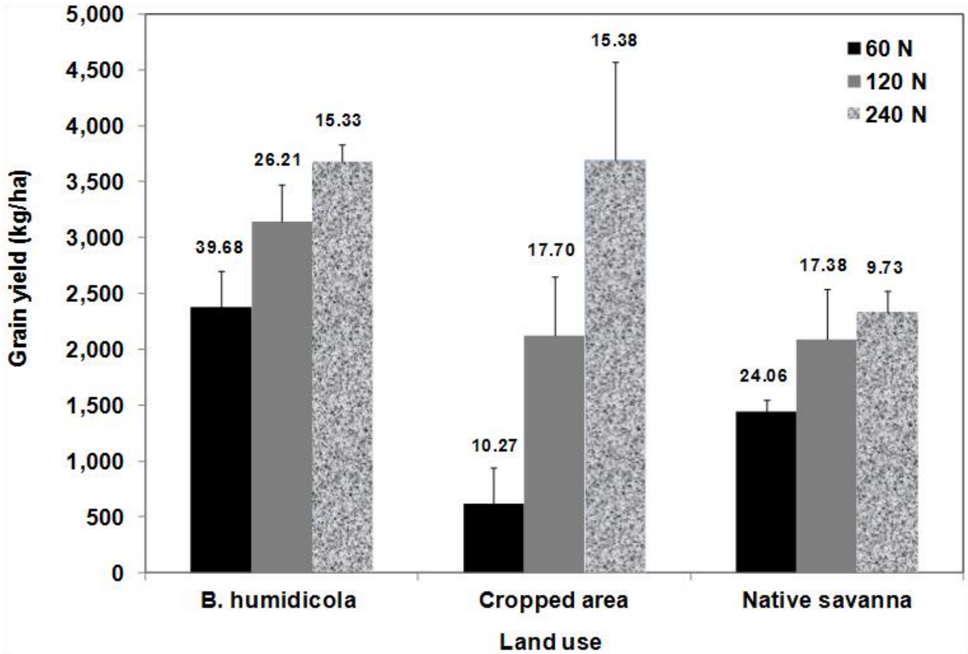

Figure 3. Grain yield (kg/ha) from maize plots fertilized with 60, 120 and 240 kg N/ha, on areas with different previous land uses (15-yr-old *B. humidicola* pasture; 4 years maize-soybean rotations; and native savanna). Agronomic nitrogen use efficiency (kg grain yield/kg N applied) values are shown above the s.e. bars. Values are means ± s.e. from 3 replications.

Relative preference for, palatability and intake of *Stylosanthes scabra* accessions adapted in Pretoria

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Keywords: Forage legumes, chemical composition, acceptability, tannins, goats.

Introduction

Inadequate supply and quality of forage, particularly during the dry season, is a major constraint to livestock production in sub-Saharan Africa (Anele et al. 2011), including South Africa. Poor management of the available feeds, seasonal variability in weather and climate change contribute to the high fluctuation of forage quality and quantity between seasons and years (Sultan et al. 2008). To improve livestock production, there is a need to improve both quantity and quality of available feed through the use of alternative forage crops.

Stylosanthes scabra cv. Seca has been evaluated for dry season feed supplementation, and was found to be adapted to and productive in the subtropical climate of Gauteng Province (Mpanza et al. 2013). The objective of this study was to determine the preference for, and palatability and intake of forage from 5 different *Stylosanthes scabra* accessions offered to Saanen goats.

Materials and Methods

Five accessions of *S. scabra* from the ILRI genebank: ILRI Nos. 9281, 11252, 11255, 11595 and 11604, were grown in Pretoria and their forage, 10 weeks old and at 100% flowering, offered to 5 Saanen goats (48.7 ± 2.78 kg) that were individually housed in 8-m^2 pens. Following a 10-day adaptation period, forage consumption data were collected for 5 consecutive days. Each animal was offered fresh branches of the 5 forages, mounted on a foraging board in a cafeteria system, for 30 minutes/day.

Forages were weighed before and after being browsed by the goats to estimate daily intake (on dry matter basis), and a relative preference index (RPI) was calculated as described by Larbi et al. (1993). Chemical composition, plant secondary metabolites, in vitro organic matter digestibility and gas production characteristics were determined using standard procedures. The data were analyzed by GLM procedure of SAS and, where F value showed a significant difference at P<0.05, means were separated using Duncan's multiple range test.

Results and Discussion

The chemical composition and digestibility of the 5 *Stylosanthes scabra* accessions are presented in Table 1. The accessions generally did not differ in terms of crude protein (CP), in vitro organic matter digestibility (IVOMD) and gas production at 24 and 48 hours. While there were marked differences between accessions for neutral detergent fiber (NDF) and total extractable tannins (TET), differences were not statistically significant. There was significant variation in terms of total extractable phenols (TEP) and ash content. The CP concentration of all forages was well above the critical level (8%) that supports normal intake and rumen functioning (Ikhimioya 2008), and NDF was below the upper limit of 60% (Meissner et al. 1991) that limits forage intake by the animal. Similarly, the tannin concentrations were lower than the critical level (9%) that affects digestion and intake by goats (Nastis and Malachek 1981). Despite the foregoing, there were significant variations (P<0.01) between accessions in terms of average daily forage intake and relative palatability index (RPI) (Table 2).

All accessions were browsed by the goats and thus were acceptable and palatable to animals. However, intake of accession ILRI 11604 was highest, and those of ILRI 11255 and 9281 were the lowest.

Conclusions

The study showed that all *Stylosanthes scabra* accessions tested are acceptable and palatable to goats. While ILRI 11604 and 11595 achieved highest intakes by goats, further studies are required to determine how these preferences are

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Table 1. Forage chemical composition, digestibility and gas production characteristics of 5 *Stylosanthes scabra* accessions.

ILRI accession No.	Chemical composition (g/kg DM)					IVOMD[1] (%)	Gas production (mL/0.2 g DM)	
	CP	Ash	NDF	TEP	TET		G_24	G_48
9281	184.1a[2]	96.9ab	418.7a	1.99d	1.22a	74.22a	80.04a	91.11a
11252	177.5a	93.6ab	439.9a	2.60b	1.02a	71.77a	75.37a	88.43a
11255	182.8a	80.1b	334.3a	2.90a	1.14a	71.61a	76.16a	89.58a
11595	185.4a	94.4ab	483.4a	2.51c	1.64a	69.83a	78.86a	89.39a
11604	181.7a	102.2a	499.3a	2.04d	0.87a	68.43a	78.71a	89.51a

[1]IVOMD, in vitro organic matter digestibility; CP, crude protein; NDF, neutral detergent fiber; TEP, total extractable phenols; TET, total extractable tannins; G_24 and G_48, gas production after 24 and 48 h, respectively.
[2]Values within columns followed by different letters differ at P<0.05.

Table 2. Daily intake and relative preference index of 5 *Stylosanthes scabra* accessions fed to Saanen goats.

ILRI accession No.	Average daily intake (g DM/d)	Relative preference index (%)
9281	63.4b[1]	40.5b
11252	95.3ab	60.9ab
11255	52.2b	35.5b
11595	112.2ab	67.0ab
11604	139.3a	84.4a

[1]Values within columns followed by different letters differ at P<0.01.

converted into animal product. Factors like dry matter yield are also important in terms of choosing a suitable accession for supplementary feeding.

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Challenges to domesticating native forage legumes

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Keywords: Ecotypes, forbs, germplasm, herbaceous plants, plant adaptation regions.

Introduction

If ruminant production from cultivated and natural grasslands is to depend less on petroleum-based products, forage legumes must serve as protein sources. Commercially available legumes for warm-dry climate grasslands are, however, very limited and resources available for developing such legumes are inadequate. Indeterminate flowering and dehiscent seed pods combined with the need for specialized seed harvesting equipment are major impediments (Butler and Muir 2012). In warm climates, challenges to legume establishment and persistence include poor rainfall distribution, extended dry seasons, temperature extremes and aggressive grass species (Muir et al. 2011). Erosion of indigenous knowledge and replacement with inappropriate land management approaches from moist-temperate regions compound the challenges.

Limited efforts to commercialize local native legumes have addressed this opportunity. The few current programs are regional and limited to locations with support from wealthy segments of the population. South Texas Natives (Smith et al. 2010), a success story in North America, receives support from ranchers interested in wildlife restoration, government agencies under pressure to use other than exotic germplasm for rangeland restoration and roadside revegetation, energy companies obligated to restore disturbed grasslands with natives and interested local commercial seed companies. Such broad-based support, including involvement of grazing managers, is rare, especially where the need is greatest.

Germplasm for native area restoration is sought from the target ecosystem, but such local seed is often expensive and may not be available. Some herbaceous grassland legumes, however, are found across wide ranges of latitude, longitude, soil, climate and ecosystems. Examples in North America include *Desmanthus illinoiensis*, found from southern Canada to northern Mexico, and *Desmodium paniculatum*, native from the Rio Grande to the Atlantic coast (Diggs et al. 1999). Specific ecotypes of these species are rarely suitable everywhere the species is endemic. To provide varieties with broad adaptation for use on a commercial scale, groups such as South Texas Natives are forced to work within plant adaptation regions (Vogel et al. 2005) with genetically diverse populations.

Current Status

Past and current research topics

Research on local herbaceous legumes in warm-dry climates has been ongoing for decades and brief details on some projects are provided in Table 1. With few exceptions, insufficient germplasm has been collected for thorough evaluation. Hardseededness is widespread and scarification is required for rapid stand establishment. A broad range in growth form among species and wide genetic variation within some promising species provide opportunities. Forage nutritive value and palatability differences among legume species and between legumes and grasses require consideration if resulting stands are to be sustainable, and growth form of the grass is important, as bunch grasses are more compatible with most legumes than sod-forming grasses.

Future research needs

Future research is needed on seed harvest technology (especially how to overcome pod dehiscing), seedling vigor, grazing/browsing tolerance, persistence under

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natural conditions, and long-term population dynamics. An alternative approach from the typical trial will be needed for a successful outcome.

Conclusions

Results of efforts to domesticate native legumes for warm-dry climates have had little adoption in grasslands. While some progress has occurred, seed cost of even the most successful varieties limits extensive use. Further research and marketing are required if native legumes are to contribute to productive and sustainable natural and cultivated grasslands. A commercially viable seed industry to support widespread use of native legumes will require acceptance by end users of broadly adapted, genetically diverse, and superior genotypes rather than only local ecotypes. Discerning and wealthy clientele are also a prerequisite for success.

Table 1. Examples of published research focusing on domestication of native herbaceous grassland legumes.

Topic	Genera	Location	Results	Citation
Diversity/collection	Multiple	Southern Africa, USA, Brazil	Variable	Maposse et al. (2003) Smith et al. (2010) Trytsman et al. (2011)
Germination	Multiple	USA	Scarification	Multiple
Seed yield	*Neptunia*, others	USA	Variable	Muir et al. (2005)
Agronomy	*Desmodium* *Dalea, Rhynchosia*	USA	Determinate, upright	McGraw et al. (2004) Muir et al. (2005)
Quality	*Strophostyles*	USA	High	Foster et al. (2007)
Mixes	*Desmanthus* *Lespedeza*	USA	Bunch grasses	Springer et al. (2001) Muir and Pitman (2004)
Persistence	*Dalea*	USA	Relative palatability	Berg (1995)
Genetic variability	*Desmanthus* *Acacia*	USA	Wide	Kulakow (1999) Noah et al. (2012)
Releases	Multiple	USA	Universities, NRCS	Muir et al. (2011)

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The emergence and survival of *Digitaria eriantha* and *Chloris gayana* seedlings on mine tailings planted with coated and non-coated seed

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Keywords: Growth medium quality, soil water content, seed pelleting, mine reclamation.

Introduction

The importance of vegetation in the process of rehabilitation and stabilization of mined land is becoming more critical as the size of the affected areas and the impact on urban development increase. Successful establishment of vegetation on these areas is complicated by adverse physical and chemical properties of the growth media. These include: soil compaction, acidity, salinity, heavy metal contamination, extreme temperatures, low soil water content and soil erosion (Oncel et al. 2000; Turner et al. 2006; Aken et al. 2007). Many of these soil/substrate conditions limit the establishment of vegetation from seed.

Turner et al. (2006) suggested that seed coating technologies were a possible solution to difficult seeding challenges, by facilitating more successful establishment of vegetation in these hostile environments. From humble beginnings, seed coating technologies can now be used to ameliorate the root zone by chemically changing the environment, aerating the root zone or improving the seedling's health through inoculation with beneficial micro-organisms (Harman 1991; Ashraf and Foolad 2005; Thrall et al. 2005; Turner et al. 2006). These specific attributes are not always clear and environmental specialists do not always know they have access to technologies that can change the micro-environment of a seedling.

Methodology

Phytotron studies at the University of Pretoria's Experimental Station were conducted to determine whether, and under which conditions, coated seed can assist in establishing a strong sward. Two species, *Digitaria eriantha* (Smuts finger grass) and *Chloris gayana* (Rhodes grass), were used to evaluate the efficacy of seed coating (AgriCOTE®) in improving growing conditions. Five replicates of 100 coated and uncoated seeds of each species were planted on the surface of the growth media and slightly compacted to ensure good soil contact. The 4 growth media used in this trial, namely: a red sandy loam; gold tailings with <1% pyrite; gold tailings with >2% pyrite; and platinum tailings, are described in Table 1.

Soil water content was manipulated by using field capacity (FC) (-0.03 MPa) as the reference point, adding 25% more (125%) and 25% less water (75%), to create 3 soil water content treatments. The treatments were placed in a randomized design, within a growth chamber at 23 ± 5 °C and covered with a clear plastic to prevent excessive water loss. The percentage of live seedlings was monitored daily over periods of 20 and 24 days for *D. eriantha* and *C. gayana*, respectively, to give an indication of germination percentage and survival likely under these growing conditions. This test was 10 days longer than the ISTA guidelines recommend for determining germination percentage for these species (ISTA 2006). Analysis of variance (PROC GLM) was done using SAS 9.2 software. Analysis was done within species and $P \leq 0.05$ was used to determine significant differences.

Results and Discussion

No consistent differences in germination and survival between coated and uncoated seed were observed for the two grass species tested on any growth medium (Figure 1). Overall germination and survival of the two species followed a similar pattern, with worst results on

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Table 1. Growth medium properties.

Growth medium	pH(KCl)	EC[1] (mS/m)	SO_4-S (mg/kg)	Texture		
				% sand	% silt	% clay
Red sandy loam	4.1	13.0	12.0	92.8	2.9	4.3
Platinum tailings	8.0	205.0	143.0	90.5	7.4	2.1
Gold tailings with <1% pyrite	5.3	193.0	1674.0	71.2	24.2	4.6
Gold tailings with >2% pyrite	6.4	422.0	447.0	86.1	11.8	2.1

[1]EC = electrical conductivity.

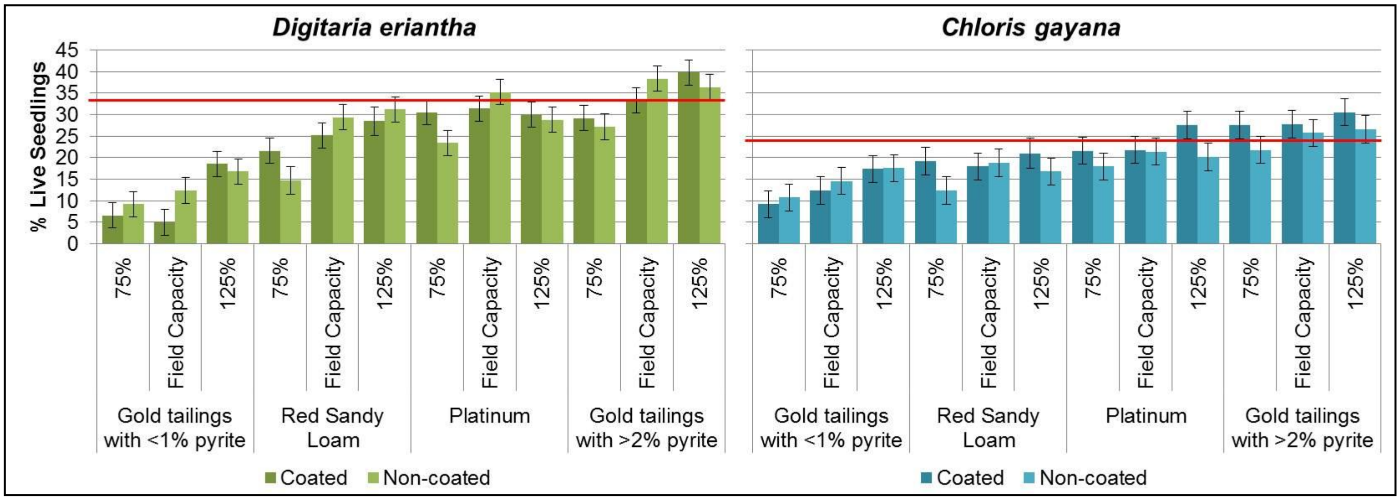

Figure 1. The maximum percentage live seedlings from coated and uncoated seed of *Digitaria eriantha* and *Chloris gayana* over 20−24 days for the different growth media, within a range of soil water content levels, field capacity (FC), 75% of FC and 125% of FC. Red lines show germination % for these species as reported by a seed test laboratory.

gold tailings with <1% pyrite and best on gold tailings with >2% pyrite; red sandy loam and platinum tailings were intermediate. The poor results on the gold tailings with <1% pyrite are possibly due to the high sulfate (SO_4-S) content of this growth medium responsible for the formation of sulfuric acid, which influences germination (ISTA 2006; Aken et al. 2007). The results may also be influenced by the large fraction of fine particles <75 µm in the gold tailings with <1% pyrite (28.8%), which can contribute to crust formation and sealing, and impede subsequent germination. It is also important to note that the clay fraction refers to the particle size of very fine grained rock <2 µm and not to a functional clay as found in natural soils (Ashraf and Foolad 2005).

In general, within growth media, there was a tendency for the best germination and survival levels to be obtained with the 125% field capacity treatments.

Conclusion

The results of this study failed to show any consistent benefit of seed coating on germination and survival of seedlings on the growth media tested. However, there was a trend for *C. gayana* to be more responsive to seed coating than *D. eriantha*.

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Production of giant *Panicum* in semi-arid Kenya

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Keywords: Dry matter yield; livestock feed; panicum ecotypes.

Introduction

Giant panicum (*Panicum maximum*) is a tall, vigorous perennial grass that is native to tropical and subtropical Africa. It is drought-tolerant due to its deep and dense fibrous root system and grows in a wide range of soil types. It is an important livestock feed and has been extensively cultivated in Brazil (Santos et al. 2006). Despite its wide genetic diversity in East Africa, its potential for livestock feed has not been exploited there due to limited research. Our study aimed at evaluating the production of several giant panicum ecotypes in a range of environments in semi-arid areas of Kenya.

Methods

The study was conducted at Kambi ya Mawe (KYM) (1°57' S, 37°40' E), Katumani (1°35' S, 37°14' E) and Ithookwe (1°37' S, 38°02' E) in the semi-arid, mid-elevation region of eastern Kenya. The elevation of this area ranges from 1,100 to 1,600 m asl with mean annual rainfall between 500 and 1,000 mm. All locations have a bimodal rainfall distribution with long rains occurring from March to May and short rains from October to December. The soil ranges from chromic luvisols to red sandy soils.

Nineteen giant panicum ecotypes collected in Kenya were evaluated along with a commercial cultivar (cv. Makueni) as a control. The experiment was a randomized complete block design with 3 replications. Plot sizes were 4 m x 4 m with 1 m between plots and 1.5 m between replications. A single root split was planted in each hole at a spacing of 1 m both between and within rows in November 2008. Dry matter (DM) yields were measured every 8 weeks for a period of 3 years from 2009 to 2011and tiller numbers were recorded on a sample of plants in 2009, 2010 and 2011 at Katumani and KYM, and for Ithookwe in 2010 and 2011.

Data were subjected to analysis of variance, and least significant differences between means were calculated.

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Results

The DM yields averaged over the 3 years at each site (2009-2011) differed significantly ($P<0.05$) among panicum ecotypes (Table 1). Mean yield was highest at Katumani (6.56 t/ha) and lowest at KYM (5.27 t/ha). Seven of the 20 ecotypes failed to survive at KYM, and this was attributed to low rainfall at this site (annual rainfall <500 mm). The DM yield averaged across sites was highest in 2010 (9.37 t/ha) and lowest in 2011 (3.60 t/ha).

The number of tillers accounted for 43.7, 48.2 and 59.4% of the variation in DM yield at Katumani, KYM and Ithookwe, respectively (Figure 1).

No ecotype achieved high yields consistently across sites and years. However, a number of them produced as much DM as cv. Makueni.

Conclusions

A number of giant panicum ecotypes were shown to be productive and have potential use as fodder in the semi-arid area of Kenya. However, before being integrated into the farming systems, management practices need to be developed for the most productive ecotypes and their feeding value to livestock needs to be evaluated.

Acknowledgments

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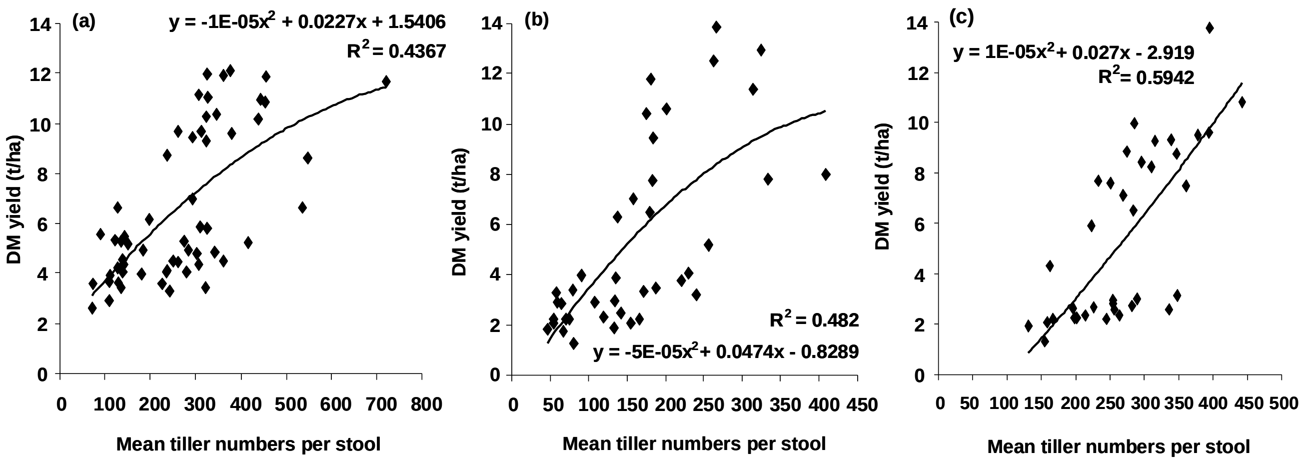

Figure 1. The effects of number of tillers on dry matter (DM) yield of giant panicum at: (a) Katumani; (b) Kambi ya Mawe; and (c) Ithookwe. The prediction equations were derived from data for total DM yield and tiller numbers obtained in 2009, 2010 and 2011 at Katumani and KYM, and for Ithookwe in 2010 and 2011.

Table 1. Dry matter yields (t/ha) of giant panicum ecotypes across locations and through time.

Ecotype Number	Location				Year			
	Katumani	Kambi ya Mawe	Ithookwe	Mean	2009	2010	2011	Mean
2	7.09	-[1]	2.87	4.98	-	-	-	-
15	6.62	-	3.93	5.27	-	-	-	-
17	5.45	7.30	6.64	6.46	4.75	10.93	3.71	6.46
19	5.64	6.36	6.31	6.10	4.38	10.27	3.66	6.10
25	7.01	6.15	6.15	6.44	5.47	10.17	3.66	6.44
35	6.52	4.86	4.98	5.46	3.12	8.00	5.25	5.46
64	6.02	-	4.87	5.45	4.47	6.96	-	5.71
76	7.68	4.02	7.83	6.51	5.73	9.84	3.95	6.51
85	6.87	5.41	5.85	6.04	5.01	10.00	3.11	6.04
93	6.48	3.48	5.31	5.09	4.49	7.72	3.07	5.09
97	7.64	-	7.45	7.55	-	-	-	-
99	5.99	3.49	5.65	5.04	3.50	8.88	2.75	5.04
100	7.61	5.05	7.64	6.77	6.02	10.26	4.03	6.77
104	5.88	7.01	6.01	6.30	4.94	10.00	3.96	6.30
105	5.79	-	10.41	8.10	6.98	-	-	6.98
106	6.67	5.39	5.42	5.83	4.82	9.33	3.33	5.83
107	6.38	-	6.29	6.33	-	-	-	-
108	6.89	-	7.30	7.09	-	-	-	-
K52-129	5.71	5.84	8.77	6.77	7.28	10.23	2.80	6.77
cv. Makueni	7.21	4.16	4.56	5.31	3.76	8.64	3.53	5.31
Mean	6.56	5.27	6.21	6.14	4.98	9.37	3.60	6.05

[1]Ecotype failed to survive at Kambi ya Mawe; LSD (P<0.05): ecotype effect = 1.68; location effect = 0.66; ecotype x location effect = 2.60.

LSD (P<0.05): ecotype effect = 1.12; year effect = 0.54; ecotype x year effect = 1.95.

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Rates of urinary toxin excretion in unprotected steers fed *Leucaena leucocephala*

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Keywords: Leucaena, mimosine, 3-hydroxy-4(1H)-pyridone.

Introduction

Leucaena (*Leucaena leucocephala*) is a productive, nutritious, leguminous forage tree with high capacity for ruminant liveweight gain. The plant does, however, contain the non-protein amino acid, mimosine, which is degraded within the rumen to 3-hydroxy-4(1H)-pyridone (3,4-DHP) with potential to cause adverse effects on animal health and production. Stock can be protected via rumen inoculation with the bacterium *Synergistes jonesii*, which is capable of degrading the toxin. However, surveys have demonstrated that subclinical toxicity persists in Queensland herds (Dalzell et al. 2012).

Currently, testing for toxicity involves analysis of urine samples using high performance liquid chromatography (HPLC); a colorimetric urine test protocol has also been developed with the aim of providing a robust and reliable means for routinely testing herds (Graham et al. 2013). A significant problem affecting interpretation of the results from either method is the high variation in the concentrations of toxins excreted by animals on similar diets and by individual animals over time (Dalzell et al. 2012). Factors such as feed intake, water consumption and urine volume, as well as timing of sampling may be the cause of this variation.

This research investigated the effects of sample timing by measuring the time taken for mimosine and its breakdown products to present in the urine following the introduction of leucaena to the ration of cattle naïve to the plant.

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Methods

Seven naïve, stall-housed Charolais x Santa Gertrudis steers of average weight 328 kg were fed an initial ration of barley chaff at a daily intake of 2.5 kg DM/100 kg body weight (BW) for 10 days. The animals were then placed on a 60:40 leucaena cv. Tarramba and barley chaff diet for 3 days before being returned to a barley chaff only diet for a further 7 days. Water was provided ad libitum. Leucaena leaves were hand-harvested during active summer growth, so as to target seasonally high leaf mimosine levels (Masafu 2006) and then dried. Animals were fed routinely at 09.00 h each day. Intakes were high with minimal refusals, consisting only of lowly palatable leucaena stalks.

Sampling frequency was every 2.5 h for the first 24 h of leucaena feeding, every 4 h for days 2−5, then every 6 h for the remainder of the feeding period. Urine samples were preserved in a 1:19 HCl:urine solution and subsequently analyzed using HPLC for concentrations of mimosine, 3,4-DHP and 2,3-DHP (Dalzell et al. 2012).

Results and Discussion

Mimosine and 3,4-DHP were detected in urine approximately 9 h after the commencement of leucaena feeding. Mean mimosine concentrations peaked at 11.6 ppm 35 h into the leucaena feeding period and remained low, but persisted for 67 h until cessation of the leucaena feeding (Figure 1). No mimosine was detected thereafter. The low levels of mimosine excretion indicated that the majority of mimosine was degraded to 3,4-DHP. Accordingly, urinary 3,4-DHP concentrations continued to increase throughout the leucaena feeding period, reaching a mean peak of 316 ppm at 67 h. Following cessation of leucaena feeding, mean 3,4-DHP concentrations fell slowly to low levels <20 ppm within 58 h of

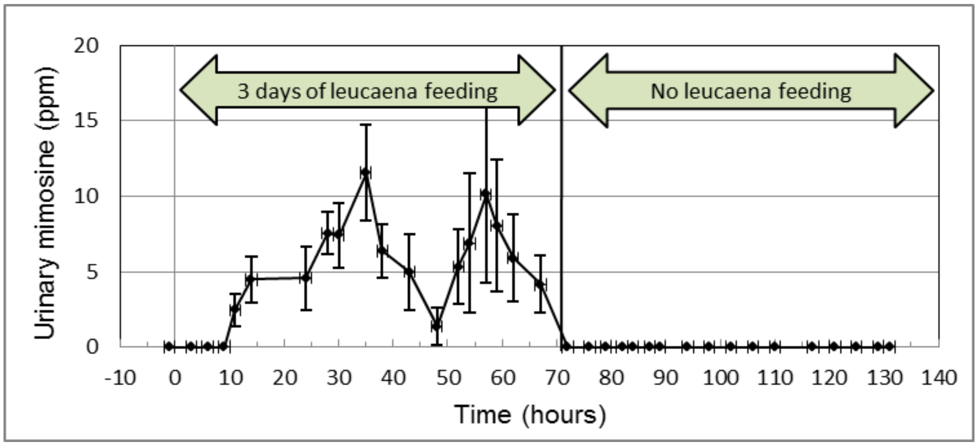

Figure 1. Mean excretion of mimosine ± s.e. for periods during and post leucaena feeding.

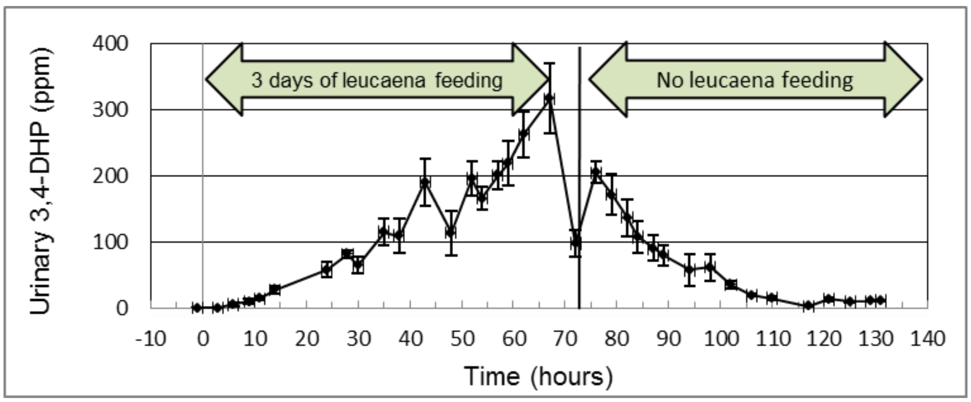

Figure 2. Mean excretion of 3,4-DHP ± s.e. for periods during and post leucaena feeding.

the last leucaena ration (Figure 2). Very low concentrations of 2,3-DHP were detected (<15 ppm) from 6 to 28 h after commencement of leucaena feeding, but none thereafter (data not presented).

The data demonstrated significant variation, both between animals and temporally across the sampling period despite similar leucaena intake, perhaps related to differences in water consumption and urine volume. Data for both mimosine and 3,4-DHP excretion appeared to demonstrate diurnal patterns of excretion (Figures 1 and 2). The patterns were likely an effect of varying patterns of leucaena intake (largely occurring from 09.00 to 12.00 h each day), rather than fluctuating rates of digestive processes or kidney glomerular activity. The experimental animals also consumed their daily rations at different rates.

Conclusions

Given the potential for lost production from subclinical toxicity, it is important that a methodology for testing of urinary DHP is robust and reliable. It is clear from this and other work (Giles et al. 2013; Graham et al. 2013) that testing of multiple samples will be necessary to obtain a reliable assessment of toxicity status of animals. Our experimental findings indicate that urine testing for presence of DHP should occur only during periods when there are high levels of leucaena in the diet for at least 3 days prior to sampling and preferably within 5 h after removal of animals from leucaena feeding. Fasting overnight may lead to reduced urinary DHP concentrations and a possible false assessment of toxicity status of the herd.

Acknowledgments

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Morning and afternoon sampling and herbage chemical composition of rotationally stocked elephant grass cv. Napier

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Keywords: Soluble carbohydrates, sampling time, rotational grazing, nutritive value, *Pennisetum purpureum.*

Introduction

Nutrient intake by grazing animals depends on the amount of dry matter consumed and its chemical composition. Forage grasses produce assimilates during the day via photosynthesis to sustain live tissues, plant growth and organic reserves (Taiz and Zeiger 2013). In that context, herbage chemical composition may vary according to variations in the photosynthesis-respiration balance throughout the day. From dawn to dusk photosynthesis predominates and herbage dry matter content and concentration of soluble carbohydrates increase; the reverse happens from dusk to dawn. That could influence nutritive value and nutrient intake of grazing animals (Delagarde et al. 2000), since for a given bite volume the amount of herbage and its composition could vary depending on the time of the day. This phenomenon could have implications for rotationally managed pastures, with time of changing animals from one paddock to the other assuming greater importance.

Against that background, the objective of this experiment was to evaluate dry matter (DM) content and the concentrations of soluble carbohydrates (SC), crude protein (CP), neutral (NDF) and acid (ADF) detergent fiber in herbage samples harvested during the morning and afternoon periods from rotationally stocked elephant grass (*Pennisetum purpureum*) cv. Napier.

Methods

The experiment was carried out at the Escola Superior de Agricultura “Luiz de Queiroz”, University of São Paulo, Piracicaba, SP, Brazil (22°43’ S, 47°25’ W; 554 m asl), from October 2011 to April 2012 (mid-spring and summer). Treatments corresponded to combinations between 2 post-grazing (post-grazing heights of 35 and 45 cm) and 2 pre-grazing (95% and maximum canopy light interception during regrowth – $LI_{95\%}$ and LI_{Max}) conditions, and were allocated to experimental units (850 m^2 paddocks) according to a 2 x 2 factorial arrangement and in a randomized complete block design, with 4 replications.

Monitoring of canopy light interception was carried out with a canopy analyzer LAI 2000 (LI-COR, Lincoln, NE, USA). Herbage samples (one composite 1000 g sample per paddock) of *P. purpureum* were harvested by hand plucking at the pre-grazing condition late in the afternoon before grazing (18.00 h) and early in the morning of the grazing day (06.00 h). Samples were separated into 2 subsamples, weighed, and one dried in a forced-draught oven at 65 ºC until constant weight and the other frozen at -18 °C for future chemical analysis. In this case samples were lyophilized and ground using a 1 mm sieve in preparation for laboratory analysis of concentrations of soluble carbohydrates (SC) using the total 80% Ethanol-Soluble Carbohydrate method (Hall 2000), neutral (NDF) and acid (ADF) detergent fiber (Van Soest et al. 1991) and crude protein (CP) (Leco Nitrogen Analyzer, Leco Corporation, St. Joseph, MI, USA).

Analysis of variance was carried out using SAS®, version 8.2 for Windows® using time of the day (morning and afternoon sampling) as the only cause of variation (n = 16), since there was no treatment effect. When appropriate, means were calculated using the "LSMEANS" statement and comparisons made with the Student t-test at 5% probability.

Results and Discussion

DM content ($P<0.0001$) and concentrations of SC ($P<0.0001$) and CP ($P=0.0048$) varied between morning

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Table 1. Dry matter content (DM) and concentrations of soluble carbohydrate (SC), crude protein (CP), neutral (NDF) and acid (ADF) detergent fiber in herbage samples harvested during the morning and afternoon periods from rotationally stocked elephant grass cv. Napier.

Period of the day	DM (%)	Chemical composition (%)			
		SC	CP	NDF	ADF
Afternoon	20.5	7.6	16.7	56.8	30.2
Morning	16.8	4.1	18.9	57.9	31.5
s.e.m.	0.21	0.25	0.45	0.35	1.26
P-value	<0.0001	<0.0001	0.0048	0.0549	0.4558

and afternoon samplings ($P<0.0001$), with lower values of DM and SC and higher values of CP recorded during the morning. There was no variation in NDF and ADF concentrations (Table 1). The results reflect the absence of photosynthesis during the night period relative to respiration (Taiz and Zeiger 2013), a condition that results in carbohydrate consumption (Lunn and Hatch 1995) and decrease in SC and DM concentrations. Further, the decrease in SC results in a relative increase in CP concentration, explaining the differences between the morning and afternoon samplings. The magnitude of variations results in large changes in the CP:SC ratio (4.6 and 2.2 for the morning and afternoon samplings, respectively) that, associated with % increase in DM content in the afternoon sampling, may have an impact on nutrient intake, considering the circadian rhythm and foraging strategies of grazing animals (Delagarde et al. 2000).

Conclusion

Since time of day influences DM content and chemical composition of the consumed herbage, particularly the CP:SC ratio, nutrient intake of grazing animals will also vary, particularly under rotational stocking management, suggesting potential benefits of changing animals to a new paddock in the afternoon period.

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Pelletized forage-based rations as alternative feeds for improving goat productivity

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Keywords: Pellets, *Leucaena*, liveweight gains, milk production, Philippines.

Introduction

Goat farming is very popular in the Philippines, as it is considered by many to be a viable rural enterprise. However, the goat industry is faced with many challenges, including high pre-weaning mortality, poor nutrition and lack of strategic approaches to accelerate genetic improvement. The long-term rate of increase in goat numbers is only 0.97% per annum, due to high offtake rates and low productivity, and interventions are needed to accelerate growth of the population. The Philippine goat population was 3.88 M in 2010 and is expected to reach only 4.27 M by 2020 (compared with the target of 6.2 M) (Alo 2012).

Goats are typically fed on locally available resources, which are characterized by low quality and highly variable availability. These constraints can be overcome through processing techniques such as sun-drying and pelleting to ensure year-round feed supply. Pelleting offers particular advantages. Feeding animals with pellets provides better feed efficiency, greater starch digestibility, less feed waste, non-selective feeding, better handling and storage, and increased income due to more efficient feeding and higher productivity. The aim of this study was to develop pelletized forage-based rations for goats and evaluate them for their technical and financial viability.

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Methods

The study was conducted at the Small Ruminant Center (SRC) of Central Luzon State University, Science City of Muñoz, Philippines. Leaves of the tree legume, *Leucaena leucocephala*, and Napier grass (*Pennisetum purpureum*) were harvested at about 35 days of age, shredded and sun-dried for 3−4 days to attain 80−85% DM. These were ground to pass through 1 mm screen mesh using a hammer mill to produce leaf meals, which were mixed in different proportions (Table 1), and combined with protein, energy and mineral supplements to form 2 rations: for growing goats (PRG); and lactating goats (PRL). The meals were moistened to attain the desired binding effects, and pelletized using a machine designed and fabricated for this purpose. The pellets were cylindrical (20−25 mm in length and 8 mm in diameter).

To evaluate PRG, a total of 16 Anglo-Nubian crosses with mean body weight (BW) of 12.46 kg were used in a 120-day feeding trial. The animals were kept in individual pens and divided into 2 groups: 6 animals in the Control 1 group (forage + 120 g concentrate); and 10 animals in the PRG. In the middle of the feeding trial, 3 animals were randomly selected from each group to determine digestibility of the PRG. Voluntary DM intake and fecal output were measured for 7 days.

To evaluate the feeding value of PRL, a 105-day feeding trial was conducted using 12 multiparous goats [6 Anglo-Nubian crosses and 6 Boer crosses with mean body weight (BW) of 32.65 kg]. For each breed type, 3 does were fed PRL + fresh Napier, while 3 does were fed with Control 2 diet, forage + 250 g concentrate mix.

The Control 1 and Control 2 diets represent the standard feed used at the Small Ruminant Center (SRC) for growing and lactating goats, respectively, and consisted of chopped *P. purpureum* and a mixture of fresh forage legume foliage: *Leucaena leucocephala*, *Gliricidia sepium* and *Desmodium cinereum* in equal proportions, plus concentrate mix.

About 10% representative samples of feed, orts and feces were collected, pooled and subjected to DM and crude protein (Kjeldahl method) analysis following the AOAC (1984) procedure. Neutral detergent fiber was analyzed following Goering and Van Soest (1970) method.

Feed intake, BW, milk yield and nutrient digestibility data were subjected to ANOVA using the General Linear Model procedure of Statistica for Windows, Version 8. Partial budget analysis was conducted to determine the financial benefits of feeding PRG and PRL pellets versus the control diets.

Results and Discussion

Growing goats fed PRG had higher consumption and nutrient digestibility than those fed Control 1, resulting in bigger and heavier animals (22.35 vs. 19.74 kg) (Table 2). Aside from the higher BW, animals fed PRG had a better feed conversion efficiency (7.44 vs. 9.66 kg DM intake/kg bodyweight gain).

Lactating goats fed PRL had DM intakes and milk yields comparable with those fed with Control 2 diet (Table 3). DM intake was >3% of BW, indicating that normal consumption was achieved. This suggests that PRL could be a viable feeding option for lactating does. Feeding pellets is a labor-reducing and productivity-increasing technology.

Table 1. Composition (%) of feed rations for growing (PRG) and lactating (PRL) goats. Rations contained the nutrient requirements for growing and lactating goats (Kearl 1982).

	Growing Goats		Lactating Goats	
	Control 1	Pelletized ration (PRG)	Control 2	Pelletized ration (PRL)
P. purpureum	60	10	50	-
Fresh legumes	30	-	30	-
Leucaena leaf meal	-	35	-	45
Concentrate mix	10	-	20	-
Rice bran (D_1)	-	42	-	42
Copra meal	-	3	-	3
Molasses	-	7	-	7
Dicalcium PO_4	-	2	-	2
Common salt	-	1	-	1

Partial budget analysis showed a net gain of ₱242.93/growing goat and ₱825.93/doe in comparison with the control ration-fed animals. The pelletized rations are an acceptable feeding option, as goat raisers are willing to buy pellets and pay a small premium for quality.

Table 2. DM intake, final weight, average daily gain (ADG) and feed conversion efficiency of growing goats fed with Control 1 and a pelleted ration (PRG).

	Control 1	PRG	Significance
Daily DM intake (kg)	0.574	0.688	*
Final weight (kg)	19.74	22.07	*
ADG (kg)	0.061	0.079	*
Feed conversion efficiency (kg DM/kg gain)	9.66	7.44	*
DM digestibility (%)	70.96	68.42	ns
CP digestibility (%)	65.13	80.04	**
NDF digestibility (%)	52.42	74.21	**

Table 3. Average daily DM intake and milk yield of Anglo-Nubian and Boer cross goats fed with Control 2 and a pelleted ration (PRL).

	Breed type	Control 2	PRL	s.e.m.
DM intake (kg/d)	Anglo-Nubian	1.10	1.08	0.09
	Boer	1.11	1.05	0.10
Milk production (mL/d)	Anglo-Nubian	527. 7	587.3	2.00
	Boer	464. 7	475.3	1.93

Conclusion

The results of the feeding trials and financial analysis indicated the high potential of forage-based pelletized rations as alternative feeds for productive and sustainable goat farming enterprises.

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Response of *Axonopus catarinensis* and *Arachis pintoi* to shade conditions

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Keywords: Silvopastoral systems, yield, nutritive value.

Introduction

In the northeast of Argentina, there are more than 100,000 ha of silvopastoral systems, where trees, forages and livestock are combined with the goal to diversify income, reduce financial risk, obtain more profit and enhance environmental benefit (Cubbage et al. 2012). The rapid adoption of these production systems by farmers has generated high demand for information on shade-tolerant forage grass and legume species.

Axonopus catarinensis is a native grass from Itajaí Valley (Brazil), that was introduced to the northeast of Argentina 10 years ago, and *Arachis pintoi* is a subtropical legume (also native to Brazil) adapted to acid soils and tolerant of medium levels of shade (Fisher and Cruz 1994). Visual observation of these species in the field indicated high yields and acceptable tolerance to shade.

A trial was subsequently carried out with the aim to quantify dry matter yield and nutritive quality of the species under different levels of shade for silvopastoral use.

Materials and Methods

The trial was located on the experimental station of the National Institute of Agricultural Technology (INTA), Montecarlo, Misiones province, Argentina (26º33'27.98" S, 54º33'25.01" W; 210 m asl). The climate is subtropical humid, with a mean annual precipitation of 1,824 ± 435 mm, evenly distributed throughout the year, and an average annual temperature of 21 ºC, with a maximum of 37.2 ºC (January) and a minimum of -0.2 ºC (July).

Both *Axonopus catarinensis* and *Arachis pintoi* were established in 15 m^2 plots (3 x 5 m) arranged as a randomized complete block design with 4 shade treatments (100, 62, 47 and 29% ambient light = 0, 38, 53 and 71% shade) and 3 replications. The shade condition was simulated using a method proposed by Peri et al. (2002), which provided continuous and fluctuating shade conditions in the field. Dry matter (DM) yield was estimated by subsampling 5 random 0.25 m^2 areas within each plot on 6 occasions during a period of 390 days (23 May 2007–16 June 2008). The height of cutting was 10 cm for the grass and 5 cm for the legume. At each harvest, 3 samples of >100 g fresh matter/treatment were collected for nutritive analysis by INTA's Forage Quality Laboratory.

Data were analyzed by ANOVA, using repeated measures to determine differences between variables by level of shade. The LSD test was used for comparing treatment means with a level of significance of $P<0.05$. The statistical software used was ESTATISTICA 6.0.

Results and Discussion

There was an effect of shade ($P<0.001$) for both *A. catarinensis* and *A. pintoi* yields over the experimental period (Table 1). The increased DM production in *A. catarinensis* with 38% shade was due to the high rate of growth achieved from the beginning of spring until the start of drought in summer, when plant available soil water did not limit growth. In summer, plants under shade would suffer less water stress than plants exposed to full sun (Pachas et al. 2011). Increases in DM yield under artificial shade or trees have been reported for many grass and legume species and are generally attributed to the positive effect of shade on soil moisture and the increased availability of nutrients such as nitrogen (Wilson 1990). While the grass showed some response to shading, there was no effect of shading on the growth of the legume.

The shade treatments did not have a significant effect ($P>0.05$) on cell wall components in either species

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Table 1. Average DM yield and chemical composition of *Axonopus catarinensis* and *Arachis pintoi* over 390 days with different levels of shade.

Species	Shade treatment (%)	DM yield (g/m^2)	NDF (%)	ADF (%)	Lignin (%)	Protein (%)	P (%)	K (%)	Mg (%)	Mn (mg/g)	Cu (mg/g)	Fe (mg/g)	Zn (mg/g)
Axonopus catarinensis	0	437	59.9	37.5	4.0	9.1	0.16	1.5	0.19	475	5.6	278	39.7
	38	617*	60.9	38.2	3.8	9.4	0.13	1.8	0.20	396	5.7	344	39.9
	53	484	60.7	37.2	3.4	10.8*	0.18	2.3*	0.21	394	6.6	290	44.8*
	71	478	58.6	37.5	3.9	12.6*	0.14	2.4*	0.22	310	8.3*	615*	42.8*
Arachis pintoi	0	478	38.5	28.7	8.0	22.8	0.20	1.9	0.30	240	14.2	402	47.1
	38	538	39.2	30.0	8.7	22.3	0.19	2.0	0.30	225	16.1	461	43.2
	53	542	38.7	32.3	9.8	22.3	0.20	2.0	0.40	284*	17.1	707*	48.2
	71	416	40.5	31.8	9.4	22.2	0.20	2.0	0.40	247	16.8*	683*	40.5

*Significant difference ($P<0.05$) between sun and shade values.

(Table 1). Overall, under shade, concentrations of Cu and Fe increased in both species, suggesting increased uptake of these elements in the shaded area, and K and Zn concentrations increased in the grass. There was a significant increase ($P<0.001$) from 9.1 to 12.6% in protein concentration in *A. catarinensis* with shade but no response in *A. pintoi* (average of 22.4%).

The likely explanation for the positive effect of shade on yield and protein content of the grass is the rapid mineralization of organic matter due to improved soil moisture content and moderate temperatures generated by the shade (Wilson and Wild 1991). This may also explain the improvement in the absorption rate of some macro- and micronutrients (Cruz 1997). Therefore, the observed increase in DM yield and nutrient content in *A. catarinensis* and *A. pintoi* is possibly due to both enhanced soil moisture and greater nutrient availability.

Conclusions

Both species showed good performance under intermediate levels of shade, and thus are promising for use in silvopastoral systems. Future research should focus on plant responses in the field under tree canopies and animal grazing.

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Is there genetic diversity in the 'leucaena bug' *Synergistes jonesii* which may reflect ability to degrade leucaena toxins?

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Keywords: SNPs, 16S PCR, 2,3 & 3,4-DHP, rumen fluid, sequencing.

Introduction

Leucaena leucocephala, a nutritionally rich forage tree legume, contains a non-protein amino acid, mimosine, which is degraded by ruminal bacteria to toxic metabolites 3,4-DHP and 2,3-DHP, resulting in goitre-like symptoms in animals, severely restricting weight gain. Raymond Jones, in the early 1980s, discovered the 'leucaena bug' in the rumen of goats in Hawaii that degraded these toxic DHP metabolites into non-toxic compounds (Jones and Lowry 1984), which was named *Synergistes jonesii* (Allison et al. 1992). Subsequently, a rumen inoculum containing *S. jonesii* was used as an 'oral drench' for cattle, kept in continuous culture (Klieve et al. 2002) and supplied to farmers to dose cattle foraging on leucaena.

Studies on Queensland herds that received this oral drench showed that up to 50% of 44 herds grazing on leucaena had apparent subclinical toxicity based on high 3,4-DHP and 2,3-DHP excretion in urine (Dalzell et al. 2012). In another study by Graham et al. (2013), a 16S rDNA nested PCR showed that rumen digesta from 6 of 8 farms tested had a variant DNA profile from *S. jonesii* ATCC 78.1 strain, which suggested a different strain of the bacterium.

It was postulated that the continually cultured oral inoculum may have undergone genetic modification and/or animals could harbor other DHP-degrading bacteria or *S. jonesii* strains with differential DHP-degrading potential (C. McSweeney et al. unpublished). The present study looks at changes in the 16S rDNA gene at the molecular level, that may suggest divergence from the type strain *S. jonesii* ATCC 78.1 in Queensland cattle as well as in cattle and other ruminants internationally. These changes can appear as discrete mutations or 'single nucleotide polymorphisms' (SNPs) and may be correlated with their ability to degrade DHP, relative to the type strain.

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Materials and Methods

Rumen fluid or feces was collected from cattle in Queensland, Australia and from cattle, sheep, goats, buffalos, native cattle and yak from Indonesia, Thailand, Vietnam, China and Brazil, mainly owned by local farmers. Microbial DNA was extracted from these samples and amplified with a set of 16S rDNA nested PCR primers, which are specific for *S. jonesii*. PCR products positive for *S. jonesii* were then aligned against full-length *S. jonesii* 16S rDNA sequence for identification of SNPs.

Results

The nested PCR was able to detect *S. jonesii* in rumen samples from the majority of Australian cattle tested (Table 1). Overseas ruminants (cattle, buffalos, goats, sheep and yak), whether feeding on leucaena or not, had nested PCR detectable *S. jonesii* 16S rDNA sequences, suggesting that the 'leucaena bug' is indigenous to many of these animals (Table 1). In general, fecal samples failed to generate PCR products for *S. jonesii* from either Australian or international samples. Mutations (SNPs) are distributed primarily at 'hot-spots' in bases corresponding to *E. coli* nucleotide positions 268 (C→T), 306 (A→G), 328 (G→A) and 870 (A→C) between bases 200-900 (~700 bp) of the *S. jonesii* ATCC 16S rDNA. Of these, '306' & '870' are almost always mutated when SNPs are detected; these 4 SNPs are present in the Queensland Department of Agriculture, Forestry and Fisheries (DAFF) inoculum, which was provided to the farmers. The '268' & '328' are frequently present when good quality sequence reads are available (Table 1). Cattle from the University of Queensland, Gatton campus, had all 4 SNPs. In animals overseas, the very same SNPs (Table 1) were also detected, ranging from frequencies of 15% (for '870' in Brazilian cattle) to 100% (all 4 SNPs in Vietnamese cattle and goats). Among all the international samples analyzed, only Jinnan cattle, Tibetan yak and Indonesian buffalos returned 100% identity with the type strain of *S. jonesii*. Interestingly, these buffalos were on 100% leucaena for 0.5−1 year and had high clearance of 3,4-DHP and 2,3-DHP (data not shown). The Jinnan cattle and Tibetan yak were naïve to dietary leucaena. Other SNPs were spread along this fragment of the 16S rDNA, whose frequencies were not consistent across animals, geographical regions or loci.

Conclusions

S. jonesii appears to be indigenous to the rumen across all types of ruminants and geographical regions tested. Classical SNPs are located in base positions 268, 306, 328 & 870. Their distribution is seen across all geographical regions and animal species; however, frequencies may vary. Other, minor mutations are distributed infrequently. Two of the SNPs (306 & 870) are always present in the DAFF oral drench, and the other two in <50% of sequences. Vietnamese animals and Gatton campus cattle had all 4 SNPs with 100% frequency. Only Indonesian buffalos, Jinnan cattle and Tibetan yak sequences were identical with the *S. jonesii* ATCC 16S rDNA sequence; these buffalos were on 100% leucaena and had high DHP clearances. The SNPs indicate genetic diversity at the species level, which may be reflected in varying ability to degrade DHP. This study is ongoing.

Acknowledgment

We gratefully acknowledge the support of ACIAR.

Table 1. Presence of SNPs in *Synergistes jonesii* nested PCR positive (+ve) Australian (Qld) and international samples.

Country/Property	Samples from:	Animals (n)	*S. jonesii* +ve		SNPs Frequency (%)			
			n	%	268 'T'	306 'G'	328 'A'	870 'C'
Australia: Farms & Institutions								
Lansdowne	Cattle	7	5	71	0	100	8	100
Byrne Valley	Cattle	8	7	88	100	100	100	IS[3]
Townsville	Cattle	10	5	50	IS	IS	100	100
Mt. Garnet	Cattle	5	3[2]	60	0	100	0	100
Murgon	Cattle/Enrich[1]	2	2	100	IS	100	0	100
UQ Gatton campus	Cattle	2	2	100	100	100	100	100
DAFF Oral Drench	Rumen Culture	NA	NA	100	50	100	50	100
Indonesia (Farms in NTB & NTT Provinces)	Goats	19	18	95	89	89	85	90
	Cattle	39	7	18	0	20	0	20
	Buffalo	7	5	71	0	0	0	0
Thailand (Farms & Khon Kaen University)	Goats	28	9	32	30	100	30	100
	Buffalo	4	4	100	25	88	32	56
Vietnam (Can Tho University farms)	Cattle	6	1	17	100	100	100	100
	Goats	6	3	50	100	100	100	100
	Goats (+Leuc)	6	1	17	100	100	100	100
China (Qinghai-Tibet Plateau farms)	Jinnan cattle	3	3	100	0	0	0	0
	Gansu sheep	3	3	100	50	50	50	50
	Tibetan sheep	3	2	67	50	50	50	50
	Yak	3	1	33	0	0	0	0
Brazil (São Paulo University farm)	Cattle	25	13	52	54	69	61	15

[1]Enriched rumen digesta
[2]One Sj +ve animal had no SNPs.
[3]IS = Insufficient sequences.

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Growth of Bali bulls fattened with *Leucaena leucocephala* in Sumbawa, Eastern Indonesia

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Keywords: *Bos javanicus*, growth rates, cut-and-carry, smallholder.

Introduction

The contribution of West Nusa Tenggara Province to domestic beef supply in Indonesia is relatively small; however, beef cattle are very important for the livelihoods of smallholder farmers in the region. Bali cattle (*Bos javanicus*) are the predominant breed, as they are adapted to harsh nutritional conditions, are highly fertile and have low calf mortality (Toelihere 2003). While these cattle are genetically capable of achieving a growth rate of 0.85 kg/d (Mastika 2003), this is rarely achieved as poor nutrition is a severe limitation to animal growth in traditional village systems (Panjaitan 2012). Improving feed quality and supply is vital to increasing growth rates and product quality. Forage tree legumes such as leucaena (*Leucaena leucocephala*) offer the best chance of providing high quality feed to fatten Bali bulls in village systems, where leucaena is well-adapted. Leucaena has been fed for about 2 decades in Sumbawa district of West Nusa Tenggara, although the practice is limited to specific villages, mostly Balinese, even though farmers nearby have similar biophysical conditions and livestock nutrition problems.

The objective of this work was to document the practices employed by farmers in Sumbawa to maximize growth rates by feeding leucaena, so that their detailed knowledge can be passed onto other villagers in a pilot roll-out program (Kana Hau 2014).

Materials and Methods

The study was conducted from April 2012 to March 2013 with 21 farmers in the hamlet of Jatisari in Sumbawa district of Nusa Tenggara Province, Indonesia, which has an annual rainfall of 865 ± 246 mm, mostly falling between November and May. Bull fattening in Jatisari is based on feeding high leucaena diets in a cut-and-carry system to animals tethered in simple sheds (roof, cement floor, feed bunker but no side walls). Farmers' norm0al management and trading practices result in constantly changing numbers of bulls being fattened. Parameters monitored included average daily gain (ADG), feed offered including amount of leucaena in the diet and sale weight. All cattle were weighed each month following overnight fasting (feed and water). Fresh feed offered was determined over 3 consecutive days each month. Bulls were treated with albendazole to control internal parasites prior to being fattened and were sprayed regularly with deltamethrin to control external parasites.

Results and Discussion

In general, farmers had 3 fattening periods each year. The average fattening period was 127 ± 58 days; the shortest and the longest fattening periods were 37 and 296 days, respectively. The number of bulls purchased and fattened during the wet season was more than twice that of the dry months, due to increased feed resources available. The initial weight of bulls varied within and between farms with an average of 191 ± 41 kg at 18 ± 7 months of age; the lightest and heaviest initial weights were 97 and 277 kg, respectively. Farmers with younger cattle had a longer fattening period. The average sale weight of bulls was 229 ± 27 kg, while the lowest and the highest were 188 and 318 kg, respectively. Average sale weight was thus well below the accepted standard for slaughtering beef (300 kg). This low sale weight may contribute to the low dressing percentages commonly stated by traders and butchers in the region.

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There was no overall pattern of animal sales, which was generally based on the need for money, rather than on optimal bull parameters. Increasing sale weight by delaying sale time and extending the fattening period may be an option to not only increase dressing percentage but also obtain premium prices. The ADG over the 11 months was 0.42 ± 0.12 kg/d. The highest average point of 0.61 kg/d was obtained early in the dry season in June, while the lowest average point of 0.23 kg/d occurred at the end of the dry season in October (Table 1). However, bulls belonging to the best farmers achieved ADGs of 0.83 kg/d over the 11-month period including ADGs of ≥1 kg/d for May, June and August. As most bulls were under-nourished on arrival, the highest ADGs were achieved in the initial month due to compensatory weight gain.

It was not possible to determine the precise amount of feed consumed, as dry matter content could not be calculated and refusals varied according to the stemminess of the leucaena branches being fed. Nevertheless, the highest amount of fresh feed offered was at the end of the wet season in May, while the lowest offer occurred in the dry season between August and October. The average percentage of leucaena in diets over the year was approximately 80%, followed by corn straw 13% and native grass 7%. The percentage of leucaena in the diet was highest (100%) between May and July, and lowest (approximately 50%) in October.

The overall average daily gain recorded for all Bali bulls over the measurement period (0.42 kg/d) was 60% more than that achieved under the traditional system (0.26 kg/d) (Panjaitan 2012). It was similar to the 0.44 kg/d reported for other improved feeding systems by Mastika (2003), but only half the potential growth rate of Bali bulls (0.85 kg/d) also reported by Mastika (2003). This was most likely due to an insufficient amount of feed offered, especially during the dry season, as the best ADGs (0.56−0.61 kg/d) were recorded in the wetter months of May, June and January, when feed supply and percentage leucaena in the diets were highest (close to 100%). Significantly, the best farmers achieved maximum weight gains ≥0.8 kg/d for 6 of the 11 months, close to the genetic potential of Bali bulls reported by Mastika (2003). Further monitoring is planned to understand the practices of the best farmers.

Conclusions

It is concluded that increasing supply of leucaena, either by planting more leucaena or altering the number of bulls to fit available feed supply, will increase growth rates to near the potential for Bali bulls. This will enable smallholders to more quickly achieve the appropriate sale weight of 300 kg.

Wider adoption of the feeding and management strategies employed by the best farmers of Jatisari provides an excellent opportunity to increase the output of fattened bulls from other smallholders in other regions of West Nusa Tenggara and East Nusa Tenggara. Achieving this potential will require not only a thorough knowledge of leucaena establishment, improved management, housing and hygiene of the bulls, but also an understanding of the barriers to adoption. It will require "an effective outreach strategy to address perceptions, access and regulations that are barriers to implementation of the innovations. The outreach strategy will need to be comprehensive, long term, and involve multiple stakeholders" (Kana Hau 2014).

Table 1. Average daily gains (±s.e.) and weights of 276 Bali bulls fattened on leucaena under a smallholder cut-and-carry system between May 2012 and March 2013 in Sumbawa, Indonesia.

Parameter	25 May 2012	25 Jun 2012	25 Jul 2012	25 Aug 2012	25 Sep 2012	25 Oct 2012	28 Nov 2012	23 Dec 2012	23 Jan 2013	23 Feb 2013	23 Mar 2013
Average daily gain (kg/hd)	0.56 ±0.09	0.61 ±0.05	0.47 ±0.03	0.40 ±0.06	0.37 ±0.04	0.23 ±0.05	0.25 ±0.02	0.38 ±0.02	0.56 ±0.03	0.41 ±0.03	0.42 ±0.03
No. of bulls weighed	49	55	59	54	55	55	95	134	68	130	136
Average weight bulls purchased (kg)	145	186	182	136	186	156	137	141	128	118	150
Average weight bulls sold (kg)	188	237	158	220	242	216	214	184	198	176	206
Average weight gain of best herd (kg/hd/d)	1.4	1.0	0.8	1.1	0.7	0.7	0.5	0.8	0.8	0.6	0.7
No. of bulls in best herd	1	3	1	2	3	2	3	3	4	10	3

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Total accumulative losses during the fermentation of Pioneiro grass (*Pennisetum purpureum*) silages with addition of whole plant maize and maize grain

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Keywords: Additives, effluents, ensilage, gaseous losses, forage mixtures.

Introduction

Pioneiro grass (*Pennisetum purpureum*) has gained importance in silage production mainly due to its robust habit, perenniality and high yield capacity, although its typically high moisture content may reduce its potential for conservation as silage. High moisture content at the time of ensilage has resulted in increased losses as gases and effluents (Balsalobre et al. 2001; Nussio 2005). Despite these losses, the high yields of tropical forages still justify their use and study as roughage and silage in ruminant nutrition.

However, maize silage is still used widely across different systems because of its favorable natural characteristics for fermentation, resulting in production of high quality silage (Anaya-Ortega et al. 2009). An experiment was conducted to evaluate the individual and combined effects of maize and Pioneiro grass on the total losses from the silages during the ensiling process.

Methods

This research was carried out at the Federal University of Paraná, Palotina Campus, Palotina, PR, Brazil. Pioneiro grass and whole maize plants were chopped to 20 mm segments and placed into PVC experimental silos with 600 kg of fresh mass/m^3. The silos were provided with upper Bunsen valves to allow escape of gases and bottom valves for effluent drainage.

A completely randomized design was used within a split-plot scheme, with ensilage processes as main plots and times of evaluation as subplots, with 8 replicates. Four silage types (Pioneiro grass 100%; Pioneiro grass 90% + whole plant maize 10%; Pioneiro grass 98% + maize grain 2%; whole plant maize 100%) at 12 periods after ensiling (0, 1, 2, 3, 4, 5, 6, 7, 14, 21, 28 and 35 days) were examined.

The addition of whole plant maize and maize grain to the treatments was calculated on a fresh mass basis. In each treatment, the effluent harvested was discounted from the weight of silos for proper adjustment of losses.

Statistical analysis was performed using the GLM procedure, with multiple comparison of means (Tukey) and an exponential model adjusted to the losses during fermentation. All tests were performed using the SAS software (version 9.0) at a level of 5% significance.

Table 1. Means of total accumulated losses (% fresh matter, FM) of different silages during fermentation (P: Pioneiro grass; PWPM: Pioneiro grass with whole plant maize; PMG: Pioneiro grass with maize grain; M: whole plant maize). Values within rows followed by different letters differ by Tukey test (P<0.05).

Time since ensiling (days)	Total accumulated losses (% FM) of silages			
	P	PWPM	PMG	M
0	0.00 a	0.00 a	0.00 a	0.00 a
1	0.05 b	0.06 ab	0.17 ab	0.24 a
2	0.08 b	0.11 b	0.19 ab	0.29 a
3	0.14 b	0.17 ab	0.27 ab	0.34 a
4	0.20 a	0.18 a	0.30 a	0.36 a
5	0.21 a	0.20 a	0.31 a	0.37 a
6	0.22 a	0.20 a	0.33 a	0.38 a
7	0.28 ab	0.21 b	0.36 ab	0.41 a
14	0.39 ab	0.27 b	0.44 ab	0.48 a
21	0.47 a	0.29 a	0.45 a	0.49 a
28	0.54 a	0.32 a	0.52 a	0.49 a
35	0.63 a	0.34 b	0.55 ab	0.53 ab

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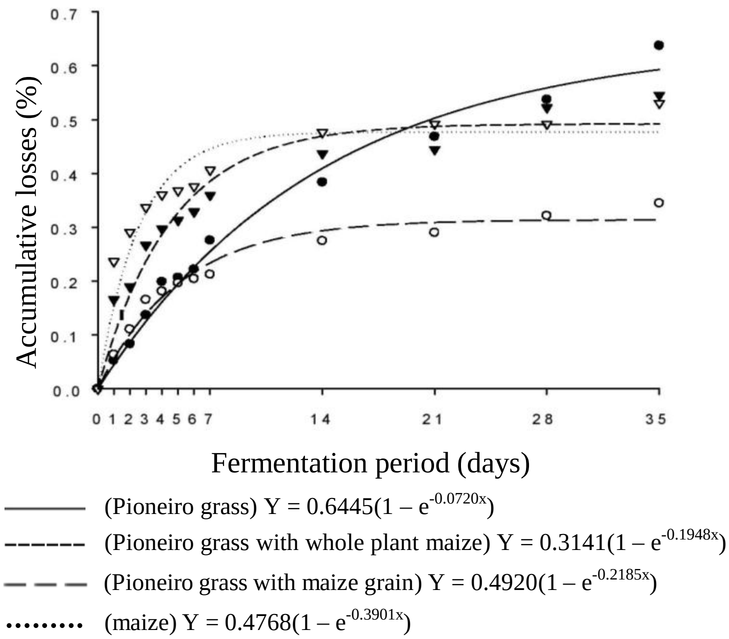

Figure 1. Total accumulated losses during the period of fermentation of single and mixed silages of Pioneiro grass and maize.

Results

Accumulated losses were very low throughout (<1% FM). There was an interaction ($P<0.05$) between the types of silage and time since ensiling in relation to the total accumulated losses (Table 1; Figure 1). While losses from the Pioneiro silage were lower than from whole plant maize silage during the first 3 days after ensiling, there were no differences between these treatments at 35 days. Overall, losses from the mixture of Pioneiro grass and whole plant maize were lower than from Pioneiro grass alone.

The addition of a moisture-absorbing component (maize grain) failed to affect the fermentation losses.

Conclusion

Although maize may be considered the best forage for conservation as silage, the similar losses to Pioneiro during the process of fermentation mean that other factors like differences in nutritive value, and higher yield of Pioneiro grass need to be considered in making a choice of what forage to ensile. Combinations of the two forages may have lower losses but the differences in magnitude of the losses might not justify the additional effort involved.

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Soil organic carbon stocks in a Brazilian Oxisol under different pasture systems

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Keywords: Land use changes, SOC accumulation, soil bulk density, soil compaction.

Introduction

Pastures are the main land use systems in the world and in Brazil they occupy 115 Mha. A major part of Brazil´s greenhouse gas emissions is due to land use change and agriculture. Livestock production is responsible for >90% of methane and about 55% of CO_2-equivalent emissions due to agriculture (Cerri et al. 2009). However, productive well-managed pastures can improve degraded soils and increase soil organic carbon (SOC) stocks through humification of grass and root residues. In order to enhance pasture yields and SOC sequestration, nutrient availability in soils must also be improved, especially for N and P. This work aimed to assess how SOC stocks are affected by the combination of grasses and legumes, in comparison with pure grass pastures and other land uses in a clayey Oxisol in southeast Brazil.

Methods

This research was conducted in the campus of the Universidade Federal de Lavras (21º13'42" S, 44º58'13" W; 925 m asl). Five neighboring areas were selected for sampling, comprising: (1) a native, semi-deciduous forest; (2) pure *Brachiaria decumbens* pasture (planted in 1990, under continuous grazing by bovines); (3) mixed *B. brizantha* and *Arachis pintoi* pasture; (4) mixed *B. brizantha* and *Stylosanthes guianensis* pasture; and (5) corn under annual tillage for 25 years. Both pasture + legume plots were planted in 2007 after 15 years under conventional tillage corn, and kept under cyclic bovine grazing. The local soil is a Humic Rhodic Acrudox with clayey (>60% clay) texture and granular structure. Soil sampling for SOC and bulk density (core method) was done in March 2010 using 3 pits per treatment, at depths of 0−5, 5−10, 10−20, 20−40, 40−60 and 60−100 cm. Soil samples were air-dried, sieved (<2 mm) and ground to pass a 100 mesh (0.150 mm) sieve for SOC determination by dry combustion in a Vario Micro Cube (Elementar, Hanau, Germany) apparatus. SOC stocks were calculated using an equivalent mass approach due to soil compaction. The experimental design was completely randomized in triplicate. Treatment means were compared by the Tukey test.

Results and Discussion

Soil bulk density increased significantly in pastures and corn plots in comparison with the native forest (Figure 1); the highest levels were found in areas currently or formerly cultivated with corn. Remarkably, such compaction occurred to a depth of 1 m, due to the very low soil densities and macroporosities in the native forest and the intensity of plowing/harrowing. The opposite occurred for SOC concentration, since the highest values were, as expected, found in the native forest, especially in the top 20 cm (Figure 2). At the 0−5 cm depth, the lowest values were found for the *Brachiaria* + *Stylosanthes* pasture, which can be ascribed to intense organic matter decomposition due to a very low C:N ratio of 7.0 (Pimentel 2012), and in the corn site.

The effect of land use change on SOC stocks occurred for all depths (Table 1). Pure *Brachiaria* pastures had significantly less SOC than native forest for the 0−20 cm (most intensively cultivated layer) and 0−40 cm (maximal arable layer) depths, but not for the 0−60 and 0−100 depths. Since most SOC changes typically occur in the top 20 cm, this trend is primarily due to the decreasing ratio of SOC change:total SOC as increasingly deeper layers are considered for the *Brachiaria* pasture. However, SOC losses for the grass-legume pastures increased from 30 t C/ha for the 0−20 cm depth to

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90 t C/ha for the 0−100 cm layer in comparison with native forest, and even more for the corn. Therefore, the data showed that intense SOC losses can occur with annual cultivation even to very deep layers, contrasting with the typically superficial effect noted for Brazil as a whole (Zinn et al. 2005). It is possible that such heavy losses are also due to originally very high SOC stocks of >200 t/ha for this area, which are not common in Brazilian savanna and Amazonian soils. However, mixed pastures of *Brachiaria* + *Arachis* seem to increase SOC levels in comparison with corn, but this effect was weaker in the case of the *Brachiaria* + *Stylosanthes* pasture. Such difference was probably due to the greater predominance of *Stylosanthes* in this association, which generated residual organic matter with high N content and thus more susceptible to microbial decomposition.

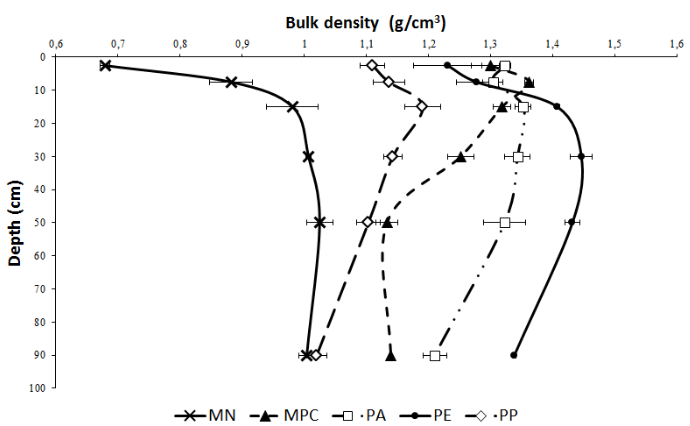

Figure 1. Means of soil bulk density (g/cm^3) to a depth of 100 cm. Bars show standard error of the mean. Land use systems are native forest (MN), corn (MPC), *Brachiaria* + *Arachis* pasture (PA), *Brachiaria* + *Stylosanthes* pasture (PE), and pure grass pasture (PP).

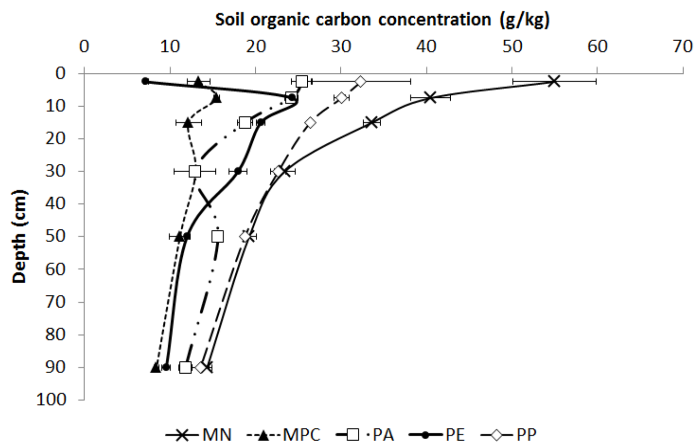

Figure 2. Means of soil organic carbon concentration (g/kg) to a depth of 100 cm. Bars show standard error of the mean. Land use systems are native forest (MN), corn (MPC), *Brachiaria* + *Arachis* pasture (PA), *Brachiaria* + *Stylosanthes* pasture (PE) and pure grass pasture (PP).

Conclusion

Replacing native forests with pastures, where inherent SOC stocks are high, apparently leads to heavy SOC losses, even when pastures are well managed and productive. However, SOC is preserved better under pastures than under annual crops with conventional tillage, and pastures can sequester SOC after croplands are turned into grazing lands. Nevertheless, this study also indicates that excessive N inputs through biological fixation in legume-grass mixtures can unexpectedly accelerate organic matter decomposition and delay or preclude SOC sequestration on degraded or over-exploited land.

Table 1. Soil organic carbon stocks for different standardized depths. Means within columns followed by the same letter do not differ by the Tukey test at P<0.05.

Land use	Soil organic C stocks (t/ha)			
	0−20 cm	0−40 cm	0−60 cm	0−100 cm
Native forest	71.8 A	128.5 A	171.8 A	239.9 A
Brachiaria	50.7 B	100.2 B	142.2 A	207.8 A
Brachiaria + *Arachis*	39.4 BC	71.3 C	100.3 B	155.9 B
Brachiaria + *Stylosanthes*	33.2 CD	71.8 C	102.2 B	145.9 BC
Corn	24.1 D	49.5 C	74.0 B	113.7 C

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Methane emissions from ruminants in integrated crop-livestock systems

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Keywords: Subtropics, southern Brazil, CH_4, greenhouse gas, SF_6, grasses.

Introduction

Ruminant livestock produce ~80 Mt of methane (CH_4) annually, accounting for ~33% of global anthropogenic emissions of CH_4 (Beauchemin et al. 2008). CH_4 is a powerful greenhouse gas, with a global warming potential of 25 (Eckard et al. 2010) and represents a significant loss of dietary energy (2–12% of gross energy of feeds; Patra 2012) in the ruminant production system. Despite greenhouse gas (GHG) emissions having become an increasingly important topic worldwide, there is still high variability in the estimated values of these emissions, mainly those attributable to livestock (range 8–51%; Herrero et al. 2011). This variability creates confusion among researchers, policy makers and the public, particularly in tropical/subtropical regions. Therefore, using rigorous and internationally accepted protocols, a Brazilian national project was established to contribute to improving estimates of GHG emissions attributable to livestock in Brazilian ruminant production systems. Moreover, enteric CH_4 emissions are a major challenge for research, in order to develop technologies and strategies for sustainable ruminant production systems in the future (Eckard et al. 2010).

In recent years, integrated crop-livestock systems (ICLS) have gained interest due to, for example, the potential abatement of methane emissions from livestock production: directly through a reduction in CH_4 per unit of animal product resulting from the increase in feed quality and animal welfare (i.e. improved environmental temperature for ICLSs with trees); and indirectly through reduction of area subjected to land use changes (i.e. leading to loss of soil C stocks).

This paper deals with: the preliminary results from quantifying CH_4 emissions by beef heifers grazing in 2 ICLSs (i.e. production systems that integrate corn or soybean crops during the warm season, and cattle grazing on pasture during the cool season, on the same area and in the same cropping year, with or without trees); and how these findings contribute to determining soil C balance and mitigation measures.

Materials and Methods

A field experiment was carried out at the Agronomic Institute of Paraná, Ponta Grossa, PR (25°07’22” S, 50°03’01” W), in a subtropical area in southern Brazil. The effect of 2 nitrogen (N) fertilization treatments (90 and 180 kg/ha) and 2 ICLS (with and without trees) were investigated in a complete randomized block design, with 4 treatments and 3 replicates each (a total of 12 paddocks of 0.99 ± 0.231 ha each). In 2006, 3 tree species (eucalyptus, *Eucalyptus dunnii;* pink pepper, *Schinus molle*; and silver oak, *Grevillea robusta*) were planted at 3 x 14 m spacing (237 trees/ha), on 6 of the 12 paddocks. In May 2012, a mixture of black oat + ryegrass (*Avena strigosa* + *Lolium multiflorum*) was sown for cattle grazing during the cool season.

The paddocks were managed in order to maintain a target surface sward height of 20 cm by adjusting the number of grazing animals weekly (put-and-take approach). In August 2012, a gas collection campaign was

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performed over 5 days in order to quantify CH_4 emissions by cattle. CH_4 production was estimated by the sulphur hexafluoride (SF_6) tracer technique (Johnson et al. 1994) for 2 animals per paddock (total of 24 Purunã beef breed heifers). Animals were selected based on their live weight (mean LW, 286 ± 6.7 kg), measured prior to the SF_6-campaign, so that CH_4 emissions could be expressed on a LW basis. CH_4 budget per unit ground area was calculated by multiplying the average CH_4 emission rate per kg of LW (CH_4/day/kg LW) x number of days x live weight of animal x animals per area. The data were statistically analyzed using ANOVA with the Statgraphics (Magnugistics, USA) package. Prior to ANOVA, data were normalized using log transformation.

Results and Discussion

There were no significant treatment (i.e. N fertilization levels and ICLS) effects for CH_4 emissions per unit LW (P>0.05). CH_4 emissions ranged from 0.32 to 0.93 g CH_4/d/kg LW, but tended to be lower for livestock with tree shelter than without (Figure 1). Variation coefficients were 28 and 35% for the systems with and without trees, respectively; this may explain the limited treatment effect, and underline the need to increase the number of sampled animals equipped with an SF_6 collection device or the number of measurement occasions throughout the year. A range from 0.36 to 0.52 g CH_4/d/kg LW was observed by Allard et al. (2007) over 8 measurement times in temperate semi-natural grassland. Similar values (0.30–0.53 g CH_4/d/kg LW) were reported for beef steers in a recent review (Eckard et al. 2010). These results highlighted likely excessive CH_4 emissions in our system when compared with the values

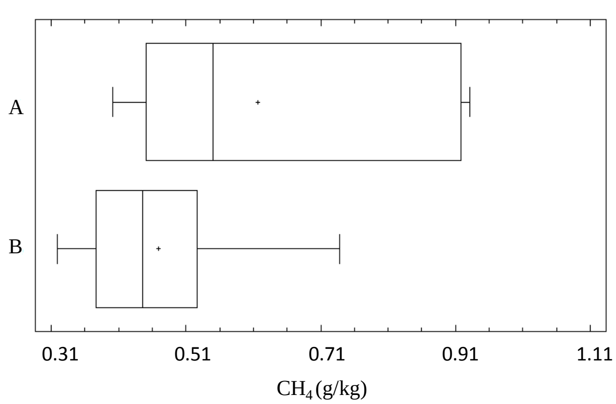

Figure 1. Ranges of CH_4 (g/d/kg of live weight) emissions from ruminants in two integrated crop-livestock systems: A, without trees; and B, with trees.

cited above. Since in species-rich grasslands animals cope with diverse combinations of plant species and parts, methane production could be reduced by feeding forage with higher quality than that of plant communities containing only few grass species.

Annual emissions of CH_4 from enteric fermentation, using values per unit ground area (means of 2 years, i.e. 1,030 kg LW/ha), were estimated at 5.54 g CH_4/m^2. However, this value was obtained assuming a grazing period around 100 days per year on areas with ICLS. The ICLS described here can be used for finishing animals. On the other hand, summer pastures, associated with winter species, could be used in order to supply forage throughout the year. Accordingly, a diversity of integrated systems is possible, making it hard to estimate annual CH_4 production by animals. Further, this CH_4 budget per unit ground area was calculated by using the average CH_4 emission rate per kg of LW obtained from a single gas collection campaign, which allows us only an approximative value for the grazing period. Therefore, additional research efforts will be required to make further progress in our current understanding of methane emissions per unit of animal products of such integrated systems.

Conclusions

Presence of trees tended to reduce methane emissions by cattle in integrated crop-livestock systems. Additional methane measurement occasions are planned for the cool-season grazing of 2013 in an attempt to provide more detailed insights into the underlying processes.

Acknowledgments

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The effect of *Leucaena leucocephala* on beef production and its toxicity in the Chaco Region of Argentina

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Keywords: Legume trees, tropical pastures, mimosine, semi-arid tropics.

Introduction

Hedgerows of the fodder tree legume, *Leucaena leucocephala* ssp. *glabrata* (leucaena), planted with a companion grass, provide productive, profitable and sustainable tropical pasture (Shelton and Dalzell 2007). Although leucaena can improve beef production, poor grower adoption has limited development of leucaena in the Chaco Region of Argentina. Factors contributing to poor adoption include: (1) unsuccessful establishment; (2) limited understanding of leucaena management as a forage resource; and (3) concerns about mimosine toxicity. While these 3 limitations have been overcome in other regions of the world (e.g. northern Australia and the Chaco Region of Paraguay), in Argentina little is known about leucaena management and the protection of ruminants against mimosine toxicosis.

The objective of this study was to evaluate the effects of leucaena on beef production and its toxicity in the west of the Argentine Chaco Region. We hypothesized that the introduction of leucaena into grass pastures would significantly increase beef productivity, if mimosine toxicosis did not appear.

Methods

Site description and treatments

The experiment was established at the Animal Research Institute of the Semi-arid Chaco Region, operated by the National Institute of Agricultural Technology (INTA), located at Leales, Tucumán (27º11´ S, 65º14´ W; 335 m asl), in northwest Argentina. The climate is subtropical subhumid with a dry season from April to September and average annual rainfall of 880 mm (75% from October to March). Average maximum/minimum temperatures are 32/20 ºC in January and 22/7 ºC in July; on average 16 frosts occur each year, with an average ground surface temperature of -2.2 ºC and minimum temperature of -7 ºC. Mean evaporation exceeds mean rainfall in all months.

The experiment used 6 ha of *Brachiaria brizantha* cv. Marandú (brachiaria) pasture, established in 1995 on Ustipsamment aquic and Fluvaquentic Haplustoll soil types (US Soil Taxonomy system). A stand of leucaena cv. K636 was zero till-planted into this pasture in hedgerows 5 m apart in December 2009 to form 3 treatments with different proportions of leucaena in the feed available to animals (2 ha each): (1) leucaena in twin rows (LLB); (2) leucaena in single rows (LB); and (3) brachiaria only (BB).

Fodder availability, animal production and signs of toxicosis

Dry matter (DM) availability of leucaena and brachiaria was estimated at the beginning of each grazing period by adapting the comparative yield method of Mannetje and Jones (2000). Animal production was determined using 10-month-old Braford steers with an initial bodyweight of 217 ± 7 kg over 98 days (9 December 2010 to 16 March 2011), divided into 5 consecutive grazing periods: P1, 12 days (9 Dec−20 Dec); P2, 16 days (21 Dec−5 Jan); P3, 20 days (6 Jan−25 Jan); P4, 28 days (26 Jan−22 Feb); P5, 22 days (23 Feb−16 Mar). Before the first grazing period, the steers were familiarized with leucaena by providing access to the legume for 16 days (23 Nov−8 Dec). Steers were randomly allocated to each treatment at a variable stocking rate, according to fodder availability. At the end of each grazing period, steers were individually weighed to determine mean liveweight gains per day (LWG). Steers were observed daily to record any of the typical signs of leucaena toxicosis, such as lethargy and depressed appetite, excessive salivation, skin sores, and hair loss from the pizzle and tail

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switch, reported by Jones and Jones (1984). Urine could not be collected and tested for mimosine and its derivative DHP, as described by Dalzell et al. (2012).

Statistical analysis

Twelve, 8 and 4 steers in the LLB, LB and BB treatments, respectively, were evaluated by longitudinal data analysis according to the time-sequential measurements collected (Littell et al. 1998). The repeated measures in time were analyzed using mixed models (with treatment as fixed effect) and using the auto-correlation structure produced by the sequentially repeated measures on the same animals during the 5 periods.

Results

Rainfall data and fodder availability

Accumulated rainfall from the first fall (7 October) to the end of the trial (16 March) was 774 mm; 202 mm before the first grazing period, 0 mm in P1, 41 mm in P2, 79 mm in P3, 327 mm in P4 and 125 mm in P5. Leucaena availability increased throughout the experiment, with LLB exceeding LB in all periods (range 680 and 240 kg DM/ha in P1 to 2,570 and 1,290 kg DM/ha in P5 for LLB and LB, respectively). Brachiaria availability was similar in all treatments throughout, so that the proportion of leucaena in the total available fodder ranged from 40 to 60% in LLB and from 20 to 30% in LB.

Animal production and signs of toxicosis

Steers with access to leucaena (LLB and LB) had higher LWG/hd than steers without access (BB) during the first period (Table 1). However, thereafter LWG/hd on LLB pasture declined continuously till animals were barely maintaining weight in Period 5. Steers on the LB pasture exhibited LWG of 1.33 kg/hd/d during P2, but then followed the same trend of declining LWG as those on the LLB pasture. Weight gains of animals on brachiaria alone increased steadily through Periods 1, 2 and 3, then declined, but steers still gained 0.53 kg/d in Period 5. Liveweight gain/ha followed a similar trend with gains in P1 favoring LLB (Table 1). However, LWG/ha decreased towards the end of the experiment on all treatments, with gains on LLB and LB inversely proportional to leucaena availability.

Visible signs of mimosine toxicosis first appeared during P4 and P5 in LLB and LB treatments, respectively. At the end of the trial, after 98 days grazing leucaena, 5 steers (41% of the herd) on LLB and 2 steers (25% of the herd) on LB pastures exhibited visible signs. The main symptoms, apart from lethargy and depressed appetite, were excessive salivation, skin sores and hair loss from the pizzle and tail switch.

Table 1. Liveweight gain (LWG) per day, expressed per head and per hectare, during 5 grazing periods (P1−P5; 9 December–16 March) in 3 treatments: leucaena in twin rows with brachiaria (LLB), leucaena in a single row with brachiaria (LB) and brachiaria pasture alone (BB).

Grazing period	Grazing days (no.)	kg LWG/hd/d			kg LWG/ha/d		
		LLB	LB	BB	LLB	LB	BB
First period (P1)	12	1.07a[1]	1.00a	0.65b	4.32a	3.08a	1.33b
Second period (P2)	16	0.62b	1.33a	0.97ab	1.89b	2.72a	1.99ab
Third period (P3)	20	0.55b	0.64b	1.18a	2.51b	1.97b	2.41a
Fourth period (P4)	28	0.10b	0.24ab	0.48a	0.60b	0.97ab	0.99a
Fifth period (P5)	22	0.02b	0.09b	0.53a	0.12b	0.37b	1.10a

[1]Values within periods and parameters followed by different letters differ at $P<0.05$.

Conclusions

The high weight gains obtained initially indicated that the introduction of leucaena into grass pastures could increase beef cattle productivity (LWG per unit area and per head) in the Chaco Region of Argentina. However, the development of signs of mimosine toxicosis and decline in weight gains with time, despite very high yields of available leucaena, indicated that remedial measures were needed to control this condition and take advantage of the high protein feed on offer. The benefits of ruminal inoculation with mimosine (DHP)-degrading bacteria, as used in other tropical areas, must be assessed urgently, if the potential benefits from grazing leucaena pastures in the Chaco Region of Argentina are to be realized.

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Climate-smart crop-livestock systems for smallholders in the tropics: Integration of new forage hybrids to intensify agriculture and to mitigate climate change through regulation of nitrification in soil

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Keywords: *Brachiaria*, molecular markers, nitrous oxide emissions, nitrogen use efficiency, participatory evaluation.

Introduction

It is widely recognized that less than 50% of applied nitrogen (N) fertilizer is recovered by crops and, based on current fertilizer prices, the economic value of this “wasted” N globally is currently estimated as US$81 billion annually. Worse still, this "wasted" N has major effects on the environment (Subbarao et al. 2012). CIAT researchers and their collaborators in Japan reported a major breakthrough in managing N to benefit both agriculture and the environment (Subbarao et al. 2009). Termed "Biological Nitrification Inhibition" (BNI), this natural phenomenon has been the subject of long-term collaborative research that revealed the mechanism by which certain plants (especially the tropical pasture grass *Brachiaria humidicola*) naturally inhibit the conversion of N in the soil from a stable form to forms subject to leaching loss (NO_3) or to the potent greenhouse gas N_2O (Subbarao et al. 2012). *B. humidicola*, which is well adapted to the low-nitrogen soils of South American savannas, has shown high BNI capacity among the tropical grasses tested (Subbarao et al. 2007). The major nitrification inhibitor in *Brachiaria* grasses is brachialactone, a cyclic diterpene (Subbarao et al. 2009). Reduction of N loss from the soil under a *B. humidicola* pasture has a direct and beneficial environmental effect. We hypothesize that this conservation of soil N will have an additional positive impact on a subsequent crop (e.g. maize). At present, recovery of fertilizer N and the impact on crop yield is not known. The main purpose of our interinstitutional and multidisciplinary project, targeting small-scale farmers, is to develop the innovative approach of BNI using *B. humidicola* hybrids to realize sustainable economic and environmental benefits from integrated crop-livestock production systems.

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Methods

The project is focused on 5 major outputs that will be accomplished through the development of new research tools and methodologies to test the BNI concept within a holistic agricultural context, namely: (1) Enhancement of rural livelihood benefits by involving small-scale farmers as decision makers and co-researchers in the integration of new *B. humidicola* hybrids in small-holder crop-livestock systems; (2) Identification of *B. humidicola* hybrids with different levels of BNI; (3) Identification of quantitative trait loci (QTL) associated with the BNI trait and development of molecular markers for *B. humidicola* hybrid selection; (4) Development of indicators of BNI activity for use under field conditions based on the role of BNI in improving the efficiency of utilization of fertilizer nitrogen, while reducing N_2O emissions from agricultural production systems; and (5) Identification of application domains of BNI technology in crop-livestock systems, assessment of potential economic benefits and strengthening of local capacity to evaluate BNI. Research progress made by the project team will be presented.

Results

Output 1: Rural livelihood benefits enhanced

A set of 30 apomictic hybrids was transferred to partners in Nicaragua for agronomic evaluation with farmers in 3 regions (Camoapa, Nueva Guinea, El Rama). These hybrids were also made available to partners in Colombia for farmer participatory evaluation in the Piedmont region of the Llanos of Colombia.

Output 2: B. humidicola *hybrids with different levels of BNI identified*

A greenhouse trial was established to evaluate phenotypic differences in BNI using 118 apomictic hybrids of *B. humidicola*. They are being evaluated for growth and nutritive value, N uptake, N use efficiency and potential ability to inhibit nitrification (BNI index and ^{15}N natural abundance) in soil. Estimation of nitrification rates (mg NO_3/kg soil/d) and determination of soil microorganism populations through Real-Time PCR are currently ongoing to survey potential BNI function.

Output 3: QTLs identified and molecular markers developed

Genomic DNA from a *B. humidicola* biparental mapping population (CIAT 26146 x CIAT 16888) of 134 hybrids was extracted for genotyping purposes towards the generation of a high-density linkage map and identification of QTLs associated with the BNI trait. Genetic markers were identified from the above genotypes through Next-generation RNA sequencing (GS-FLX Plus and Illumina Hiseq 2000). More than 25,000 molecular markers (SSR and SNPs) have been identified and at least 500 markers will be selected for polymorphism screening. Phenotyping efforts are underway to generate data for QTL analysis.

Output 4: Indicators of BNI activity developed

Stable carbon and N isotope analyses are being used to evaluate contrasting *B. humidicola* hybrids with different BNI capacity for their ability to release carbon in deeper soil layers, recover native and applied N and minimize leaching and gaseous losses of N in soil columns under greenhouse conditions. Natural abundance of ^{15}N was estimated in leaf samples of the *B. humidicola* biparental population (CIAT 26146 x CIAT 16888) to develop new indicators for evaluating BNI of contrasting hybrids under greenhouse and field conditions. A new analytical method based on high performance liquid chromatography (HPLC) is also under development for a precise detection and quantification of brachialactone. A bioassay using recombinant *Nitrosomonas* is being improved to detect BNI activity in root exudate samples. Sampling of nitrous oxide emissions is being adapted for large-scale screening of pot trials under greenhouse conditions. The residual value of the BNI function in long-term pastures (15 years old) on N use efficiency and grain yield of subsequent crops (maize) is being determined along with the estimation of carbon footprints of different systems.

Output 5: Application domains of BNI technology identified, benefits assessed and local capacity strengthened

Extrapolation domains for potential adoption of BNI technology beyond the study areas are being estimated using data collected from local conditions in Nicaragua and Colombia. Spatial data sets, maps, demographic data, and land use information will be matched with farm-level economic surveys for further analysis. Public information available online is also being gathered from local institutions in Nicaragua and Colombia as complementary information. A survey was designed to collect information on farming systems to identify farming similarities through a microeconomic model for resource optimization.

Conclusions

The natural phenomenon of BNI is being characterized through an interinstitutional and multidisciplinary research project funded by BMZ-GIZ, Germany. The main aim is to develop new research tools and proven methodologies to detect BNI function to minimize N losses from crop-livestock systems. Farmer involvement is a key component of the project to ensure that the new forage germplasm is successfully integrated into existing crop-livestock systems in the face of climate change.

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Litter decomposition of Xaraés grass pasture subjected to different post-grazing residuals

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Keywords: Nutrient cycling, residual leaf area index, *Brachiaria brizantha.*

Introduction

Since fertilizers are used less extensively on Xaraés grass (*Brachiaria brizantha* cv. Xaraés) pastures in Brazil because of costs, the main route of nitrogen (N) supply to plants is through nutrient recycling via litter decomposition. One of the strategies used to maintain the supply of N to the pasture is to manipulate the grazing pressure so that the amount of recycled nutrients in the residue is sufficient to meet the pasture requirements (Jantalia et al. 2006). Thus, the aim of this study was to evaluate different residual leaf area indices (RLAIs), to determine which one provides the best restoration considering the decomposition and mineralization of organic matter.

Methods

The experiment was conducted at Unesp, in Jaboticabal, SP, Brazil. The experimental area of 0.28 ha was divided into 12 paddocks in order to evaluate 4 different RLAIs (0.8, 1.3, 1.8 and 2.3). The experimental design was completely randomized with 3 replications. Litter decomposition measurements followed the nylon bag technique (adapted from Dubeux Jr. et al. 2006). The litter layer on the soil was collected from each paddock, weighed and placed inside nylon bags (15 g/bag). Subsequently, the bags were placed on the ground, covered with existing litter from that experimental paddock and examined after 0, 4, 8, 16, 32, 64, 128 and 256 days. The concentrations of organic matter (Silva and Queiroz 2002), N (AOAC 1995) and carbon (Bezerra Neto and Barreto 2004) were determined in order to calculate the carbon:nitrogen (C:N) ratio of the material during the evaluation period. Litter decomposition data were analyzed with an exponential regression model using POC NLIN of the SAS statistical software.

Results and Discussion

The percentage of organic matter found in the residual material of Xaraés grass litter decreased as the exposure time increased (Figure 1), fitting an exponential model ($P<0.0001$). This was probably the result of microbial activity. Microorganisms need carbon as an energy source for their metabolic processes and formation of organic compounds and so they use the organic carbon present in plant residues deposited on the soil.

The C:N ratio also decreased throughout the exposure time and fitted the exponential model ($P<0.0001$; Figure 2). This behavior is expected since microorganisms use the carbon contained in the organic material and reduce the carbon content of the remaining material, thus decreasing the C:N ratio. According to Kiehl (1979), residues with a C:N ratio higher than 33 are at an initial decomposition stage, where immobilization of mineral N and its transformation into organic N to form the microorganism cells occurs. When the C:N ratio reaches 33, a new decomposition phase of the residue called biostabilization occurs, in which N is mineralized and immobilized at the same time and there is no competition for the mineral N that was already on the soil.

In this study, at the end of 256 days of exposure, the residual material on all treatments displayed C:N ratios lower than 33, but this ratio was attained more quickly for the material under the 1.8 RLAI, leading us to infer that the litter decomposition process also happened more quickly.

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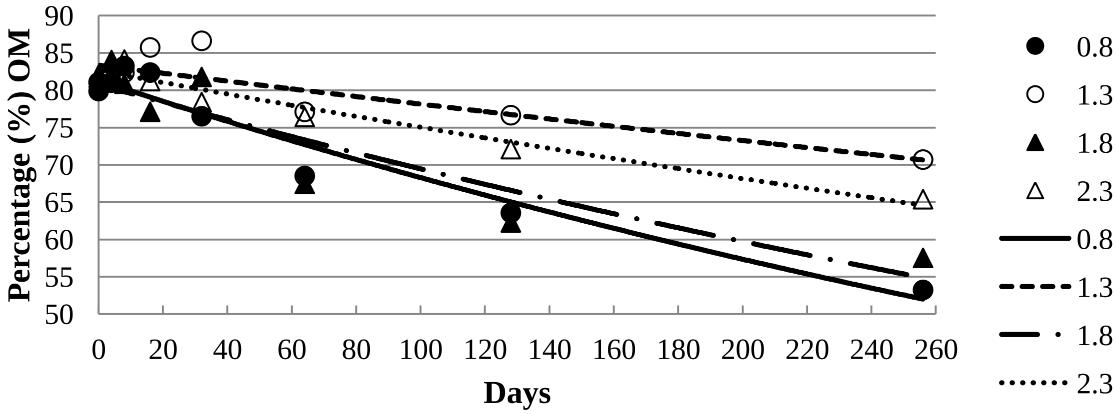

Figure 1. Effects of exposure time on percentage of organic matter (OM) in the remaining material of Xaraés grass litter on a pasture managed with different residual leaf area index (RLAI).
Exponential equations: RLAI 0.8 ($y = 81.64e^{-0.002x}$); RLAI 1.3 ($y = 83.37e^{-0.001x}$); RLAI 1.8 ($y = 81.32e^{-0.002x}$); RLAI 2.3 ($y = 82.72e^{-0.001x}$).

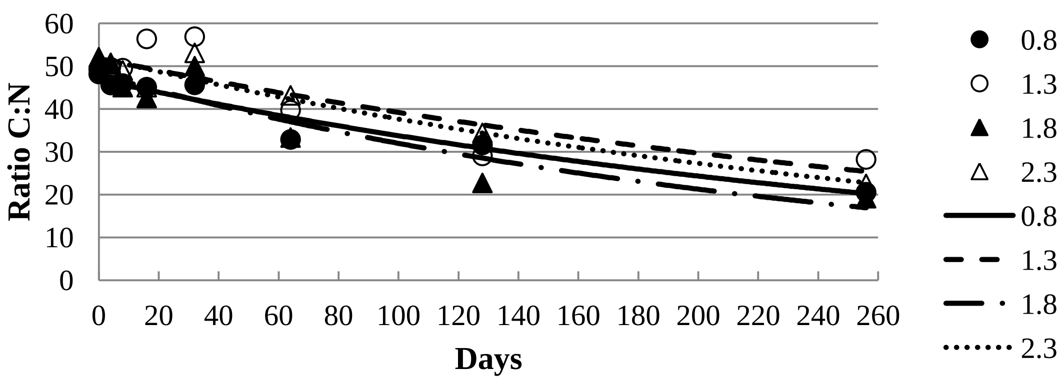

Figure 2. Effects of exposure time on C:N ratio of the remaining material of Xaraés grass litter on a pasture managed with different residual leaf area index (RLAI).
Exponential equations: RLAI 0.8 ($y = 47.24e^{-0.003x}$); RLAI 1.3 ($y = 52.81e^{-0.003x}$); RLAI 1.8 ($y = 49.68e^{-0.005x}$); RLAI 2.3 ($y = 51.78e^{-0.003x}$).

Conclusions

Despite marked decomposition of organic matter during the exposure period on all treatments, more than 50% of the original material still remained after 256 days. The residual leaf area index seemed to influence litter decomposition, but more work should be performed before recommendations are made on the desirable RLAI to adopt. Rate of litter decomposition is only one of the factors to be considered in determining grazing management strategy.

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Nitrogen fixation potential with *Macroptilium* of native rhizobial populations in semi-arid Pernambuco, Brazil

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Keywords: Biological nitrogen fixation, selection, native rhizobial strains, *Macroptilium lathyroides*.

Introduction

Nitrogen (N) is one of nature´s most abundant elements, accounting for about 78% of the atmospheric gases, but mostly as the inert N_2 form. As such it is not directly available to plants, and is relatively scarce in most agroecosystems. Biological nitrogen fixation (BNF) through diazotrophic bacteria represents about 63% of the yearly N input in terrestrial ecosystems (Taiz and Zeiger 2004). Legumes, which form effective symbiosis with the diazotrophic group of bacteria commonly known as rhizobia, are an important source of available N. Tropical forage legumes can usually nodulate with a diverse population of rhizobia, and may make a significant contribution to nitrogen availability in pastures (Santos et al. 2005). Identification and isolation of symbiotically most efficient rhizobial strains would enhance the beneficial effects of legumes in pastures. This could be achieved by quantifying the BNF ability of strains from different regions, vegetation covers, cultivation systems and environmental conditions (Chagas Jr. et al. 2010). Native legumes, including several species of *Macroptilium*, are an important forage resource in the semi-arid northeast of Brazil, contributing to the quality of ruminant diets, but with unquantified BNF ability. This study evaluated nodulation efficiency of *Macroptilium lathyroides*, when inoculated with Litolic Neossols from 8 municipalities of the semi-arid Pernambuco State.

Methods

Soil samples from Litolic Neossols collected in 8 municipalities of Pernambuco State (Caetés, Santa Cruz, Petrolina, Floresta, Bom Jardim, Jataúba, Santa Cruz do Capibaribe and Tupanatinga) were evaluated, along with 2 uninoculated controls. Sterile plastic bottles were used as Leonard jars (Santos et al. 2009), containing an autoclaved 1:1 (v:v) sand:vermiculite mixture and Hoagland´s nutrient solution without N (Hoagland and Arnon 1950), except for a control with the full Hoagland solution. *M. lathyroides* seeds were scarified with concentrated sulphuric acid for 10 minutes, rinsed in potable water and allowed to germinate in germtest paper. After 10 days, 2 seedlings were transferred to each jar and inoculated with 2 g of the soil samples. Harvest was 50 days after transplanting and shoots, roots and nodules were separated; nodules were counted (NN) and preserved with silica gel for bacterial isolation. Shoot, root and nodule dry masses (SDM, RDM and NDM, respectively) and N concentration (NC) were determined according to AOAC (1990). Data were evaluated by ANOVA, and when significant, means were compared by the Scott-Knott test at 5% significance level using Sisvar 4.0 (Ferreira 2008). SDM, RDM, NN and NDM were transformed by square root.

Results

NNs for Santa Cruz do Capibaribe (SC Capibaribe), Jataúba and Tupanatinga were greater ($P<0.05$) than for the remaining municipalities (Table 1). NDMs from those 3 areas plus Bom Jardim and Floresta were greater ($P<0.05$) than for Caetés, Santa Cruz and Petrolina. While the highest SDM and RDM were found for plants receiving N (control with N), plants inoculated with soils from Bom Jardim, Floresta, Jataúba, Tupanatinga and SC Capibaribe had significantly ($P<0.05$) higher SDM and RDM than those inoculated with the remaining soils, plus the uninoculated plants. The direct relationship between nodule mass and plant growth suggests that there is also a direct correlation between nodule mass and BNF potential.

The absence of any difference in growth between plants inoculated with soils from Caetés, Santa Cruz and Petrolina and the control without N suggests that any

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Table 1. Nodule number (NN), nodule dry mass (NDM), shoot dry mass (SDM), root dry mass (RDM) and nitrogen concentration (NC) of *Macroptilium lathyroides* inoculated with soil from 8 municipalities in the semi-arid region of Pernambuco State, Brazil.

Municipality	NN	NDM (mg/plant)	SDM (mg/plant)	RDM (mg/plant)	NC (dag[2]/kg)
Bom Jardim	6 b[1]	17 a	280 b	70 b	1.0 b
Caetés	0.6 b	1.0 b	27 c	10 c	---
Floresta	4.0 b	14 a	230 c	90 b	2.8 a
Jataúba	13.2 a	21 a	350 b	75 b	3.4 a
Petrolina	2.5 b	5 b	113 c	30 c	3.4 a
Santa Cruz	0.6 b	1 b	59 c	30 c	1.0 b
SC Capibaribe	19.2 a	24 a	410 b	96 b	3.3 a
Tupanatinga	14.2 a	32 a	560 b	120 b	3.1 a
Control without N	0	0	64 c	20 c	1.1 b
Control with N	0	0	1,880 a	420 a	3.1 a
CV	48.1	12.7	12.6	4.1	12.2

[1]Averages followed by the same letter in a column are not significantly different according to Tukey's test.
[2]dag = dekagram; 1 dag = 10 g.

native rhizobia in these soils have limited ability to fix atmospheric nitrogen in conjunction with *M. lathyroides*. This was reinforced by the absence of any differences in nitrogen concentration for uninoculated control plants and those inoculated with soil from Santa Cruz. The low N concentration in plants inoculated with soil from Bom Jardim raises issues about how much nitrogen was fixed in this treatment.

Conclusions

While all soils had rhizobial populations, there were marked differences in the ability of the native rhizobial strains to nodulate with *M. lathyroides* and fix atmospheric nitrogen. Native rhizobial populations from Floresta, Jataúba, Tupanatinga and Santa Cruz do Capibaribe and possibly Bom Jardim seemed quite effective in BNF ability with *M. lathyroides*. The amount of N retrieved in the plants varied considerably, highlighting the extreme variation in ability to fix atmospheric N.

Acknowledgment

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Resilience and degradation in a tropical wetland overgrazed by cattle

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Keywords: Natural pastures, state and transition model, Pantanal, vegetation monitoring, pasture degradation indicators, pasture resilience.

Introduction

The Pantanal, one of the largest wetlands in the world, has a great diversity of flora and fauna. The dynamic hydrological regime, combined with heterogeneous topography, has resulted in a mosaic of diverse habitat types in terms of species and physical structure. Due to the abundance of forage resources, the Pantanal floodplains are important for beef cattle production. Cattle prefer grazing near water bodies because these areas have high quality forage as a result of flooding regimes (Santos et al. 2002). Many wetlands go through a wet/dry cycle that is essential to maintain their productivity and function. In drier years, wetland drawdown provides optimal conditions for a diverse range of forage species, and cattle can graze continuously, leading to pasture degradation. It is therefore essential to understand the spatial and temporal dynamics of forage production and consumption.

In this study we assessed and monitored vegetation at the edge of one of the pond habitats intensively grazed by cattle, in order to evaluate degradation and quantify indicators of resilience (Briske et al. 2006).

Methods

To measure changes in vegetation during these periods, 25 plots of 0.25 m^2 were randomly selected at 10-m intervals along a permanent transect of 250 m situated on the edge of a wetland pond at a constant elevation. Measurements were taken at the end of the wet season (March) and dry season (September) in each plot during 3 hydrological years (2007−2010). Variables measured within each plot were: number of plant species (richness); visual estimate of percent live plant species cover; visual estimate of percent soil covered with plants, litter and gravel; mean plant height; and total dry matter yield. We also developed a state and transition model using plant functional groups (Figure 1). Plant cover was classified as: C3 and C4 grasses; invasive forbs; macrophyte forbs; exotic forages; and shrub cover. To determine the loss of grassland resilience, we estimated a threshold between forage cover (functional indicator) and invasive forbs cover (degradation and structural indicator) (López et al. 2011), using piecewise regression (Muggeo 2008). Temporary exclosure cages (1 m^2) were allocated along a transect in order to examine recovery of forage cover for at least one complete growth cycle, and permanent exclosure cages to monitor long-term effects.

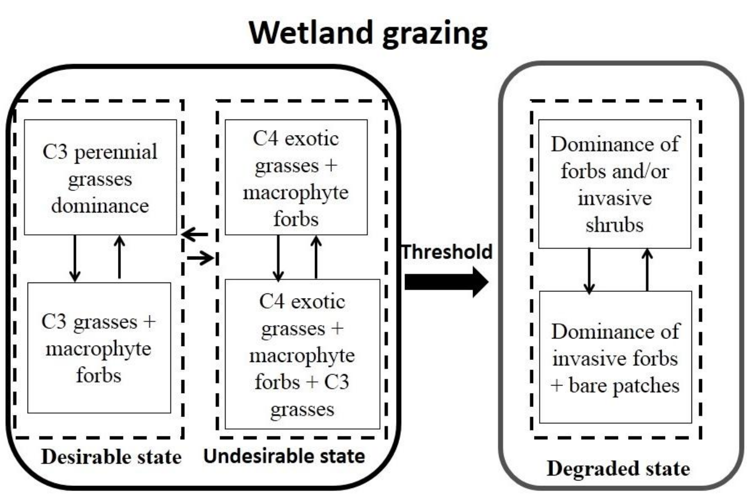

Figure 1. State and transition model for wetland grazing areas using plant functional groups.

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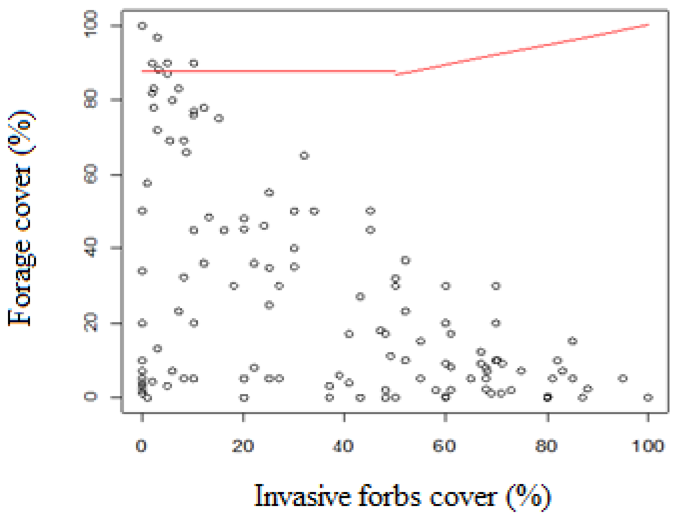

Figure 2. Relationship between forage cover (%) and invasive forbs cover (%) in a wetland grassland, showing the position of the functional threshold identified by piecewise regression.

Results

During the study period we identified and monitored 40 plant species that decreased, while invasive forbs increased. Piecewise regression of forage cover and invasive forbs cover identified a breakpoint at ~50% invasive forbs cover, indicating a loss of function in relation to forage production (Figure 2).

This loss of resilience for forage production was demonstrated in an exclosure cage set up at a site with invasive forbs cover over 70% and around 10% forage cover. The values for forage cover after 6 months, 1 year and 2 years of rest were 5, 3 and 2%, respectively. Permanent exclosure also presented predominance of invasive forbs after 3 years indicating that long rest periods did not ensure the return of desirable species.

Conclusion

During the observations, invasive forbs replaced perennial grasses. This is probably a result of a combination of below average rainfall and the associated overgrazing. Therefore, the main challenge in relation to sustainable management of these wetland areas is to identify grazing thresholds to avoid severe disturbances and subsequent loss of resilience, as well as to define optimal timing, intensity and frequency of grazing. As such, invasive forbs cover can be used as an early warning indicator of habitat degradation.

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Losses and dry matter recovery of Pioneiro grass (*Pennisetum purpureum*) and maize silages in mixtures

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Keywords: Additives, effluents, gases, maize grain.

Introduction

Forages ensiled with high moisture content produce increased quantities of effluents, losing highly digestible nutrients (McDonald 1981). The silage making process usually involves gaseous and effluent losses, which are related to the moisture content of the plants used for forage conservation. The additions of material with high dry matter content and material to improve the fermentation pattern have been strategies to reduce these effluent losses. Whole maize plants and maize grain, because of their physical and fermentative characteristics, are possible materials to reduce the losses in the process (Anaya-Ortega et al. 2009). This study aimed to evaluate the effects of the addition of whole plant maize and maize grain to Pioneiro grass at ensiling as a way to reduce dry matter (DM) losses.

Methods

The research was carried out at the Federal University of Paraná, Palotina Campus, Palotina, PR, Brazil. Pioneiro grass (*Pennisetum purpureum*) and maize were chopped to 20 mm segments and placed into PVC experimental silos with 600 kg of fresh mass/m^3. The silos were provided with upper Bunsen valves for the escape of gases and bottom valves to drain effluents. A completely randomized design was used, with 4 treatments and 8 replicates. The treatments involved 4 types of silage mixtures: Pioneiro grass 100%; Pioneiro grass 90% + whole plant maize 10%; Pioneiro grass 98% + maize grain 2%; and whole plant maize 100%. The quantities of whole plant maize and maize grain added to the treatments were calculated on a fresh mass basis.

Losses by gases (GL) and effluents (EL), and dry matter recovery (DMR) of the silages were measured. DMR was calculated using the following equation:
DMR = [(smso x dmso) / (sme x dme)] x 100, where:
DMR = dry matter recovery (%); smso = silage mass at silo opening (kg); dmso = dry matter at silo opening (%/100); sme = silage mass at ensiling (kg); dme = dry matter at ensiling (%/100).

Statistical analysis was performed using the GLM procedure and test of multiple comparison of means (SNK) at 5% level of significance by the SAS software (version 9.0).

Results and Discussion

Table 1 presents the average percentages of DM at ensiling, ensiled DM lost as gases (GL) and effluents (EL) and dry matter recovery (DMR). Silage type had a significant effect ($P<0.05$) on GL and DMR. The whole plant maize silage (M) and Pioneiro grass silage with maize grain (PMG) had lower GL and, although differences were not significant, no EL. The large GLs of Pioneiro grass silage (P) and Pioneiro grass silage with whole plant maize (PWPM) are likely due to lower carbohydrate and higher moisture contents of the ensiled material. As with most tropical grasses, for Pioneiro to reach a DM content comparable with the maize plant, it would need to grow for a longer period – but the increase would be at the expense of forage/silage quality. Although the effluent losses were not significant with the different DM contents, Pioneiro grass silage had the lowest DMR, which, however, could be considerably improved by adding maize grain.

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Table 1. Mean values of dry matter (DM) content at ensiling, gaseous losses (GL), effluent losses (EL) and dry matter recovery (DMR) of Pioneiro grass and maize silages in mixtures. (P: Pioneiro grass; PWPM: Pioneiro grass with whole plant maize; PMG: Pioneiro grass with maize grain; M: whole plant maize).

	P	PWPM	PMG	M
DM content (%)	23.1d[1]	24.2c	24.9b	32.8a
GL (% DM)	11.14 a	8.65 b	0.69 c	1.25 c
EL (kg/t silage)	2.36 a	0.17 a	0.00 a	0.00 a
DMR (%)	88.78 d	91.30 c	99.30 a	97.49 b

[1]Values within rows followed by different letters differ by SNK test (P<0.05).

Conclusion

High DM losses from Pioneiro silage alone are a concern in ensiling this material. Addition of maize to Pioneiro grass when ensiling offers an excellent strategy to reduce gaseous losses and improve dry matter recovery. Mixing Pioneiro grass with whole plant maize when ensiling seems an ineffective way to reduce losses and savings might not justify the extra effort involved.

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Effects of land use intensification on soil C dynamics in subtropical grazing land ecosystems

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Keywords: Rangeland, silvopasture, stable isotope ratios ($\delta^{13}C$), warm-season grass, coastal plain soils, bahiagrass.

Introduction

The impacts of land intensification on carbon (C) responses are important components of soil organic carbon (SOC) management. Grazing land intensification typically involves the use of highly productive plant species that can support greater grazing pressure, removal of higher proportions of site biomass and nutrients during mechanical harvest or grazing, and increased use of fertilizers, particularly N. Current improved grazing land management strategies are aimed at increasing above-ground biomass yield, with less regard for below-ground C dynamics. Since intensive management affects above- and below-ground C inputs (Schuman et al. 1999; Liu et al. 2011a, 2011b), it can have important implications for the amount and characteristics of SOC stored in grazing lands (Franzluebbers and Stuedemann 2003; Dubeux et al. 2006; Silveira et al. 2013). The objective of this study was to investigate the long-term impacts on SOC dynamics in subtropical ecosystems of converting native rangeland ecosystems into intensively managed systems.

Methods

The study was conducted at the University of Florida, Range Cattle Research and Education Center in South Central Florida (27°35’ N, 81°55’ W). Mean annual precipitation is ~1,650 mm. Average maximum/minimum temperatures are 28/17 °C. Soil was classified as a Spodosol [Ona and Smyrna fine sands (sandy, siliceous, hyperthermic Typic and Arenic Haplaquods)]. The experimental sites (~6 ha) consisted of 3 grazing land biomes with increasing management intensity: native rangeland; silvopasture; and improved pasture. The vegetation in the native rangeland was predominantly saw palmetto (*Serenoa repens*) and a wide variety of grass genera including *Andropogon*, *Panicum*, *Aristida* and *Schizachyrium* spp. The improved pasture consisted of an established bahiagrass (*Paspalum notatum*) stand and the silvopasture was slash pine (*Pinus elliottii*) trees and bahiagrass. Each grazing land biome was replicated twice and was under similar soil type and climatic conditions. Twenty-five soil core samples (0−10 and 10−20 cm depths) were collected from each biome for C and N determinations. Soil samples were dried at 65 °C and analyzed for C and N on a Flash EA 1112 CN analyzer. Natural abundance stable isotope ratios ($\delta^{13}C$) were measured on a *Thermo-Finnigan MAT Delta*^{Plus} *XL Isotope Ratio Mass Spectrometer (IRMS) interfaced via a Conflo-III device to a Costech ECS 4010 elemental analyzer* (Costech, Valencia, CA). Potentially mineralizable C and N were determined following laboratory incubation. Statistical analyses were performed using SAS Mixed procedure (SAS 2001). Grazing land biome was considered a fixed effect with replicates considered random effects. The PDIFF test of the LSMEANS procedure and single degree of freedom orthogonal contrasts were used to compare means. Treatments and their interactions were considered significant when F-test P values were <0.05.

Results and Discussion

Grazing land intensification showed significant effects on SOC and N stocks and $\delta^{13}C$ signature at both depths (Table 1). Accumulation of C and N in the improved pasture was due to the relatively high N inputs and greater biomass production of the warm-season grass as compared with the native vegetation. The $\delta^{13}C$ values at the 0–10 cm depth varied from -22.4 (native rangeland) to -14.7 (improved pasture), indicating the proportion of recently incorporated C4-derived C was more pronounced in improved pasture as compared with other ecosystems. A similar trend was observed in the 10–20 cm depth.

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Table 1. Effects of grazing land intensification on soil organic C and N stocks and $\delta^{13}C$ values. Means within soil depth and parameter followed by the same letter are not different using the LSMEANS procedure (P>0.05).

Site	Total C		Total N		C:N ratio	$\delta^{13}C$
	g/kg	t/ha	g/kg	t/ha		‰
0–10 cm depth						
Native rangeland	12.9 b	13.9 b	0.8 b	0.8 b	17 b	-22.4 a
Silvopasture	19.4 a	22.9 a	1.4 a	1.6 a	14 a	-20.3 a
Improved pasture	21.4 a	21.2 a	1.6 a	1.6 a	13 a	-14.7 b
s.e.	1.8	1.9	0.08	0.1		0.8
10–20 cm depth						
Native rangeland	7.9 b	10.2 b	0.8 b	1.0 b	10 a	-22.7 a
Silvopasture	15.5 ab	21.1 a	1.1 a	1.4 a	14 a	-20.9 b
Improved pasture	17.1 a	22.7 a	1.1 a	1.5 a	15 a	-18.8 c
s.e.	1.7	1.7	0.08	0.2		0.2

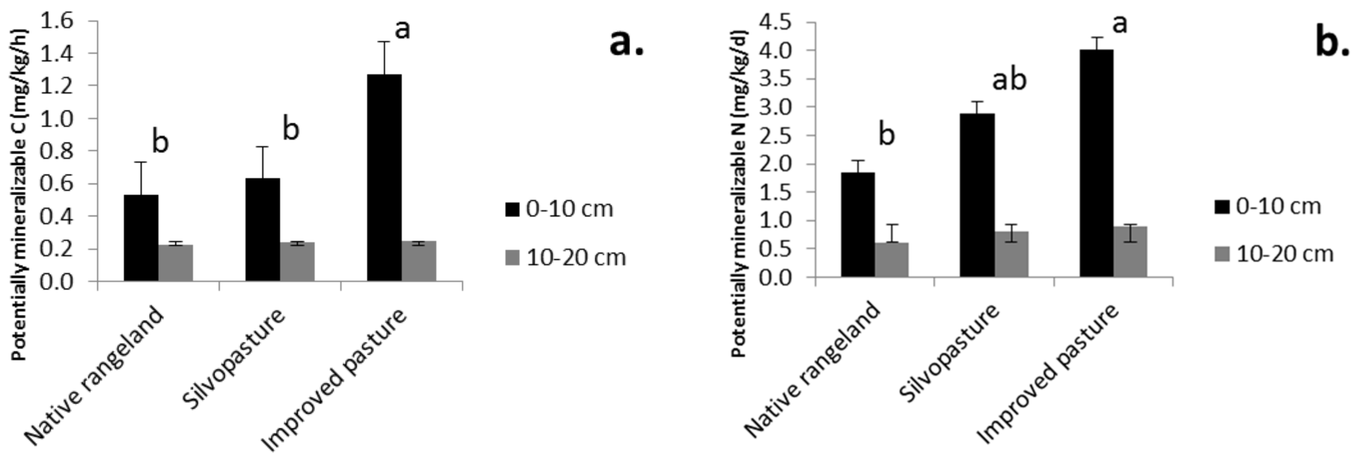

Figure 1. Potentially mineralizable C (a) and N (b) as affected by grazing land ecosystem.

Despite the relatively greater SOC and N stocks, grazing land intensification (native vs. silvopasture and improved pasture) increased C and N mineralization rates at the 0−10 cm soil depth (Figure 1). Data indicated that C and N associated with the improved pasture were present in forms that were more readily bioavailable than those in the less intensively managed ecosystems. These increases in more labile C and N forms were augmented by N fertilization.

Conclusion

Grazing land intensification using proper management techniques promoted SOC and N accumulation. This response occurred because of greater primary productivity in response to the introduction of a highly productive warm-season grass species and the use of N fertilizer. Intensively managed pastures and silvopasture systems have the potential to retain more C and N than native rangeland ecosystems. Nevertheless, C and N stored under improved pastures can be more easily susceptible to decomposition. As indicated by the $\delta^{13}C$ data, a large proportion of the native C stored in intensively managed pastures is being replaced by newly added C derived from the C4 grass species. Although current grazing land intensification has a positive effect on SOC stocks, much of the C is stored in relatively more labile forms of SOC than that in the native ecosystems.

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A case study of evaluation, demonstration and adoption of improved forages for a cut-and-carry system in Eritrea

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Keywords: *Panicum, Setaria, Brachiaria, Leucaena, Desmanthus, Macroptilium.*

Introduction

Eritrea, a largely arid or semi-arid country in north-east Africa, lies on the western side of the Red Sea between about 12 and 18° N, and has an elevation ranging from -75 m to 3,018 m asl. Soils span from shallow, often infertile stony soils in steeper areas to fertile clays and clay loams on the flats. Soil pH ranges from slightly acid to moderately alkaline. About 80% of the population is engaged in subsistence mixed farming, with livestock being used for meat, milk, draft and fiber, as well as serving as a financial reserve. Average farm size in the most intensively populated area (central highlands) is about 0.2 ha, and about 2 ha in the less populated western lowlands.

In extensive farming systems, the rangelands that account for more than 90% of livestock feed, have a carrying capacity ranging from about 20 ha/Tropical Livestock Unit (TLU ≡ one bovine with a body weight of 250 kg) in the 100 mm rainfall zone to about 4 ha/TLU in the 600 mm rainfall zone (Kayouli et al. 2002). Crop residue is the second largest source of feed for livestock, with sorghum residue being the most important by a large margin. In the more intensive dairy systems, perennial forages such as *Medicago sativa* cvv. Hunter River (uplands) and Hairy Peruvian (lowlands) and *Pennisetum purpureum* are used by some farmers. Columbus grass (*Sorghum* x *almum*) has been introduced in limited areas in recent years. The combination of an extensive and diverse livestock population, and unreliable and strongly seasonal rainfall, has contributed to widespread overgrazing, which in turn has led to significant loss of ground cover and soil erosion. Much of the native grassland is now severely degraded, and more productive endemic species largely lost.

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The aim of this project was to enhance the sustainability of keeping livestock in Eritrea through improvement of the forage base. As in many countries, it was considered that this improvement might be best achieved through the incorporation of high quality, productive species that are adapted to the wide range of environments and applications found in Eritrea (Wolfe et al. 2008). This paper presents an account of progress in one of these situations, irrigated dairying in the central highlands.

Methods

A collaborative program of plant introduction and evaluation between NARI and New South Wales DPI was commenced in 2006 to select a range of forage grasses and legumes adapted to the various Eritrean environments, and appropriate to current farming systems in the country. Potential introductions were identified through a combination of collection site details (passport data) and the expert knowledge selection tool SoFT developed by Cook et al. (2005). A total of 262 accessions of cool season species (predominantly legumes) were sown in 50 cm square micro-plots in 2006, and 53 accessions of warm season grasses and 242 warm season legumes were introduced during 2006 and 2007, and sown in single or double 5 m rows on NARI research facilities in the central highland region and western lowlands. Twenty-seven cultivars of *M. sativa* were sown in 2008 to compare with locally used varieties. All plots were flood-irrigated when water was available to ensure establishment and rapid development for vegetative propagation and seed set. Phenology of all genotypes was recorded and each rated for yield and leafiness. Seed was harvested, threshed and winnowed by hand.

In the unreliable rainfall environment of Eritrea, it is usually more reliable to use the limited irrigation resource for vegetative propagation of grasses, since plants become less moisture-dependent more quickly than with sowing. Accordingly, larger plots of elite lines were established to provide a source of seed or vegetative propagating material for dissemination of varieties beyond the NARI facility.

Since all species included in the trials had been found beneficial in research in other countries, interested farmers visiting the plots during the evaluation phase were not discouraged from taking propagating material from these plots to establish on their own farms.

On completion of the on-station evaluation, 2 technical guides, one on establishment and management of sown forages generally, and the other relating specifically to the shrub legume, *Leucaena leucocephala*, were prepared and widely distributed to extension staff and education institutions in Eritrea. More promising lines were established on a private farm at Shiketi in the central highlands in 2011. The farm is owned by an influential farmer, who is identified as an innovator by other farmers in the area. This farm is now being used to influence other farmers and senior officials to include the improved species in farm and policy plans.

Results

From the plot work, some of the most productive and best adapted species overall include the grasses, *Panicum maximum* (syn. *Megathyrsus maximus*), *Setaria sphacelata*, *Brachiaria* (syn. *Urochloa*) spp. and several forage *Sorghum* varieties, plus the legumes, *Desmanthus* spp. (particularly *D. leptophyllus* and *D. virgatus*), *Stylosanthes seabrana*, *Macroptilium atropupureum* and *L. leucocephala*. Farmers have shown an interest in using *Lablab purpureus* and *Vigna unguiculata* intercropped with forage sorghum for dairy cows.

Elite lines of the above species, *P. maximum* (syn. *M. maximus*) cvv. Gatton and Tanzania, *S. sphacelata* var. *splendida*, *S. sphacelata* hybrid cv. Splenda, *Brachiaria decumbens* (syn. *U. decumbens*) cv. Basilisk and *Brachiaria* (syn. *Urochloa*) hybrid cv. Mulato, have been established on the model/demonstration farm in plots ranging in size from 80 to 175 m^2. Larger plots of *M. sativa*, *P. purpureum*, *Sorghum* x *almum* and *Ipomoea batatas* have been established to provide for visitors a comparison of the new varieties with existing varieties. The forages currently provide cut-and-carry feed for dairy goats and rabbits on the farm. Legumes (*M. atropurpureum*, *Desmanthus* spp., *S. seabrana*, *L. leucocephala*) will be established in the 2013 wet season. The farm owner can see the economic potential of the forages and is planning to enlarge the area of the cultivated forages. Limited funding and availability of transport have restricted researchers and extension staff, but the enthusiasm of the farmer has offset this difficulty to some extent.

Conclusion

The project has not only led to the introduction and adoption of a wider range of well-adapted, productive forages into Eritrea, but also has had the additional benefit of broadening the professional networks of R & D personnel in the country. Future work will follow a similar format to address the needs of other farming systems in Eritrea, particularly in relation to development of dairying on the extensive fertile clay soil areas of the western lowlands, where irrigation from large dams is available.

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Performance of calves receiving a by-product of the babassu oil palm during the dry season in an integrated pasture-forestry system in the pre-Amazon region of Brazil

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Keywords: Livestock, forest, supplementation, by-product feeding, vegetable protein.

Introduction

Integration of farming, livestock and forestry constitutes a viable alternative for the advancement of sustainable agriculture through its effects on social and ecological processes. Silvopastoral systems are integrated systems characterized by the management of animals in an agriculture-forestry association. These systems aim to stabilize forage production for meat and/or milk production and provide forestry products as well as various environmental services, such as shade for animals (Maurício et al. 2010). Despite the benefits mentioned, the seasonality in the production of tropical forages needs to be considered. An efficient way to avoid losses in animal production in the dry season is with the use of supplementation, e.g. soybean meal. However, other by-products from agri-business with high nutritional value are often not recovered and rather discarded, sometimes harming the environment. The use of these residues in animal feed can reduce environmental impacts and the cost of animal feed.

The aim of this study was to evaluate the performance of cattle in a silvopastoral system in the dry season, supplemented with babassu meal, a by-product of the native oilpalm, babassu (*Orbygnia phalerata,* syn. *Attaleia speciosa*).

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Methods

The experiment was conducted in the pre-Amazon region (transitional zone bordering the Amazon rain forest), at Tank Farm property in the municipality of Matinha, Maranhão, Brazil (45°06'25" W, 02°59'35" S), in an Aw climate according to the Köppen classification. The pasture grass used was *Brachiaria brizantha* cv. Marandu in a silvopastoral system with babassu as the tree component. Soil fertility for the pasture was corrected with lime, superphosphate as P source, potassium chloride as K source and urea as N source, according to soil test-based recommendations. We used a 3 x 3 factorial design: 3 tree densities (39, 72 and 92 palms per hectare); and 3 levels of replacement of soybean meal by babassu meal: 10, 20 and 30%, allocated in a completely randomized design. The diets were isonitrogenous and the supplement concentrate was provided every morning at a rate of 2% of the test animals' body weight.

The pasture was continuously grazed. Available herbage mass and sward structural components were monitored by two 1-m² samplings at 3 points in each paddock, during the experimental period (data not presented). The experimental period was 76 days, with 10 days of adaptation and 66 days of evaluation (from 2 December 2012 to 6 February 2013), the dry season in the region.

The experimental units were 27 Nelore Guzonel cattle, 9−10 months old and of approximately 200 kg initial weight. The animals were allocated to 9 groups, which were allocated into 9 paddocks of 0.61 ha. Animals were weighed every 2 weeks after a 16-h fast. Data were analyzed by the statistical program InfoStat® (Infostat Statistical Software, Córdoba, Argentina).

Results and Discussion

Data on weight gain of animals receiving different levels of babassu meal to replace soybean meal, on pastures with different densities of the babassu palm are found in Table 1. There was no statistical difference (P>0.05) between treatments, and no interaction. These results corroborate those obtained by Castro (2012), who evaluated the addition of increasing levels of babassu meal as a substitute for sugar cane for heifers and found that the final weight of the heifers was not altered by the diets. However, in her study the average daily gain of the animals had a quadratic relationship, with the greatest average daily gain (ADG) when feeding 19% babassu meal. Xenofonte et al. (2008) evaluated the performance of lambs fed diets containing different levels of babassu meal bran (0, 10, 20 and 30% on a DM basis) and observed a linear decrease of ADG with increasing babassu proportion. However, Castro (2012) reported that the inclusion of 15% babassu meal in place of soybean meal in the diet of dairy cows produced no differences in ADG.

Table 1. Total weight gain (kg/animal) during the experiment (66 days). There were no significant differences (P>0.05).

Replacement levels	Density of palm trees (no./ha)		
	92	72	36
30% babassu meal	34.2	49.7	49.5
20% babassu meal	49.2	45.2	39.5
10% babassu meal	44.8	57.0	42.2

In our experiment, the cost of 100 kg feed supplement was R$ 94.36, 92.55 and 90.67 for the 3 replacement levels by babassu meal, respectively.

Conclusion

We conclude that replacing up to 30% of soybean meal with babassu meal and a tree density of up to 92 babassu palms/ha in pastures did not interfere with weight gain of cattle. Due to local-market availability and lower price compared with soybean meal, babassu meal is a promising option for inclusion in the diet of ruminants.

Acknowledgments

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Evaluation of limpograss (*Hemarthria altissima*) breeding lines under different grazing management systems

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Keywords: Light interception, canopy structure, forage productivity, post-grazing stubble height.

Introduction

Limpograss (*Hemarthria altissima*) is a stoloniferous, warm-season perennial grass from South Africa and is frequently used to extend the grazing season in poorly drained soils of subtropical regions (Quesenberry et al. 2004). The cold tolerance of limpograss allows it to grow at temperatures below which other commonly used warm-season grasses (e.g. bermudagrass) become unproductive. Use of limpograss has helped to reduce forage shortfall during winter, therefore reducing feeding costs. In the past 30 years, the area planted to limpograss in Florida, USA has grown faster than that of any other forage grass species. It is estimated that over 0.2 million ha are planted to limpograss (Quesenberry et al. 2004).

Recent University of Florida research with limpograss has focused on developing new hybrids, which incorporate the persistence of the most widely used cultivar Floralta with the digestibility of cv. Bigalta. Preliminary clipping and grazing trials evaluated 50 breeding lines and identified 5 lines (designated 1, 4F, 10, 32 and 34) with superior performance. Within the overall program goal of identifying the best limpograsses for cultivar release, the specific objective of this experiment was to investigate the forage productivity and sward canopy characteristics of these 5 breeding lines, relative to Floralta, in response to different grazing management strategies.

Materials and Methods

The research was conducted from May to October 2012 at the University of Florida Beef Research Unit, northeast of Gainesville, FL, USA. The soils are classified as sandy Spodosols of the Pomona series (sandy, siliceous, hyperthermic Ultic Alaquods), with pH of 5.3 and P, K and Mg levels of 5.5, 36 and 109 mg/kg, respectively. Limpograss plots were planted in July 2011 and allowed to establish until May 2012, when they were uniformly mowed to 20 cm prior to initiation of rotational stocking treatments. Based on soil test recommendations, pastures were limed (2.2 t/ha) and fertilized with 19 kg P and 75 kg K/ha in April, and N was applied at 135 kg/ha in 3 equal applications of 45 kg/ha in April, June and August.

The study included 24 treatments, arranged as a 6 x 2 x 2 factorial experiment with 2 replications in a randomized complete block design. Experimental units were 8 m x 8 m. Treatments included the 6 limpograss entries (1, 4F, 10, 32, 34 and Floralta), 2 pre-graze light interception levels (LI; 80 and 95%) that determined when the pasture was ready to be grazed, and 2 post-graze stubble heights (SH; 20 and 30 cm). LI was measured with a SunScan Canopy Analysis System model E-312-SS1-COM (Delta-T Devices, Cambridge, UK). Using LI as the grazing trigger generally results in more uniform canopy characteristics across grazing events, compared with calendar-based timing. The 95% LI value had previously been proposed as an 'optimum' threshold for initiation of grazing, because it reflects the inflection point of the growth curve where growth rates are maximum but before herbage accumulation rate starts decreasing (Lemaire and Chapman 1996; da Silva and Nascimento Jr. 2007). The reason for using 80% LI and shorter SH (20 cm) than the recommended (30 cm) for limpograss was to apply significant selection pressure on the entries. Cross-bred Angus yearling heifers (~400 kg) were used to graze the pastures using mob stocking.

Herbage mass was quantified before and after each grazing event from four 0.25 m² quadrats per pasture. Forage was dried to constant weight to determine dry matter (DM). Herbage mass harvested by grazing (HH; kg DM/ha) was calculated as the difference between pre- and

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post-grazing herbage mass of a given grazing cycle, and herbage accumulation (HA; kg DM/ha) was determined as the pre-graze herbage mass minus post-graze mass of the previous grazing cycle. The HA of the first grazing cycle was considered to be pre-graze herbage mass of that cycle. Canopy height was measured at 20 locations per pasture prior to grazing. Leaf and stem mass and leaf:stem ratios were measured for the third grazing event of the season on entries 1, 4F, 10 and cv. Floralta. Two 0.25 m² quadrats were sampled per pasture for this evaluation. Data were analyzed using PROC GLMMIX of SAS.

Results and Discussion

HA and HH for entries 10 and 4F were as great as or greater than those for any other entry, but values were not statistically different from those for Floralta (F) (Table 1). There was no effect of either LI or SH on HA or HH.

Table 1. Total herbage accumulation (HA), total herbage harvested (HH) and number of grazing periods at 2 pre-graze light interception (LI) levels, for 6 limpograss entries.

Entry	Total HA (t/ha)	Total HH (t/ha)	Number of grazing periods	
			LI80	LI95
10	11.6a[1]	9.9a	5a	4a
4F	10.4ab	8.9ab	5a	3b
F	9.5abc	7.9abc	5a	3b
32	8.4bc	7.1bc	4c	3b
1	8.0c	6.4c	4.5b	3b
34	7.8c	6.0c	4c	3b

[1]Means within a column not followed by the same letter are significantly different (P<0.05).

The number of grazing events during the season was greater for LI80 than LI95, regardless of entry (4.6 vs. 3.2, respectively). Entry 10 had more grazing events than any other entry for LI95 and more than all but 4F and Floralta for LI80.

Canopy height across entries was affected by both LI and SH levels. At initiation of grazing, LI95 pastures were taller (73 cm) than LI80 (59 cm). Post-grazing SH also affected canopy height at which target LI was reached. For pastures grazed to 20 cm SH, there was an 11 cm difference between LI80 (59 cm) and LI95 (70 cm), whereas for pastures grazed to 30 cm, the difference was 16 cm (60 vs. 76 cm, respectively). This difference most likely reflects phenotypic plasticity associated with use of a shorter SH, whereby regrowth was denser, allowing target LI to be reached at a shorter canopy height (Lemaire and Chapman 1996). This is supported by data showing that swards grazed to 20 cm SH had greater bulk density than those grazed to 30 cm (69 vs. 62 kg DM/ha/cm; P<0.10). The taller canopy of LI95 treatments imposed constraints on grazing efficiency, because the forage was prone to lodging and trampling. Limpograss grows upright when there is significant light competition; therefore, the LI95 treatment resulted in greater stem accumulation than did LI80 (1,079 vs. 853 kg DM/ha, respectively; P=0.07). These data indicate that use of 95% LI as a trigger for initiating grazing is not as appropriate for limpograss as it is for other species (da Silva and Nascimento Jr. 2007).

Conclusions

Limpograss entries 10 and 4F performed at least as well as cv. Floralta and are good candidates for cultivar release. Unlike the recommendation for several tropical grasses, the use of 95% light interception is unlikely to be a useful threshold to commence grazing of limpograss, because canopies at this level of light interception are very tall, stemmy and susceptible to lodging and trampling.

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Impacts of projected climate change on pasture growth and safe carrying capacities for 3 extensive grazing land regions in northern Australia

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Introduction

The northern beef industry is a major component of the regional economies of Queensland, Northern Territory and northern Western Australia, and has contributed an estimated $5 billion to Australia's economy in 2009-10. Projected climate change will have an adverse impact on Australia's agricultural production (McKeon et al. 2008), with an expected 3.5% decline in beef production in northern Australia by 2030 (Heyhoe et al. 2008). The GRASP pasture production model (McKeon et al. 2000) has been used to evaluate impacts of climate change in Australia's rangelands (Crimp et al. 2002; McKeon et al. 2008), with the positive effects of higher carbon dioxide (CO_2) on pasture growth likely to be offset by reductions in pasture productivity and digestibility due to lower rainfall and higher temperatures (Crimp et al. 2002). The impacts of 3 projected future climates on livestock carrying capacity of grazing lands in the Fitzroy, Maranoa-Balonne and Victoria River District regions were assessed using GRASP.

Methods

The impacts of future climates on moderately productive pastures in each of the Fitzroy, Maranoa-Balonne and Victoria River District (VRD) regions were simulated using GRASP over a 30-year period (1981−2010). Results are presented as percent changes in pasture growth and safe stocking rate relative to the current climate. Current climate files for 3 locations (Duaringa in Fitzroy, Mitchell in Maranoa-Balonne, Wave Hill in VRD) were obtained from Specialised Information for Land Owners (SILO) climate database. For each location, the Queensland Climate Change Centre of Excellence (QCCCE) provided climate data from 19 Global Circulation Models with 3 global sensitivities to rising greenhouse gases, that included a seasonal change factor for climate attributes, under 8 climate emission scenarios. Climate projections that represented the 90th percentile (High), 50th percentile (Median) and 10th percentile (Low) rainfall for an approximate 3 ^{o}C increase in maximum temperature were extracted from the QCCCE climate data. Selected climate projections were under A1F1 and A2 emission scenarios in 2050. The effects of CO_2 on plant growth (C4 warm season grasses) are represented in GRASP by varying parameters that increase the efficiency, with which plants use light, water and nitrogen resources at a specified CO_2 level (Stokes et al. 2012).

Results and Discussion

Variation in projected rainfall was the major driver of regional differences in projected impacts on pasture growth and carrying capacity. Declines in pasture production and carrying capacity of moderate productivity grazing lands were projected for all regions under the Low and Median rainfall future climates (Figure 1). Maranoa-Balonne was the most severely impacted region with pasture growth (6–79%) and safe stocking rates (14–60%) lower than current climate for all projected climates (Figure 1a). In the Fitzroy region (Figure 1b), even under the High future climate, projected pasture growth and safe stocking rates were at best on par with current climate. Only in the VRD, when annual rainfall was projected to be 20% higher than current climate (High), were projected pasture growth (9%) and stocking rates (11%) higher than those for the current climate (Figure 1c).

Projected seasonal rainfall for spring (50% lower than current climate) and autumn (40% higher than current climate) indicate a delayed start and finish to the wet

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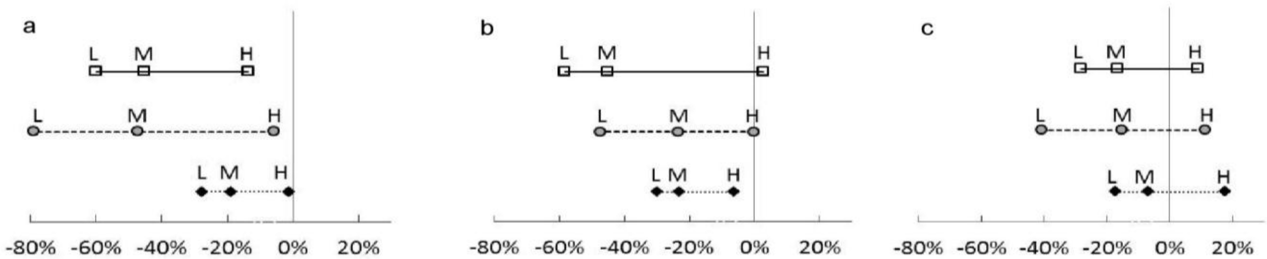

Figure 1. Percent change in projected rainfall ( ), pasture growth ( ) and safe stocking rates ( ) from current climate (0 in X axis) for High (H), Median (M) and Low (L) rainfall climate outcomes for: (a) Maranoa-Balonne; (b) Fitzroy; and (c) Victoria River District moderate productivity land types.

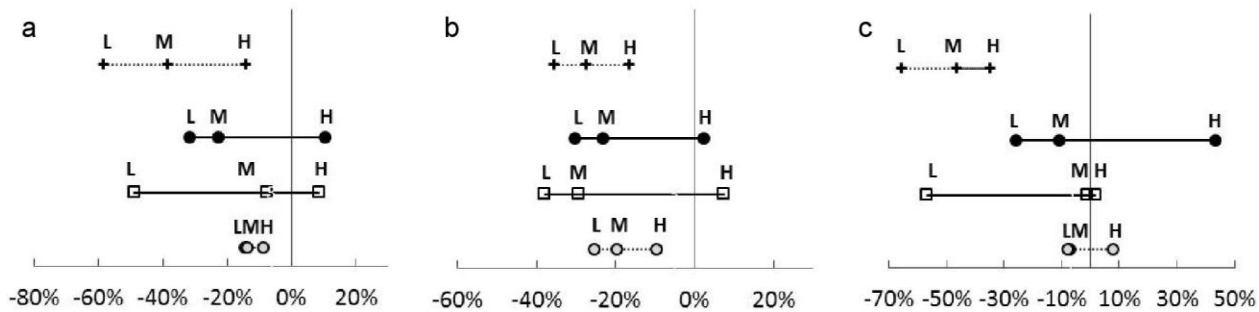

Figure 2. Percent change in projected mean monthly rainfall for Summer ( ), Winter ( ), Autumn ( ) and Spring ( ) from current climate (0 in X axis) for High (H), Median (M) and Low (L) rainfall climate outcomes for: (a) Maranoa-Balonne; (b) Fitzroy; and (c) Victoria River District moderate productivity land types.

season in VRD under the High future scenario (Figure 2c). Conversely, for both Maranoa-Balonne and Fitzroy regions, rainfall during summer was lower than current climate for all future climates (Figures 2a and 2b). In these regions, High projected rainfall was 10% less than current climate during the optimal pasture growing months. For this High rainfall outcome, the projected increases in rainfall (10%) occur within the cooler autumn/winter months, when light, temperature and moisture conditions are less conducive for C4 pasture growth.

Conclusion

Declines in pasture production and carrying capacity were projected for 3 extensive grazing regions in northern Australia under climate change scenarios. The positive effects of CO_2 fertilization on pasture growth, including improved water-use and nitrogen-use efficiencies, were offset by lower annual and seasonal rainfall. Grazing management practices, that include matching stocking rates to forage availability, maintaining land in good condition and resting pastures, will assist producers adapt to changing climate. Adjusting the timing and frequency of management practices (mustering, calving) and maintaining high tropical breed content of herds will assist producers adapt to extended late dry seasons. Managing pasture composition to match rainfall distribution of future climates will help ensure potential carrying capacities are achieved. Incorporating winter growing grasses (C3) into pastures in regions, where 25−50% of annual rainfall falls during cooler months, may achieve better pasture growth under higher rainfall future climates. In regions where nitrogen is limiting, the addition of legumes may facilitate better pasture growth under higher rainfall scenarios.

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