Resource mediated competition of two South Texas natives: *Acacia berlandieri* and *Trichloris pluriflora*

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Abstract

Acacia berlandieri, an early-successional C3 woody shrub legume, and *Trichloris pluriflora*, a late-successional C4 mid-tall grass, reside in similar habitats and have both been documented in South Texas for over 150 years. This study examines the resource mediated intra- and interspecific competition of these species which may illuminate some of the dynamics involved in the encroachment of woody shrub species into grasslands. These species, started from seed, were grown outdoors (5 replicates) using sandy clay loam soil in plastic lined pots for 155 days and watered daily. Half of these pots received 12.5% Hoagland's solution. Growth measurements were taken 3 times, after a 72 day establishment period and prior to harvest. The plants were then harvested intact and dried at 60°C. The above and below ground dry mass for each individual plant was separated and the roots were ashed at 650°C. The growth parameters of *A. berlandieri*, basal diameter, height, and number of leaves, increased with density (P=0.0024, P<0.0001, and P<0.0001), when grown in competition with *T. pluriflora*. None of these growth parameters for *A.* berlandieri had an effect on the variables of density, nutrients or and their interaction (P>0.0500), when grown alone. The growth parameters of *T. pluriflora*, culms and height, decreased with increasing density (P=0.0077 and P=0.0006), when grown in competition with *A. berlandieri*. The culms, tillers, and height of *T. pluriflora*, when grown alone, decreased with increasing density (P<0.0001, P=0.0312, and P<0.0001). The measurement parameters of harvested *A. berlandieri*, above ground and ash-free root biomass, increased with density (P=0.0463 and P=0.0389), when grown in competition with *T. pluriflora*. The root biomass of harvested *A. berlandieri*, grown alone, decreased with the interaction of density and nutrients (P=0.0068). The total plant dry mass, above ground, root, and ash-free root biomass of harvested *T. pluriflora*, grown in competition with *A. berlandieri*, decreased with increasing density (P<0.0001, P<0.0001, P=0.0235, and P=0.0145). These same measurement parameters of harvested *T. pluriflora*, grown alone, increased with density (P<0.0001 for all four parameters). The addition of nutrients had little or no effect on the growth or harvest of *A. berlandieri* and *T. pluriflora* for either intra- or interspecific competition (P>0.0500). Density appeared to be the driving force for the intra- and interspecific competition of these two species and potentially an important variable in the disappearance of grasslands.

Introduction

- The increasing abundance of woody plants in grassland and savanna ecosystems have been reported worldwide (Archer, 1994; Zitzer et al., 1996; McPherson, 1997) and very apparent in the South Texas Plains and Coastal Prairies and Marshes of Texas (Bentley, 1898).

- The encroachment of woody plants into the grasslands has become a major concern to scientific researchers and range managers due to the implications for livestock production systems (Scifres, 1980; Scifres et al., 1983), wildlife habitat (Ben-Sharer, 1992), and the potential for dramatic changes in biochemistry (Schlesinger et al., 1990). However, little is known of the rates, dynamics, patterns, or successional processes involved in these vegetational changes (Brown and Archer, 1999).

- There are a variety of accepted factors involved in the increasing abundance of woody plants in the grasslands including: overgrazing, erosion and soil compaction, fire suppression, and climate change. Further, it has been suggested that all of these factors have interacted to produce the current vegetational shift (Archer et al., 1995; Van Auken, 2000).

- Livestock grazing has clearly been demonstrated to be a primary factor (Brown and Archer, 1999). The timing has been consistent with the observed encroachment of woody vegetation into the South Texas and Northeastern Mexico grasslands since 1870 (Cook, 1908). Heavy, continuous cattle grazing combined with fencing of the range has further intensified the grazing effect, directly via consumption, and indirectly, via trampling (Archer, 1995).

- Suppression of fire is another factor responsible for the encroachment of woody shrubs into the grasslands (Brown and Archer, 1990; Mecke, 1996). Further, these frequent fires facilitate the recycling of valuable nutrients for the grasses. Consequently, the absence of fires alters the available nutrient levels, allowing the woody shrub species to establish and flourish.

- Climate change is the last factor considered here for contributing to the disappearance of the grasslands. There is little doubt that the magnitude, duration, and season of climate change play an important role in regulating the rate and direction of plant community changes (Archer and Smeins, 1991). This is very apparent in arid and semi-arid ecosystems where temperature and precipitation are so critical.

- Evidence suggests that the increase in woody plants; many of which are capable of N2 fixation, has altered the control of element inputs into ecosystems. These woody plants facilitate the mineralization of excess Nitrogen at higher temperatures with increased levels of CO2. It has been suggested that the recent rise in atmospheric CO2 levels should favor C3 woody plants over C4 grasses (Mayeux et al., 1991; Polley et al., 1992; Idso, 1992; Johnson et al., 1993). However, this shift has not been demonstrated (Archer et al., 1995; Anderson et al., 2001).

- *Acacia berlandieri* is a prolific, spreading, medium-sized woody shrub species with fernlike leaves and short, recurved thorns (Fig. 1). It grows in a variety of soil types, including clay and sandy loam, and is common on caliche ridges and shallow soils of brushy pastures throughout the Edwards Plateau, South Texas Plains, Northern Mexico, and the Trans-Pecos Region (Uvalde Research and Extension Service Staff, 2000). This legume, not known for nodulation (Zitzer et al., 1996), is considered an increasing early successional species with a good forage value and cover value for both cattle and wildlife (Texas Parks and Wildlife Staff, 2004). It also has a high economic value as a source of honey production (Texas Parks and Wildlife Staff, 2004).

- *Trichloris pluriflora* is a warm-season, perennial bunch grass, that grows up to 1.5 m tall in a variety of soil types, including silt, clay, or sandy loam, in the plains and dry woods in South Texas, Mexico, and South America (Uvalde Research and Extension Service Staff, 2000; Fig. 2). This C4 grass is one of two co-dominate climax community species, indicative of the South Texas mixed grass and tall grass communities. It has excellent forage and cover value for cattle and wildlife, and is considered an indictor of good range conditions (Lloyd-Reilly et al., 2002).

Objective

- The objective of this study was specifically to examine the resource mediated intra- and interspecific competition of two Texas natives: *Acacia berlandieri*, a C3 woody shrub, and *Trichloris pluriflora*, a C4 grass. Both of these species are found in many of the same habitats and have been documented for over 150 years in the grasslands and surrounding areas (Jones, 1977). The results should ultimately illuminate some of the variables involved in the encroachment of woody shrubs in the grasslands. Further contributions are that while a considerable amount of research has been done on *A. berlandieri*, very little has been done on *T. pluriflora* (Everitt and Gonzales, 1979; Everitt and Mayeux, 1983; Johnson and Fulbright, 2008).

Hypothesis

- The hypothesis tested in this study is that changes in resource levels contribute to the encroachment of woody species into the native grasslands. The competition between and among C3 woody shrubs and C4 grasses may be mediated by available nutrients.

Methodology

- Samples of *T. pluriflora* seeds and *A. berlandieri* seeds were collected in Hidalgo County (both locations are on the Santa Ana Wildlife/Lower Rio Grande National Wildlife Refuge, Texas).
- Soils identified at the seed collection sites were the Camargo Series (*T. pluriflora*), and the McAllen Series (*A. berlandieri*; Jacobs, 1981). The Camargo Series, classified as a hyperthermic Typic Ustivent, is a silty clay loam (Soil Survey Staff, 2003). The McAllen Series, classified as a hyperthermic Aridic Calciustept, is a fine sandy loam (Soil Survey Staff, 2000). A soil similar to the Camargo Series, the Zavalla Series, was identified locally in Wilson County, Texas (Taylor et al., 1966). Classified as hyperthermic Typic Ustivent, the Zavalla Series is a fine sandy loam (Soil Survey Staff, 2001). Soil was collected from this site; up to 14 inched in depth, sieved with a 2 mm sieve to remove foreign debris, and thoroughly mixed (A sample was sent to the Texas A&M University Soil, Water, and Forage Testing Lab for texture and nutrient analysis).
- The recommended amendment was 11.2 kg/hectare of P2O5 added as fertilizer (Texas A&M University Soil, Water and Forage Testing Laboratory, 2006). Consequently, a 12.5% Hoagland's Solution, containing Phosphorus in the form of KH2 PO4, was selected for the resource mediated competition (Van Auken and Bush, 1995).
- A local, outdoor experimental site (Lat: 29° 34' 03.1" N, Long: 98° 29' 26.4" W) was selected with adequate protection from predators and extreme physical conditions, and easily accessible for watering, monitoring, and taking measurements. In the event of extreme weather conditions, a cover was placed over the site with sufficient pitch to deflect rainfall and yet provided air flow.
- On August 2-3, 2006, the seeds of both plant species were planted (using a factorial designed treatment regime listed below) in 15×15 cm plastic pots, each lined with a one gallon plastic bag to prevent nutrient loss, and filled with 1500 grams of soil which had been dampened with 100 ml of distilled/de-ionized water. Five replicates were prepared for each treatment. Each *A. berlandieri* seed was presumed to produce one seedling. The *T. pluriflora* seeds were so small that more seeds were planted and thinned once established.
- *A. berlandieri* intraspecific competition included the following treatments (+ or - designate nutrients added or not, number is the density of plants in the treatment, letter A or T designates species): +1A, - 1A, + 2A, - 2A, + 4A, and - 4A. The treatments for the *T. pluriflora* intraspecific competition treatments included: + 1T, - 1T, + 2T, - 2T, + 4T, - 4T, + 8T and - 8T.
- The treatments for the interspecific competition of *A. berlandieri* and *T. pluriflora* included the following (numbers in front of letters designate the density of said species; all other symbols are the same as previously described): + 0A/4T, - 0A/4T, + 1A/3T, - 1A/3T, + 2A/2T, - 2A/2T, + 3A/1T, - 3A/1T, + 4A/0T, and – 4A/0T.
- All of the planted pots were placed randomly in study site and watered daily with 150 ml of distilled/de-ionized water. After a three day germination period, 62.5ml of Hoagland's Solution (equaling 12.5%) was added to the pots designated for nutrients. Other pots received 62.5 ml of distilled/de-ionized water. The planted pots were rotated every two weeks (Fig. 3).
- Statistical analyses were performed on square-root transformed data unless otherwise noted; utilizing the least squares fit Analysis of Variance (ANOVA) for the resource mediated intra- and interspecific competition of *A. berlandieri* and *T. pluriflora*. When the results were statistically significant, figures were presented, based on the original raw data. Same letters within the figures indicated that they were not significantly different from each other (P>0.0500) utilizing the Tukey-Kramer HSD for three or more variables while the Student t-Test was utilized when comparing two variables.

Fig. 1. *Acacia berlandieri*, Caesar Kleberg Wildlife Research Institute

Fig. 2. *Trichloris pluriflora*, Rudman Prairie by Chris Best

Results

- There was no statically significant overall model testing the intraspecific competition of *A. berlandieri* with respect to the growth parameters of basal diameter, height, or number of leaves, across all three measuring dates for the variables of date, density, nutrients, or any of their interactions (P>0.0500; data not shown).

- There was a statically significant overall model testing the interspecific competition of *A. berlandieri* with respect to the growth parameters of basal diameter, height, and number of leaves, grown in combination with *T. pluriflora*, across all three measuring dates for the variable of density (see Fig. 4; P<0.0500; data not shown).

- There was a statically significant overall model testing the intraspecific competition of *T. pluriflora* culms, tillers, and height, grown across all three measuring dates for density (see Fig. 5; P<0.0500; data not shown).

- There was a statically significant overall effect on the interspecific competition of *T. pluriflora* culms and height for density, grown with *A. berlandieri* (see Fig. 6; P<0.0500; data not shown). However, *T. pluriflora* tillers were not included in this statically significant overall effect (P>0.0500; data not shown). Further, there was a statically significant overall effect on the interspecific competition of *T. pluriflora* height, grown with *A. berlandieri*, for the interaction of nutrients and planted density (see Fig. 7; P<0.0500; data not shown).

- Fig. 6 represents the significant density effect on the interspecific competition of *T. pluriflora* mean culms (± one standard error), grown with *A. berlandieri* (P=0.0077). The number of culms was the highest for the density of 1/3 (*Trichloris*/*Acacia*), followed by those for 2/2. The lowest number of *T. pluriflora* culms was for the density of 4/0 (P<0.0500).

- Fig. 7 represents the significant interactive effect of nutrients within the planted density on the interspecific competition of *T. pluriflora* mean height (± one standard error), grown with *A. berlandieri* (P=0.0391). The height was the greatest for -1/3 (P<0.0500), which was not significantly different from +1/3 and +2/2 (P>0.0500 for both). The lowest height was for - 4/0 (P<0.0500), which was not significantly different from the height for -3/1, +3/1, +4/0, and +1/3 (P>0.0500 for all four).

- There was a statistically significant overall model testing the intraspecific competition of harvested *A. berlandieri* ash-free root biomass for the interaction of nutrients within planted density (see Fig. 8; P<0.0500, data not shown). Neither nutrients nor planted density alone, have a significant effect (P>0.0500; data not shown). *A. berlandieri* ash-free root biomass was significantly the highest for -1 (P<0.0500) over all treatments except for +2 (P>0.0500). The lowest harvested *A. berlandieri* ash-free root biomass was for -2 (P<0.0500).

- There was a statistically significant overall model testing the interspecific competition of harvested *A. berlandieri* above ground biomass and ash-free root biomass, grown with *T. pluriflora*, for density (see Fig. 9; P<0.0500, data not shown). Neither nutrients nor the interaction for either of these two harvest parameter had a significant effect (P>0.0500; data not shown).

- There was a significant overall model testing the intraspecific competition of harvested *T. pluriflora* total plant dry mass, above ground biomass, dry root mass (data not shown), and ash-free root biomass for density (P<0.0500; data not shown). There was also a significant effect on the intraspecific competition of harvested *T. pluriflora* above ground biomass for the interaction of nutrients and density (see Fig. 10; P<0.0500; data not shown).

- Fig. 11 represents the significant interactive effect of nutrients and planted density (P=0.0299) on the intraspecific competition of harvested *T. pluriflora* mean above ground biomass (+/- one standard error). Harvested *T. pluriflora* above ground biomass was the highest for -1 (P<0.0500). The lowest harvested *T. pluriflora* above ground biomass was for -8 (P<0.0500), which was not significantly different from that for +8 (P>0.0500).

- There was a statically significant overall model testing the interspecific competition on the harvested *T. pluriflora* total plant dry mass, above ground biomass, root dry mass, and ash-free root biomass when grown with *A. berlandieri* for density (P<0.0500; data not shown) and the interaction of nutrients and density (see Fig. 12; P<0.0500; data not shown). Nutrients, alone did not have a significant effect (P>0.0500; data not shown).

Fig. 3. Experimental Planted Pots for Both Plant Species, 12/11/06

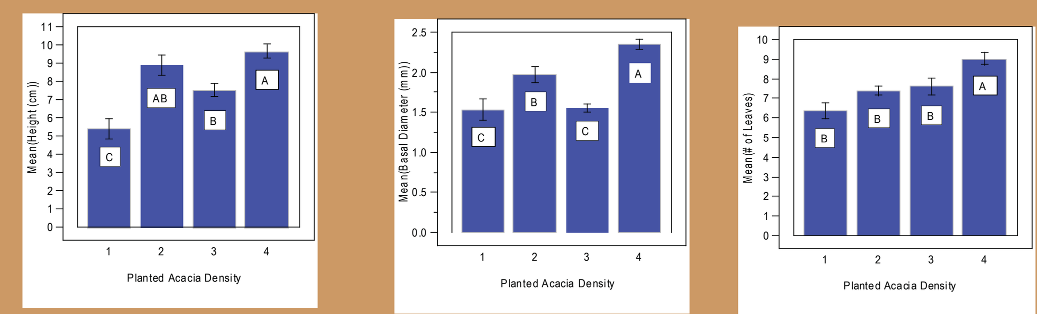

Fig. 4. Testing the Interspecific Competition of *A. berlandieri*, grown with *T. pluriflora*, using (a) Mean Basal Diameter, (b) Mean Height, and (c) Mean Number of Leaves for Planted Density.

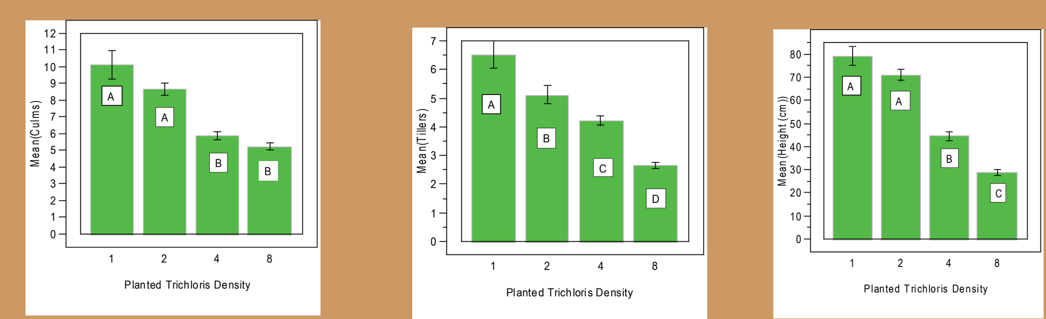

Fig. 5. Testing the Intraspecific Competition of *T. pluriflora* using (a) Mean Culms, (b) Mean Tillers, and (c) Mean Height Growth for Planted Density.

References

References are Available on Request

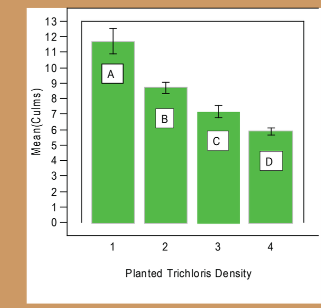

Fig. 6. Testing the Interspecific Competition of *T. pluriflora*, grown with *A. berlandieri* using Mean Culms for Planted Density.

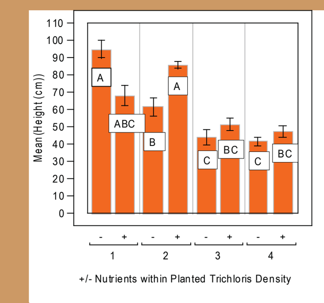

Fig. 7. Testing the Interspecific Competition of *T. pluriflora*, grown with *A. berlandieri* using Mean Height for the Interaction of Nutrients and Planted Density.

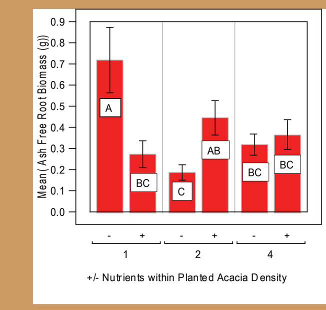

Fig. 8. Testing the Intraspecific Competition of Harvested *A. berlandieri* using Mean Ash-Free Root Biomass for the Interaction of Nutrients and Planted Density.

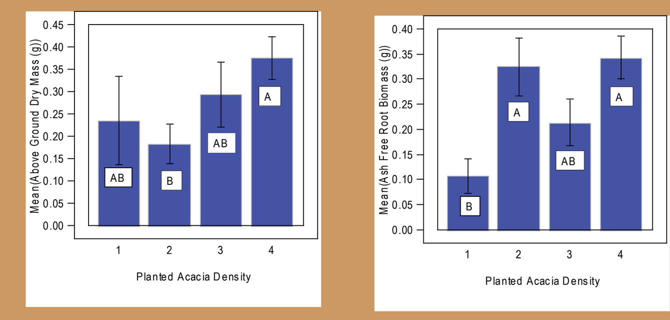

Fig. 9. Testing the Interspecific Competition of Harvested *A. berlandieri*, grown with *T. pluriflora* using (a) Mean Above Ground Biomass and (b) Mean Ash-Free Root Biomass for Planted Density.

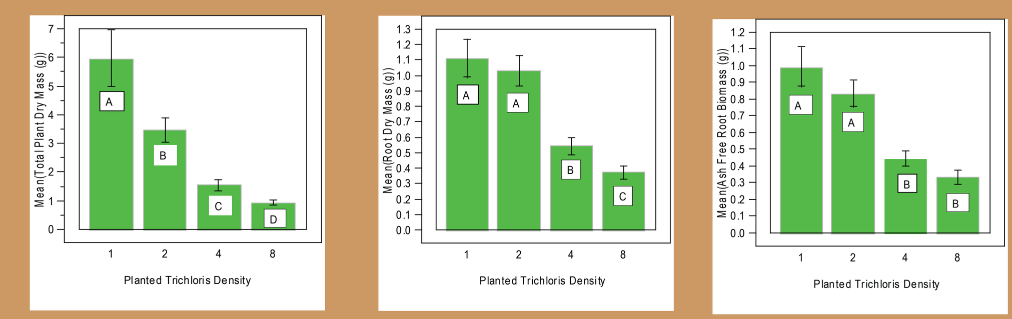

Fig. 10. Testing the Intraspecific Competition of Harvested *T. pluriflora* using (a) Mean Total Plant Dry Mass, (b) Mean Root Dry Mass, and (c) Mean Ash-Free Root Biomass for Planted Density.

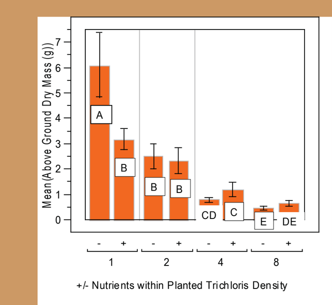

Fig. 11. Testing the Intraspecific Competition of Harvested *T. pluriflora* using Mean Above Ground Biomass for the Interaction of Nutrients and Planted Density.

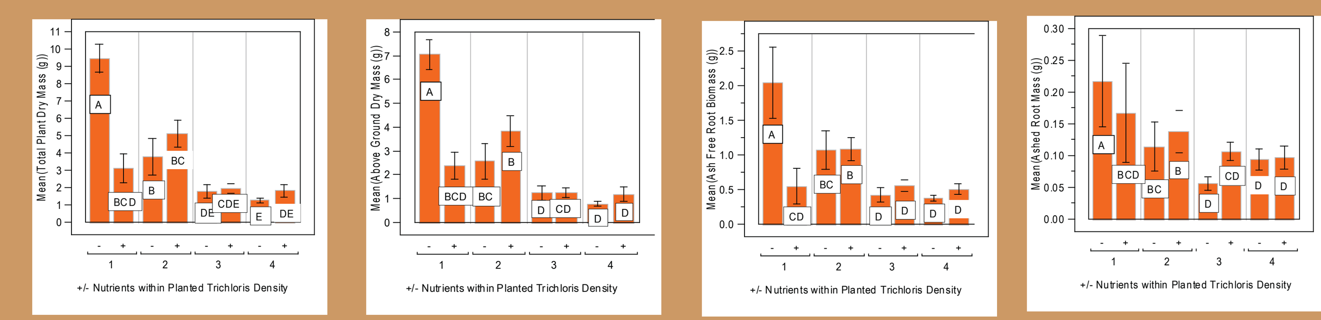

Fig. 12. Testing the Interspecific Competition of Harvested *T. pluriflora*, Grown with *A. berlandieri*, using (a) Mean Total Plant Dry Mass, (b) Mean Above Ground Biomass, (c) Mean Root Dry Mass, and (d) Mean Ash-Free Root Biomass for the Interaction of Nutrients and Planted Density.

Conclusions

- None of the independent variables of date, density, nutrients, or any of their interactions had an effect on the growth parameters of basal diameter, height, or number of leaves for the intraspecific competition of *A. berlandieri*.

- Density was the only variable to have an effect on the growth parameters of *A. berlandieri* for interspecific competition, grown with *T. pluriflora*. Specifically, density had a positive effect on all of the *A. berlandieri* growth parameters.

- Density was the one variable to have an effect on all of the growth parameters (culms, tillers, and height) of *T. pluriflora* in intraspecific competition with the greatest effects shown for the planted densities of 1 to 2 *Trichloris* plants per pot.

- The interaction of density and nutrients had an overall negative effect on the height of *T. pluriflora* grown in competition with *A. berlandieri*. Density, alone had an effect on the culms and height for the interspecific competition of *T. pluriflora*, grown with *A. berlandieri*. The lower densities of 1 to 2 *A. berlandieri* plants per pot produced higher measurements for these growth parameters This was indicative of density-dependent interspecific competition (Odum, 1983) with a carrying capacity (K) of 1-2 plants for the target species.

- The interaction of the variables of density and nutrients had an overall negative effect on the intraspecific competition of harvested *A. berlandieri* ash-free root biomass. There was a decrease in this measurement parameter with an increase in the interaction. Neither density nor nutrients had an effect on any of the measurement parameters for the harvested *A. berlandieri*.

- Density had a positive effect on the measurement parameters of the above ground biomass and ash-free root biomass for the harvested *A. berlandieri*, grown in competition with *T. pluriflora*, in accordance with species abundance within the population. The greater the abundance of individual plants per pot, the better the response of these measurement parameters (Tilman, 1997).

- The interaction of density and nutrients had a significant effect on the above ground dry mass of *T. pluriflora*, grown alone, where this measurement parameter appeared to be higher at the lower densities, irrespective of the presence or absence of nutrients. Density alone, had an effect on all of the measurement parameters of harvested *T. pluriflora*, exhibiting a density-dependent competition control within a population with a carrying capacity (K) of 1 to 2 plants per pot (Tilman, 1997).

- The interaction of density and nutrients had an effect on all of the measurement parameters of harvested *T. pluriflora* interspecific competition, grown with *A. berlandieri*. All four measurement parameters decreased with an increasing interaction, based primarily on density, regardless of nutrients The significant density effect, alone exemplified the replacement competition within a population (Tilman, 1997), with the measurement parameters of *T. pluriflora* reacting in response to the species abundance of its competitor, *A. berlandieri*.

- Although grassland and woody shrub interactions should be mediated by resource availability (Scholes and Archer, 1997), that was not the case in this study. Nutrients alone clearly did not mediate the intra- or interspecific competition of the two South Texas native plant species: *Acacia berlandieri* and *Trichloris pluriflora* in this study.

- There were several potential causes suggested that either limited or negated the effect of nutrients. The absence of a nutrient response suggested that either the nutrient requirements were satisfied in the soil itself, or that the nutrients added were not sufficient to initiate a response by the selected parameters in the allotted time frame. The documented establishment period for A. berlandieri, having a low short-term biomass, requiring a one-year or less establishment period (Texas Parks and Wildlife Staff, 2004) could have limited the nutrient effect.

- The potentially detrimental effects of high temperatures in excess of 35°C (National Weather Service Forecast Office, 2007) observed for the entire month of August, 2006, could have affected both species. Soil temperatures in excess of 35°C reduce woody plant emergence (Scifres and Brock, 1969) and hamper the ability of grasses to establish good root systems (Lloyd-Reilly et al., 2002), negating the nutrient effect. Further, Lloyd-Reilly et al. (2002) suggested not fertilizing *T. pluriflora* until once the plants are established, based on a soil analysis performed at that time.

- Density was unequivocally the driving force for the intra- and interspecific competition of these two South Texas native plants. This study strongly suggests that density is an important variable involved in the disappearance of the grasslands.

Acknowledgements

We also would like to thank Stuart Foote for his technical assistance with presentation. Additionally, we also would like to thank the University of Texas at San Antonio and the Center for Water Research for partial funding of this project through faculty research and scholarship awards for the authors.