Mycorrhiza efffect on nutritional quality and biomass production of Agave (*Agave americana* L.) and cactus pear (*Opuntia lindheimeri* Engelm.)

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Received 6 August, 2008; accepted 30 May, 2009

Abstract

An experiment was conducted in Marín, Nuevo León, México to evaluate nutritional quality and biomass production of agave (*Agave americana* L.) and cactus pear (*Opuntia lindheimeri* Engelm.), including inoculation with commercial and native mycorrhiza under non–irrigated land conditions. A field experiment was carried out under a 2 x 2 factorial arrangement of treatments with two inoculants (commercial and native) and these two species. Treatments were distributed randomly within three blocks. Plants were seeded on April, 2006 and data collected on April, 2007. Studied variables were biomass production and contents of crude protein (CP), neutral–detergent fiber (NDF), ash, calcium (Ca) and phosphorous (P). We observed a ($p<0.05$) significant interaction between CP and NDF. Commercial inoculation was better in agave than in cactus pear, but native inoculation was best in cactus pear. Biomass production, ash and P contents were greater ($p<0.05$) in agave than in cactus pear. Inoculation type alone did not affect these variables. Calcium levels did not reach significant ($p<0.05$) differences between inoculation levels or between species. Results showed higher forage quality and biomass production in agave than in cactus pear.

Key words: Cactus pear, Agave, Biomass, Forage quality, Crude protein, Neutral–detergent fiber.

Introduction

Northern Mexico has large desert and semi–desert areas with frequent long drought periods that generate low forage production. In addition, areas that have been under inadequate range management, affect the soil, a non–renewable ecosystem part (CONAZA, 1993; Fuentes–

Rodríguez, 1997). Misuse of rangeland has declined soil fertility in about 80% of the Mexican territory (CONAZA, 1993). Even under these climatic and soil conditions, there are plants that have been adapted, like *Agave* and *Opuntia*, which due to their anatomy and physiology characteristics, have formed real islands of fertility in desert ecosystems, used as hedgerows to control erosion in eroded soils (Pimienta *et al.,* 2003; Granados and Castañeda, 1996; Cervantes and Madinaveitia, 2000).

Use of cactus pear and agave in Mexico goes back to its first inhabitants. At present, they are used in many ways: as vegetable and fruit, forage, fuel, live fences, medicine, cosmetics, and they help to control erosion. Use of the cactus pear and agave as forage to feed livestock began with the colonization of northern Mexico in the 16th century, even when they have low nutritional quality (Flores–Valdés and Aranda–Osorio, 1997).

Important results have been reported in tender pads, fruits and forage about nutrient content and interactions of macro and micronutrients (Magallanes–Quintanar *et al.,* 2006; Blanco–Macías *et al.,* 2006; Nobel, 1988), correlations between soil and cladode nutrient concentrations (Galizzi *et al.,* 2004), and biomass production and nutritional quality (Guevara *et al.,* 2004; Guevara *et al.,* 2003). However, one of the most important problem that limit this activity is the lack of knowledge that allow systematic and rational use of these resource, specifically in native populations used as forage, because other nutritional qualities are important to consider. On the other hand, because of dominance in some cactus pear and agave areas, it can be an important element for wildlife habitats both as structure (shade, shelter, nesting substrate) and food for many mammals, avian species, reptiles and invertebrates (Chavez–Ramirez *et al.,* 1997; Mellink and Riojas–López, 2002). Pinos–Rodríguez e*t al.* (2006) have made research with agave on sheep, studying the average daily weight gain, reporting gains from 99 to 157 g day^{-1}.

In recent years, there has been special emphasis on mycorrhiza fungi, particularly arbuscular mycorrhizas, which develops a complex and specialized structure that contributes mainly in adaptation and development of plants (Smith and Douglas, 1987), where more than 90% of plant communities in the world can form mycorrhiza symbiosis. These fungi enter into cortical area of plants and help the absorption of less soluble and mobile elements as phosphorus, ammonium, potassium, copper, iron and zinc. However, these effects have been observed mostly in annual plants (Koide and Mosse, 2004; Augé, 2004; Alarcón and Ferrera, 1999; Bolan, 1991). Research performed in *Opuntia* and *Agave* has shown mycorrhiza symbiosis; nevertheless, they have been limited to its microbiological description (Rodríguez–Hernandez, 2002; Armenta *et al.,* 2003; López *et al.,* 1999). In this study, the main objectives were 1) to estimate nutritional value of agave and cactus pear based on contents of crude protein, fiber and minerals and 2) to estimate dry matter production of agave and cactus pear as depending on mycorrhiza inoculation.

Materials and methods

This experiment began on April, 2006, in the Experimental Field of the Agronomy Faculty of the Universidad Autónoma de Nuevo León, located in Marin, N.L., Mexico. It is located at 25^{o} 23’ N and 100^{o} 03’ W, at 367 meters above sea level (INEGI, 1978). Native cactus pear (*Opuntia lindheimeri* Engelm.) and agave (*Agave americana* L.) were the species evaluated. Granados and Castañeda (1996) describe *O. lindheimeri* as a shrub plant that grows 1 to 3 meters in height; and its flowers can be yellow to orange to red in color and bloom from April to June. *A. americana* is a perennial, acaule and resistant to drought plant; its leaves are 15 to 30 cm wide and more than a meter long, moreover they are lanceolated and fleshy white–blue or grayish–white in color. Leaves grow from soil, all originate from the center where they roll to a central stem which will form until their separation, with spines on its edge of almost 3 cm and they are hard, stiff and thin. The apex ends in a needle about 5 cm long and up to 1 cm wide at its base (Gentry, 1982). Henceforth, these species will be called Opuntia and Agave for *O. lindheimeri* and *A. americana*, respectively.

Plants used in this study were collected in the same area of study. *Opuntia* cladodes and agave seedlings had a weight of 52 ± 5 g and 541 ± 10 g, respectively, both in fresh weight. Cladodes and seedlings were seeded in three contour strip or lines. Each contour strip was considerate as a block. Contour strips were 80 cm wide, 50 cm high and 200 m length, with a distance between contour strips of 30 m. Each block was seeded with 30 cladodes or seedlings per treatment to ensure enough experimental units for each treatment. The experimental design was a completely random blocks design with a 2 x 2 factorial arrangement and LSD method was used to compare means (Snedecor and Cochran, 1980). The treatments were two species (Agave and Opuntia) and two types of mycorrhiza inoculation (Commercial and Native); therefore, we evaluated four treatments (Agave–Commercial, Agave–Native, Opuntia–Commercial, Opuntia–Native). SPSS Program v.12 (2003) was used for statistical analysis.

Commercial inoculation was made with *Glomus intraradices*, using a biofertilizer developed by Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), which contains at least 400 spores $100g^{-1}$ of inoculum. Each plant was provided with 25 g of inoculum, representing a minimum of 100 spores, dose recommended by the literature (Augé, 2004; Velasco–Velasco *et al*., 2001; González–Chávez and Ferrera–Cerrato, 2000; Alarcón *et al*., 2000). For the native inoculation, a native strain of *Glomus intraradices* was used, a different strain of that produced by INIFAP, and plants were seeded at the same contour strip. The experiment was carried out under non–irrigated land conditions.

Studied variables after one year were dry matter production per plant (DM $plant^{-1}$), ashes, calcium (Ca%), phosphorous (P%), crude protein (CP%) neutral detergent fiber (NDF%) and plant dry matter percentage (DM%). Two cladodes and leaves of cactus pear and agave were sampled per plant, and then, its weight was averaged. This weight was multiplied by the total number of leaves and cladodes to obtain the total weight of the plant. In addition, cactus pear cladodes and agave leaves were sampled one year after seeded. They were cut in small size pieces, ranging from 5 to 10 cm and dried in an oven at 60° C during 72 h to obtain dry matter content. Samples were ground by a Wiley mill equipped with 2 mm mesh and analyzed for CP (A.O.A.C, 1990), NDF (Van Soest *et al.,* 1991), ash, P, Ca (Fick *et al.,* 1976). Samples of Opuntia and Agave were extrapolated with the number of total leaves and cladodes to get DM $plant^{-1}$ production per year.

Results and discussion

In relation with nutritional quality, analysis of variance demonstrated that CP and NDF had significant ($p<0.05$) interaction between species and inoculation (Figure 1). The commercial mycorrhiza provided better forage in Opuntia while the native mycorrhiza was better for Agave. This is because forage is better in quality when the NDF is lower and CP is higher (Holland and Kesar, 1990).

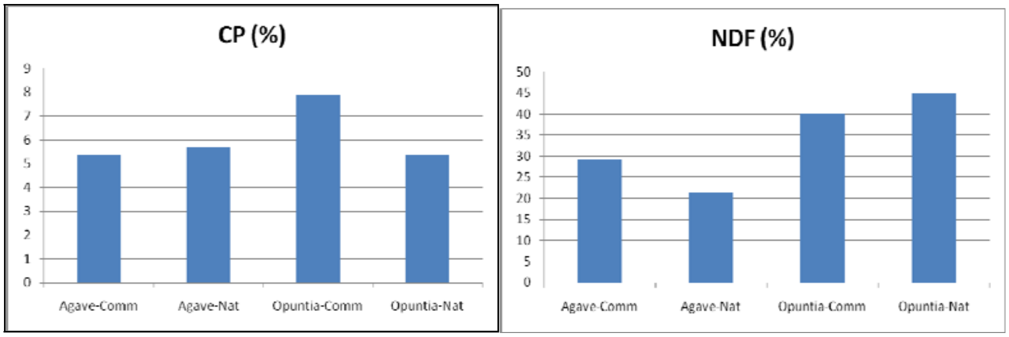

Figure 1. CP and NDF interaction for Opuntia and Agave with commercial (Comm) and native (Nat) inoculation.

CP behaves better in Opuntia and commercial mycorrhiza (7.6%), meanwhile, the rest of the treatments averaged 5.6%. These results are in agreement with Gutiérrez *et al.* (2006) in Spineless cactus pear *(Opuntia ficus–indica)*; however Fuentes–Rodríguez (1997) reported 4% CP in *O. lindheimeri* for the same species investigated here. In agave, Martínez (1994) found 4.5 and 4.6% for *A. atrovirens* and *A. salmiana*, respectively, values similar to those found in this study, while Fraps (1932) reported 7.4% for *A. Americana* and Pinos–Rodríguez (2006) 4.1% for *A. salmiana*. Typical range in CP is reported for *Opuntia ficus–indica* ranging from 4 to 7.25% (Magallanes Quintanar *et al*., (2006), Blanco Macías *et al*., (2006), Galizzi *et al*., (2004), Guevara *et al*., (2004). This effect may be because *Glomus intraradices*, both commercial and native strains, helps absorb ammonia (Velasco Velasco *et al*., 2001), which could increase CP, however, further research should be done on these species to improve the understanding of their behavior.

NDF is the insoluble portion of forage and contains cellulose, hemicelluloses, lignin and silica and is commonly referred as the cell–wall fraction. Thus, high content of NDF is negative correlated with dry matter intake (Guevara *et al.,* 2004). Here, NDF also showed interaction, being the best and worst performing Agave and Opuntia with native mycorrhiza treatments, respectively, ranging from 21.3 to 45.1% (Figure1). Literature reports values for NDF from 17 to 33.8% for *O. ficus–indica* (Gutiérrez Ornelas *et al*., 2007, Ben Salem *et al*., 2004, Guevara *et al*., 2004). Since *O. lindheimeri* is a native cactus pear species, its high NDF content can help to avoid herbivores. In agave, Pinos–Rodríguez (2006) found 18.01% of NDF in *A. salmiana*, being close to 21.3% measured here for Agave with native mycorrhiza.

Species effect was significant ($p<0.05$) for DM plant^{-1}, Ash, P, and DM%, showing no effect of interaction (Table 1).

DM plant^{-1} had greatest production in Agave. In adult plants, Martinez (1994) found that 750 agave plants produced about 6.1 ton of DM ha^{-1}; likewise, Hamilton (1992) reported that 1250 *Opuntia* plants produced 3.5 tons of DM ha^{-1}. Here we found biomass production of 338.5 and 60 g of DM plant^{-1}, in agave and cactus pear, respectively (Table 1), that extrapolating represent 254 and 75 kg ha^{-1}, respectively, which is explained because they are one–year old plants. In Argentina, Guevara *et al.* (2003) reported biomass production of 170 kg DM ha^{-1} after the 2–year growth period in *O. ellisiana.* In *O. ficus–indica*, Guevara *et al.* (2004) found from 125 to 215 g plant^{-1} in 1.5–year old plants. Since production of biomass depends on interactions of genotype and environment, these results are in the range of values reported in literature.

Table 1. Means and standard error (SE) of variables in Agave and Opuntia.

	Agave (Mean)	Opuntia (Mean)	SE
DM Plant^{-1} (g)	338.58[a]	60.61[b]	23.297
Ash (%)	18.15[b]	20.08[a]	0.805
P (%)	0.12[a]	0.07[b]	0.012
Ca (%)	8.82	8.26	0.547
CP (%)	5.57	6.53	0.513
NDF (%)	25.31[b]	42.65[a]	0.025
DM (%)	14.15[a]	10.59[b]	0.003

[a,b] Means within the same row and different letter are significantly different ($p<0.05$).

Ash content was 18.15 and 20.08% for agave and cactus pear, respectively. In *A. Americana,* Fraps (1932) found 12.3% ash, while Laksevela and Said (1970) reported 15.6% in *A. Fourcroyde*. In cactus pear, Gutiérrez *et al*. (2006) and Fuentes–Rodríguez *et al.* (1997) found 30.5% and 25.5%, respectivily. On the other hand, Guevara *et al.* (2004) reported 15.6% Ash for *Opuntia ficus–indica*, and Pinos–Rodríguez *et al.* (2006) measured 12.7% in immature *Agave salmiana* plants being more similar to those reported in this investigation. Both agave and cactus pear, show high content of ash, compared with buffel grass *(Cenchrus ciliaris)*, which contains about 11.6%, falling heavily in organic matter content in Agave and Opuntia, however, both species are used in drought periods.
Even as agave had greater percentage of P than cactus pear, both species contain low concentrations for livestock production. Gutiérrez *et al.,* (2006) found in spineless cactus pear values about 0.08%, according with our findings (Table 1).

DM was significantly greater for agave (14.15%), compared to Opuntia (10.59%), which are similar to results reported in cactus pear by Gutiérrez *et al*. (2006) and Fuentes–Rodriguez (1997b) ranging from 7.5% to 11.6%. Pinos–Rodríguez *et al.* (2006) measured 14.6 % of DM in immature *Agave salmiana* plants, values comparable with our data (Table 1).

Statistical analyses did not detect ($p<0.05$) effect of inoculation in any variables (Table 2), which mean that native mycorrhiza can replace commercial biofertilization in these species under non–irrigated land conditions. Similar results were reported for *Opuntia matudae*. However, in *Agave cocui* positive effect to commercial inoculation was found, where was observed greater biomass and more N y P concentrations in seedlings with mayor mycorrhiza inoculation.

Ca was not significant for any factor, which coincides with results found by Gutiérrez *et al.,* (2006) in Spineless cactus pear (*Opuntia sp*.). In agave, we did not located P and Ca nutritional data in literature.

Table 2. Means and standard error (SE) of variables in commercial and native mycorrhiza.

	Commercial Mycorrhiza (Mean)	Native Mycorrhiza (Mean)	SE
DM Plant^{-1} (g)	189.17[a]	210.03 [a]	42.53
Ash (%)	18.80[a]	19.43 [a]	0.80
P (%)	0.1 [a]	0.09 [a]	0.012
Ca (%)	8.33[a]	8.75 [a]	0.54
CP (%)	6.53[a]	5.56 [a]	0.51
NDF (%)	34.0 [a]	33.1 [a]	2.60
DM (%)	11.8 [a]	12.9 [a]	0.60

[a] Means within the same row and different letter are significantly different ($p<0.05$).

Conclusions

Forage production and quality were higher for agave than cactus pear in the first year of production. Inoculation only showed significant effect on the interaction of CP and NDF, two of the most important variables in forage quality. Even when only five quality characteristics were measured to determine forage quality, they give us enough evidence that these species are a good alternative as forage even in one year.

Acknowledgements

Senior author thanks to Mexico's 'Consejo Nacional de Ciencia y Tecnología' for the scholarship during his Ph.D. studies. Financial support from 'Programa de Apoyo e Investigación Científica y Tecnológica' under the contract CN1723–07 is also acknowledged.

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