Nitrogen fertilization in a psammophilous grassland of San Luis, Argentina

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Three treatments were conducted to assess and compare in psammophilous grasslands the effect of different urea doses on the DM production, as well as to determine and compare the efficiency of utilization of the nitrogen applied in an area closed to the water supply. The three treatments were implemented in spring: N0 = natural grassland burnt without fertilizer, N140 = natural grassland burnt and fertilized with 140 kg of urea ha^{-1} and N240 = natural grassland burnt and fertilized with 240 kg of urea ha^{-1}. Split plot design in blocks was applied (two repetitions). Cuts were performed in January and March. In each sampling unit, the dry matter production was quantified and the forage species were differentiated from the non-forages. The efficiency of nitrogen utilization emerged from the difference between the fertilized and the non-fertilized material, compared with the nitrogen applied. Factorial ANOVA was used. The factors fertilization, forage aptitude, and cut time affected the DM production ($P < 0.05$). The grassland had very low production of forage species (N0: 38.33 g DM m^{-2}). The N application provoked increment in them (N140: 83.13 g MS m^2 and N240: 83.33 $P < 0.05$), as well as in the non-forages (N0: 85.67 vs. N140: 133.83 g MS m^2; $P < 0.05$). In March, the forage species reached the maximum production, with 240 kg of urea ha^{-1} (174 g DM m^{-2}) and they surpassed the non-forages (116.33 g DM m^{-2}). The highest efficiency in the utilization of the applied nitrogen was shown in the group of non-forage species, with 140 kg urea ha^{-1} (13.54 kg of DM kg of N $applied^{-1}$). The fertilization with high doses of urea improved the productive condition and the receptivity of the degraded grasslands, being possible to use the forage and biomass accumulation in seasons of pasture shortage.

Key words: *natural grassland, degraded areas, burning, N efficiency, production.*

In San Luis, Argentina, arid areas with grasslands and chañar (*Geoffroea decorticans*) comprise two million hectares in the central part of San Luis (Anderson *et al.* (1970). The soil is of sandy texture, with slightly acid pH. It contains 0.8 % organic matter and 0.36 % N (upper 30 cm). The plants vary from almost pure grassland without any trees up to chañar planted spots. It has intermediate zones, with caldenes (*Prosopis caldenia*) that grow alone or that group in lowlands. Jobbágy and Nosetto (2006) reported that average annual rainfall is 550 mm. Seventy-nine percent is reported in the spring-fall period.

The grass stratum is composed of 95 % summer grasses and 5 % winter grasses. Marchi (1989) noted an annual production between 500 and 800 kg of DM ha^{-1}, provided by native forage species. Aguilera (2003) classified grasslands in different utilitary conditions, according to their annual forage productivity. Aguilera *et al*. (1999, cited by Aguilera 2003) mentioned annual productivities between 900 and 1500 kg of forage and biomass ha^{-1}, with 20-30 % of forage species (*Sorghastrum pellitum*).

Aguilera (2003) reported that the grasslands in which there is predominance of the non-forage species paja amarga (*Elyonurus muticus*) there is variability in their productivity, according to their higher or lower abundance of subdominant forage species (good utilitarian condition: 1000 kg/ha and regular utilitarian condition: 700 kg.ha^{-1} of forage and biomass).

In semiarid grasslands, the movement of herbivores is related directly to the size of the paddocks and the location of the water supply, which provokes differential and areal utilization. The stratum next to the water supply has higher grazing pressure, loss of leaves, density of palatable species, and specific richness and rise of dead leaves and exposed soil (Morici *et al*. 2006 a, b).

For years researches have been conducted with the aim of improving the status of the natural grasslands. Scheduled and controlled fire is used to remove the accumulation of senescent aerial biomass and to make use of the green sprouts of the plants. Thus, some environmental variables should be considered such as temperature, humidity, and wind speed. Privitello *et al*. (2005), by comparing the effects of a fast burn (August) with those of soil tillage (spring), concluded that tillage reduces the botanical composition and the psammophilous grassland condition, and increases the bare soil coverage. Also, the coverage, the density, and the frequency of some dominant winter (*Poa ligularis* and *Stipa tenuisima*) and summer (*Bothriochloa springfieldii*) species is diminished, not provoking drastic changes in the status or mean production of the grassland. Orive *et al*. (2009) studied the effects provoked in the grassland by the burn and the burn-tillage at the end of the winter. They concluded that these management actions do not modify the original production, but the botanical composition at the end of the summer.

The implantation of megathermal perennial grasses constitutes a management alternative to increase the receptivity. Orive *et al*. (2009) reported that the degraded psammophilous grassland produces lower amount of DM (15 g MS m^{-2}) than *Digitaria eriantha* or *Panicum* *coloratum* (36 g DM m^{-2}) and *Eragrostis curvula* (166.33 g DM m^{-2}).

Studies are demanded about the incorporation of N to the semi-arid systems. In the arid area, the introduction of legume species such as *Melilotus sp*. is limited due to the low rainfall during the implantation period (March). The experiences of fertilization in the grasslands of San Luis are scarce. In the arid region, works of Cano *et al*. (1985) in La Pampa are outstanding. In the region of San Luis, those of Romero *et al*. (2004 a, b), Ramírez *et al*. (2007), Privitello *et al*. (2007) and Harrison and Privitello (2009) are also outstanding.

In order to assess the effect provoked by the nitrogen fertilization on the grassland next to the water supply, the effect of different urea doses on the DM production is intended to be analyzed and compared, as well as for determining and comparing the efficiency in the utilization of nitrogen in a degraded grassland.

Materials and Methods

The test was performed in the arid area of grasslands and in spots cultivated with chañar of San Luis (Anderson *et al*. 1970). The test surface corresponded to a natural grassland area next to the water supply (500 m), degraded by effect of overgrazing and with weeds. Three treatments were implemented: N0= natural grassland burnt without fertilization, N140= natural grassland burnt and fertilized, with 140 kg of urea ha^{-1} and N240= natural grassland burnt and fertilized, with 240 kg of urea ha1.

In a sector of the area, fast, programmed and controlled burnt was performed to destroy the accumulated senescent material (October 2007). After the burnt, and after the rain, (30 mm) three stripes were limited: one as control (N0: without fertilizer), and the other two, N 140 and N 240, were fertilized (November 7) with urea (46 % N). The fertilization was carried out with machinery to spread the fertilizers, and later the paddock was closed.

The design was of split plots in blocks, with two repetitions. In each block, it was considered as principal plot (36 m x 20 m) the fertilization effect (N0, N140 and N240), and as subplot (20 m x 2 m) the cut time (January or March). In each subplot, two cuts were conducted with scissors (0.25m^2 c/u) at 10 cm above the soil, at each time of the cycle of the summer species. In January, it was determined the accumulation of the spring growth, and in March, the accumulation of the spring-summer growth.

The cut species were differentiated and grouped according to their forage aptitude (Anderson *et al*. 1970), into forages and non-forages. The group of forages was composed of *Poa ligularis*, *Piptochaetium napostaense*, *Eragrostis lugens*, *Eustachys retusa*, *Schizachyrium plumigerum*, *Poa lanuginosa* and *Cenchrus pauciflorus* (vegetative state), and the non-forages *Elyonorus muticus*, *Panicum urvilleanum*, *Stipa tenuissima* and *Cenchrus pauciflorus* (with fruits). The collected material was put in an oven at 65 ºC until reaching constant weight, to later determine the DM production.

The efficciency in the use of nitrogen (kg DM kg N applied^{-1}) was determined out of the difference in the DM production between the treatments with and without fertilization, compared with the nitrogen applied.

ANOVA was applied according to the consideration of the principal factors: fertilization (N0, N140, and N240), forage aptitude (forages and non-forages) and cut time (January and March). The efficiency in the nitrogen utilization, corresponding to each fertilization level, group of species, and cut time, was determined through the multiple range test (Duncan 1955). The statistical software was Statgraphics 5.1 (Pérez 1998).

Results and Discussion

DM production. The principal factors fertilization, forage aptitude, and cut time showed interaction and were affected significantly ($P < 0.05$). There was double interaction between the fertilization and the forage aptitude ($P < 0.10$).

Out of the triple interaction, for the same group of species and fertilization factor, the difference in the DM production between cut times, was given by the normal growth of the species (table 1). During the testing period (September 2007- March 2008), the accumulated rainfall was normal for the spring-summer period in this area, thus, it did not take part in the production changes in the grassland.

When considering the different times of the growth cycle of the grassland, the highest forage and biomass yields were obtained with 240 kg N ha^{-1}, at the end of the growth cycle of the summer species (table 1). This indicates that to determine the spring fertilization effect with high N doses, it should be expected that the grassland accumulates forage biomass. The late rise in the summer forage and in the biomass was attributed to the advance in the species cycle and to change sin the botanical composition of the grassland, which favored the growth of the summer forages, as a consequence from the combined effect of the initial burn and the nitrogen applied. Fedrigo *et al*. (2011), when fertilizing natural grasslands at the south of Brazil, mentioned the late effect of the nitrogen on the forage accumulation. These authors attributed them to changes in the botanical composition. Orive *et al*. (2009) noted flower modifications in the grassland by effect of the fire at the end of the winter.

Romero *et al*. (2004 a, b) and Ramírez *et al*. (2007) found positive productive responses to the nitrogen fertilization at the end of summer (March) in forage species of winter growth. In this study, and with the highest urea dose, there was lower productive response to the fertilization, compared with Cano *et al*. (1985), who reported lower doses (120 kg of urea ha^{-1}, spread in October and December) in a psammophilous grassland at the North of the La Pampa province (mostly *Sorghastrum* *pellitum* and monthly cut), where they obtained productive increments of 89 %, in respect to the aerial phytomass without fertilizer.

The non-forage species also responded to the fertilization, but they attained their maximum production with lower dose (140 kg N ha^{-1}) at the end of the summer (table 1). Except in the second evaluation time, and with dose of 240 kg urea ha^{-1}, the non-forage group predominated as compared with the forage (whatever the dose of urea and the cut time).

Table 1. Comparison of grassland DM productions, according to the interaction of the effects: fertilization, forage aptitude, and cut time

Interaction: Fertilization, forage aptitude, cut time	DMP (kg DM ha^{-1})
N0 forage January	33.67^{a}
N0 forage March	43.00^{ab}
N0 non-forage January	69.67^{abc}
N0 non-forage March	101.67^{bcd}
N140 forage January	85.33^{abc}
N140 forage March	81.00^{abc}
N140 non-forage January	120.0^{0cde}
N140 non-forage March	147.67^{de}
N240 forage January	83.33^{abc}
N240 forage March	174.00^{e}
N240 non-forage January	126.67^{cde}
N240 non-forage March	116.33^{cde}
SE±	6.81

^{abcde}Means in columns with different letters differ between themselves significantly at P < 0.10 (Duncan).

When applying the criteria of utilitarian condition of the grassland, according to Aguilera (2003), it turns out that the non-fertilized grassland kept its “poor” condition (next to 300 kg DM^{-1}). Out of the evaluation of the DM production recorded in January, it can be inferred that that the nitrogen fertilization provoked change in the condition, from “poor” to “good” (700-900 kg DM ha^{-1}). With the highest dose and at the end of the summer, the production increase in the summer species enhanced even more the productive condition of the grassland.

Gong *et al.* (2011), in a semi-arid steppe at the North of China, reported positive effects of the nitrogen fertilization on the production of the natural grasslands. Nakamatsu *et al.* (2011) noted the same in the Argentina Patagonia.

Out of the analysis of double interaction, between the forage aptitude and the fertilization factor, it was concluded that the lowest production corresponded to the forage group, which agreed with Morici *et al.* (2006 a, b) for the most degraded sector of the grassland. The fertilization stimulated the production of both groups of species, but showed higher impact on the non-forage aerial biomass accumulation. Not considering the measurement times, with doses of 65 kg N ha^{-1}, both groups attained the maximum yields (table 2).

Table 2. Comparison of grassland DM productions, according to the interaction of the effects: fertilization and forage aptitude

Interaction: Fertilization forage aptitude	DMP kg DM ha^{-1}
N0 forage	38.33^{a}
N0 non-forage	85.67^{b}
N140 forage	83.17^{b}
N140 non-forage	133.83^{c}
N240 forage	83.33^{b}
N240 non-forage	121.50^{c}
SE±	5.87

^{abc}Means in columns with different letters differ between themselves significantly at P < 0.05 (Duncan)

Despite the fact that the forage species of the grassland without fertilizer showed low production, it was higher than the report of Orive *et al.* (2009) in a non-changed psammophilous grassland, burnt or burnt and tilled (14 to 17 g DM m^{-2}).

Harrison and Privitello (2009), with doses of 120 kg N ha^{-1}, did not find significant differences in the DM production without fertilizer. However, they noted more forage and biomass (249 g fertilized DM ha^{-1} and 135 g Non-fertilized DM ha^{-1}), and inferior or superior non-forage production, whether being fertilized or not (104 g fertilized DM ha^{-1} and 146 g non-fertilized DM ha^{-1}). In this study, an abrupt change was also manifested in the forage aptitude of the grassland with the nitrogen fertilization, which favored the production of summer species of forage value.

Efficiency in the nitrogen utilization. The calculation of the efficiency in the nitrogen utilization reveals losses of applied N, provoked by processes of volatilization and lixiviation of NH_3. At any measurement time, the non-forage group, with 140 kg of urea ha^{-1} showed higher efficiency. The forage manifested similar efficiencies with the different doses of urea (P > 0.05) (table 3).

Privitello *et al.* (2007) determined, for the summer forage species of a fertilized psammophilous grassland (120 kg urea ha^{-1}), higher efficiency in the nitrogen utilization (22 kg DM kg of applied N^{-1}).

The area of the psammophilous grassland, where there was predominance of species with null or poor forage value, increased the accumulation of the total aerial biomass with the spring nitrogen fertilization. The application of high doses of N provokes, during the summer, abrupt increment of forage and biomass, decreasing the non-forage biomass.

Table 3. Comparison of the efficiency of nitrogen utilization, according to the forage aptitude of the grassland

Treatment	Efficiency of nitrogen utilization (kg DM kg N applied^{-1})
N140 forage January	5.74^{ab}
N140 forage March	4.66^{ab}
N140 non-forage January	7.76^{b}
N140 non-forage March	1.54^{c}
N240 forage January	5.18^{ab}
N240 forage March	6.36^{ab}
N240 non-forage January	4.07^{ab}
N240 non-forage March	2.44^{a}
SE±	0.70

^{abc}Means in columns with different letters differ between themselves significantly at $P < 0.05$ (Duncan).

In the fertilized grassland, the efficiency of the forage group improved the productive and the flowering conditions, as well as the receptivity at the end of the summer. This permitted to postpone the accumulated summer forage and the biomass in times of pasture shortage.

The fertilization in the most degraded areas of the grassland should be accompanied by process technologies: fit of the stocking rate, grazing schedule, subdivision of the paddocks, and location of water supplies. As complement, the low ratio between the Price of the fertilizer and the meat will help defining the alternative of the fertilizer.

Although the number of samples applied allowed finding differences between the treatment under study, further studies are recommended about the fertilization in grasslands, with larger number of repetitions to diminish the variability of the results.

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