ABSTRACT

Agricultural expansion, which has been occurring in the region during the last two decades, has not only reduced considerably livestock production but also displaced it to marginal areas. In this context, the incorporation of species that improve productivity, forage quality and availability throughout the year, is a contribution to the livestock development potential in the region. Panicum coloratum and Chloris gayana are subtropical perennial grasses, used in other areas as fodder and characterized by their tolerance to different stresses (drought, salinity, waterlogging, alkalinity and frost). In this work we evaluate the behavior of Panicum coloratum cv. Klein Verde and Chloris gayana cv. Finecut during four growth cycles in an alkaline / sodic soil in the Salado River Basin, and we compared the results with the natural grassland and with Agropyron elongatum. Cynodon dactylon stood out for being always present and second in order according to the cover percentage in the planted plots; which may have limited the expression of subtropical species. On the average of the four growth cycles, P. coloratum (1390.32 ± 73.96 kg ha⁻¹) exceeded A. elongatum (1081.26 ± 73.96 kg ha⁻¹) and the natural grassland (961.18 ± 73.96 kg ha⁻¹), and was not statistically different from C. gayana (1147.18 ± 73.96 kg ha⁻¹). Forage quality in terms of digestibility and fiber content did not show differences between the evaluated materials. The crude protein content in P. coloratum and C. gayana was not different from that recorded in the natural grassland but was lower than that of A. elongatum.

Keywords: Forages, subtropical, natural grassland, Agropyron elongatum.
eds of a low REQUIREMENT livestock, such as cattle breeding (Vázquez et al., 2001; Vázquez and Rojas, 2006; Vázquez et al., 2006). The agricultural expansion that the region is undergoing for the last two decades caused a significant reduction in the area destined to livestock (Rearte, 2011), which was displaced towards marginal areas. According to the Provincial Program for the Production of Livestock and Meat [Programa Provincial de Producción de Ganados y Carnes] of the Ministry of Agrarian Affairs of the province of Buenos Aires (MAA, 2010), the potential for livestock development in this region would be based, on the one hand, on an increase in efficiency in the livestock management and its genetic improvement and, on the other hand, in the incorporation of an adequate forage offer, improving its quality and availability throughout the year.

In this context, Agropyron elongatum (Host) P. Beauv. plays a key role because it is a pasture that rehabilitates marginal soils and improves its productive capacity with high production of quality forage during the winter (Agnus-dei et al., 2011; Acuña et al., 2014, Borrajo and Cuenca, 2016). Panicum coloratum and Chloris gayana are subtropical perennial grasses characterized by the production of summer biomass with an acceptable nutritive value (Stritzler, 2008; Avila et al., 2014) and tolerance, to a different extent, to drought (Ghannoum, 2009; Ponsens et al., 2010), salinity (Talesisnik et al., 1998; Ribotta et al., 2013), short periods of waterlogging (Imaz et al., 2012; Imaz et al., 2015), alkalinity (Bui, 2013; García et al., 2015; Avaca et al., 2015) and frosts (Jones, 1969; Pesqueira et al., 2016).

Up to now, studies conducted in the region on C. gayana and P. coloratum demonstrated, on the one hand, that both species slowly establish in a natracaual soil (Otondo, 2011), with an outstanding behavior of the Finiecet varieties of C. gayana and Klein Verde from P. coloratum (Borrajo et al., 2014), and productions that doubled to the steppe of halophytes during the year of implantation (Pérez et al., 2007).

On the other hand, there are studies that evidenced the good recovery of both species after winter periods (Otondo, 2011), the higher production of aerial dry biomass when compared to natural pastures in a soil degraded by overgrazing, and the perenniality of 3 years in C. gayana and 5 years in P. coloratum, with significant responses to nitrogen fertilization (75 kg ha-1) (Pesqueira et al., 2016).

As for forage quality, previous reports for P. coloratum and C. gayana usually show lower values than those of species from temperate areas. But with an adequate management levels compatible with the most demanding requirements of breeding herds can be achieved (Stritzler, 2008; Ferri, 2011; Monti et al., 2013).

In order to study the behavior of Panicum coloratum cv. Klein Verde and Chloris gayana cv. Finiecet in an alkaline/sodic soil of the Salado Basin, the following goals were proposed: i) to evaluate the implantation and evolution of the coverage; ii) to evaluate biomass production during 4 years; iii) to determine forage quality; iv) to compare the results with natural pastures and with Agropyron elongatum.

MATERIALS AND METHODS

Plant material

The evaluated subtropical species were Panicum coloratum cv. Klein Verde and Chloris gayana cv. Finiecet (both provided by the seed company Peman) and were compared with Agropyron elongatum cv. Hulk (provided by Gentos) and with the natural pastures of the experimental site (control).

Experimental site

The trial was conducted an the Chascomús Integrated Experimental Farm [Chacra Experimental Integrada Chascomús] (35° 44' 39" S and 58° 03’ 25" W), located in the Depresión del Salado within the Depressed Pampa (province of Buenos Aires). The soil properties (pH= 9.8, Cs= 0.69 dS m-1 and PSI= 26.2%) were determined on randomly collected samples (0-20 cm depth) within the experimental plots. Table 1 shows the average temperatures and accumulated rainfall during the evaluated period.

Cultivation conditions

Planting in the plots (63 m2) was conducted during 2012. A. elongatum (32.5 kg ha-1) was planted in May, and P. coloratum (13.7 kg ha-1) and C. gayana (16.4 kg ha-1) were planted on November 7. In both cases, a direct seeding machine was used, regulated at 0.5 cm depth. Distance between rows was 0.175 m.

Prior to sowing, the plots were sprayed with glyphosate (5 L ha-1). The soil was not mechanically removed.

Evaluated parameters

We counted (n= 9) the plants and determined the obtained densities in order to evaluate implantation on a known surface (1 m2) and at the end of the first growth cycle. The total aerial dry biomass (ADB) of all the plots was calculated on the basis of periodic harvests on a known surface (@ 9 m2) during the months of growth (from October to April) of the subtropical species.

In each growth cycle we performed on average two cuts of each plot, leaving a remnant of 7 cm in height. The harvested material was weighed in situ, a sample was fractioned and dried in an oven at 70 °C until constant weight and extrapolated to productivity per hectare. The plant cover was determined visually with a cut square (1 m2) thrown at random (n= 4) at each harvest date.

Plant material samples were separated during the harvest conducted during March 2015 for forage quality analysis. The parameters evaluated were crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin and in vitro dry matter digestibility (IVDMD). The dry, milled and sieved samples were sent to the Forage Analysis Laboratory of the Animal Production Area of the Agricultural Experimental Station of INTA Rafaela.
Data analysis

The experimental design consisted of a random full block design with 3 repetitions. The data were analyzed by ANOVA and Tukey’s mean comparison test (α = 0.05) grouped as follows: i) a factorial of 2 (species) x 3 (block) to evaluate the obtained density of plants and the coverage during the first growth cycle, ii) a factorial of 3 (species) x 4 (growth cycle) to evaluate the evolution of the coverage of the sown species; iii) a factorial of 4 (forage resource) x 4 (growth cycle) to evaluate productivity per hectare and forage quality.

RESULTS

We evaluated the implantation of subtropical species before the decrease in temperatures (161 days from sowing). Plant density of C. gayana and P. coloratum showed no differences between species or significant variation between blocks (Table 2). The percentages of coverage of the dominant species and of other species were not different between the plots of C. gayana and P. coloratum. The percentage of bare soil was higher in the plots of P. coloratum than in those of C. gayana and there was no significant interaction with the blocks (Table 2).

Cynodon dactylon was the dominant species in the control plots, with an average coverage of 69.03 ± 3.68%, followed by Diplachne uninervia, Chaetotropis chilensis and Setaria sp. and the percentage of total coverage of natural pastures was never less than 90%.

There were no significant differences between blocks for the studied variables (Table 2).

The interaction between species (A. elongatum, C. gayana and P. coloratum) and growth cycles was significant for the percentage of total coverage of the plots. While there were no variations in this percentage between cycles in the plots of P. coloratum, in the plots of C. gayana and A. elongatum we noted a reduction during the 3rd cycle (Figure 1).

The coverage percentage of the dominant species varied depending on the growth cycle and the species. Usually, during the 2nd cycle the percentage of dominant species was higher than during the 3rd cycle, and the per-
The presence of other species that appeared in the coverage records changed according to the climatic conditions of the year. However, Cynodon dactylon stood out for being always present and being the second species in order, according to the percentage of coverage of the planted plots.

The other species found, ordered from highest to lowest according to the number of times and the proportion in which they appeared, were Diplachne uninervia, Chaetropis elongata, Setaria sp., Lotus tenuis, Sporobolus indicus, Digitaria sanguinalis, Festuca arundinacea, Senecio madagascariensis, Ambrosia tenuifolia, Coniza bonariensis and Distichlis spicata.

The production of ADB was generally affected by the growth cycle, without interaction with the forage resource factor (p = 0.1131). The ADB of C. gayana and P. coloratum (Figure 2), in the period between January and April 2013 (1st growth cycle), was higher than that of the natural pasture, and in the case of C. gayana it also exceeded that of A. elongatum (p = 0.0076).

During the 3rd growth cycle, P. coloratum cv. Klein Verde produced 36% more ADB than the average between natural grassland, A. elongatum and C. gayana. In the 2nd and the 4th growth cycle there were no differences between the evaluated forage resources.

On average of the 4 growing cycles, P. coloratum (1,390.32 ± 73.96 kg ha-1) exceeded A. elongatum (1,081.26 ± 73.96 kg ha-1) the and pasture (961.18 ± 73.96 kg ha-1), and was not statistically different from C. gayana (1,147.18 ± 73.96 kg ha-1).

The forage quality values of C. gayana, P. coloratum, A. elongatum and the natural pasture were similar for the parameters NDF (p = 0.3380), FAD (p = 0.2321) and IVDMD (p = 0.1910) (Table 3). CP of P. coloratum and C. gayana was not different from that of pasture, but it was lower than that of A. elongatum (p = 0.0049). The percentage of lignin in C. gayana tissue was lower than that of A. elongatum, and did not differ from that of P. coloratum or pasture (p = 0.0272, Table 3).

**DISCUSSION**

The plant densities obtained in the C. gayana and P. coloratum (Table 2) plots were comparable with the values obtained in other studies conducted in shallow, saline-alkaline and with halomorphism problems soils (Otondo, 2011; Martín et al., 2012; Borrajo, 2015). Martín et al., (2012) doubled the density of plants (plants m-2) when they planted C. gayana cv. Katambora in a soil without vegetable coverage and in lines (21.40 ± 4.2), in comparison with broad sowing (10.54 ± 5.6).

In previous trials, our group found that planting in line at 0.5 cm depth increased plant density of C. gayana and P. coloratum per square meter (5 and 6 times, respectively) when compared to superficial planting. We also found that the fertilization with phosphorus did not affect the emergence (Otondo et al., 2014). Borrajo (2015), in a low area of the Depression del Salado registered an average density for C. gayana and P. coloratum of 37 plants m-2 when planting in October, while that average decreased to 20 when planting was conducted in November.

The percentage of bare soil in the plots of P. coloratum was higher than in those of C. gayana (Table 2). This may be due to the creeping behavior of C. gayana, which determines a higher coverage in a short time (Avila et al., 2012). C. gayana is characterized as stoloniferous, develops roots in the knots and, as a consequence, efficiently covers the soil (Martin, 2010; Avila et al., 2014).

Otondo (2011) also reported a higher percentage of bare soil in P. coloratum when compared to C. gayana (12% and 5%, respectively), and both are significantly lower than the values of natural pasture, which in that case was dominated by Distichlis spicata, and more of half of the soil remained without coverage.

The dominant species in the control plots of our study was Cynodon dactylon, with an average coverage of 69%, followed by Diplachne uninervia, Chaetropis chilensis and Setaria sp . Unlike the study of Otondo (2011), the percentage of total coverage of natural grassland was never less than 90% (Table 2).

Cynodon dactylon has a growth cycle similar to that of subtropical species, with early regrowth and the simultaneous presence of aerial stolons and underground rhizomes, which results in an advantage when it comes to competing for the use of resources (Dong and de Kroon, 1994).

In the winter of 2014 (before the 3rd growth cycle) rainfall was abundant, 50.5% more than the historical average of the region, and rainfall was scarce in the warm months of 2014-2015, 24% less than the average. These conditions could account for the plant loss (lower coverage) that was observed, in general, during the 3rd growth cycle (Figure 1).

Unlike what we observed in previous studies (Pesqueira et al., 2016) and the reports of other authors (Ré, 2013), P. coloratum cv Klein Verde established quickly, with coverage percentages close to those of C. gayana (Table 2 and Figure 1). In alkaline lowlands of the southern region of the province of Santa Fe, studies report that C. gayana has a tolerance to sodicity and a rapidly covers soil thanks to its high tillering and stolonization capacity (Monti et al., 2013).

Water deficits were recorded in 2013-2014, 31.5% in the winter and 21.6% during the period from November to February, when compared to the historical average of the area (Table 1). During this growth cycle no differences were recorded in the ADB production between materials, and the overall average was lower than during the following cycles (Figure 2).

In this area, C. gayana and P. coloratum stop growing during winter, whereas growth rates begin to increase during the following spring and summer (Pesqueira et al., 2015, December 2017, Argentina).
Pesqueira et al., 2016). Usually, the ADB production results agree with the reports of Otondo (2011), although in our case the values were lower. This may possibly be due to the unfavorable climatic conditions and the strong presence and competition of Cynodon dactylon.

In regards to the local historical average, excessive rainfall occurred during the winters before the 3rd (50.5%) and 4th cycle (34%), and water deficit (from 5 to 24%) occurred during the months of growth of the subtropical species (Table 1). However, during the evaluated periods, ADB productions of C. gayana and P. coloratum equaled and even surpassed natural pastures and A. elongatum (Figure 2).

Imaz et al. (2015) observed a greater tolerance of P. coloratum to waterlogging periods during winter when compared to C. gayana, which could explain the recovery and higher production of P. coloratum during the 3rd cycle (36% more ADB), when compared to the average of the other evaluated forage resources.

The forage quality of C. gayana, P. coloratum, A. elongatum, and the natural grassland shows similar values for the parameters FDN, FDA and IVDMD (Table 3). According to Avila et al. (2010 and 2012), the forage quality in terms of fiber content and digestibility is not a static property of the species, but is a plastic characteristic that can be modified and improved by controlling the height of the pasture.

They observed that the defoliation management of C. gayana significantly improved the digestibility of the pasture during the autumn regrowth, equaling that of A. elongatum. The CP values we report for P. coloratum and C. gayana are not different from those of the pastures, but were lower than those of A. elongatum (Table 3).

Ferri (2011) observed in P. coloratum cultivated in the semi-arid Pampas region that the accumulation of ADB increased with thermal time, while the percentage of CP in the total biomass decreased. This decrease corresponded to a reduction in the proportion of green sheet. Changes in the structure and nutritive value of the pasture during the growing season are determinants of the management practice to be applied (Ferri, 2011).

Lignin content increases with the age of the plant and reduces forage digestibility (Moore and Jung, 2001). Although we did not detect differences in the IVDMD, the lignin content of C. gayana was lower than that of A. elongatum (Table 3).

The presence of Cynodon dactylon as the main competitor in the plots could have limited the expression of subtropical species as they have a similar growth cycle, and even sprouting a little earlier and competing for the use of resources. Accordingly, the observations of Borrajo et al. (2015) suggest that we could improve the obtained plant density if we advance planting from November to October. In this way it is possible to prioritize, first, the establishment of C. gayana and P. coloratum, and consequently, improve the productivity per hectare.

<table>
<thead>
<tr>
<th>Coverage (%)</th>
<th>Total</th>
<th>Dominant species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species x Cycle</td>
<td>p = 0.0155 *</td>
<td>p = 0.4568</td>
</tr>
<tr>
<td>Species</td>
<td>p = 0.0163 *</td>
<td>p = 0.0451 *</td>
</tr>
<tr>
<td>Cycle</td>
<td>p &lt; 0.0001 *</td>
<td>p = 0.0223 *</td>
</tr>
</tbody>
</table>

**Table 1.** Evolution of the total cover and of the dominant species in the plots of A. elongatum, C. gayana and P. coloratum during the 4 growth cycles in the Depression del Salado. The data are average of 3 repetitions and the different letters on the bars of the total coverage indicate significant differences in the interaction between species and cycles (Tukey, p < 0.05).
CONCLUSIONS

After four growth cycles in an alkaline/sodic soil (pH= 9.8, Cs= 0.69 dS m-1 and PSI= 26.2%) of the Depression del Salado with diverse climatic conditions between years, P. coloratum cv. Klein Verde and C. gayana Finecut maintained their perenniality and continued to produce biomass with acceptable forage quality. On average of the evaluated cycles, the productivity of P. coloratum exceeded that of wheatgrass and pastures, and was no different than that of C. gayana.

In terms of digestibility and fiber content, forage quality presented no differences between the evaluated materials. The crude protein content of P. coloratum and C. gayana was no different than that of pastures, but was lower than that of A. elongatum.

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