

## Research Paper

# Agronomic characterization of *Paspalum atratum* Swallen and *P. lenticulare* Kunth

## Caracterización agronómica de *Paspalum atratum* Swallen y *Paspalum lenticulare* Kunth

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### Abstract

*Paspalum atratum* and *P. lenticulare* are perennial grasses, native to South America. The objective was to evaluate seasonal growth, frost tolerance, cattle preference, nutritional characteristics, seed yield and germination of 11 ecotypes of *P. atratum* and *P. lenticulare* with regard to their potential as alternatives to introduced species. Forage yield was evaluated during 3 growing seasons between 2011 and 2014. Digestibility and CP concentration were assessed in summer 2014, cattle preference in winter 2013 and summer 2015, frost tolerance after the first frosts in June 2012, flowering time during 2013 and 2014 and seed yield and germination in 2014. A marked warm-season growing period was observed for both species with annual forage yields varying from 5 to 12 t DM/ha. Flowering did not occur until autumn, with mean seed yield of 280 kg/ha and germination of 16% for *P. atratum* and 19% for *P. lenticulare*. Most ecotypes were able to tolerate winter temperatures and behaved as perennials. Although no differences were observed for DM digestibility and CP concentration among accessions, cattle preferentially grazed accession *P. atratum* U44. Further studies are needed to evaluate persistence under grazing and animal performance.

**Keywords:** Cattle preference, forage yield, frost tolerance, nutritive value, seed yield.

### Resumen

En Corrientes, Argentina, se evaluaron algunas características agronómicas y de calidad de 11 ecotipos de *Paspalum atratum* y *P. lenticulare*, especies nativas de Sur América. La producción de forraje fue determinada entre 2011 y 2014, la digestibilidad y concentración de proteína en verano 2014 y la preferencia animal en invierno 2013 y verano 2015. La tolerancia al frío fue estimada en junio de 2012, el momento de floración durante 2013 y 2014, y la producción de semilla y la germinación en 2014. Los ecotipos de ambas especies mostraron un crecimiento estival marcado y la producción anual de forraje varió entre 5 y 12 t MS/ha. La floración ocurrió a comienzos del otoño, la producción de semillas fue de 280 kg/ha en promedio, y la germinación de 16% (*P. atratum*) y 19% (*P. lenticulare*). Con excepción de un ecotipo de *P. lenticulare* el germoplasma evaluado persistió en la época de invierno y se comportó como perenne. No se observaron diferencias entre los ecotipos en la concentración de proteína cruda y digestibilidad; sin embargo el ecotipo *P. atratum* U44 fue pastoreado preferencialmente. Futuros estudios serán necesarios para determinar la persistencia en pastoreo y la producción animal de los diferentes ecotipos.

**Palabras clave:** Preferencia animal, producción de semilla, rendimiento de forraje, tolerancia al frío, valor nutritivo.

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## Introduction

Beef-cattle production systems in South America are based mostly on natural rangelands with only a small proportion of cultivated forage species (Berretta 2001; Maraschin 2001; Royo Pallarés et al. 2005). For example, in Argentina, only 10–20% of the total area used for livestock production is under sown species. Furthermore, in Northeastern Argentina, which is a subtropical region, only 4.5% of the total area is sown to predominantly warm-season grasses (Arelovich et al. 2011; Feldkamp 2011). The exception is Brazil, where 61% of the total area devoted to livestock production is sown with cultivated forage species, predominantly *Brachiaria* spp. (Jank et al. 2014). In South America, most forages sown in pasturelands have been introduced from Africa (Moser et al. 2004). However, there are several forage species, indigenous to South America, that have been widely sown in improved beef cattle production systems in the subtropics. For example, the grass *Paspalum notatum* (Gates et al. 2004) and the legume *Stylosanthes guianensis* (Skerman et al. 1991) were selected directly from wild populations, based on their agronomic qualities.

Since wild species have evolved in this environment, it seems logical to evaluate wild grasses and legumes to assess their potential as cultivated forages. The native genus *Paspalum* appears to possess great forage potential in South America. This genus contains about 330 species that grow in the New World (Zuloaga and Morrone 2005). The Plicatula group is an informal taxonomic group of *Paspalum* (Chase 1929) that contains about 30 species, most of which are recognized as good quality forages (Zuloaga and Morrone 2005). This group contains those species related to *P. plicatulum* Michx., characterized by spikelets with transversely wrinkled lemma and shining dark brown antherium. Species within the Plicatula group vary in many characters, notably morphological characteristics, with the geographic center of variation of the group occupying Central and Western Brazil, Eastern Bolivia and Paraguay (Quarin et al. 1997). Most species of the Plicatula group are important native forages and some have become cultivated pasture plants (Quarin et al. 1997).

Species of the Plicatula group reproduce primarily by apomixis, which is an asexual mode of reproduction through seed, present in more than 500 species distributed in 40 families (Savidan 2007). The genus *Paspalum* contains the highest number of apomictic species in the Poaceae family (Ortiz et al. 2013).

Genetic improvement of apomictic species has been achieved mostly through ecotype selection (Blount and Acuña 2009). In apomictic species ecotypes are individual genotypes that have been able to colonize a

particular area (Brugnoli et al. 2014) and new cultivars resulting from the selection of superior ecotypes have the distinction of being highly stable in their agronomic characteristics (Acuña et al. 2007).

Within the Plicatula group, *P. atratum* Swallen and *P. lenticulare* Kunth are characterized by rapid growth. *Paspalum atratum*, a warm-season grass grown on seasonally waterlogged, infertile, acid soils in the tropics and subtropics (Evers and Burson 2004), is a perennial bunchgrass that is larger and more robust than *P. plicatulum*. It is an apomictic tetraploid ( $2n=4x=40$ ) native species from Brazil with high potential forage yield, good palatability and good seed yield (Quarin et al. 1997).

On the other hand, *P. lenticulare* is a multiploid species with diploid ( $2n=20$ ), tetraploid ( $2n=40$ ) and hexaploid ( $2n=60$ ) cytotypes. Diploids reproduce sexually while polyploids are apomictic (Galdeano et al. 2016). The most common cytotype is tetraploid (Norrman et al. 1994; Espinoza et al. 2001). The species is distributed throughout seasonally inundated savannas in Eastern Bolivia, Paraguay and the Center-West region of Brazil.

There is growing interest in developing native species as cultivated forages. Regional evaluation of native ecotypes of promising apomictic species may offer a valuable approach for identifying potential new cultivars. Protection and preservation of native species is also of importance and this is simultaneously addressed through the submission of native ecotype seed or vegetative collections to various national and international germplasm banks. At present, germplasm of many *Paspalum* species from different locations in South America and the rest of the world is conserved at the Instituto de Botánica del Nordeste (IBONE) in Northeastern Argentina.

The objectives of this research were to evaluate seasonal growth, frost tolerance, cattle preference, nutritional characteristics, seed yield and field germination of wild accessions of *P. atratum* and *P. lenticulare* collected from different locations in South America and grown in Northeastern Argentina. Additionally, the chromosome numbers in 2 accessions were determined to ensure all conserved germplasm is characterized by its ploidy level.

## Materials and Methods

### Plant material

Five accessions of *P. atratum* and 6 of *P. lenticulare* collected from different sites in South America were used in this study. The origins and chromosome numbers of these accessions are described in Table 1. Seeds have been maintained in seed storage at moisture content below 10% and approximately 5 °C.

**Table 1.** Origin and chromosome number of *Paspalum atratum* and *P. lenticulare* accessions used in the study.

Species and accession	Origin	Chromosome number and reference
<i>P. atratum</i>		
U39	Brazil, Miranda, Mato Grosso do Sul	40 <a href="#">Freitas et al. 1997</a>
U42	Brazil, Aquidauana, Mato Grosso do Sul	40 <a href="#">Pagliarini et al. 2002</a>
U44	Brazil, Cáceres, Mato Grosso do Sul	40 <a href="#">Freitas et al. 1997</a>
N153	Paraguay, Guayaibí, Dpto. Caa Guazú	40 <a href="#">Espinoza et al. 2001</a>
N164	Paraguay, Bella Vista, Arroyo Alegre and route 3, Dpto. Amambay	40 <a href="#">Espinoza et al. 2001</a>
<i>P. lenticulare</i>		
L347	Paraguay, near the Aguaray-mí River, Dpto. San Pedro	40 This work
U41	Brazil, Miranda, Mato Grosso do Sul	40 <a href="#">Freitas et al. 1997</a>
U43	Paraguay, Bella Vista, Dpto. Amambay	40 <a href="#">Pagliarini et al. 1999</a>
U54	Cultivated in FCA-UNNE. Selection from TK2417	60 This work
TK2396	Bolivia, Estancia El Recreo, Concepción, Prov. Ñuflo de Chávez, Dept. Santa Cruz	40 <a href="#">Espinoza et al. 2001</a>
TK2417	Bolivia, Estancia Viera, Concepción, Prov. Ñuflo de Chávez, Dept. Santa Cruz	40 <a href="#">Espinoza et al. 2001</a>

Seed of each accession was sown in plots in the greenhouse in September 2011, and germinated seedlings were transplanted to planting trays 2 weeks later. These plants were transferred to a field site, previously native rangeland, near the city of Corrientes, Argentina (27°38' S, 58°44' W) on 7 November 2011 in plots of 2.7 m<sup>2</sup> (1.7 x 1.6 m) using a randomized complete block design with 3 replications. Each plot contained 30 plants uniformly distributed over the plot. The soil was classified as Aquic Argiudoll, a fine loam with slope between 1 and 1.5% ([Escobar et al. 1996](#)). At the beginning of the experiment the soil pH was 5.5, the P concentration 4.8 ppm (Bray II method), the K concentration 0.14 meq/100 g, and OM 1.18%. Fertilizer was not applied in this study following a low-input pasture system which is typical management in livestock production of tropical and subtropical regions.

#### Chromosome counting

Chromosome numbers of 9 of the 11 accessions used in this study were reported in past publications (Table 1), and chromosome numbers of the remaining 2 accessions were determined using root tips of young plants grown in pots in the greenhouse. Root tips were collected in the morning, washed and pretreated in a saturated solution of  $\alpha$ -bromonaphthalene for 2 h, and hydrolyzed in 1 N HCl for 10 min at 60 °C. They were then macerated in a drop of acetocarmine stain, heated, pressed under a cover-slip, and observed using a light microscope (Leica DM 2500<sup>®</sup>) at 200 and 1000 X magnification.

#### Seasonal growth

Seasonal growth was determined by harvesting plots using a sickle bar mower leaving a 10-cm stubble height. An 80 x 100 cm strip was cut from the middle of each plot, the

forage was collected, weighed and a subsample of approximately 300 g was taken immediately. The subsample from each entry was weighed and oven-dried at 60 °C for 48 h to determine percent DM and forage yield. Plots were harvested on 15 March and 3 May 2012 during the 2011/2012 growing season; 28 November 2012, 23 January and 28 March 2013 during the 2012/2013 growing season; and 4 December 2013, 8 January and 8 April 2014 during the 2013/2014 growing season.

#### Crude protein concentration, in vitro dry matter digestibility and cattle preference

At the harvest in January 2014, clipped subsamples were taken for determination of in vitro dry matter digestibility (IVDMD) and crude protein (CP) concentration in the harvested forage. Samples were analyzed for IVDMD using the technique described by [Tilley and Terry \(1963\)](#). Crude protein concentration was determined following the method of Association of Official Analytical Chemists ([AOAC 1990](#)) by determining nitrogen concentration (Kjeldahl method) and multiplying the value obtained by 6.25.

The plots were grazed by cattle (cows) in September 2013 and February 2015 using mob grazing for 4 h duration at a stocking rate of 60 cows/ha. Cattle preference was evaluated using a visual scale from 1 to 5 where 1 represented lightly grazed and 5 heavily grazed. The observations were performed on plots by 2 observers immediately after the cows were removed from the experimental area.

#### Cool-season regrowth and frost tolerance

Cool-season regrowth and frost tolerance were evaluated after the first frosts occurring on 7 and 8 June 2012 with

a minimal temperature of  $-1.8\text{ }^{\circ}\text{C}$ , and temperatures below  $0\text{ }^{\circ}\text{C}$  for 4 h on each day. The regrowth was estimated visually 30 days after the frost event using a 1–5 scale, where 1 = plants showing limited regrowth and 5 = plants showing high amounts of regrowth as described by Acuña et al. (2009; 2011). Frost tolerance was estimated visually 3 days after the frost using a 1–5 scale, where 1 = the least frost-tolerant and 5 = the most frost-tolerant plant as described by Zilli et al. (2015) and Novo et al. (2017).

#### Flowering time

Flowering date was determined by making weekly observations until the complete emergence of inflorescences in all plots. This evaluation was performed during the second and third growing seasons (2012/2013 and 2013/2014).

#### Seed yield and germination

Mature inflorescences were harvested by hand on 20 May 2014 (Figure 1). Inflorescences were air-dried, threshed and the fully formed, mature caryopses were separated from empty ones using a seed blower (Seedburo Equipment Company 1022W) and weighed to assess yields.



**Figure 1.** Hand-harvesting of seed of *Paspalum atratum* and *P. lenticulare* ecotypes in May 2014.

A field germination test was conducted in October 2014 in a plot previously cultivated with *Avena strigosa*. The sowing was done with an experimental no-till seeder a week after applying glyphosate at 3 L/ha. The seed was sown superficially using 2.3 m rows separated by 1 m. Rows were arranged following a randomized complete block design with 3 replications. Emerged plants were counted 15 days after sowing, and percentage germination was calculated.

#### Statistical analysis

The generated data were analyzed using Info-Gen software (Balzarini and Di Rienzo 2004) as a randomized complete block design. Means, coefficients of variation, analysis of variance (ANOVA) and mean separations by the Tukey test were calculated. Unless otherwise stated in the text, all differences refer to significance at  $P < 0.05$ .

## Results

#### Seasonal growth

There were no significant differences among accessions for annual forage accumulation (Table 2) but differences occurred between years with yields for the first, second and third years of 5.70, 11.72 and 12.29 t DM/ha, respectively. Growth rate varied with season of the year (Figure 2) with lowest growth during establishment, which was related to an unusually dry period (Figure 3), and between the end of the fall and the beginning of spring, while highest growth rates occurred during the warm season (December–March) through to mid-fall.

#### Crude protein concentration, in vitro dry matter digestibility and cattle preference

No significant differences among the accessions were observed for CP concentration and IVDMD of 4-week regrowth (Table 3); mean CP concentration was 87 g/kg DM and mean IVDMD, 525 g/kg DM. Accession L347 of *P. lenticulare* was not evaluated for nutritive value because it did not survive during winter 2013.

Differences between accessions in terms of cattle preference were observed in both years of evaluation (September 2013 and February 2015) (Figure 4). Cattle preferentially grazed accession *P. atratum* U44 in both years (Figure 5). However, correlations between IVDMD or CP concentration and cattle preference were not significant.

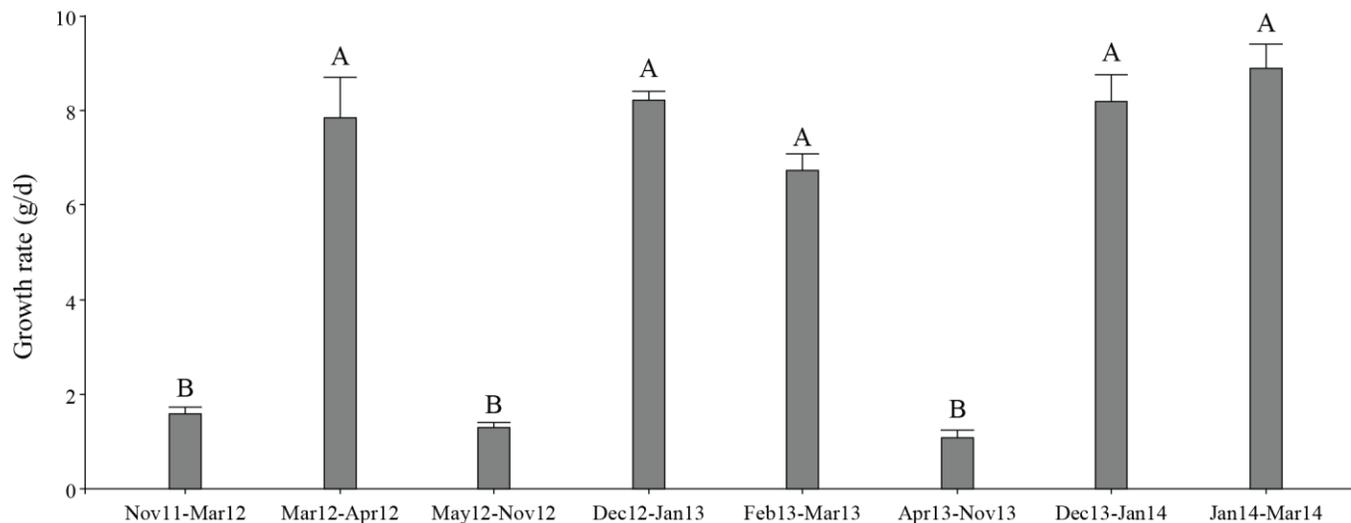
#### Cool-season regrowth and frost tolerance

After 2 consecutive frost events (7 and 8 June 2012) with temperatures below  $0\text{ }^{\circ}\text{C}$  for 4 h on both days, the leaves of all accessions were uniformly frosted and plants did not regrow for a period of 1 month after the initial frost. Therefore, we were unable to evaluate and rate frost tolerance and subsequent winter-time regrowth. While most accessions survived the winter, and regrowth occurred in October when mean air temperature was  $24\text{ }^{\circ}\text{C}$ , one accession, *P. lenticulare* L347, did not survive the second winter period.

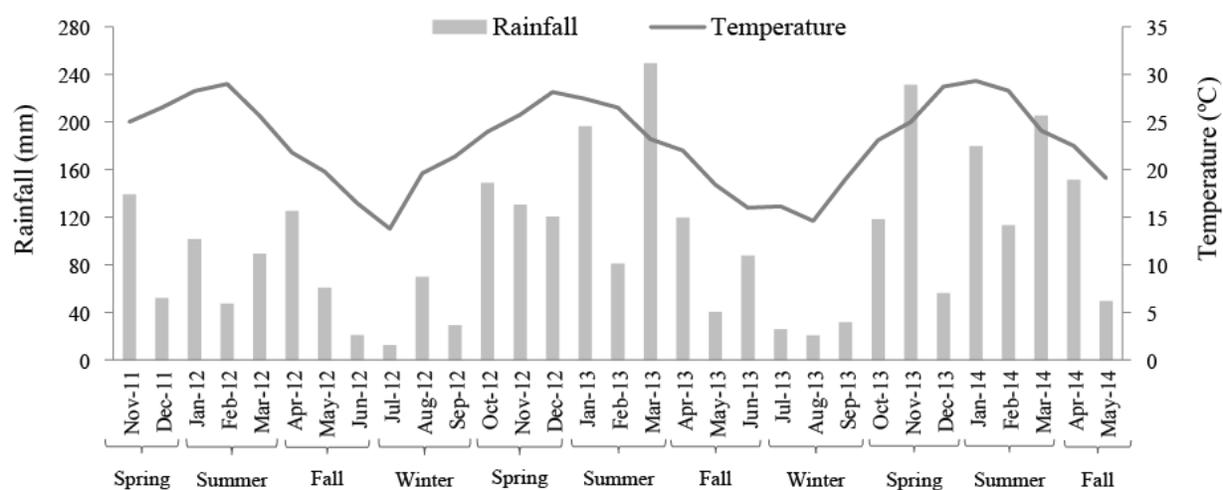
**Table 2.** Forage yields (t DM/ha) of accessions of *Paspalum atratum* and *P. lenticulare* during 3 consecutive growing seasons.

Species and accession	Growing season									Accumulation		
	2011/2012		2012/2013			2013/2014			1 <sup>st</sup> period	2 <sup>nd</sup> period	3 <sup>rd</sup> period	
	15-mar	03-may	28-nov	23-jan	28-mar	04-dec	08-jan	08-apr	2011/12	2012/13	2013/14	
<i>P. atratum</i>												
U 39	2.92	4.44	3.02	6.47	3.93	2.0	1.70	8.70	7.40	14.40	10.95	
U 42	2.89	2.98	2.82	3.51	3.30	2.37	2.84	8.51	5.86	9.22	13.10	
U 44	2.01	4.07	1.78	5.66	5.16	2.46	2.43	8.31	6.08	12.91	12.76	
N 153	2.05	3.20	2.42	4.91	3.71	3.50	2.70	7.04	5.25	10.10	12.78	
N 164	1.85	2.63	1.88	4.63	4.20	2.20	3.03	10.01	4.48	10.15	16.46	
<i>P. lenticulare</i>												
L 347	3.36	2.97	4.76	4.09	3.44	2.00	-	5.40	6.33	12.94	6.76	
U 41	1.62	3.90	2.44	4.47	5.28	2.00	2.10	8.02	5.52	12.57	11.50	
U 43	1.33	3.58	2.76	5.38	4.39	3.49	3.38	7.86	4.91	13.40	14.32	
U 54	2.11	3.12	3.15	5.37	4.61	3.31	2.57	8.30	5.23	12.61	13.24	
TK 2396	1.54	3.66	2.23	4.17	2.72	1.60	1.65	7.38	5.20	8.80	9.65	
TK 2417	2.18	4.27	2.52	5.74	3.81	3.25	2.22	9.10	6.46	11.89	13.65	
Mean	2.17	3.53	2.71	4.95	4.05	2.56	2.46	8.06	5.70	11.72	12.29	
CV <sup>1</sup>	0.37	0.40	0.43	0.25	0.25	0.49	0.28	0.21	0.29	0.26	0.21	
MSD <sup>2</sup>	2.36	4.12	3.42	3.60	3.99	3.70	2.00	6.80	4.76	12.04	10.65	
<i>P. atratum</i>	2.34	3.46	2.38	5.03	4.06	2.50	2.53	8.51	5.81	11.35	13.21	
<i>P. lenticulare</i>	2.00	3.58	2.98	4.87	4.04	2.60	2.38	7.68	5.57	12.03	11.52	
CV	0.44	0.38	0.45	0.27	0.27	0.50	0.33	0.21	0.28	0.25	0.25	
MSD	0.68	0.94	0.87	0.96	0.96	0.90	0.60	1.50	1.12	2.58	2.74	

<sup>1</sup>Coefficient of variation; <sup>2</sup>Minimum significant difference.



**Figure 2.** Growth rates of accessions of *Paspalum atratum* and *P. lenticulare* between November 2011 and March 2014. Different letters indicate significant statistical differences ( $P < 0.05$ ).

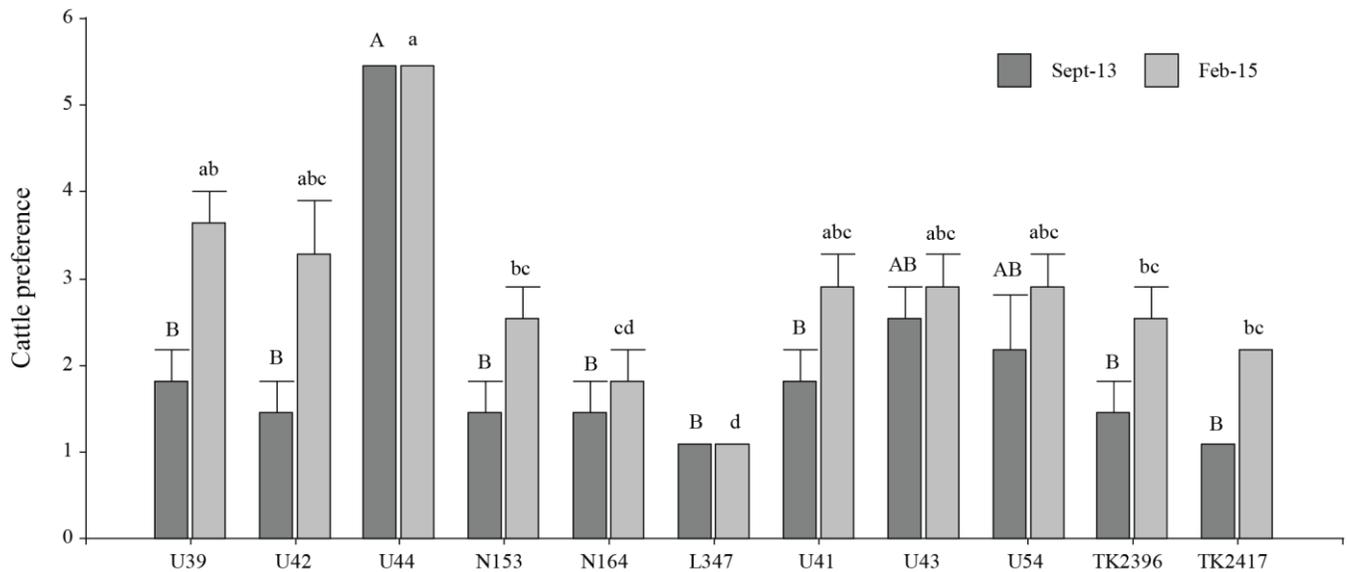


**Figure 3.** Monthly rainfall and mean temperature for each of the 3 growing seasons at Riachuelo, Corrientes, Argentina (27°38' S, 58°44' W).

**Table 3.** Crude protein (CP) concentration and in vitro dry matter digestibility (IVDMD) of *Paspalum atratum* and *P. lenticulare* accessions.

Species and accession	N° observations	CP		IVDMD	
		(g/kg)	CV <sup>1</sup> (%)	(g/kg)	CV (%)
<i>P. atratum</i>					
U 39	3	81	0.5	583	1.2
U 42	3	77	4.8	516	5.6
U 44	3	77	5.4	542	20.4
N 153	3	78	7.1	438	13.0
N 164	3	101	49.4	464	10.9
<i>P. lenticulare</i>					
U 41	3	76	5.8	508	6.6
U 43	3	70	10.1	514	13.8
U 54	3	85	6.0	595	8.8
TK 2396	3	108	5.1	565	2.1
TK 2417	3	94	3.7	542	14.0
Mean		87	20.1	525	12.9
MSD <sup>2</sup>		50		170	

<sup>1</sup>Coefficient of variation; <sup>2</sup>Minimum significant difference.



**Figure 4.** Cattle preference for *Paspalum atratum* and *P. lenticulare* accessions based on a visual scale (1–5) in September 2013 and February 2015. Different letters on columns indicate significant statistical differences ( $P < 0.05$ ). Uppercase letters belong to Sep-13 and lowercase letters to Feb-15.



**Figure 5.** Preferential grazing of accession *Paspalum atratum* U44 (left plot) over the other ecotypes during summer 2015.

#### Flowering time

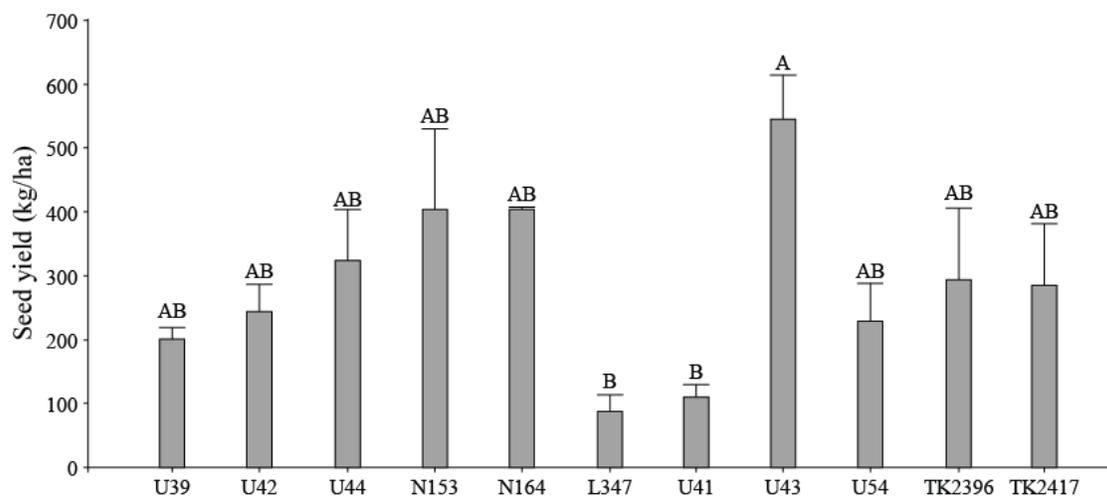
Accession L347 (*P. lenticulare*) began flowering in early

spring through September 2012, while all other accessions remained vegetative until late March 2013 (data not shown).

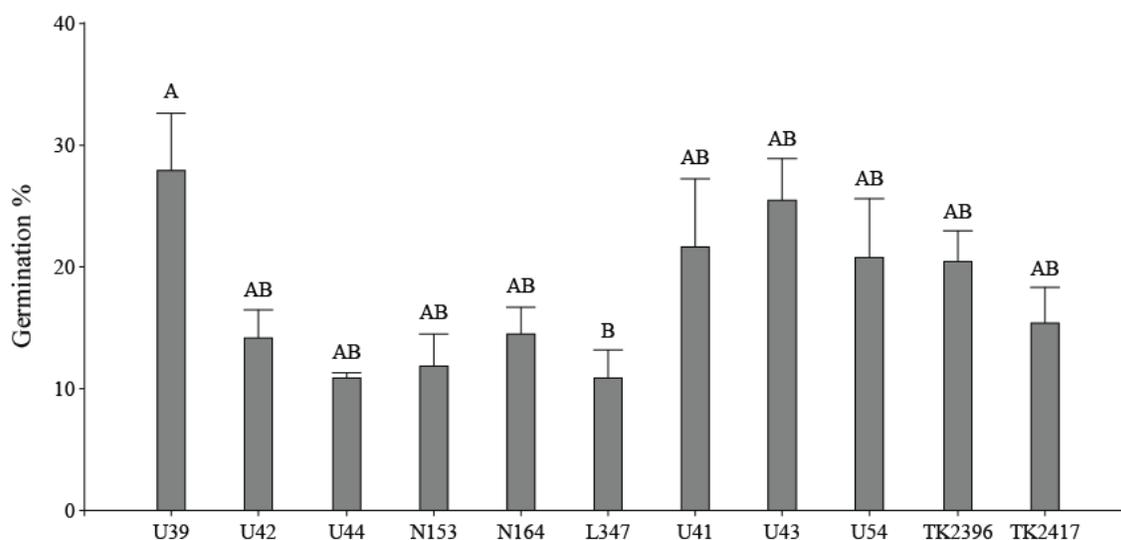
#### Seed yield and germination

Significant differences were observed among all evaluated accessions for seed yield (Figure 6). Accession *P. lenticulare* L347 had the lowest yield with 90 kg/ha and accession *P. lenticulare* U43 exhibited the highest production with 540 kg/ha. Mean seed yield of the group was 280 kg/ha. There were no differences in seed yields between *P. atratum* and *P. lenticulare* (310 vs. 260 kg/ha) ( $P > 0.05$ ).

Germination under field conditions was significantly different among accessions (Figure 7). Accession *P. atratum* U39 displayed the highest germination (28%) while *P. lenticulare* L347 and *P. atratum* U44 exhibited the lowest (11%). Overall mean germination percentage was 16% for *P. atratum* and 19% for *P. lenticulare*.



**Figure 6.** Seed yield of *Paspalum atratum* and *P. lenticulare* accessions evaluated during fall 2014. Different letters on columns indicate significant statistical differences ( $P < 0.05$ ).



**Figure 7.** Field germination percentages of *Paspalum atratum* and *P. lenticulare* accessions in October 2014. Different letters on columns indicate significant statistical differences ( $P < 0.05$ ).

## Discussion

We hypothesized that the introduction of native forage species into rangeland-based beef cattle production systems in the subtropics could increase the productive potential of these rangelands. To test this hypothesis the first step was to evaluate the growth and quality of some promising native grass species. In this research we evaluated a group of wild apomictic ecotypes of *Paspalum atratum* and *P. lenticulare* for a series of agronomic and forage quality characteristics.

Forage yield is the most important trait to consider before introducing a new cultivar into a pasture system. The mean yields we obtained during the second and third years from *P. atratum* and *P. lenticulare* (up to 11.7 and 12.8 t DM/ha) were quite substantial and quality was acceptable at 8.7% CP and 52.5% IVDMD. This was despite the fact that soils in this area of subtropical Argentina are generally inherently low in fertility and are acidic as they are in many pasturelands of South Brazil, Paraguay, Uruguay, Bolivia and Peru, and no fertilizer was applied. Typically pastures utilized by grazing cattle

in the tropics and subtropics are not fertilized, so accessions evaluated in this study were not fertilized to obtain a more realistic evaluation of their potential under low-input pasture systems. As was expected, accessions in this study behaved as perennials in this region of Argentina, except for *P. lenticulare* accession L347, which behaved as a biennial.

The yield and quality data are similar or superior to those recorded for cultivated grass species frequently used in South America. For example, *Setaria sphacelata* cv. Narok is one of the most cultivated forages in North-eastern Argentina because of its ability to regrow rapidly after the winter and produce acceptable yields of good quality forage. [Llamas et al. \(2016\)](#) reported that this cultivar produced 5.1 t DM/ha/yr in Chaco, Argentina on an unfertilized Oxic Argiudoll soil with a harvest frequency of 40 days. Another example is *Brachiaria brizantha* cv. Marandu, the most cultivated warm-season grass in subtropical South America because of its high production in the acid soils of this region. This cultivar produced 3.75 t DM/ha/yr on infertile soils at Campo Grande, MS, Brazil with the addition of 50 kg N + 40 kg P + 40 kg K/ha ([Euclides et al. 2008](#)). Forage production of *P. atratum* and *P. lenticulare* is similar to or better than that of other species of the same genus such as *P. notatum* cv. Argentine, which is one of the principal cultivated forage species in the Coastal Plain region of Southeastern United States of America. [Vendramini et al. \(2013\)](#) reported annual forage yields of Argentine bahiagrass between 4.3 and 6.4 t DM/ha at the University of Florida Range Cattle Research and Education Center, Ona, FL, following the addition of 56 kg N + 14 kg P + 24 kg K/ha 2 weeks after planting and 60 kg N/ha annually. Similarly, *P. atratum* cv. Suerte produced 8.9–9.8 t DM/ha and 9.9–11.0 t DM/ha/yr following nitrogen fertilization of 180 kg N/ha and 220 kg N/ha, respectively, in north and central Florida ([Kalmbacher et al. 1997](#)).

The concentration of growth of *P. atratum* and *P. lenticulare* during late spring, summer and early fall was not surprising, as these are tropical-subtropical grasses. With the exception of *P. lenticulare* L347 all accessions of both species had exclusive vegetative growth during the spring-summer period with a concentrated flowering and seed production during the fall. Both species were considered to be frost-sensitive, but able to survive the mild winters of the subtropics. This is a common response of warm-season perennial grasses when grown in the subtropics ([Moser et al. 2004](#)). These characteristics allow for overseeding with annual winter forages, like *Avena strigosa* or *Lolium multiflorum*, to maintain adequate levels of forage production throughout the year. However, attempts are being made to breed

strains of *Paspalum* species with increased forage production during the cool-season ([Blount and Acuña 2009](#)).

The mean CP concentration and IVDMD values for the accessions were similar to those of other warm-season grasses cultivated in the subtropics like *B. brizantha* cv. Marandu or *S. sphacelata*. [Euclides et al. \(2009\)](#) reported leaf CP of 9.2% and IVDMD of 53.2% in Marandu when fertilized with 50 kg N + 120 kg P + 40 kg K/ha prior to grazing in Campo Grande, MS. The mean CP percentage and IVDMD values of *S. sphacelata* in South Sulawesi, Indonesia without fertilization were 7.2% and 68.2%, respectively ([Nasrullah et al. 2004](#)).

While cattle preferentially grazed *P. atratum* accession U44, differences in acceptability were not related to the CP and IVDMD levels or the growing seasons, and may be due to differences in tactile and visual leaf texture, as the more palatable accession had softer leaves. However, further evaluations are needed to determine why cattle preferred U44, and if intakes were correspondingly higher on this grass.

Time to flowering was considered an important factor in this study. Ten of the 11 accessions we studied had a long vegetative phase and a concentrated reproductive phase at the end of the growing season. Only one accession, *P. lenticulare* L347, flowered early. This characteristic has also been observed in other species and cultivars of *Paspalum*, like *P. atratum* cv. Cambá FCA and *P. guenoarum* cv. Chané FCA ([Evers and Burson 2004](#)). However, this behavior is not displayed by other grasses like *P. notatum* ([Blount and Acuña 2009](#)) and *S. sphacelata* ([Jank and Hacker 2004](#)) that commence flowering early in November-December. An extended vegetative phase is considered advantageous as a longer duration of vegetative growth could result in a higher leaf percentage and better nutritive value at any given time. A concentrated reproductive phase may result in more uniform ripening of seed and better seed harvest.

The mean seed yield obtained in this study (280 kg/ha) can be considered most acceptable for a native warm-season perennial grass which is undomesticated. The most common cultivated species in the tropics and subtropics actually produce similar seed yields. Seed yields reported in the literature are: 57 kg/ha/yr for *S. sphacelata* cv. Narok receiving 50 kg N/ha at monthly intervals at Lawes, Australia over 2 years ([Hacker 1991](#)); 75 kg/ha for *P. dilatatum* ([Evers and Burson 2004](#)); and 110–220 kg/ha for *P. atratum* cv. Suerte ([Kalmbacher et al. 1997](#)). The mean field germinations for the *Paspalum* accessions, evaluated 5 months after seed harvest, of 16 and 19%, would allow good grass stands to be achieved with low amounts of seed sown ([Newman and Moser 1988](#);

[Masters et al. 2004](#)). However, further research is needed to determine if seed dormancy is limiting germination soon after harvest, a common characteristic in species of Paniceae ([Loch et al. 2004](#)).

## Conclusions

This study has shown that *P. atratum* and *P. lenticulare* have an extended warm-season growth and, despite being sensitive to low temperature, survived frosting. Their high forage and seed yields, as well as their capacity to survive the winter season in the subtropics, suggest that these undomesticated species can produce well in the northeast of Argentina and with their good seed yields may be potential candidates for sowing in the humid subtropics of South America as well as similar locations around the world. Most accessions are late-flowering, with a concentrated reproductive phase during the fall. This results in an extended period when forage quality should be acceptable, with the added benefit that seed harvesting should be more efficient with concentrated seed-set and ripening in the fall.

The extended growing period and persistence during the cold season should be compatible with over-sowing of the stands with winter-growing species to extend the period of productive forage availability. Considering that the accessions did not differ in forage yield, CP percentage and IVDMD, other factors like the high palatability of *P. atratum* U44 may determine the accession to sow in a given situation. Additional research is warranted to evaluate these accessions further in terms of persistence under grazing and animal performance in a beef cattle production system.

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## References

Acuña CA; Blount AR; Quesenberry KH; Hanna WW; Kenworthy KE. 2007. Reproductive characterization of bahiagrass germplasm. *Crop Science* 47:1711–1717. DOI: [10.2135/cropsci2006.08.0544](#)

Acuña CA; Blount AR; Quesenberry KH; Kenworthy KE; Hanna WW. 2009. Bahiagrass tetraploid germplasm: Reproductive and agronomic characterization of segregating progeny. *Crop Science* 49:581–588. DOI: [10.2135/cropsci2008.07.0402](#)

Acuña CA; Blount AR; Quesenberry KH; Kenworthy KE; Hanna WW. 2011. Tetraploid bahiagrass hybrids: Breeding technique, genetic variability and proportion of heterotic hybrids. *Euphytica* 179:227–235. DOI: [10.1007/s10681-010-0276-y](#)

AOAC (Association of Official Analytical Chemists). 1990. Official methods of analysis. 15th Edn. AOAC Inc., Arlington, VA, USA.

Arelovich HM; Bravo RD; Martínez MF. 2011. Development, characteristics, and trends for beef cattle production in Argentina. *Animal Frontiers* 1:37–45. DOI: [10.2527/af.2011-0021](#)

Balzarini M; Di Rienzo J. 2004. Info-Gen: Software para análisis estadístico de datos genéticos. Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, Argentina.

Berretta EJ. 2001. Ecophysiology and management response of the subtropical grasslands of southern South America. Proceedings of the XIX International Grassland Congress, São Pedro, SP, Brazil, 11–21 February 2001. p. 939–946. [goo.gl/MLQwwT](#)

Blount AR; Acuña CA. 2009. Bahiagrass. In: Singh RJ, ed. Genetic resources, chromosome engineering, and crop improvement series: Forage crops - Volume 5. CRC Press, Boca Raton, FL, USA. p. 81–101. DOI: [10.1201/9781420047400.ch4](#)

Brunoli EA; Urbani MH; Quarín CL; Zilli AL; Martínez EJ; Acuña CA. 2014. Diversity in apomictic populations of *Paspalum simplex*. *Crop Science* 54:1656–1664. DOI: [10.2135/cropsci2013.11.0780](#)

Chase A. 1929. The North American species of *Paspalum*. Contributions of the United States National Herbarium 28:1–310. [hdl.handle.net/10088/27051](#)

Escobar E; Ligier HD; Melgar R; Matteio H; Vallejos O. 1996. Suelos de la provincia de Corrientes 1:500,000. Instituto Nacional de Tecnología Agropecuaria (INTA), Corrientes, Argentina. [goo.gl/VgyS99](#)

Espinoza F; Urbani MH; Martínez EJ; Quarín CL. 2001. The breeding system of three *Paspalum* species with forage potential. *Tropical Grasslands* 35:211–217. [goo.gl/JCTbFG](#)

Euclides VPB; Macedo MCM; Valle CB do; Barbosa RA; Gonçalves WV. 2008. Produção de forragem e características da estrutura do dossel de cultivares de *Brachiaria brizantha* sob pastejo. *Pesquisa Agropecuária Brasileira* 43:1805–1812. DOI: [10.1590/S0100-204X2008001200023](#)

Euclides VPB; Macedo MCM; Valle CB do; Difante GS; Barbosa RA; Cacere ER. 2009. Valor nutritivo da forragem e produção animal em pastagens de *Brachiaria brizantha*. *Pesquisa Agropecuária Brasileira* 44:98–106. DOI: [10.1590/S0100-204X2009000100014](#)

Evers GW; Burson BL. 2004. Dallisgrass and other *Paspalum* species. In: Moser LE; Burson BL; Sollenberger LE, eds. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. p. 681–713. DOI: [10.2134/agronmonogr45.c20](#)

Feldkamp CR. 2011. Beef production in Argentina: Situation and challenges. In: O'Rourke J, ed. Proceedings of the 9th

- International Rangeland Congress, Rosario, Argentina, 2-8 April 2011. CD-ROM. p. 26–30.
- Freitas PM de; Takayama SY; Pagliarini MS; Batista LAR. 1997. Evaluation of meiotic behavior in polyploid accessions of *Paspalum* (Plicatula group). *The Nucleus* 40:47–52. [goo.gl/aKMz8R](http://goo.gl/aKMz8R)
- Galdeano F; Urbani MH; Sartor ME; Honfi AI; Espinoza F; Quarín CL. 2016. Relative DNA content in diploid, polyploid, and multiploid species of *Paspalum* (Poaceae) with relation to reproductive mode and taxonomy. *Journal of Plant Research* 129:697–710. DOI: [10.1007/s10265-016-0813-4](https://doi.org/10.1007/s10265-016-0813-4)
- Gates RN; Quarín CL; Pedreira CGS. 2004. Bahiagrass. In: Moser LE; Burson BL; Sollenberger LE, eds. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. p. 651–680. DOI: [10.2134/agronmonogr45.c19](https://doi.org/10.2134/agronmonogr45.c19)
- Hacker JB. 1991. Seed production potential in bred populations and cultivars of *Setaria sphacelata*. *Tropical Grasslands* 25:253–261. [goo.gl/sfp1qf](http://goo.gl/sfp1qf)
- Jank L; Hacker JB. 2004. *Setaria*. In: Moser LE; Burson BL; Sollenberger LE, eds. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. p. 785–807. DOI: [10.2134/agronmonogr45.c23](https://doi.org/10.2134/agronmonogr45.c23)
- Jank L; Barrios SC; Valle CB do; Simeão RM; Alves GF. 2014. The value of improved pastures to Brazilian beef production. *Crop and Pasture Science* 65:1132–1137. DOI: [10.1071/cp13319](https://doi.org/10.1071/cp13319)
- Kalmbacher RS; Brown WF; Colvin DL; Dunavin LS; Kretschmer Jr. AE; Martin FG; Mullahey JJ; Recheigl JE. 1997. Suerte atra paspalum, its management and utilization. Circular S-397. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL, USA. [goo.gl/D8MVKj](http://goo.gl/D8MVKj)
- Llamas JO; Leonhard EAA; Yfrán EMM; Pereira MM; Bernardis AC; Fernández JA. 2016. Evaluación de la fertilización nitrogenada sobre la producción y el valor nutritivo de *Setaria sphacelata* cv. Narok. *Agrotecnia* 24:17–21. [goo.gl/R7JKAY](http://goo.gl/R7JKAY)
- Loch DS; Adkins SW; Heslehurst MR; Paterson MF; Bellairs SM. 2004. Seed formation, development, and germination. In: Moser LE; Burson BL; Sollenberger LE, eds. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. p. 95–144. DOI: [10.2134/agronmonogr45.c4](https://doi.org/10.2134/agronmonogr45.c4)
- Maraschin GE. 2001. Production potential of South America grasslands. Proceedings of the XIX International Grassland Congress, São Pedro, SP, Brazil, 11–21 February 2001. p. 5–15. [goo.gl/KXsRXy](http://goo.gl/KXsRXy)
- Masters RA; Mislevy P; Moser LE; Rivas-Pantoja F. 2004. Stand establishment. In: Moser LE; Burson BL; Sollenberger LE, eds. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. p. 145–178. DOI: [10.2134/agronmonogr45.c5](https://doi.org/10.2134/agronmonogr45.c5)
- Moser LE; Burson BL; Sollenberger LE, eds. 2004. Warm-season (C<sub>4</sub>) grasses. ASA, CSSA, SSSA, Madison, WI, USA. DOI: [10.2134/agronmonogr45.c1](https://doi.org/10.2134/agronmonogr45.c1)
- Nasrullah; Niimi M; Akashi R; Kawamura O. 2004. Nutritive evaluation of forage plants grown in South Sulawesi, Indonesia II. Mineral composition. *Asian-Australian Journal of Animal Sciences* 17:63–67. DOI: [10.5713/ajas.2004.63](https://doi.org/10.5713/ajas.2004.63)
- Newman PR; Moser LE. 1988. Grass seedling emergence, morphology, and establishment as affected by planting depth. *Agronomy Journal* 80:383–387. DOI: [10.2134/agronj1988.00021962008000030001x](https://doi.org/10.2134/agronj1988.00021962008000030001x)
- Norrmann GA; Quarín CL; Killeen TL. 1994. Chromosome numbers in Bolivian grasses (Gramineae). *Annals of the Missouri Botanical Garden* 81:768–774. DOI: [10.2307/2399921](https://doi.org/10.2307/2399921)
- Novo PE; Acuña CA; Quarín CL; Urbani MH; Marcón F; Espinoza F. 2017. Hybridization and heterosis in the Plicatula group of *Paspalum*. *Euphytica* 213:198. DOI: [10.1007/s10681-017-1983-4](https://doi.org/10.1007/s10681-017-1983-4)
- Ortiz JPA; Quarín CL; Pessino SC; Acuña C; Martínez EJ; Espinoza F; Hojsgaard DH; Sartor ME; Cáceres ME; Pupilli F. 2013. Harnessing apomictic reproduction in grasses: What we have learned from *Paspalum*. *Annals of Botany* 112:767–787. DOI: [10.1093/aob/mct152](https://doi.org/10.1093/aob/mct152)
- Pagliarini MS; Takayama SY; Freitas PM de; Carraro LR; Adamowski EV; Silva N; Batista LAR. 1999. Failure of cytokinesis and 2n gamete formation in Brazilian accessions of *Paspalum*. *Euphytica* 108:129–135. DOI: [10.1023/A:1003660327223](https://doi.org/10.1023/A:1003660327223)
- Pagliarini MS; Carraro LR; Freitas PM de; Adamowski EDV; Batista LAR; Valls JFM. 2002. Cytogenetic characterization of Brazilian *Paspalum* accessions. *Hereditas* 135:27–34. DOI: [10.1111/j.1601-5223.2001.00027.x](https://doi.org/10.1111/j.1601-5223.2001.00027.x)
- Quarín CL; Valls JFM; Urbani MH. 1997. Cytological and reproductive behavior of *Paspalum atratum*, a promising forage grass for the tropics. *Tropical Grasslands* 31:114–116. [goo.gl/DBiQSi](http://goo.gl/DBiQSi)
- Royo Pallarés O; Berreta EJ; Maraschin GE. 2005. The South American Campos ecosystem. In: Suttie JM; Reynolds SG; Batello C, eds. Grasslands of the world. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. p. 171–219. [goo.gl/qJZCAq](http://goo.gl/qJZCAq)
- Savidan Y. 2007. Apomixis in higher plants. In: Hörandl E; Grossniklaus U; van Dijk PJ; Sharvel TF, eds. Apomixis. Evolution, mechanisms and perspectives. A.R.G. Gantner Verlag, Ruggell, Liechtenstein. p. 15–22.
- Skerman PJ; Cameron DG; Riveros F. 1991. Leguminosas forrajeras tropicales. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.
- Tilley JMA; Terry RA. 1963. A two-stage technique for the *in vitro* digestion of forage crops. *Grass and Forage Science* 18:104–111. DOI: [10.1111/j.1365-2494.1963.tb00335.x](https://doi.org/10.1111/j.1365-2494.1963.tb00335.x)
- Vendramini JMB; Sollenberger LE; Blount AR; Aguiar AD; Galzerano L; Valente ALS; Alves E; Custodio L. 2013. Bahiagrass cultivar response to grazing frequency with limited nitrogen fertilization. *Agronomy Journal* 105:938–944. DOI: [10.2134/agronj2012.0404](https://doi.org/10.2134/agronj2012.0404)
- Zilli AL; Brugnoli EA; Marcón F; Billa MB; Rios EF; Martínez EJ; Acuña CA. 2015. Heterosis and expressivity of apospory in tetraploid bahiagrass hybrids. *Crop Science* 55:1189–1201. DOI: [10.2135/cropsci2014.10.0685](https://doi.org/10.2135/cropsci2014.10.0685)

Zuloaga FO; Morrone O. 2005. Revisión de las especies de *Paspalum* para América del Sur austral (Argentina, Bolivia, sur del Brasil, Chile, Paraguay y Uruguay). Monographs in

Systematic Botany from the Missouri Botanical Garden 102:1–297.

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