Revista Brasileira de Zootecnia
Brazilian Journal of Animal Science
© 2017 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., 46(1):8-12, 2017

Agronomic evaluation of *Paspalum notatum* Flügge under the influence of photoperiod

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ABSTRACT - The objective of this study was to evaluate the influence of photoperiod on the forage yield by ecotypes and intraspecific hybrids of *P. notatum*. Tetraploid ecotypes from the United States Department of Agriculture and the National University of the Northeast in Argentina, in addition to six intraspecific hybrids, totaling 19 ecotypes, were assessed. The materials evaluated were subjected to an extended photoperiod (14 h of light) and natural photoperiod from July 2011 to October 2012. The experimental design was a completely randomized factorial scheme of 19 × 2 (ecotypes × photoperiod) consisting of five replicates. The materials were influenced differentially by the variation in photoperiod, with one group showing high sensitivity, whereas another, smaller group, was insensitive to this factor. The use of materials with differentiated responses to photoperiod in different climatic regions can be an important tool to increase forage yield of *Paspalum notatum*.

Key Words: ecotypes, forage yield, hybrids, subtropical grass

Introduction

The Brazilian livestock is largely raised under extensive systems, with pastures as the main source of feed for these herbivores. Brazil has a rich natural environment, with a diversity of species better adapted to local conditions than exotic species.

The genus *Paspalum* L. contains more than 400 tropical and subtropical species, whose importance is supported by adaptation to different ecosystems, representing a lower risk of biological imbalance because of existing genetic diversity (Strapasson et al., 2000). From a foraging point of view and given the large number of species present in the Pampa biome, these species are components of almost all South Brazilian grasslands. Among these species, *Paspalum notatum* Flügge has good forage quality, high resistance to grazing and trampling by animals (Pozzobon and Valls, 1997), and was included in the PROBIO project of the Ministry of Environment (Brasil, 2009), among the so-called plants of the future, because of its potential to be introduced into the agricultural matrix.

However, its production is concentrated in the summer, with a drastic yield decline occurring during the winter. The dormancy induced by reduction of the photoperiod is the most important determining factor that negatively influences seasonal yield, in addition to the low temperatures occurring in this season (Sinclair et al., 2003). Thus, ecotypes or species considered sensitive to photoperiod display a decline in forage yield with the reduction of photoperiod, regardless of temperature.

The existence of intraspecific variability has aroused the interest of studies in selecting materials with higher forage yield and more adapted to different environmental conditions. Thus, crosses between sexual and apomictic ecotypes can be performed to obtain superior characters set by apomixis (Acuña et al. 2009).

To this end, assessments of genitors that have the capacity to convey traits of interest to their progeny are required, in addition to determining the genetic potential of

Received: May 23, 2016
Accepted: August 21, 2016
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http://dx.doi.org/10.1590/S1806-92902017000100002

How to cite: Machado, J. M.; Dall'Agnol, M.; Motta, E. A. M.; Pereira, E. A.; Simioni, C.; Weiler, R. L.; Zuñeda, M. P. and Ferreira, P. B. 2017. Agronomic evaluation of *Paspalum notatum* Flügge under the influence of photoperiod. Revista Brasileira de Zootecnia 46(1):8-12.

hybrids from these crosses. The realization of agronomic field trials is important to provide a more precise and safe selection of these materials, which facilitates the indication for release as new commercial cultivations. Thus, the objective of this study was to evaluate the influence of photoperiod in the forage yield based on ecotypes and intraspecific hybrids of *P. notatum*.

Material and Methods

The experiment was conducted in Porto Alegre - RS, Brazil (latitude 30°1′16.13″ S, longitude 51°13′23.99″ W). The photoperiod at this latitude varies from 10 h on June 21 to 14 h on December 21. The experiment was conducted from July 2011 to October 2012. The climate is classified as humid subtropical (Cfa) according to the Köppen classification (Moreno, 1961). We evaluated apomictic tetraploid ecotypes of *Paspalum notatum* Flügge from the United States Department of Agriculture (USDA), denominated 30N, 36N, 48N, 70N, 83N, 95N, and V4, which were collected in South America, and sexual ecotypes from the National University of the Northeast in Argentina, denominated Q4188, Q4205, and C44X. In addition, we evaluated intraspecific hybrids of *P. notatum* resulting from crosses between the ecotypes Q4205 × André da Rocha (Progeny "C") and Q4205 × Bagual (Progeny "D"), totaling six superior hybrids selected for production of total dry mass, denominated C1, C2, C15, C17, D3, and D16 (Table 1). The work was performed in this breeding program. The reproduction mode of the sexual genitors was described by Quarin et al. (2001) and the ploidy level of the other ecotypes was analyzed by Fachinetto et al. (2012). *Paspalum notatum* 'Pensacola' and two native ecotypes of Rio Grande do Sul, denominated André da Rocha and Bagual, collected in the 1980s, were used as sources. The apomictic ecotypes have gone through a selection process for production of total dry mass (Fachinetto et al., 2012). Five clones of each ecotype were prepared, placed in 2.8-L pots with a commercial substrate, and placed in an open area where they were subjected to natural and extended photoperiods (14-h light) between July and August 2011 and from March to August 2012. Four 250-W metal halide lamps were placed 1.5 m from the plants in the extended photoperiod treatment. We used a light meter to measure the light intensity received by the plants subjected to the extended photoperiod. As different light intensities were detected, the plants were reallocated every three days. The experimental design was completely randomized in a 19 × 2 (ecotypes × photoperiod) factorial design with extended and natural photoperiod consisting of five replicates. The total dry weight yield of the ecotypes was evaluated by cutting, resulting in twelve cuts during the evaluation period. The cuts were performed when ecotypes and hybrids reached an average height of 15 cm and a 5-cm height residue was maintained. The collected materials were placed to dry in a greenhouse with forced air at 65 °C for 72 h and were subsequently weighed. The data were subjected to analysis of variance (ANOVA) with F test and comparison of means was performed with the Scott-Knott and Tukey tests at 5% significance, using the GENES software (Cruz, 2007). We also performed a Pearson's correlation analysis among seasons.

Table 1 - Identification of ecotypes and intraspecific hybrids of *Paspalum notatum*

Ecotype	Identification	Ploidy level
30N[1]	Santa Fé - Argentina	Tetraploid
36N[1]	Santa Fé - Argentina	Tetraploid
48N[1]	Mercedes - Argentina	Tetraploid
70N[1]	Cordoba - Argentina	Tetraploid
83N[1]	Corrientes - Argentina	Tetraploid
95N[1]	Corrientes - Argentina	Tetraploid
V4[1]	Barra do Quarai/RS - Brazil	Tetraploid
André da Rocha[1]	André da Rocha/RS - Brazil	Tetraploid
Bagual[1]	Missões/RS - Brazil	Tetraploid
Pensacola[1]	Viamão/RS - Brazil	Diploid
C44x[2]	Corrientes - Argentina	Tetraploid
Q4188[2]	Corrientes - Argentina	Tetraploid
Q4205[2]	Corrientes - Argentina	Tetraploid
C1[3]	Porto Alegre/RS - Brazil	Tetraploid
C2[3]	Porto Alegre/RS - Brazil	Tetraploid
C15[3]	Porto Alegre/RS - Brazil	Tetraploid
C17[3]	Porto Alegre/RS - Brazil	Tetraploid
D3[3]	Porto Alegre/RS - Brazil	Tetraploid
D16[3]	Porto Alegre/RS - Brazil	Tetraploid

[1] Obtained by field collections.
[2] Obtained through chromosome duplication in the laboratory.
[3] Obtained through intraspecific crosses of *Paspalum notatum*.

Results and Discussion

There was an interaction between ecotypes × photoperiod ($P<0.05$) for the productivity of total dry mass (PTDM) (g pot^{-1}), with the formation of distinct groups that demonstrated the existence of genetic variability between the evaluated ecotypes (Tables 2 and 3). The reduction in forage yield of *Paspalum notatum* in the winter period characterized it as a long-day species (Newman et al., 2007), which flowers between the months of October and March, and approximately 85% of forage yield occurs during summer (Newman et al., 2011). Thus, the key issue for this type of response is whether an extended photoperiod during the cold months could have a negative impact on subsequent yields of ecotypes and hybrids, while resulting in an increase in forage yield during the cold months. A potential use of the reserve substances stored in the rhizomes could be to promote changes in forage yield during the favorable growth season for the species.

From the results of the experiment, it was possible to classify the materials evaluated as sensitive or insensitive to photoperiod. Published reports state that the earlier a species expresses its growth potential, the lower its sensitivity to photoperiod will be (Rosa et al., 2009), and consequently the reduction of the vegetative period will be lower (Garner and Allard, 1920).

Regarding the regrowth capacity during the transition from winter to spring, in the first year of evaluation, the ecotypes demonstrated rapid regrowth under both treatments (Table 2). Among the 19 materials tested, 17 showed no differences in PTDM in the transition from winter to spring when subjected to the extended photoperiod. This response did not hamper growth in the subsequent spring season, which was confirmed by the positive correlation between the two seasons (r = 0.73; P = 0.0004). Only the C2 and D3 hybrids had lower PTDM in spring when subjected to the extended photoperiod. The results could indicate that these materials consumed their energy reserves during winter, which may have affected the forage yield in the subsequent season.

The ecotype Q4205 stood out when subjected to extended photoperiod and had the highest numerical PTDM in spring; however, this ecotype was not in the most productive group during the winter season. When subjected to natural photoperiod, there was a rapid regrowth and accumulation of dry mass of hybrids in the spring season, when compared with genitors Q4205 × André da Rocha and Q4205 × Bagual, maximizing the benefits obtained by hybrid vigor (Carvalho et al., 2001). The genetic variability observed in the evaluated materials creates a substantial opportunity to perform new crosses within the breeding program. Thus, the best hybrids with regrowth capacity in spring could be used as male genitors in crosses with female genitors that have high forage yield, which could make it possible to obtain new elite recombinants to use in different environments.

Thus, when hybridization is performed between sexual and apomictic plants, there will be segregation for apomixis and sexuality in the next generation. The apomictic progenies, which present the desired agronomic traits, could be subjected to the final stages of evaluation for later release as new cultivars. On the other hand, sexual plants with superior characteristics could be used in new recombinations within the breeding program (Burton et al., 1973; Jank et al., 2011).

In the second year of assessment, there were variations with respect to regrowth of ecotypes in the transition period between winter and spring (Table 3). The ecotypes Q4188 and Q4205 had higher PTDM in spring, with increases of 1.3- and 1.4-fold, respectively. The other ecotypes, 30N, 36N, V4, C44X, C2, C15, C17, D3, and D16, also had good regrowth capacity; however, the intensity of response was relatively low. On the other hand, the ecotypes 70N and 83N had similar PTDM during this evaluation period. The ecotypes 48N, 95N, André da Rocha, Bagual, C1, and the cultivar Pensacola exhibited decreases in this parameter, displaying slower regrowth after winter.

There was variation in PTDM when the ecotypes were subjected to natural photoperiod. The majority of ecotypes presented the highest yields in spring, with the exception of ecotype 30N, which displayed the opposite behavior. The hybrid C1 and the cultivar Pensacola displayed similar yields in winter and spring.

In the second year of assessment, the productive superiority of hybrids compared with genitors was again apparent, which indicated the expression of their genetic potential after establishment. According to Pereira et al. (2002), in the year of establishment for young plants, only part of the genes responsible for traits of interest may be expressed, whereas in the adult stage, the full potential of the plant is expressed, resulting in changes in the phenotype. The cultivar Pensacola is one of the few alternative seeds of summer-cultured species available for sale in southern Brazil. Therefore, it is important to note that the native ecotypes showed greater development in

Table 2 - Yield of total dry mass of *Paspalum notatum* ecotypes in different environments and seasons

Ecotype	Year 1			
	Extended photoperiod		Natural photoperiod	
	Winter	Spring	Winter	Spring
30N	A1.2ab	A11.8def	B0.6abcde	A9.4cdef
36N	A0.7bcd	A9.3ef	A0.5abcde	A7.3ef
48N	A0.6bcd	A12.0def	A0.8abcde	A9.9cde
70N	A0.9bcd	A13.6cdef	B0.3bcde	B8.1def
83N	A0.6bcd	A9.0f	A0.7abcde	A8.5def
95N	A0.9bc	A11.1def	A0.7abcde	A11.1bcde
V4	A0.7bcd	A12.7cdef	B0.3cde	A9.4cdef
André da Rocha	A1.8a	A11.3def	A1.0abcd	A8.9def
Bagual	A1.3ab	A12.1cedef	A0.7abcd	B9.8cde
Pensacola	A1.1ab	A10.9def	B0.2e	B3.5f
Q4188	A1.1ab	A18.0b	A1.1a	B9.5cde
Q4205	A0.8bcd	A23.1a	A1.0ab	B9.9cde
C44X	A0.7bcd	A9.8ef	B0.4cde	A8.7def
C1	A0.7bcd	A13.7bcdef	A0.4abcde	A18.0ab
C2	A0.3cd	B11.1def	B0.1e	A15.0abc
C15	A0.3cd	A16.9bc	B0.2e	A18.6a
C17	A0.2d	A14.9bcd	A0.2e	B10.4bcde
D3	A0.6bcd	B17.7b	A1.0abc	A19.1a
D16	A0.6bcd	A13.9bcde	B0.3de	A13.3abcd

Means preceded by different uppercase letters in the row differ between seasons within the year by the Scott-Knott test (P<0.05) and means followed by different lowercase letters in the column differ by the Tukey test (P<0.05).

the beginning of the warm season when compared with the commercial cultivars, pointing to the need to exploit the productive potential of these materials. It is important that the highlighted materials in this study be directed to field trials to check their yield potential, persistence, and adaptation to different climatic conditions, as well as resistance to pathogens and diseases.

When the transition period between summer and autumn was analyzed, the ecotypes André da Rocha, Bagual, and the cultivar Pensacola exhibited pronounced reductions in PTDM of approximately 4.1-, 4.2-, and 2.4-fold, respectively, when subjected to natural photoperiod (Table 3). It should be noted that the tested hybrids exhibited lower or similar reduction in PTDM observed for the cultivar Pensacola, which displayed a lower growth reduction with shorter photoperiod, but had a low-yield potential.

The availability of variability in response to photoperiod is extremely important in any breeding program for forage species. This characteristic can provide a reduction in the forage deficit present in the southern region of Brazil caused by the transition period between the seasons.

There was no variation in the PTDM of ecotypes 36N, 48N, and 83N during all seasons, regardless of the photoperiod and year of assessment (Tables 2 and 3). This information suggests a greater stability of these ecotypes compared with the others and they can be classified as insensitive to photoperiod reduction, maintaining a stable yield throughout the seasons. This feature could assist in the selection process of ecotypes with greater seasonal distribution of forage yield, depending on the region in which they will be used. The results of PTDM do not serve as indicators of the behavior of the forage yield throughout the seasons and, consequently, PTDM cannot be used as the sole factor of choice of species or cultivar to be adopted.

Some of the factors that affect the physiology of forage plants are climatic factors, such as photoperiod and temperature (Whiteman, 1980). The identification of materials described as insensitive is important, as these could be used in regions with milder weather, where the decrease in yield occurs mainly because of the photoperiod in the winter season. The results obtained suggested that the male genitors could be used in schemes of intraspecific crosses with female genitor ecotypes with sexual reproduction and high forage yield during the seasons that favor their growth.

Thus, although the ecotypes Q4188 and Q4205 presented intermediate PTDM in the summer season when subjected to natural photoperiod, the fact that they presented a sexual reproduction mode makes them eligible as female genitors for crosses with the ecotypes 36N, 48N, and 83N. Hence, the progenies of the ecotype Q4188 could be used in environments with mild winters. On the other hand, within the possibilities of sexual materials available in the breeding program, the ecotype Q4205 could be used in crosses for environments with colder winters. It is also

Table 3 - Yield of total dry mass of *Paspalum notatum* ecotypes in different environments and seasons

Ecotype	Year 2							
	Extended photoperiod				Natural photoperiod			
	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
30N	A17.1cde	A7.5bcd	A5.2bcd	A5.5bc	A16.8cdef	B4.8cde	A4.6b	A4.1cd
36N	A18.2bcde	A6.3bcd	A4.9bcde	A5.5cd	A16.2cdef	A5.1cde	A2.7bc	A3.7cde
48N	A17.3cde	A8.5bc	A4.6bcde	A4.3cd	A18.3bcde	A4.8cde	A3.3bc	A5.0bcd
70N	A17.5bcde	A9.4b	A5.3bcd	A5.2cd	B12.6defg	B3.3e	B2.2bc	B3.3de
83N	A9.5f	A4.2cd	A4.9bcde	A4.8cd	A12.1defg	A3.4de	A1.5c	A3.7cde
95N	A17.5bcde	A9.2b	A6.8bcd	A6.5bcd	A18.5bcde	A8.0abc	B3.8bc	B4.9bcd
V4	A18.8bcde	A8.5bc	A3.6de	A4.6cd	A16.1cdef	A5.7bcde	A2.8bc	A4.3bcd
André da Rocha	A18.5bcde	A9.0b	A6.3bcd	A5.3cd	B10.6efg	B2.6e	B2.2bc	A3.1de
Bagual	A19.0bcd	A7.9bc	A6.8bcd	A5.4cd	A18.5cde	B4.4cde	B3.3bc	A4.0cde
Pensacola	A11.8ef	A4.5cd	A4.0cde	A3.7cd	B6.4g	B2.7e	A1.9bc	A2.0e
Q4188	A33.2a	A14.0a	A7.7ab	A10.5ab	B22.8bc	B8.0abc	B3.3bc	B5.6bc
Q4205	A24.4b	A8.5bc	A7.5abc	A12.4a	B16.3cdef	B3.1e	B2.6bc	B3.9cde
C44X	A13.6def	A3.1d	A1.5e	A3.4d	A9.3fg	A2.6e	A1.4c	A3.1e
C1	A20.0bcd	A9.0b	A11.2a	A10.54ab	A21.7bc	A6.2bcde	B7.8a	B8.0a
C2	B14.2def	A7.6bcd	A3.9cde	A5.3cd	A19.3bcd	A7.6abc	A3.4bc	A4.8bcd
C15	A22.6bc	A10.7ab	A5.2bcd	A5.8cd	A25.5ab	A9.6ab	A4.6b	A5.7bc
C17	A15.9cdef	A9.7ab	A4.8bcde	A5.5cd	A20.1bcd	B7.5abcd	B2.5bc	A5.0bcd
D3	B19.4bc	A10.6ab	A5.5bcd	A6.2cd	A32.3a	A10.9a	B3.6bc	B5.1bcd
D16	A16.9cde	A7.6bcd	A5.9bcd	A7.5bc	A19.1bcd	A8.5abc	A4.2bc	A6.3ab

Means preceded by different uppercase letters in the row differ between seasons within the year by the Scott-Knott test ($P<0.05$) and means followed by different lowercase letters in the column differ by the Tukey test ($P<0.05$).

worth noting that the presence of responsive materials is important for areas with colder climates, because this mechanism probably acts as a defense mechanism against an unfavorable season for its development.

Sinclair et al. (2001) pointed out that the selection of photoperiod-insensitive ecotypes could substantially increase forage yield in subtropical regions. The limited forage availability during the months with shorter day length has been one of the most important factors influencing animal production and the pasture management (Sinclair et al. 2003), although it cannot be used as a single parameter responsible for the low-forage yield during this period. Newman et al. (2007), in a study conducted in Florida with the genera *Paspalum*, *Panicum* and *Cynodon*, observed average yields of total dry mass 3.5 times higher with extended photoperiod when compared with the normal photoperiod that occurs during the winter.

Further studies with the goal of obtaining new crosses between elite recombinants may contribute to the achievement of progenies adapted to different climatic conditions, in which the photoperiod has an extreme influence on forage yield. Thus, the quest for sexual materials that are the source of variability in apomictic species is of utmost importance, because it can fix this characteristic within the breeding program and will contribute to a better distribution of forage throughout the year, reducing the forage deficit that occurs in subtropical regions.

Conclusions

The materials were influenced differentially by the variation in the photoperiod, with one group with great sensitivity, whereas a smaller group exhibited insensitivity to this factor. The use of materials with different responses to photoperiod in different climatic regions can be an important tool for increasing the forage yield of *Paspalum notatum*.

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