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Dynamics of forage production in annual ryegrass cultivars

Dinâmica da produção de forragem de cultivares de azevém anual

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ABSTRACT
Annual ryegrass is one of the species that best meets the needs of the farmers in south Brazil during the winter. Many of these cultivars can be found in the market. However, in some cases information on their actual adaptation to each climate situation or production system is unavailable. The present study aimed to evaluate the productive performance of diploid and tetraploid cultivars of annual ryegrass under grazing. The experiment was carried out in the municipality of Pato Branco, State of Paraná (PR), Brazil. The experimental design was a randomized complete block design with 4 replications. The following were the cultivars observed in this study: LE 284, Camaro, Bakarat, Estações, Ponteio and Nibbio (diploids; 2n), Winter Star, KLM 138, Scorpio, Titan, Barjumbo, and Potro (tetraploids; 4n). Mob grazing was used with an entry height of 25 cm and an exit height of 10 cm. It was noted that the cultivars that presented the longest period of pasture use were those that produced the greatest amount of forage. For all cultivars evaluated, the greatest accumulations of forage occurred between August, September, and October. Cultivars Winter Star (4n) and Escórpio (4n) stood out as they yielded the largest forage production. On average, tetraploid cultivars are more productive than diploid cultivars.

Keywords: *Lolium multiflorum* Lam., diploids, tetraploids

RESUMO
O azevém anual é uma das espécies que melhor atende às necessidades dos agropecuaristas da região sul do Brasil durante o período hibernal do ano. Muitas dessas cultivares podem ser encontradas no comércio, mas nem sempre há informações de sua real adaptação para cada situação de clima ou de sistema de produção. O objetivo dessa pesquisa foi avaliar o desempenho produtivo, sob pastejo, de cultivares diploides e tetraploides de azevém anual. O experimento foi conduzido no município de Pato Branco/PR. O delineamento experimental foi de blocos ao acaso com quatro repetições. As cultivares observadas foram: LE 284, Camaro, Bakarat, Estações, Ponteio e Nibbio (diploides; 2n) e Winter Star, KLM 138, Escórpio, Titan, Barjumbo e Potro (tetraploides; 4n). O pastejo foi do tipo “mob-grazing” respeitando altura de entrada de 25 cm e altura de saída de 10 cm. Foi possível observar que as cultivares que apresentaram maior período de utilização da pastagem foram as que produziram maiores quantidades de forragem. Para todas as cultivares avaliadas os maiores acúmulos de forragem ocorreram entre os meses de agosto, setembro e outubro. Destaque para as cultivares Winter Star (4n) e Escórpio (4n) pelas maiores produções de forragem. Na média, cultivares tetraploides são mais produtivas que as diploides.

Palavras-chave: *Lolium multiflorum* Lam., diploides, tetraploides

1 INTRODUCTION

Integrated production systems that intercalate agricultural crops with annual winter forage pastures have been used in south Brazil. In this region of the country, knowledge about the dynamics of forage production of the different cultivars available in the market is necessary in order to form productive pastures compatible with the production system of each property. These pastures are of great importance in the design of intensive, efficient, and sustainable systems. Historically, winter in this Brazilian region is characterized by low rates of livestock production due to the lack of good quality pastures. In southern Brazil, annual ryegrass (*Lolium multiflorum* Lam.) has great importance in livestock systems, in which the ryegrass is a spring-winter growth, in which is stands out for having high nutritional species value and can be used in the efficient and economically viable production of lambs, which are animals with high nutritional requirements (GRAMINHO et al., 2019). This is due to a number of characteristics of this grass including high forage yield, good quality, good nutritional value, adaptation to different types of soil, and natural reseeding capacity (CONTERATO et al., 2016; FONTOURA et al., 2020).

For many years common ryegrass (2n) was the forage most used by producers. However, genetic improvement of the species has been carried out in order to select superior materials of the same ploidy (2n) as well as tetraploid (4n) ones (BUSTAMANTE et al., 2015). There is a tendency for tetraploid cultivars to be more productive and of better quality with better implantation vigor and longer productive cycle (SOLOMON et al., 2017; PEREIRA et al., 2012). There are currently many alternatives of cultivars of the species available to producers - diploids and tetraploids - with different cycles and prices. Therefore, knowledge on the dynamics of forage production of these materials is essential for the adjustment of forage planning of a productive system. Thus, the present study aimed to evaluate the forage production and the distribution of this production during the cycle of cultivation of diploid and tetraploid cultivars of annual ryegrass.

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2 MATERIALS AND METHODS

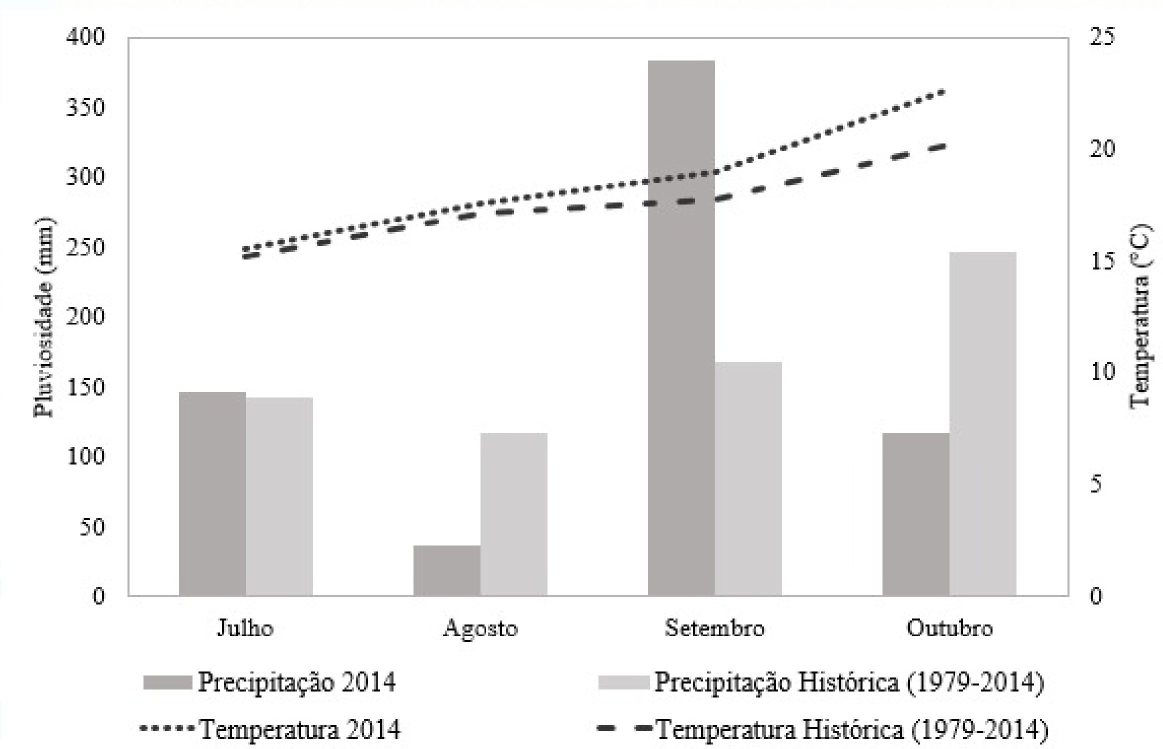
The present study was carried out in the municipality of Pato Branco, PR, Brazil (26º11'03 "S, 52º41'29"W), which is located at an altitude of 779 m. The climate, according to the Köppen climate classification, is subtropical humid (Cfa) (ALVARES et al., 2013). The soil is classified as a typical Dystroferric Red Latosol (Santos, 2006) which presented the following chemical attributes in the depth of 0 to 20 cm: pH ($CaCl_2$)=5,5; P=3,2 mg dm^{-3}; K^+=0,8 $cmol_c$ dm^{-3}; M.O.=39,1 g dm^{-3}; Al^{3+}=0,00 $cmol_c$ dm^{-3}; Ca^{2+}=4,3 $cmol_c$ dm^{-3}; Mg^{2+}=3,2 $cmol_c$ dm^{-3}, and V=65,3%.

The experiment was conducted in a randomized block design with 4 replicates; 12 annual ryegrass cultivars were evaluated as follows: 6 diploids (2n): LE 284, INIA Camaro, INIA Bakarat, BRS Estações, BRS Ponteio, and Nibbio; 6 tetraploids (4n): Winter Star, KLM 138, INIA Escórpio, INIA Titan, Barjumbo, and Potro. Each experimental unit consisted of 50 m². Sowing was carried out on May 29, 2014 using a precision seeder. The sowing density was 20 kg ha^{-1} and 25 kg ha^{-1} for diploid cultivars and tetraploid cultivars, respectively. For all materials, row spacing was 17 cm, sowing depth 2 cm, base fertilization of 250 kg ha^{-1} of a N-P_2O_5-K_2O 08-20-15 fertilizer, and cover fertilization with 150 kg of N ha^{-1} which was divided into 2 applications of 75 kg of N ha^{-1} each. The first application of the N under cover was performed during tillering whereas the second application of N was done 32 days after the first one.

Criollo mares with an average of 450 kg of body weight were used for the defoliation of the materials. Animals were fasted for 12 hours prior to being introduced into the pasture. mob grazing - rapid and intensive grazing - was used in this study. As criteria for pasture management, values of 25 and 10 cm were used as input and exit heights, respectively. When one cultivar reached the entry height, the four replicates of this material were subjected to defoliation. The height of the canopy was monitored daily with a ruler graduated in centimeters.

Climate data during the experiment was obtained from the Meteorological Station of the Instituto Agronômico do Paraná - IAPAR - as shown in Figure 1. The precipitation during the experimental period from June 2014 to October 2014 was 1.27 times greater (1082 mm) in comparison with the precipitation data (848 mm) of the period between the years 1979 and 2014. The mean temperature (18.1 °C) during the experiment was also higher than the mean temperature (16.2 °C) between 1979 and 2014.

Figure 1. Climatic data observed during the experiment (from June 2014 to October 2014).



Fonte: IDR (2016).

The variable "number of days" at the first grazing was calculated from the date of sowing (DSBG, days of sowing before the first grazing). The number of days of pasture use (DPU, days of pasture use) was considered as the time span between the date of the first grazing until the date of the last grazing.

Two forage samples of 0.25 m² each were collected before each grazing in each experimental unit in order to obtain the production of harvestable forage (PHF, production of harvestable forage, kg DM ha^{-1}). These samples were cut so that 10 cm of the grass remained (exit height). After being cut, these specimens were packed in paper bags and taken to a drying oven with forced air circulation at a temperature of 55 °C for 72 hours until attaining a constant weight. Subsequently, samples were weighed and the average of the two samples was extrapolated for forage production per hectare (kg DM ha^{-1}). The total harvested forage production (TFP, total harvested forage production - kg DM ha^{-1}) was obtained through the sum of the forage yields of each grazing plus the final forage mass value, cut close to the soil, at the last grazing.

The daily forage accumulation rate between grazings (AR, daily forage accumulation rate between grazings- kg DM ha^{-1} day^{-1}) was measured by dividing the

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forage yield of a given grazing by the number of days between the grazing mentioned and the previous grazing. After obtaining the accumulation rates of each regrowth period, we were able to calculate the monthly accumulation rates. The weighting of the accumulation rates for each month was carried out as proposed by FERRAZZA et al. (2013) in order to compare the cultivars in the same time base.

Data were subjected to analysis of variance, and the means were compared using the Tukey test at 5% of error probability. The total forage production data were grouped into two distinct groups - diploids and tetraploids - and analyzed by contrast using the Scheffè test. Pearson's correlation test was performed at a 5% probability of error between TFP, DSBG, and DPU variables. The statistics software SAS Statistical Analysis System - SAS v. 9.0 was used for these analyses.

3 RESULTS AND DISCUSSION

There was a significant difference ($p<0.05$), between cultivars regarding the number of days from sowing to the first grazing (Table 1). Impressive results were obtained using the cultivars Nibbio (2n), Barjumbo (4n) and Potro (4n) with a DSBG of 48 days as these cultivars were the earliest ones in terms of forage production. The cultivar Titan (4n) with a DSBG of 62 also stood out among the other cultivars assessed, it was the material that required a longer period of time so that its canopy was suitable for the first grazing. There was also a significant difference in terms of days of pasture use ($p<0.05$). The cultivars Camaro (2n) and Winter Star (4n) presented a DPU of 102 allowing a longer grazing period. The cultivar Nibbio (2n), with DPU of 79, was the material that provided the shortest grazing period.

Table 1. Sowing days at the first grazing (DSBG) and days of pasture use (DPU) of ryegrass cultivars under grazing.

Cultivar	DSBG	DPU
LE 284	52 ^{BC}	84 ^{E}
Camaro	50 ^{DE}	102 ^{A}
Bakarat	52 ^{BC}	87 ^{D}
Estações	53 ^{B}	83 ^{E}
Ponteiro	53 ^{B}	83 ^{E}
Nibbio	48 ^{EF}	79 ^{F}
Winter Star	50 ^{DE}	102 ^{A}
KLM 138	48 ^{EF}	99 ^{B}
Escórpio	51 ^{CD}	101 ^{AB}
Titan	62 ^{A}	90 ^{C}
Barjumbo	48 ^{EF}	99 ^{B}

Potro	51 CD	101 AB
	CV=7,14%	CV=9,39%

Means followed by distinct letters, lowercase in the row and upper case in the column, differ significantly from each other using the Tukey test ($p<0.05$).

It is hypothesized that a tetraploid cultivar establishes itself faster and provides lower DSBG in comparison with a diploid one as the former has larger seeds with higher reserve contents and presents higher rates of cell stretching (RIOS et al., 2015). However, such pattern was not uniform since there is one diploid cultivar and two tetraploid cultivars among the three earliest materials. In addition, the material later to the first grazing was a tetraploid cultivar. Oliveira et al. (2014) assessed different annual ryegrass cultivars and obtained a similar result. The tendency of tetraploids to establish themselves earlier than the diploids was not observed in their study.

The time of pasture use is determined by a number of factors including severity of defoliation, fertilization (mainly nitrogen fertilization) (BELTRÁN et al., 2019), climatic conditions (rainfall, temperature, hours of light throughout the daytime), and phenotypic plasticity - a progressive and reversible change in the phenotypic characteristics of individual plants (LEMAIRE et al., 2009), considering that leaves are the main photosynthetic components of plants in addition to being higher nutritional value that are preferably harvested by the animal on pasture (WESP et al., 2016). Since all materials were influenced by the same soil and edaphoclimatic conditions and management, phenotypic plasticity may explain the longer period of pasture utilization of some cultivars. In addition, tetraploids may provide a longer grazing period since these cultivars have a lower population density of tillers. However, tetraploid cultivars have heavier tillers with larger and wider leaves which result in more vigorous tillers with increased reserve content and faster regrowth.

There was interaction ($p<0.05$) between cultivars and grazing for the production of harvestable forage (PHF) (Table 2). In general, the lowest production of forage is observed in the first grazing. As the productive cycle progresses, the production gradually increases and then decreases again at the end of the cycle.

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Table 2. Production of harvestable fodder of ryegrass cultivars in each grazing (PHF, kg DM ha^{-1}).

Cultivars	Grazing						
	1	2	3	4	5	6	Mean
LE 284	981 ^{bB}	1647 ^{aAB}	2418 ^{aA}	2360 ^{aA}	2391 ^{aABCDE}		1959
Camaro	755 ^{cBC}	1811 ^{bAB}	2273 ^{abA}	2688 ^{abA}	2889 ^{aABC}	1378 ^{bcB}	1966
Bakarat	1126 ^{bAB}	1824 ^{aA}	2777 ^{aA}	2545 ^{aA}	2209 ^{aBCDE}		2096
Estações	886 ^{cBC}	1498 ^{bcAB}	2230 ^{abA}	2422 ^{abA}	3038 ^{aAB}		2015
Ponteiro	854 ^{cBC}	1105 ^{bcB}	2086 ^{abA}	2720 ^{aA}	2806 ^{aABC}		1914
Nibbio	905 ^{cBC}	1550 ^{bAB}	1931 ^{bA}	2388 ^{aA}	1656 ^{bE}		1686
W. Star	1019 ^{cAB}	1737 ^{bAB}	2676 ^{abA}	2706 ^{abA}	3125 ^{aA}	1674 ^{bcAB}	2156
KLM 138	496 ^{cC}	1406 ^{bAB}	1760 ^{abA}	2767 ^{aA}	1866 ^{abDE}	2348 ^{aA}	1774
Escórpio	861 ^{cBC}	1942 ^{bA}	2132 ^{abA}	2636 ^{abA}	2894 ^{aABC}	1424 ^{bcB}	1982
Titan	1442 ^{cA}	1769 ^{bcAB}	1937 ^{abcA}	2753 ^{aA}	2566 ^{abABCD}	1351 ^{cB}	1970
Barjumbo	861 ^{cBC}	1658 ^{bAB}	1583 ^{bcA}	2976 ^{aA}	2099 ^{abCDE}	1944 ^{abAB}	1854
Potro	1098 ^{cAB}	1466 ^{bcAB}	1947 ^{abA}	2796 ^{abA}	2869 ^{aABC}	1553 ^{bcAB}	1955
Mean	940	1618	2146	2647	2534	1667	

Means followed by distinct letters, lowercase in uppercase lines and capitals, differ significantly from each other using the Tukey test ($p<0.05$).

The basic unit of a forage plant is the tiller (HODGSON, 1990) which originate from the buds, which originates from the shoots, which are correlated with the rate of leaf appearance, are also influenced by interaction of various factors, such as light, temperature and nutrients in the soil, nitrogen availability can directly alter the tillering potential and have a direct link with leaf production (HUNDERTMARCK et al., 2017). However, activation of these points depends on the incidence of solar radiation. After defoliation, solar radiation is able to penetrate in greater depth in the forage canopy activating a greater number of basal buds or growth points which results in the regrowth of the forage with a larger number of tillers.

This phenomenon explains why at the beginning of the development of the cultivars in the first grazings forage production was low. As the productive cycle progressed in the third, fourth, and fifth grazing, the PHF increased significantly. On the other hand, in the sixth grazing the reduction of the forage production is a consequence of the end of the cycle of the materials. During this final stage, the plant ceases producing new tillers and does not accumulate any additional forage. Tetraploid materials generally have a lower population density of tillers when compared to diploids, and may result in lower forage yields for tetraploids. This characteristic was not observed in our study. Tetraploids accumulate larger amounts of soluble carbohydrates, produce larger and wider leaves. These characteristics make the tetraploid tiller of a cultivar larger and heavier than the diploid tiller (GRIFFITHS et al., 2016) which compensate the lower number of tillers.

There was interaction (p<0.05) between cultivars and months of the experiment for the AR variable (Table 3). Broadly speaking, the pattern observed was a linear increase in AR until the end of the experiment with higher values in the months of August, September, and October. Comparing the cultivars within each period, in relation to PHF and AR, it was noted that the greatest differences occurred in the first two grazings during the first two months. There was a trend of homogeneity of results between cultivars in the last months. A trend for differences between levels of ploidy was not observed.

Table 3. Forage accumulation rate (AR, kg DM day^{-1}) of ryegrass cultivars during the months that comprise the experiment (Jun 2014-Oct 2014).

Cultivars	Months					Mean
	June	July	August	September	October	
LE 284	18,86 ^{Cab}	44,04 ^{bABC}	79,12 ^{abA}	114,16 ^{aA}	91,96 ^{aA}	69,63
Camaro	15,1 ^{cAB}	50,5 ^{bAB}	115,8 ^{aA}	84,83 ^{abA}	99,17 ^{aA}	73,08
Bakarat	21,65 ^{cA}	51,45 ^{bAB}	116,22 ^{aA}	113,12 ^{aA}	76,17 ^{abA}	75,72
Estações	16,72 ^{cAB}	37,46 ^{bBCD}	101,17 ^{aA}	126,8 ^{aA}	116,84 ^{aA}	79,81
Ponteio	16,12 ^{cAB}	30,31 ^{bCD}	88,95 ^{aA}	132,41 ^{aA}	107,92 ^{aA}	75,14
Nibbio	18,86 ^{cAB}	51,52 ^{bAB}	95,78 ^{abA}	96,35 ^{abA}	97,41 ^{aA}	71,98
W. Star	20,29 ^{cA}	52,05 ^{bAB}	115,9 ^{aA}	127,34 ^{aA}	113,74 ^{aA}	85,88
KLM 138	10,34 ^{cB}	45,35 ^{bABC}	100,71 ^{aA}	103,6 ^{aA}	111,97 ^{aA}	74,39
Escórpio	16,89 ^{cAB}	51,44 ^{bAB}	95,61 ^{abA}	126,25 ^{aA}	104,18 ^{aA}	78,87
Titan	23,26 ^{bA}	23,26 ^{bD}	124,49 ^{aA}	125,03 ^{aA}	94,06 ^{aA}	78,02
Barjumbo	17,94 ^{cAB}	56,65 ^{bA}	98,89 ^{abA}	113,93 ^{aA}	96,92 ^{aA}	76,86
Potro	21,53 ^{cA}	43,48 ^{bABC}	86,64 ^{abA}	134,08 ^{aA}	104,86 ^{aA}	78,12
Mean	18,14	44,79	101,61	116,5	101,27	

Means followed by distinct letters, lowercase in uppercase lines and capitals, differ significantly from each other using the Tukey test (p<0.05).

The accumulation of dry matter is the result of the interaction between genotype and environment. In this sense, the photosynthetic rate of individual leaves, which are conditioned by light and temperature interception, allied to the arrangement, size and number of leaves (PONTES et al., 2003), leaf appearance rate, leaf expansion, and leaf life span directly influence the rate of dry matter accumulation (SILVA et al., 2008). Although diploid and tetraploid cultivars of annual ryegrass show morphophysiological differences, a tendency of tetraploids to have higher AR values during the months that comprised the experimental was not observed.

The fact that the highest values of AR occur in the months of August, September, and October may be explained by the sowing season which is considered a late event. The sowing season faced a period in which the climatic conditions, mainly rainfall and temperature, were very favorable. If the materials had been sown, for example, in March, the production dynamics would probably not have been the same since larger amounts of forage would have accumulated during the autumn and winter (FERRAZZA et al., 2013).

There was a significant difference ($p<0.05$) regarding TFP among the cultivars (Table 4). The Winter Star (4n) cultivar and the Escórpio cultivar (4n) presented the highest values of TFP whereas the Nibbio cultivar (2n) was the material with the lowest TFP value. The other cultivars presented an intermediate behavior similar to each other.

Table 4. Production of total harvestable forage (TFP, kg DM ha^{-1}) of ryegrass cultivars under grazing.

Cultivars	TFP
LE 284	9798,5 ^{AB}
Camaro	11795 ^{AB}
Bakarat	10482 ^{AB}
Estações	10076 ^{AB}
Ponteio	9572,5 ^{AB}
Nibbio	8431,5 ^{B}
W. Star	12939 ^{A}
KLM 138	10645 ^{AB}
Escórpio	11892 ^{A}
Titan	11820 ^{AB}
Barjumbo	11122 ^{AB}
Potro	11765 ^{AB}
	CV= 15,94%

Means followed by distinct letters, lowercase in uppercase lines and capitals, differ significantly from each other using the Tukey test ($p<0.05$). CV = Coefficient of Variation.

The TFP of all studied cultivars presented high dry mass yields ranging from 8431.5 kg DM ha^{-1} (Nibbio; 2n cultivar) to 12,939 kg DM ha^{-1} (Winter Star cultivar 4n). Some of the cultivars tested presented a different behavior when evaluated in conditions different from those of the present study and in other regions of Brazil. For example, the cultivar La Estanzuela 284 (2n) and Winter Star (4n) when studied in the West, Far West and Planalto Catarinense regions had a total forage production of 4,113.5; 3,771.8, kg DM ha^{-1} (RAMOS et al., 2017). Cultivars Camaro (2n), Ponteio (2n) and Titan (4n) presented forage yields of 5,091.1, 4,124 and 3,636 kg DM ha^{-1}, respectively (KRONING et al., 2014); in the west of Santa Catarina, the cultivar KLM 138 (4n) obtained a production of 7,190 kg DM ha^{-1} (HAHN et al., 2015). The cultivar Barjumbo (4n) produced 4,818 kg DM ha^{-1} (MARCHESAN, 2016) when evaluated in the southwest region of the state of Paraná, Brazil.

There was a significant correlation ($p<0.05$) between TFP and DPU. This finding confirms the influence of the cultivar cycle on forage production.

Table 5. Correlation values among the variables: total forage production (TFP, kg DM ha^{-1}), sowing days at the first grazing (DSBG) and days of pasture utilization (DPU).

	TFP	DSBG	DPU
TFP	1	0,17962^{ns}	0,60414*
DSBG	0,17962 ^{ns}	1	-0,21706 ^{ns}
DPU	0,60414*	-0,21706^{ns}	1

* = significant correlation using the Tukey test (p<0.05); ^{ns} = non-significant correlation using the Tukey test (p>0.05).

When a pasture is established, it is expected that it will be able to produce high amounts of precocious and long-lived dry matter. In the cultivars studied, it may be observed that, in order to reach high yields, the materials need to have a longer grazing period which will provide a longer accumulation time. This finding emphasizes the importance of reducing gaps between crops in crop-livestock integration systems so that the time available for animal production during the winter is as long as possible.

Regarding ploidy, the contrast between diploids and tetraploids for TFP was significant ($p<0.05$) (Table 6), which shows that generally tetraploid cultivars are superior in comparison with diploid cultivars.

Table 6. Contrast between diploid cultivars and tetraploid cultivars for total forage production (TFP, kg DM ha^{-1}).

Contrast	Variable	Contrast estimation
Diploid cultivars - Tetraploid cultivars	Harvestable TFP (kg DM ha^{-1})	-1671,2*

* = significant contrast through the Scheffé test (p<0.01).

A number of traits differentiate tetraploid cultivars from diploid cultivars such as larger and wider leaves (Sattler et al., 2016), lower tiller populations (Costa et al., 2018), and higher soluble carbohydrate content (ROBINS & LOVATT, 2016). This lead us to the conclusion that cultivars of this ploidy would favor consumption and animal performance. In the present study, the dry matter yield (kg DM ha^{-1}) of tetraploid cultivars on average is significantly higher than that of the diploid cultivars which reinforces the hypothesis that tetraploid materials are superior. However, it does not apply for all tetraploid materials.

4 CONCLUSIONS

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Based on our findings, we may infer those tetraploid cultivars are more productive than diploid cultivars. Among the evaluated cultivars, cultivars Winter Star (4n) and Escórpio (4n) are notable for high forage production. The significant interaction between month and cultivar for rate of daily forage accumulation indicates that it is necessary to consider the form that each cultivar distributes its forage production according to the need for forage in each season, based on the forage planning of each property.

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