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Production and nutritional composition of forage of oat cultivars cultivated singly or intercropped under successive harvests

Produção e composição nutricional da forragem de cultivares de aveia cultivadas de forma solteira ou em consórcio sob cortes sucessivos

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Highlights

Single oats produced the forage with the highest content of fiber compounds.
The harvesting strategy was positive for biomass production.
The intercropping between oats improved the ruminal degradation of the forage.

Abstract

Winter crops have a high potential for forage production, which responds to different harvest strategies, requiring research to determine the best number of harvests combined with good production. The grass intercropping system is still poorly studied, so this study aimed to evaluate the productive and bromatological characteristics of winter forages subjected to six successive cuts. Different winter forages were grown singly or intercropped, according to the treatments TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black

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oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats. On the fifth cut, the oats intercropping allowed a greater participation of leaves and a lower participation of stems in the plant's physical structure compared to the Pic treatment. The neutral detergent fiber and acid detergent fiber contents were lower for the oat intercropping, which varied from (48.09% to 51.40% and 32.29% to 34.39%, respectively) compared to the single cultivation (54.84% and 38.32% respectively). The ruminal degradation of intercropped oats was higher than that of single cultivation. The sixth harvest had the worst results for fiber content and ruminal degradation. The intercropping of the evaluated oats is recommended because they showed satisfactory morphological and chemical characteristics, and up to the fifth cut, better chemical composition and greater ruminal degradation of the forage, indicating nutritional potential.
Key words: Biomass production. Phenological cycle. Physical composition. Ruminal degradation.

Resumo

As culturas de inverno apresentam um alto potencial para a produção de forragens, as quais respondem a diferentes estratégias de cortes, surgindo a necessidade de desenvolvimento de pesquisas para determinar o melhor o número de cortes aliados a uma boa produção. O sistema de consórcios de gramíneas ainda é pouco estudado. Este trabalho teve como objetivo avaliar as características produtivas e bromatológicas de forrageiras hibernais submetidas a seis cortes sucessivos. Foram utilizados diferentes forrageias hibernais cultivadas em consórcio ou solteira, conforme designação dos tratamentos: TamPic: 90% de aveia branca GMX Tambo + 10% de aveia preta GMX Picasso; InvPicGau: 90% de aveia branca GMX Invernia + 5% de aveia preta GMX Picasso + 5% de aveia branca UPF Gaudéria; TamGau: 30% de aveia branca GMX Tambo + 70% de aveia branca UPF Gaudéria e Pic: 100% de aveia preta GMX Picasso. No quinto corte, o consórcio de aveias permitiu maior participação de folhas e menor participação de colmos na composição morfológica da planta em relação à aveia preta cultivada solteira (Pic). Os teores de fibra em detergente neutro e de fibra em detergente ácido foram menores para o cultivo das aveias em consórcio, que variaram de (48,09% a 51,40% e 32,29% a 34,39% respectivamente) frente ao cultivo solteiro (54,84% e 38,32% respectivamente). A degradação ruminal das forragens consorciadas foi superior ao cultivo solteiro. Em relação aos cortes, o sexto corte apresentou os piores resultados para os teores de fibra e degradação ruminal. Recomenda-se o consórcio das aveias avaliadas, visto que apresentaram características morfológicas e químicas satisfatórias, e até o quinto corte melhor composição química e maior degradação ruminal da forragem, o que mostra potencial do ponto de vista nutricional.
Palavras-chave: Composição física. Ciclo fenológico. Degradação ruminal. Produção de biomassa.

Introduction

Intercropping winter forages is an alternative that aims to increase production and extend the forage supply time. However, for this practice to be efficient, one cultivar must not negatively affect the other, due to competition for light and nutrients, for example, since their development cycles are often different (Dall'Agnol et al., 2021).

Intercropping tends to combine biomass production peaks, but since the climate, management, and genotype also directly influence this variable, and as these peaks are reached at different times, it is also worth noting that the climate has a major influence on plant growth behavior, regrowth capacity, and chemical composition (Sharma et al., 2019; Dall'Agnol et al., 2021).

Plants' chemical and physical composition change as their phenological cycle progresses, with greater participation of senescent stems and leaves, greater deposition of fiber compounds, and lower soluble carbohydrate content. In contrast, dry biomass production per unit area increases due to mass accumulation (Moreira et al., 2017).

Even with these inferences, the production and morphological and nutritional composition of the forage must be evaluated as its production cycle progresses and when subjected to controlled and uncontrolled actions (grazing, harvests, frosts) to understand the behavior of some cultivars, especially new cultivars in a given location. The adaptability and stability of production are important parameters to be evaluated when choosing the material to be planted since these characteristics can determine the success or failure of the cultivar or species (Kaur et al., 2021).

Given this, the present study aimed to evaluate the biomass production, plant morphology, chemical composition, and ruminal degradability of dry matter of different winter forages grown singly or intercropped, managed under six successive harvests.

Material and Methods

The experiment was conducted at the State University of the Center West (UNICENTRO), located in Guarapuava, state of Paraná.

The climate of the study region is highland temperate - Cfb (humid mesothermal subtropical), with no dry season, cool summers and moderate winters according to the Köppen classification, at an altitude of approximately 1,100 m, average annual rainfall of 1,944 mm, average annual minimum temperature of 12.7 °C, average annual maximum temperature of 23.5 °C, and relative humidity of 77.9%. The soil of the experimental area is classified as Latossolo Bruno Típico (Michalovicz et al., 2019). Upon sowing, the chemical properties of the soil (profile from 0 to 20 cm) were: pH $CaCl^2$ 0.01M: 5.98; Phosphorus: 15.30 mg dm^{-3}; K^+: 0.43 cmolc dm^{-3}; OM: 23.73%; Al^{3+}: 0.21 cmolc dm^{-3}; $H+Al^{3+}$: 6.42 cmolc dm^{-3}; Ca^{2+}: 6.33 cmolc dm^{-3}; Mg^{2+}: 1.67 cmolc dm^{-3}, and base saturation: 56.75%. The climatic data of the experimental period are illustrated in Figure 1.

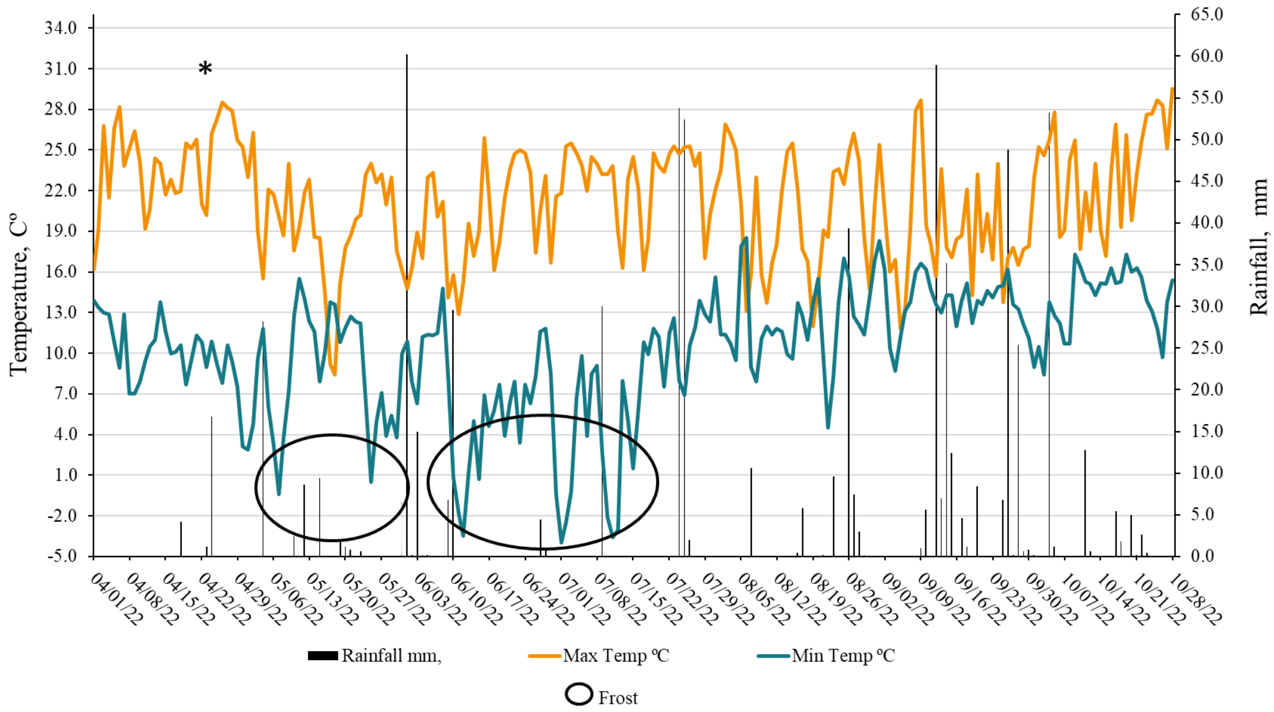

Figure 1. Rainfall, maximum temperature, and minimum temperature of the experimental period.
* Sowing date: 04/21/2022; Harvest period: from 06/05/22 to 10/25/2022.
Source: SIMEPAR/UNICENTRO experimental station, Guarapuava, state of Paraná, 2022.

The experimental period as a whole was characterized by maximum temperatures reaching 28 °C and minimum temperatures reaching -3 °C. Seven frosts occurred during the execution of the experiment; two after the desiccation and sowing period in May, and five during the harvest period, concentrated in June and July. The data in Figure 1 also indicate no frosts from August onwards, with the experiment ending in October 2022. The average rainfall during the experimental period was 3.8 mm, with maximum and minimum variations between 60 mm and 0.1 mm, respectively.

The experimental design was randomized blocks, in a 4x6 factorial arrangement. This design included four combinations of winter forages, either grown singly or intercropped, and involved six successive harvests, each with five repetitions. The treatments were as follows: TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats. The cultivars used in this experiment are novel to the region, having been sourced from another state that shares similar climatic conditions.

Forages were sown on April 21, 2022, in a no-till system, with a spacing between rows of 17 cm. The sowing process involved a row spacing of 17 cm, a depth of 2 cm, and a sowing density consistent with the recommendations provided by the seed supplier.

The experimental area was distributed into four blocks with five plots of 15.47 m² (2.21 m x 7.0 m), totaling 20 plots, with a useful area of 6.8 m² (1.36 m x 5.0 m) used for evaluations.

Basal fertilization was carried out with 300 kg ha^{-1} of fertilizer 04-20-20 (N-P_2O_5-K_2O) according to the Moreira (2017). Topdressing fertilization was carried out in two stages, the first at 45 days after sowing (DAS), at the full tillering stage with 300 kg ha^{-1} of urea (46% N), and the second, at 85 DAS, at the boot stage with 150 kg ha^{-1} of urea (46% N).

In the management of the area before sowing, preventive control of weeds and insects was carried out using a Glyphosate-based herbicide (commercial product Roundup WG®: 1.5 kg ha^{-1}) + Cletodim (commercial product Select One Park®: 3 L ha^{-1}). The doses of the chemical products used in crop management followed the manufacturer's recommendations.

The cultivars were subjected to a harvest management system, with six successive cuts. When the forage reached 32 cm, it was lowered to 12 cm, which was carried out manually using a serrated harvester, since it is important to leave 10 cm of stubble to protect the apical meristem and a larger leaf area. This approach promotes regrowth and shortens the interval between cuts and grazing (Rodrigues et al., 2023). At each evaluation, all material collected in the useful area of the plot was weighed to determine green biomass production (kg ha^{-1}).

Homogeneous samples of each material, at each harvest, were sent to the laboratory for analysis of the physical composition of the plant, through the separation of the components stem, leaves, and reproductive structure, as well as the determination of the partial dry matter content of the whole plant and its components, in a forced air oven at 55º for 72 hours (Association of Official Analytical Chemists [AOAC], 1995). The relationship between the fresh weight of the plant and the dry matter content allowed the determination of the dry biomass production (kg ha^{-1}). After, the whole plant samples were ground in a Wiley mill with a 1-mm mesh sieve.

The pre-dried and ground samples were then analyzed for total dry matter content in an oven at 105º for 4 h, crude protein (CP) by the micro-Kjeldahl method (Silva & Queiroz, 2009), and mineral matter (MM) by incineration at 550º for 4 h, according to AOAC (1995). The neutral detergent fiber (NDF) content was determined using thermostable α-amylase (Van Soest et al., 1991), and the acid detergent fiber (ADF) and acid detergent lignin (ADL) contents according to (Goering & Van Soest, 1970).

The ruminal degradability of dry matter was measured with the in situ technique (Nocek, 1988) using 12 cm x 8 cm nylon bags with 50 µm pores, containing 0.5 g of each pre-dried material ground to 1 mm. These bags were subsequently incubated in the rumen. The study utilized a male bovine, 72 months of age, weighing an average of 800 kg, which had been fitted with a permanent ruminal cannula, with approval from the Animal Ethics Committee (CEUA/UNICENTRO), under official document 029/2023. The incubation times used were 48, 72, and 168 hours.

Initially, the data were subjected to the Shapiro-Wilk and Bartlett tests to check the assumptions of normality and homogeneity of variance, respectively. Once these assumptions were met, an analysis of variance was performed on the evaluated parameters related to biomass production, morphological composition, chemical composition and the ruminal degradability of dry matter, using the following mathematical model:

$$Y_{ijkl} = \mu + F_i + EC_j + B_k + (F_iB_j)_l + {}_{ijkl,}$$

Where: μ = mean of treatments; Fi = effect of the combination of winter forages grown singly or intercropped, of order i, where 1 = TamPic, 2 = InvPicGau, 3 = TamGau, 4 = Pic; ECj = effect of the harvesting time of order j, where 1 = first, 2 = second, 3 = third, 4 = fourth, 5 = fifth and 6 = sixth; Bk = effect of the block of order k, where 1 = first, 2 = second, 3 = third, 4 = fourth and 5 = fifth; $(F_iEC_j)_l$ = effect of the interaction between different combinations of winter forages grown singly or intercropped and harvesting time; and ${}_{ijkl}$ = random error associated with each observation Y_{ijkl}. Then, Tukey's test for comparison of multiple means was applied at 5% significance, using the statistical software SAS version 9.3.

Results and Discussion

Among the variables analyzed in this study, only the participation of leaves and stems in the plant structure showed an interaction between cultivars (singly or intercropped) and harvesting time.

The first and last cuts of the forages (Table 1), intercropped and single, occurred on different dates because of the cycle of each material. The single planting of black oats (PIC) and the TamGau intercropping were cut for the first time at 44 days after emergency (DAE) and 48 DAE respectively, followed by the InvPicGau intercropping with the first cut at 51 DAE and TamPic at 54 DAE. The last cut was made at 148 DAE for InvPicGau and TamGau, 166 DAE for Pic, and 170 DAE for TamPic. Therefore, it was observed that the intercrops with a higher proportion of white oats exhibited a superior regrowth capacity, resulting in different intervals between cuts performed on different dates due to the varying growth vigor of each material evaluated.

The difference in time between the harvests and the early emergence of stems and inflorescence, especially in black oats (Table 2), suggests a greater influence of the forage response to defoliation and frost than of their cycles. These actions (harvests and frosts) possibly interfere directly with the plant's cycle, making it shorter or longer, depending on its response capacity. As can be seen in Figure 1, frosts occurred during the harvesting period, which may have interfered with the forage cycle.

On average, the highest natural biomass production was obtained in the first Harvest. For dry biomass production, the highest values were found in the last cut, regardless of the cultivars evaluated (Table 2). Therefore, the average natural and dry biomass production and the cumulative production throughout the cycle did not differ. These results show that when evaluating productivity, all materials would be suitable for forage production.

Table 1
Results of chick cloacae identification

Harvest	Forage*			
	TamPic	InvPicGau	TamGau	Pic
Harvest, days after emergence				
1st harvest	54	51	48	44
2nd harvest	64	64	62	69
3rd harvest	78	78	83	91
4th harvest	96	91	97	117
5th harvest	120	118	118	145
6th harvest	170	148	148	166
Interval of days between harvests				
From the 1st to the 2nd rest	10	13	14	25
From the 2nd to the 3rd	14	14	21	22
From the 3rd to the 4th	18	13	14	26
From the 4th to the 5th	24	27	21	28
From the 5h to the 6th	50	30	30	21

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats.

Table 2
Production of natural biomass and dry biomass of different winter forages grown singly or intercropped managed under six successive harvests

Harvest	Forage*				
	TamPic	InvPicGau	TamGau	Pic	Mean
Natural biomass production, kg ha^{-1}					
1st harvest	8.790	10.951	6.972	9.325	9.010 A
2nd harvest	4.997	5.484	7.328	6.462	6.068 C
3rd harvest	4.801	4.503	6.319	6.599	5.556 C
4th harvest	5.941	5.129	4.119	5.287	5.119 C
5th harvest	6.144	4.849	4.537	5.543	5.268 C
6th harvest	7.356	9.804	9.474	3.488	7.531 B
Mean	6.338 a	6.787 a	6.458 a	6.117 a	
Total	38.029 a	40.720 a	38.749 a	36.704 a	
Dry biomass production, kg ha^{-1}					
1st harvest	1.163	1.291	1.024	1.025	1.128 B
2nd harvest	736	800	1.025	1.063	906 C
3rd harvest	759	608	951	982	825 C
4th harvest	1.010	739	721	970	860 C
5th harvest	1.096	842	838	1.098	996 BC
6th harvest	2.109	1.688	1.870	915	1.646 A
Mean	1.146 a	995 a	1.072 a	1.009 a	
Total	6.873 a	5.968 a	6.429 a	6.053 a	

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats.
Mean values, in the same row, followed by different lowercase letters, differ by Tukey's test at 5%, when comparing forages grown singly and intercropped.
Mean values, in the same column, followed by different uppercase letters, differ by Tukey's test at 5%, when comparing harvests.

The physical composition of the forage plants (Table 3) showed an interaction between forage plants grown singly or intercropped, and the number of harvests. In the fifth cut, the Pic cultivar showed a lower participation of leaves (46.2%) and a higher contribution of stems (46.0%) compared to forage plants grown intercropped, which continued to be harvested with a plant composition with 100% leaves.

Table 3
Physical composition of the plant (% in DM) of different winter forages grown singly or intercropped managed under six successive harvests

Harvest	Forages*				
	TamPic	InvPicGau	TamGau	Pic	Mean
	Participation of leaves in the plant, % in DM				
1st harvest	100.0 a	100.0 a	100.0 a	100.0 a	100.0
2nd harvest	100.0 a	100.0 a	100.0 a	100.0 a	100.0
3rd harvest	100.0 a	100.0 a	100.0 a	100.0 a	100.0
4th harvest	100.0 a	100.0 a	100.0 a	100.0 a	100.0
5th harvest	100.0 a	100.0 a	100.0 a	46.2 b	86.5
6th harvest	14.2 c	46.2 a	36.0 b	14.6 c	27.7
	Participation of stems in the plant, % in DM				
1st harvest	0.0 a	0.0 a	0.0 a	0.0 a	0.0
2nd harvest	0.0 a	0.0 a	0.0 a	0.0 a	0.0
3rd harvest	0.0 a	0.0 a	0.0 a	0.0 a	0.0
4th harvest	0.0 b	0.0 b	0.0 b	46.0 a	46.0
5th harvest	51.4 b	53.8 b	64.0 a	47.5 c	54.1
	Participation of inflorescences, % in DM				
6th harvest	34.4 a	0.0 b	0.0 b	37.9 a	18.07

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats.
Mean values, in the same row, followed by different lowercase letters, differ by Tukey's test at 5%, when comparing forages grown singly and intercropped.
Mean values, in the same column, followed by different uppercase letters, differ by Tukey's test at 5%, when comparing harvests.

In contrast, on the sixth cut, all forages showed stem participation and reduced leaf participation. The TamGau intercropping exhibited a higher participation of stems (64.0%) compared to InvPicGau (53.8%), TamPic (51.4%), and Pic, which presented lower participation (47.5%). The participation of reproductive structures occurred only in Pic cultivar (37.9%) and TamPic (34.4) intercropping, which did not differ from each other.

The increase in the proportion of stems in the physical structure of the plant is a characteristic of the advancement of the forage phenological cycle. It is also worth remembering that with the advancement of this cycle, there is a reduction in the proportion of green leaves, which ultimately reduces the nutritional quality of the forage since the leaves have a higher percentage of protein, lower content of NDF, ADF, and lignin compared to the stem (Van Soest, 2018; Santos et al., 2015).

In general, the dry matter content of the whole plant and stem (Table 4) was higher for Pic (180.8 and 227.8 g kg^{-1}) and Tampic (179.7 and 227.3 g kg^{-1}), followed by TamGau (165.8 and 189.0 g kg^{-1}) and InvPicGau, which presented the lowest dry matter contents for these variables, respectively (149.1 and 153.3 g kg^{-1}) among the forages evaluated.

Table 4
Dry matter content of the plant and its physical components, of different winter forages, grown singly or intercropped managed under six successive harvests

Harvest	Forages*				
	TamPic	InvPicGau	TamGau	Pic	Média
	Whole plant dry matter, g kg^{-1} DM				
1st harvest	134.6	119.9	147.1	121.5	130.7 E
2nd harvest	147.1	146.3	140.0	163.8	149.3 D
3rd harvest	158.7	135.9	151.0	149.3	148.7 D
4th harvest	170.1	144.3	175.2	182.9	168.1 C
5th harvest	179.1	175.4	185.2	200.2	184.9 B
6th harvest	288.6	172.5	196.0	266.8	230.9 A
Mean	179.7 a	149.1 c	165.8 b	180.8 a	
	Leaf dry matter, g kg^{-1} DM				
1st harvest	128.7	123.6	148.5	114.4	128.8 D
2nd harvest	148.4	147.2	143.3	159.7	149.6 C
3rd harvest	158.3	133.7	150.5	161.7	151.0 C
4th harvest	173.1	145.0	175.0	181.7	168.7 BC
5th harvest	179.7	172.6	182.8	207.8	185.7 B
6th harvest	245.5	197.9	207.3	322.2	306.4 A
Mean	172.2 b	153.3 c	167.9 b	191.3 a	
	Stem dry matter, g kg^{-1} DM				
5th harvest	-	-	-	188.0	-
6th harvest	227.3 a	167.1 c	189.0 b	227.8 a	202.8
	Inflorescence dry matter, g kg^{-1} DM				
5th harvest	-	-	-	262.9	-
6th harvest	395.2	-	-	355.8	-

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats.
Mean values, in the same row, followed by different lowercase letters, differ by Tukey's test at 5%, when comparing forages grown singly and intercropped.
Mean values, in the same column, followed by different uppercase letters, differ by Tukey's test at 5%, when comparing harvests.

Higher values for dry matter content of the whole plant and stem for Pic and TamPic suggest that they reflect the phenological cycle of the cultivars in question. This inference can be supported by the lower participation of leaves, the emergence of stems, and reproductive structures before the other forages (Table 3). Based on these results, Pic and TamGau treatments are inferred to be made up of cultivars that are earlier than the others. This characteristic, compared to longer cycle cultivars, is marked by an earlier onset of the reproductive phase and senescence, as well as a rapid loss of moisture in the plants. This aligns with Tonato et al. (2014), who described that this process probably results from stem elongation due to the gradual elevation of the apical meristem with the advancement of plant phenology. According to these authors, this phenomenon is common to all forage grasses but especially relevant in winter grasses with an annual production cycle. In these cases, meristem elevation tends to occur more quickly and is difficult to delay, given the limited time for tillers to complete their phenological cycle until they reach physiological maturity.

Regarding the dry matter content of the leaves, the highest value (P<0.05) was observed in Pic (191.3 g kg^{-1}), followed by TamPic (172.2 g kg^{-1}) and TamGau (167.9 g kg^{-1}), which did not differ from each other, and InvPicGau, which showed the lowest dry matter content of the leaves (153.3 g kg^{-1}). The difference between the dry matter contents of the leaves is also linked to the phenological cycle of each forage.

When analyzing the harvests separately (Table 4), on average, the dry matter contents of the whole plant, as well as of the leaves, increased from the first (130.7 and 123.8 g kg^{-1} respectively) to the sixth cut (230.9 and 306.4 g kg^{-1} respectively). The dry matter content of the plant, as well as of the leaves, tends to increase because as the forage cycle progresses, the cells gradually lose water as the cells age, making them drier (Meinerz et al., 2011).

As for the MM, CP, and fiber compound contents between the evaluated forages (Table 5), only the NDF and ADF contents differed (P < 0.05), with higher contents in the isolated cultivation of the Pic cultivar (548.4 and 383.2 g kg^{-1} respectively) in relation to the intercroppings. Leão et al. (2019) also found higher NDF and ADF contents for black oats (EMBRAPA 139) compared to white oats. These highest values of fiber compounds in black oats are because this species is very rustic and resistant to foliar diseases (Carvalho et al., 2013). However, when the content of these fiber constituents of the plant is high, they become limiting in animal production, by reducing the intake of dry matter and the ruminal degradation of the feed, restricting the action of digestible enzymes produced by ruminal microorganisms (Garcez et al., 2016; Iqbal et al., 2018; Kir, 2020).

Table 5
Nutritional value of different winter forages, grown singly or intercropped managed under six successive harvests

Harvest	Forages*				
	TamPic	InvPicGau	TamGau	Pic	Mean
	Mineral matter, g kg^{-1} DM				
1st harvest	115.7	126.4	102.6	122.0	115.5 A
2nd harvest	108.7	109.9	115.3	143.4	119.3 A
3rd harvest	991.0	108.4	946.0	109.1	102.8 B
4th harvest	960.0	108.4	100.8	930.0	995.0 B
5th harvest	851.0	928.0	886.0	777.0	860.0 BC
6th harvest	701.0	852.0	772.0	724.0	762.0 C
Mean	958.0 a	105.2 a	965.0 a	102.9 a	
	Crude protein, g kg^{-1} DM				
1st harvest	230.1	230.6	231.3	238.1	232.5 A
2nd harvest	234.4	233.4	225.4	194.9	222.0 AB
3rd harvest	190.7	192.9	215.5	197.9	199.2 BC
4th harvest	184.8	197.6	181.7	175.3	184.8 C
5th harvest	146.0	160.9	135.6	155.9	149.6 D
6th harvest	874.0	105.9	917.0	973.0	955.0 E
Mean	178.9 a	186.9 a	180.2 a	176.6 a	
	Neutral detergent fiber, g kg^{-1} DM				
1st harvest	506.7	469.1	455.5	496.0	481.8 B
2nd harvest	507.2	468.5	457.8	500.5	483.5 B
3rd harvest	448.8	486.1	466.3	536.2	484.3 B
4th harvest	469.2	485.7	456.3	506.2	479.3 B
5th harvest	475.1	458.4	464.6	585.0	495.7 B
6th harvest	677.0	549.4	584.7	666.3	619.3 A
Mean	514.0 b	486.2 c	480.9 c	548.4 a	
	Acid detergent fiber, g kg^{-1} DM				
1st harvest	321.5	338.9	296.9	364.8	330.5 B
2nd harvest	322.0	338.3	298.5	368.1	331.7 B
3rd harvest	354.6	409.7	403.8	424.3	398.1 A
4th harvest	350.1	370.4	316.3	391.6	357.1 B
5th harvest	286.3	281.7	285.8	349.5	300.8 C
6th harvest	403.3	324.4	336.1	400.9	366.1 B
Mean	339.6 b	343.9 b	322.9 b	383.2 a	

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats. Mean values, in the same row, followed by different lowercase letters, differ by Tukey's test at 5%, when comparing forages grown singly and intercropped. Mean values, in the same column, followed by different uppercase letters, differ by Tukey's test at 5%, when comparing harvests.

When evaluating the influence of the harvests, regardless of the cultivar or intercropping used, the MM and CP contents did not show a significant difference (P>0.05) between the first and second cuts. After that, the values gradually decreased, with the lowest contents in the sixth cut (Table 5). In turn, the NDF and ADF contents showed the opposite behavior.

The highest MM and CP contents of forages occur when they are young, and this is due to their low concentration of fiber compounds. However, as the phenological stage of the forage advances, there is a reduction in the contents of non-fiber carbohydrates, an increase in structural compounds, and lignification of the cell wall (Horst et al., 2018).

On average, regardless of the harvest evaluated, the lowest mean values of ruminal degradation after 48, 72, and 168 hours of ruminal incubation (Table 6) were observed for black oats grown singly (Pic) compared to the intercroppings (65.28%, 71.33% and 77.27% respectively). However, it is worth mentioning that intercropping black oats with white oats presented, on average, better values of ruminal degradation in the evaluated times.

The lower degradation of black oats, GMX Picasso, is related to its higher ADF content (Table 5). Higher ADF in the forage impairs its ruminal degradation since the compounds that form it restrict microbial activity (Kir, 2020). This statement agrees with the results obtained here (Tables 5 and 6), that is, lower ADF contents resulted in greater degradation.

Ruminal degradation, regardless of incubation time, was greater between the 1st and 5th cuts, and lower on the 6th cut. As the phenological cycle of the forage advances, there is a greater deposit of cell wall content, making its degradation difficult (Sbrissia et al., 2017), and the greatest deposit of these contents occurs in the stem, a structure with a greater proportion in plants at more advanced stages.

Table 6
Ruminal degradation rate of dry matter of different winter forages, grown singly or intercropped managed under six successive harvests

Harvest	Forages*				
	TamPic	InvPicGau	TamGau	Pic	Mean
	Dry matter degradation 48 hours^{-1}, % DM				
1st harvest	74.02	77.11	74.82	73.09	74.76 A
2nd harvest	74.41	70.51	70.65	68.54	71.02 A
3rd harvest	77.69	72.70	72.86	68.06	72.82 A
4th harvest	68.94	77.56	70.83	71.46	72.19 A
5th harvest	73.35	71.49	74.85	60.12	69.95 A
6th harvest	45.71	63.71	58.85	50.43	56.67 B
Mean	69.02 ab	72.18 a	70.48 a	65.28 b	
	Dry matter degradation 72 hours^{-1}, % DM				
1st harvest	80.16	78.82	76.74	75.94	77.91 A
2nd harvest	76.14	75.69	79.36	74.91	76.52 A
3rd harvest	79.06	79.11	75.62	74.73	77.13 A
4th harvest	76.03	81.67	76.88	74.53	77.27 A
5th harvest	79.91	75.02	73.32	71.19	74.86 A
6th harvest	68.86	72.17	67.61	56.59	66.30 B
Mean	76.69 a	77.08 a	74.92 ab	71.33 b	
	Dry matter degradation 168 hours^{-1}, % DM				
1st harvest	83.62	81.44	81.91	80.19	81.79 A
2nd harvest	77.94	85.53	80.33	78.88	80.67 A
3rd harvest	80.47	81.65	77.28	76.95	79.08 AB
4th harvest	84.58	83.52	81.36	75.43	81.22 A
5th harvest	84.10	77.12	77.83	77.50	79.13 AB
6th harvest	75.65	78.18	73.00	74.71	75.38 B
Mean	81.06 a	81.24 a	78.61ab	77.27 b	

*TamPic: 90% GMX Tambo white oats + 10% GMX Picasso black oats; InvPicGau: 90% GMX Invernia white oats + 5% GMX Picasso black oats + 5% UPF Gaudéria white oats; TamGau: 30% GMX Tambo white oats + 70% UPF Gaudéria white oats, and Pic: 100% GMX Picasso black oats.
Mean values, in the same row, followed by different lowercase letters, differ by Tukey's test at 5%, when comparing forages grown singly and intercropped.
Mean values, in the same column, followed by different uppercase letters, differ by Tukey's test at 5%, when comparing harvests.

Conclusion

Considering the cultivars analyzed, intercropping black oats with white oats is recommended. This combination demonstrates greater production stability, a higher proportion of leaves in the final cut, and improved ruminal degradation due to lower levels of NDF and ADF compared to the single cultivation.

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