



Production and bromatological quality of cool-season intercropped forage

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ABSTRACT: The present study assessed dry biomass production, morphological composition, nutritional value, and rumen degradation of different intercropped cool-season forage species and cultivars harvested in the pre-flowering and mealy grain stages. The materials evaluated consisted of combinations of black oat (*Avena strigosa* Schreb.), white oat (*Avena sativa* L.), and rye (*Secale cereale* L.). A randomized block design was used, with a 4x2 factorial scheme consisting of four forages (ABT+APP- white oat cv. GMX Tambo + black oat cv. GMX Picasso; ABT- white oat cv. GMX Tambo; APB+APP - black oats cv. GMX Bagual + black oats cv. GMX Picasso; ABT+CT - white oat cv. GMX Tambo + rye cv. Temprano), and two harvest times (pre-flowering and mealy grain), with four replicates. The different intercrops exhibited superior physical composition and; consequently, chemical composition and dry matter rumen degradation when harvested in the pre-flowering compared to the mealy grain stage. Among the different forage combinations, the 90% GMX Tambo white oat and 10% GMX Picasso black oat treatment obtained a lower stalk percentage. However, it did not differ from the other forages, whether in combination or as monoculture species, in terms of physical and bromatological composition, as well as dry matter rumen degradation. The pre-flowering stage showed more desirable bromatological characteristics for animal feed, along with a production per area similar to that of the mealy grain stage.

Key words: intercropped species, ruminal degradation, cool-season forage.

Produção e qualidade bromatológica de consórcios de forrageiras de estação fria

RESUMO: O presente trabalho objetivou avaliar a produção de biomassa seca, a composição morfológica, o valor nutricional e a degradação ruminal da forragem de diferentes consórcios de cultivares e espécies de forrageiras de estação fria, colhidas em estágio de pré-florescimento e grão farináceo. Os materiais avaliados consistiam em combinações de aveia preta (*Avena strigosa* Schreb.), aveia branca (*Avena sativa* L.) e centeio (*Secale cereale* L.). O delineamento experimental foi o de blocos ao acaso, em esquema fatorial 4x2, sendo quatro pastagens: ABT+APP- aveia branca cv. GMX Tambo + aveia preta cv. GMX Picasso; ABT- aveia branca cv. GMX Tambo; APB+APP - aveia preta cv. GMX Bagual + aveia preta cv. GMX Picasso; ABT+CT - aveia branca cv. GMX Tambo + centeio cv. Temprano, associado a dois momentos de colheita: pré-florescimento e grão farináceo, com quatro repetições. Os diferentes consórcios foram superiores em composição física da planta e consequentemente em composição química e degradação ruminal da matéria seca quando colhidos em estágio de pré-florescimento, frente ao estágio de grão farináceo. Dentre as diferentes combinações de forrageiras, o consórcio composto por 90% de Aveia branca GMX Tambo e 10% de Aveia preta GMX Picasso apresentou menor participação de colmo, porém não diferiu das demais forrageiras de forma combinada ou solteira, em relação à composição física e bromatológica, bem como na degradação ruminal da matéria seca. O estágio de pré-florescimento apresentou características bromatológicas mais desejáveis à alimentação animal, associado a uma produção por área semelhante ao estágio de grão farináceo.

Palavras-chave: consórcio de espécies, degradação ruminal, forrageiras hibernais.

INTRODUCTION

In several regions of Brazil, agricultural areas often remain fallow and uncovered during winter. However, more advanced agricultural systems mitigate this issue by planting cool-season forages, which are used as pasture for animals or preserved to be sold commercially or for use on the farm. Black oat (*Avena strigosa* Schreb.) is one of several species that can be used in these systems (DOCHWAT et

al., 2020), along with white oat (*Avena sativa* L.) and rye (*Secale cereale* L.), which can be grown in monoculture or intercropped with other species (GUZATTI et al., 2015).

One of the advantages of these species is their ability to grow between April and August, when they reach maximum yield and nutritional quality, with crude protein content and dry biomass production ranging from 2 to 6 tons per hectare (SOARES et al., 2013; DEMÉTRIO et al., 2012). Intercropping two or

more forages can be used as a tool to prolong their use and also enables greater forage production compared to monocultures (FERREIRA et al., 2017).

Intercropping also has the potential to combine peak dry matter production, which occurs at different times, thereby balancing the nutritional value of the animal feed. As forages mature, plant digestibility tends to decrease due to the unavailability of certain fibrous fractions and an increase in others, such as lignin (SENA et al., 2014). Given that forage maturation is an unavoidable physiological process, conserving these forages in certain periods may be a good alternative. However, it is important to note that the resulting feeds will be different.

Typically, the nutritional value of forage leaves and stems decreases when they reach the mealy grain stage. However, an increase in dry biomass production per area, dry matter content, and energy content is expected (PRATES et al., 2017), which justifies using these plants for silage. Although, lower dry matter production per area is expected at the pre-flowering stage, forage has better nutritional value, higher fibrous fraction quality, and lower dry matter content. This justifies its use for pre-dried silage, which requires forage to undergo dehydration before ensiling to ensure adequate fermentation (NATH et al., 2018; COSTA et al., 2019).

Given the above, this study assessed the agronomic traits and nutritional value of different intercropped cool-season forages, harvested in the pre-flowering or mealy grain stage, to guide them towards preserved feed production.

MATERIALS AND METHODS

The experiment was conducted at the Animal Production Center (NUPRAN) of the Master's Program in Plant Production of the Agricultural and Environmental Sciences Department at the Universidade Estadual do Centro-Oeste (UNICENTRO), located in Guarapuava, Paraná state, Brazil. The climate of the region is classified as humid subtropical mesothermal (Cfb), with no dry season, cool summers and moderate winters, according to Köppen's classification. Guarapuava is situated at an altitude of approximately 1,100 meters, with average annual rainfall of 1,944 mm, relative humidity of 77.9%, and average annual minimum and maximum temperatures of 12.7 and 23.5 °C, respectively. The soil in the experimental area is classified as Typical Dark Red Latosol (POTT et al., 2007). At the time of sowing, the soil chemical properties (0-20 cm profile) were as follows: pH CaCl₂ 0.01M: 4.7; phosphorus:

1.1 mg dm⁻³; K⁺: 0.2 cmolc dm⁻³; organic matter: 2.62%; Al³⁺: 0.0 cmolc dm⁻³; H+Al³⁺: 5.2 cmolc dm⁻³; Ca²⁺: 5.0 cmolc dm⁻³; Mg²⁺: 5.0 cmolc dm⁻³; and base saturation (V%): 67.3%.

The climatic data for maximum and minimum temperatures (in °C) and rainfall during the experimental period are illustrated in figure 1. Temperatures fluctuated significantly during the study period, which hindered ideal plant development. From sowing to final harvest, the average minimum and maximum temperature was 9.7 and 22.1 °C, respectively, resulting in an average temperature of 15.9 °C. Average rainfall was 609.2 millimeters. There were thirteen severe (below 0.5 °C) and five moderate frosts (between 0.5 and 3.0 °C), which significantly affected normal plant physiology.

The yield traits and nutritional value of different cool-season forages, grown in monoculture or intercropped, were assessed. The study was conducted in randomized blocks arranged in a 4x2 factorial scheme, consisting of four pasture types: ABT+APP - 90% white oat cv. GMX Tambo + 10% black oat cv. GMX Picasso; ABT - 100% white oat cv. GMX Tambo; APB+APP - 90% white oat cv. GMX Bagual + 10% black oat cv. GMX Picasso; and ABT+CT - 90% white oat cv. GMX Tambo + 10% rye cv. Temprano, at two harvesttimes: pre-flowering and mealy grain, with four repetitions.

Sowing took place on April 15, 2021, using a no-till system with 17 cm row spacing, sowing depth of two centimeters, and seed density following the supplier's recommendations. The experimental area was divided into four blocks with eight 15.47 m² plots (2.21 m x 7.0 m), totaling 32 plots, with an experimental area of 5.1 m² (1.02 m x 5.0 m). Base dressing was conducted with 288 kg ha⁻¹ of 04-20-20 fertilizer (N-P₂O₅-K₂O), according to the Fertilization and Liming Recommendations for Paraná State (SBCS/NEPAR, 2017). Topdressing was carried out 35 days after plant emergence (DAE), during the full tillering phase, with 136 kg ha⁻¹ of nitrogen (N). Pre-sowing area management focused on preventive weed and insect control, applying a glyphosate-based herbicide (2.5 L ha⁻¹) + metsulfuron-methyl (3 g ha⁻¹) and zeta-cypermethrin insecticide (125 mL ha⁻¹).

The plants were manually harvested using a serrated sickle, cut 12 cm above the ground at the pre-flowering or mealy grain stage. Harvesting at the pre-flowering and mealy grain stage occurred 140 and 180 days after sowing, respectively. No pre-dried silage or silage was made from the harvested material, but the data simulate the appropriate cutting time to produce these feeds. Based on the nutritional

values obtained, more reliable decisions can be made for each situation.

All the material harvested from the 5.1 m² experimental area of each experimental unit, whether at the pre-flowering or mealy grain stage, was taken to the UNICENTRO Multidisciplinary Laboratory of Food and Ruminant Nutrition Analysis and weighed to determine fresh biomass production (kg ha⁻¹). Homogeneous whole plant samples from each experimental unit were obtained to determine partial dry matter content and conduct structural composition analysis. Partial dry matter determination was based on a 300 g sample dried in a forced-air oven at 55 °C for 72 hours (AOAC, 2000), allowing the estimation of dry biomass production (kg ha⁻¹) by multiplying fresh biomass production by the partial dry matter content obtained from each sample. Structural composition analysis was performed on fresh forage, manually separating stems, leaves, and reproductive structures, followed by drying in a forced-air oven at 55 °C to obtain the proportion of each component in relation to total forage weight.

The pre-dried whole-plant samples were then ground in a Wiley mill with a 1 mm mesh screen and submitted to total dry matter determination in an oven at 105 °C for 4 hours, crude protein (CP) using the micro-Kjeldahl method, ether extract (EE), and mineral matter (MM) by incineration at 550 °C for 4 hours, in accordance with AOAC (2000). Neutral detergent fiber (NDF) was determined using α -amylase (VAN SOEST et al., 1991), and acid detergent fiber (ADF) and acid detergent lignin (ADL) according to GOERING & VAN SOEST (1970). Non-fibrous carbohydrates (NFC) were calculated using the formula: $100 - (MM + CP + EE + NDF)$. Total digestible nutrients (TDN, %) were estimated using the equation: $TDN (\%) = 74.49 - 0.5635 \cdot ADF$ (CAPPELLE et al., 2001).

The ruminal dry matter disappearance rate was measured using the *in situ* technique, and 12 cm x 8 cm nylon bags with 40 to 60 μ m pores, containing 5 g of pre-dried and 1 mm of ground material, incubated in the rumen (NOCEK, 1988). To that end, a 60-month-old bull, with an average body weight of 800 kg and fitted with a rumen cannula, was used. The rumen incubation times were 24, 72, and 168 hours.

After obtaining data from all the variables analyzed, these were initially submitted to Shapiro-Wilk and Bartlett tests to check the assumptions of normality and homogeneity of variance, respectively. Once these assumptions were met, the F-test was applied at a 95% confidence level using analysis of

variance (ANOVA), followed by Tukey's test for multiple mean comparisons at 5% significance, using SAS statistical software (1993).

The analysis of biomass production, plant physical composition, bromatology, and dry matter rumen degradation parameters was performed using the mathematical model $Y_{ijkl} = \mu + M_i + EC_j + B_k + (MiER_j)l + E_{ijkl}$, where: μ = treatment mean; M_i = forage intercrop effect of the i^{th} order, where 1 = ABT+APP, 2 = ABT, 3 = APB+APP, and 4 = ABT+CT; EC_j = harvest time effect of the j^{th} order, where 1 = pre-flowering and 2 = mealy grain; B_k = block effect of the k^{th} order, where 1 = first, 2 = second, 3 = third, and 4 = fourth; $(MiER_j)l$ = interaction effect between different forage combinations and harvest times; and E_{ijkl} = random error associated with each Y_{ijkl} observation.

RESULTS AND DISCUSSION

There was no interaction between forage and harvest times for the parameters related to plant dry matter content and its components, or for plant structural composition (Table 1), production (Table 2), fibrous composition, and dry matter rumen degradation (Table 3).

Assessment of the forage combinations showed that whole plant dry matter content, reproductive structure, and the percentage contribution of leaves and reproductive structures, did not differ significantly from each other (Table 1).

Leaf dry matter content showed the highest average in ABT+CT (56.96%) and the lowest in APB+APP (52.24%). Average stem dry matter content and its contribution to plant structure were higher in ABT+CT (26.60% and 55.57%, respectively) compared to the other combinations, but did not differ from the ABT monoculture (54.98%).

The dry matter content of plant components, and the percentage contribution of each component to plant structure, depend on the characteristics of each species and genotype, as well as adaption to soil and to climatic variability (MEINERZ et al., 2011). It is important to emphasize that an increase in percentage stem contribution (stem percentage) is undesirable but occurs naturally. Higher stem percentage negatively affects plant nutritional composition and limits degradation due to the larger amount of lignin (PEREIRA et al., 2012).

Assessment of phenological stages, regardless of the intercropping system used (Table 1) showed that forages harvested in the pre-flowering stage had lower average whole plant dry matter (19.78%), leaf

Table 1 - Dry matter content (DM) of the plant and its structural components, as well as physical composition, for different combinations of cool-season forages harvested in the pre-flowering and mealy grain stages.

Stage	-----Forage-----				-----Mean-----
	ABT+APP	ABT	APB+APP	ABT+CT	
-----Whole plant dry matter, %-----					
Pre-flowering	18.37	19.94	20.59	20.21	19.78 B
Mealy grain farináceo	34.10	37.46	35.79	39.15	36.58 A
Mean	26.24 b	28.70 a	28.19 a	29.68 a	
-----Plant dry matter, %-----					
Pre-flowering	26.60	26.76	27.85	30.27	27.87 B
Mealy grain	85.76	83.04	76.63	83.64	82.27 A
Mean	56.18 ab	54.90 ab	52.24 b	56.96 a	
-----Stem dry matter, %-----					
Pre-flowering	16.04	16.79	16.46	19.29	17.15 B
Mealy grain farináceo	26.22	25.92	26.41	33.90	28.11 A
Mean	21.13 b	21.36 b	21.44 b	26.60 a	
-----Reproductive structure dry matter, %-----					
Pre-flowering	25.66	24.98	27.31	28.83	26.70 B
Mealy grain farináceo	55.97	60.12	54.35	54.81	56.31 A
Mean	40.82 a	42.55 a	40.83 a	41.82 a	
-----Plant leaf contribution, % of DM-----					
Pre-flowering	42.00	40.16	40.62	38.24	40.26 A
Mealy grain farináceo	16.91	17.53	21.06	16.03	17.88 B
Mean	29.46 a	28.85 a	30.84 a	27.14 a	
-----Plant stem contribution, % DM-----					
Pre-flowering	50.38	54.20	52.12	55.27	52.99 A
Mealy grain farináceo	52.09	55.75	52.18	55.86	53.97 A
Mean	51.24 c	54.98 ab	52.15 bc	55.57 a	
-----Plant reproductive structure contribution, % DM-----					
Pre-flowering	7.61	8.57	8.55	11.01	8.94 B
Mealy grain farináceo	27.68	28.20	28.80	28.11	28.20 A
Mean	17.65 a	18.39 a	18.68 a	19.56 a	

Means followed by different uppercase letters in the column differ according to the F-test at 5% in the comparison between harvest times. ABT+APP - 90% white oat cv. GMX Tambo + 10% black oat cv. GMX Picasso; ABT 100% white oat cv. GMX Tambo; APB+APP 90% white oat cv. GMX Bagual + 10% black oat cv. GMX Picasso; and ABT+CT 90% white oat cv. GMX Tambo + 10% rye cv. Temprano.

dry matter (27.87%), reproductive structure dry matter (26.70%), and reproductive structure contribution (8.94%) compared to those harvested in the mealy grain stage. By contrast, the percentage contribution of leaves to the plant structure (leaf percentage) was higher when harvested in the pre-flowering (40.26%) than in the mealy grain stage (17.88%).

The aforementioned characteristics of forage harvested at pre-flowering demonstrated that its nutritional value is higher than that of forage harvested in the mealy grain stage. Higher leaf percentage is associated with higher soluble carbohydrate and protein contents (SBRISIA et al., 2003). However, its low dry matter content requires dehydration after cutting to reduce its buffering

capacity and create a favorable microenvironment for adequate fermentation. This is achievable when dry matter content is between 30 and 40% (NATH et al., 2018; COSTA et al., 2019; BUENO et al., 2020).

The intercropping combinations studied showed no differences in natural and dry biomass production (Table 2). However, analysis of phenological stages revealed that only natural biomass production was significantly different ($P < 0.05$), with higher production observed for forage harvested at pre-flowering when compared to the mealy grain stage (23,237 kg ha⁻¹ versus 12,972 kg ha⁻¹, respectively). This difference is justified by the greater intracellular water content in these plants. Typically, an increase in dry biomass production occurs when plants progress

Table 2 - Biomass production and average crude protein, mineral matter, ether extract, non-fibrous carbohydrates, and total digestible nutrient levels of different combinations of cool-season forages harvested in the pre-flowering and mealy grain stages.

Stage	-----Forage-----				-----Mean-----
	ABT+APP	ABT	APB+APP	ABT+CT	
-----Fresh biomass production, kg ha-1-----					
Pre-flowering	24,607	22,275	22,493	23,573	23,237 A
Mealy grain farináceo	13,780	12,330	12,665	13,115	12,972 B
Mean	19,194 a	17,303 a	17,579 a	18,344 a	
-----Dry biomass production, kg ha-1-----					
Pre-flowering	4,513	4,429	4,636	4,760	4,585 A
Mealy grain farináceo	4,685	4,619	4,534	5,140	4,745 A
Mean	4,599 a	4,524 a	4,595 a	4,950 a	
-----Crude protein, % DM-----					
Pre-flowering	7.57 b	6.95 b	10.55 a	10.95 a	9.01
Mealy grain farináceo	8.54 a	7.71 ab	8.01 ab	7.39 b	7.91
Mean	8.05	7.33	9.28	9.17	
-----Mineral matter, % DM-----					
Pre-flowering	8.59	7.73	7.66	7.83	7.95 A
Mealy grain farináceo	5.41	5.50	5.58	4.95	5.36 B
Mean	7.00 a	6.61 a	6.62 a	6.39 a	
-----Ether extract, % DM-----					
Pre-flowering	2.84	2.41	2.20	2.33	2.44 A
Mealy grain farináceo	2.49	2.64	2.19	2.31	2.41 A
Mean	2.67 a	2.52 a	2.19 a	2.32 a	
-----Non-fibrous carbohydrates, % DM-----					
Pre-flowering	19.08	20.09	17.90	14.43	17.87 A
Mealy grain farináceo	12.72	11.36	11.84	13.89	12.45 B
Mean	15.90 a	15.72 a	14.87 a	14.16 a	
-----Total digestible nutrients, % DM-----					
Pre-flowering	60.68	60.89	61.85	59.25	60.66 A
Mealy grain farináceo	55.78	54.13	55.08	54.39	54.84 B
Mean	58.23 a	57.51 a	58.45 a	56.82 a	

Means followed by different lowercase letters in the row differ according to Tukey's test at 5% in the comparison between intercropped forage combinations.

Means followed by different uppercase letters in the column differ according to the F-test at 5% in the comparison between harvest times. ABT+APP - 90% white oat cv. GMX Tambo + 10% black oat cv. GMX Picasso; ABT 100% white oat cv. GMX Tambo; APB+APP 90% white oat cv. GMX Bagual + 10% black oat cv. GMX Picasso; and ABT+CT 90% white oat cv. GMX Tambo + 10% rye cv. Temprano.

to the mealy grain stage. However, this trend was not observed in the present study. This parameter should be assessed when deciding the optimal cutting time for a particular species and/or intercropped forages, given that dry biomass production dictates the volume of feed available for animal consumption and is directly related to production costs (BUENO et al., 2020). This is due to the significant environmental changes faced by the forage species and/or intercropping systems during the productive cycle, such as temperature fluctuations, intense frost, and rainfall variations (Figure 1).

With respect to the bromatological composition of the materials studied (Table 2),

there was an interaction between the intercropping systems and phenological stages. The ABT+CT and APB+APP systems harvested at pre-flowering and ABT+APP in the mealy grain stage obtained the highest averages (10.95, 10.55, and 8.54%, respectively), while the lowest were recorded in ABT+APP (7.57%), ABT+CT (7.39%), and the ABT monoculture (6.95%).

Forage crude protein content is influenced by leaves replacing stems as the growth cycle progresses, which not only reduces protein concentration but also overall forage nutritional value due to fibrous compound deposition (SBRISIA et al., 2003). However, in this study, whereas the protein

Table 3 - Average neutral detergent fiber, acid detergent fiber, and lignin content, and dry matter rumen degradation at incubation times of 24, 72, and 168 hours for different combinations of cool-season forages harvested in the pre-flowering and mealy grain stages.

Stage	Forage				Mean
	ABT+APP	ABT	APB+APP	ABT+CT	
-----Neutral fiber detergent, % DM-----					
Pre-flowering	61.92	62.82	61.70	64.46	62.73 B
Mealy grain farináceo	70.84	72.79	72.38	71.46	71.87 A
Mean	66.38 a	67.81 a	67.04 a	67.96 a	
-----Acid detergent fiber, % DM-----					
Pre-flowering	38.80	38.49	37.13	40.84	38.82 B
Mealy grain farináceo	45.80	48.15	46.79	47.79	47.13 A
Mean	42.30 a	43.32 a	41.96 a	44.31 a	
-----Lignin, % DM-----					
Pre-flowering	9.79	7.85	9.73	9.14	9.13 B
Mealy grain farináceo	11.16	12.42	12.74	11.60	11.98 A
Mean	10.47 a	10.14 a	11.23 a	10.37 a	
-----Rumen degradation of DM in 24 hours, % DM-----					
Pre-flowering	57.61	57.50	56.10	53.47	56.17 A
Mealy grain farináceo	35.30	31.26	32.37	36.89	33.95 B
Mean	46.46 a	44.38 a	44.24 a	45.18 a	
-----Rumen degradation of DM in 72 hours, % DM-----					
Pre-flowering	68.87	63.85	64.12	63.82	65.16 A
Mealy grain farináceo	38.54	38.57	40.72	43.81	40.41 B
Mean	53.71 a	51.21 a	52.42 a	53.82 a	
-----Rumen degradation of DM in 168 hours, % DM-----					
Pre-flowering	79.85	73.81	77.77	75.32	76.69 A
Mealy grain farináceo	55.65	54.22	54.68	57.13	55.42 B
Mean	67.75 a	64.01 a	66.22 a	66.22 a	

Means followed by different lowercase letters in the same row differ according to Tukey's test at 5%, comparing intercropping systems.

Means followed by different uppercase letters in the same column differ according to the F-test at 5%, comparing harvest times.

ABT+APP: 90% white oat cv. GMX Tambo + 10% black oat cv. GMX Picasso; ABT: 100% white oat cv. GMX Tambo; APB+APP: 90% white oat cv. GMX Bagual + 10% black oat cv. GMX Picasso; ABT+CT: 90% white oat cv. GMX Tambo + 10% rye cv. Temprano.

content of ABT+CT declined as the cycle advanced, it increased in ABT+APP and remained stable in APB+APP and the ABT monoculture (Table 2). This behavior suggested that, despite being planted together, the intercropped species and/or cultivars have distinct growth cycles, which is an important feature to exploit in intercropped forage, since it helps maintain nutritional value for longer (FERREIRA et al., 2017).

Knowing how the nutrients behave in intercropping systems as the growth cycle progresses results in more accurate decision-making in terms of harvest time. Crude protein analysis revealed that harvesting for ABT+CT should occur at pre-flowering stage, given that protein content declines significantly with growth, while ABT+APP can be harvested in the mealy grain stage, since its protein content increases with the phenological stage. This stage also tends to

increase yield per area, making pre-drying operations unnecessary. Materials that maintain protein levels allow more flexibility in determining harvest time. However, it is important to emphasize that a single parameter should not be used to determine the ideal forage harvesting time.

For mineral matter content, ether extract, non-fibrous carbohydrates, and total digestible nutrients showed no significant difference ($P > 0.05$) between intercropping combinations, with average values of 6.65, 2.42, 15.16%, and 57.76, respectively. Analysis of harvest time alone showed a decline ($P < 0.05$) in mineral matter (7.95 to 5.36%), non-fibrous carbohydrates (17.87 to 12.45%), and total digestible nutrients (60.66 to 54.84%) from the pre-flowering to the mealy grain stage, respectively. This behavior is normal during maturation, due to the replacement of soluble carbohydrates with fibrous compounds (LEÃO et al., 2016).

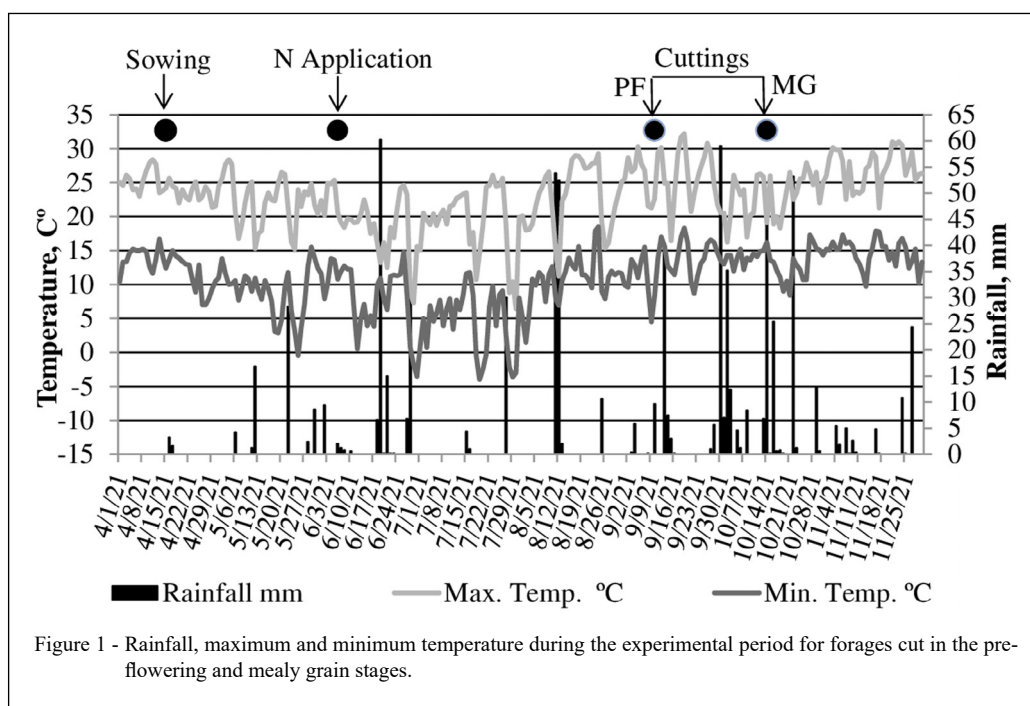


Table 3 presents the fibrous compounds and forage rumen degradation for different intercropped cool-season forages harvested in the pre-flowering and mealy grain stages. Overall, no significant differences ($P < 0.05$) were found in fibrous compounds between the intercropping combinations, with average values of 67.30% for neutral detergent fiber, 42.97% for acid detergent fiber, and 10.55% for lignin. However, in relation to phenological stages, advancing from pre-flowering to mealy grain resulted in increases ($P < 0.05$) in neutral (62.73 to 71.87%) and acid detergent fiber (38.82 to 47.13%), and lignin (9.13 to 11.98%). The increase in fibrous compounds as the plant matures occurs due to stem growth and structural compound deposition in the cell walls, making them thicker (HORST et al., 2018; HOPPEN et al., 2021).

Regarding dry matter rumen degradation at incubation times of 24, 48, 96, and 168 hours (Table 3), similar values were observed between the different intercropping systems, making them viable options for producing preserved feed, with similar use by animals.

When all parameters are considered, harvesting ABT+APP in the mealy grain stage would be more appropriate, since it exhibited lower average dry matter and an increase in protein content as the stage advanced. The ABT+CT combination experienced a decline in protein content as the cycle progressed, but bromatological composition and

rumen degradation were similar to the other systems should be harvested at pre-flowering to produce higher quality feed.

Advancing from pre-flowering to the mealy grain stage resulted in a decrease ($P < 0.05$) in rumen dry matter degradation, with reductions of 22.22% at 24 hours of incubation, 24.75% at 72 hours, and 21.27% at 168 hours. Rumen degradation is directly affected by increased ADF and lignin content as the plant matures. The increase in lignin restricts the enzymatic hydrolysis of both cellulose and hemicellulose, leading to reduced fiber degradation (HORST et al., 2018).

Assessing all tested parameters and disregarding specific intercropping combinations, harvesting younger material (pre-flowering), which exhibits higher non-fibrous carbohydrate content, lower fibrous compounds (NDF, ADF, and lignin), and greater rumen degradation, would be preferable because feed would be more efficiently used by animals, leading to better conversion into meat and milk, for example.

CONCLUSION

Due to the similarities in dry matter content, production, fibrous composition, ether extract, and rumen degradation, the intercropping combinations proved to be promising for preserved

feed production. Crude protein behavior suggested that ABT+APP should be harvested in the mealy grain stage, ABT+CT at pre-flowering stage, and for the other combinations, harvesting can be performed in either stage. With respect to the phenological stage, fibrous compound levels were lower, while their non-fibrous carbohydrate and rumen degradation counterparts were higher in the pre-flowering stage, regardless of the combination assessed.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

The experimental procedures involving the use of animals were approved by the Animal Experimentation Ethics Committee (CEUA/UNICENTRO), under protocol no. 008/2023.

REFERENCES

- ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. **Official methods of analysis**. Gaithersburg: AOAC International, 2000. 17.ed.
- BUENO, A. V. I. et al. Nutritional value and digestible dry matter production of oat cultivars for silage production. **Ciência Animal Brasileira**, v.21, 2020. Available from: <<https://www.scielo.br/j/cab/a/J8LykZmKFZkrQSQY8B9QHRx/abstract/?lang=pt>>. Accessed: Jan. 27, 2024. doi: 10.1590/1809-6891v21e-58129.
- CAPPELLE, E. R. et al. Estimativas do valor energético a partir de características químicas e bromatológicas dos alimentos. **Revista Brasileira de Zootecnia**, v.30, p.1837-1856, 2001. Available from: <<https://www.scielo.br/j/rbz/a/HLRc6DKXPtWzCLPcsNdvdNN/>>. Accessed: Jan. 27, 2024. doi: 10.1590/S1516-35982001000700022.
- COSTA, M. L. L. et al. Valor nutricional da silagem pré-secada de capim Tifton-85. **Revista Brasileira de Meio Ambiente**, v.6, p.26-33, 2019. Available from: <<https://revistabrasileirademeioambiente.com/index.php/RVBMA/article/view/192>>. Accessed: Jan. 31, 2024.
- DEMÉTRIO, J. V. et al. Biomass yield of oat cultivars under different cutting management systems. **Pesquisa Agropecuária Tropical**, v.42, p.198-205, 2012. Available from: <<https://www.scielo.br/j/pat/a/n3bxLhWZpbJWr4GRH4W7rvf/>>. Accessed: Feb. 01, 2024. doi: 10.1590/S1983-40632012000200011.
- DOCHWAT, A. et al. Forage production and nutritional quality at different development stages of black oat. **Semina: Ciências Agrárias**, v.41, p.647-660, 2020. Available from: <<https://www.scielo.br/j/abmvz/a/DmwbkTKvw5cCS6j7QkZxQdk/?lang=en&format=pdf>>. Accessed: Jan. 20, 2024. doi: 10.1590/1678-4162-11313.
- FERREIRA, O. G. L. et al. Rendimento estacional de forrageiras de inverno em cultivo isolado e consorciado. **Revista Eletrônica de Veterinária**, v.18, p.1-13, 2017. Available from: <<https://www.redalyc.org/pdf/636/63654640045.pdf>>. Accessed: Jan. 20, 2024.
- GOERING, H. K.; SOEST, P. J. V. **Forage Fiber Analyses: Apparatus, Reagents, Procedures, and Some Applications**. Washington, 1970. 379p.
- GUZATTI, G. C. et al. Aspectos qualitativos e produção de biomassa em pastos de aveia e azevém cultivados puros ou consorciados e submetidos a pastejo leniente. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.67, p.1399-1407, 2015. Available from: <<https://www.scielo.br/j/abmvz/a/ZC3bYySbVJNcJP9Ykkr3dWG/abstract/?lang=pt>>. Accessed: Jan. 05, 2024. doi: 10.1590/1678-4162-8103.
- HOPPEN, S. M. et al. Effects of intercropping on temperate grasses canopy architecture and nutritive profile. **Research, Society and Development**, v.10, p.1-11, 2021. Available from: <<https://rsdjournal.org/index.php/rsd/article/view/19831>>. Accessed: Jan. 05, 2024. doi: 10.33448/rsd-v10i11.19831.
- HORST, E. H. et al. Nutritional composition of pre-dried silage of different winter cereals. **Acta Scientiarum Animal Sciences**, v.40, p.1-7, 2018. Available from: <<https://www.scielo.br/j/asas/a/Mnx49kmNRLnZFt6rTgFbzpy/>>. Accessed: Jan. 7, 2024. doi: 10.4025/actascianimsci.v40i1.42500.
- LEÃO, G. F. M. et al. Parâmetros nutricionais e estabilidade aeróbia de silagens de cereais de inverno submetidos a diferentes regimes de corte no estágio vegetativo. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.68, p.168-175, 2016. Available from: <<https://www.scielo.br/j/abmvz/a/JTgWh4g6RQVGbp9B9RXpr4K/?lang=pt>>. Accessed: Jan. 06, 2024. doi: 10.21071/az.v68i262.4132.
- MEINERZ, G. R. et al. Silagem de cereais de inverno submetidos ao manejo de duplo propósito. **Revista Brasileira de Zootecnia**, v.40, p.2097-2104, 2011. Available from: <<https://www.scielo.br/j/rbz/a/xwVQPZNccnh7qXGWMfJwMZc/>>. Accessed: Jan. 16, 2024. doi: 10.1590/S1516-35982011001000005.
- NATH, C. D. et al. Characterization of Tifton 85 bermudagrass haylage with different layers of polyethylene film and storage time. **Asian-Australasian Journal of Animal Sciences**, v.31, p.1197-1204, 2018. Available from: <<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6043440/>>. Accessed: Jan. 06, 2024. doi: 10.5713/ajas.17.0604.
- NOCEK, J. E. In situ and Other Methods to Estimate Ruminant Protein and Energy Digestibility: A Review. **Journal of Dairy Science**, v.71, p.2051-2069, 1988. Available from: <<https://www.sciencedirect.com/science/article/pii/S0022030288797817>>. Accessed: Jan. 12, 2024. doi: 10.3168/jds.S0022-0302(88)79781-7.
- PEREIRA, E. A. et al. Variabilidade genética de caracteres forrageiros em Paspalum. **Pesquisa Agropecuária Brasileira**, v.47, p.1533-1540, 2012. Available from: <<https://www.scielo.br/j/pab>>.

pab/a/wB33vQpDcYWyn8hFFZpsXSN/?lang=pt>. Accessed: Jan. 26, 2024. doi: 10.1590/S0100-204X2012001000017.

POTT, C. A. et al. Adubação verde como alternativa agroecológica para recuperação da fertilidade do solo. **Revista Ambiência**, v.3, p.51-63, 2007. Available from: <<https://revistas.unicentro.br/index.php/ambiencia/article/view/300>>. Accessed: Dec. 28, 2023.

PRATES, C. J. N. et al. Biomass productivity and bromatological composition of forage oat genotypes in Vitória da Conquista, BA. **Scientia Plena**, v.13, p.1-10, 2017. Available from: <<https://www.scientiaplenu.org.br/sp/article/view/3449>>. Accessed: Jan. 06, 2024. doi: 10.14808/sci.plena.2017.030201.

SAS INSTITUTE. **SAS/STAT user's Guide**: statistics, version 6. 4.ed. North Caroline, v.2, 943, p.1993.

SBRISIA, A. F. et al. Tiller size/density compensation in grazed Tifton85 bermudagrass swards. **Pesquisa Agropecuária Brasileira**, v.38, p.1459-1468, 2003. Available from: <<https://www.scielo.br/j/pab/a/PTLT4b67DbJ96jr8tPnJgPz/?lang=en>>. Accessed: Jan. 14, 2024. doi: 10.1590/S0100-204X2003001200013.

SENA, L. S. et al. Degradabilidade das silagens de diferentes frações da parte aérea de quatro cultivares de mandioca. **Ciência Animal Brasileira**, v.15, p.249-258, 2014. Available from: <<https://www.scielo.br/j/cab/a/G4Ky6VLgsbBdC9xNdrqmGmB/?lang=pt>>. Accessed: Jan. 14, 2024. doi: 10.1590/1809-6891v15i316567.

SOARES, A. B. et al. Valor nutritivo de plantas forrageiras anuais de inverno em quatro épocas de semeadura. **Ciência Rural**, v.43, p.120-125, 2013. Available from: <<https://www.scielo.br/j/cr/a/B9r3YBDVYPJy83x886rgtQx/>>. Accessed: Jan. 14, 2024. doi: 10.1590/S0103-84782012005000131.

SOCIEDADE BRASILEIRA DE CIÊNCIA DO SOLO, NÚCLEO ESTADUAL DO PARANÁ (SBCS/NEPAR). **Manual de adubação e calagem para o Estado do Paraná** - CURITIBA: SBSC/NEPAR, 2017. 301p.

VAN SOEST, P. J. et al. A Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. **Journal of Dairy Science**, v.74, p.3583-3597, 1991. Available from: <[https://doi.org/10.3168/jds.S0022-0302\(91\)78551-2](https://doi.org/10.3168/jds.S0022-0302(91)78551-2)>. Accessed: Dec. 12, 2023. doi: 10.3168/jds.S0022-0302(91)78551-2.