DOI: 10.5433/1679-0359.2020v41n2p647

Forage production and nutritional quality at different development stages of black oat

Produção e qualidade nutricional da forragem em diferentes fases de desenvolvimento da aveia preta

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Highlights:
The first cut at the vegetative stage in black oats promoted greater dry biomass production with 2,478 kg ha^{-1} and greater participation of green leaves when comparing with the second cut at the full vegetative stage.
The in situ digestibility of green leaves and stem was higher in the first cut of the crop.
The delay of 7 or 14 days after the ideal harvesting time resulted in higher dry biomass production in kg ha^{-1}. but a significant reduction in the in situ digestibility of dry matter of the plant occurred.

Abstract

The present study evaluated the agronomic productive and qualitative traits of black oat (*Avena strigosa*) forage harvested at different developmental stages for haylage production. This was a 2 x 3 factorial randomized complete block design consisting of six treatments, two stages of development of the crop (vegetative and full vegetative) associated with three harvest seasons, with four replications: T1 - vegetative stage, first cut, when light interception reached values between 90 and 95 %; T2 - vegetative stage with harvest seven days after the first cut; T3 - vegetative stage with harvest fourteen days after the first cut; T4 - full vegetative stage, second cut, when again the light interception reached values between 90 and 95 %; T5 - full vegetative stage with harvest seven days after the second cut; and T6 - full vegetative stage with harvest fourteen days after the second cut. The first cut at the vegetative stage of black oat generated a larger dry biomass production with 2.478 kg ha^{-1} and a greater participation of green leaves compared to the second cut at the full vegetative stage, as well as the in situ degradability of green leaves and the stem was higher in the first cut. The delay of 7 or 14 days from the ideal harvest time of the black oat forage reduced the nutritional quality. The first cut at the vegetative stage resulted in higher dry biomass production, greater participation of green leaves in the dry matter and better digestibility of green leaves and stem compared to the second cut at the full vegetative stage.
Key words: *Avena strigosa*. Dry matter degradability. Harvest stage. Winter forage.

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Received: May 17, 2019 - Approved: Oct. 12, 2019

Resumo

O presente trabalho objetivou avaliar as características agronômicas produtivas e qualitativa da forragem da aveia preta (*Avena strigosa*) colhida em diferentes momentos de desenvolvimento para produção de pré-secado. O delineamento experimental foi o de blocos ao acaso, num fatorial 2 x 3, composto por seis tratamentos, sendo dois estádios de desenvolvimento da cultura vegetativo e pleno vegetativo associado a três épocas de colheita, com quatro repetições: T1 - estádio vegetativo, primeiro corte, quando a interceptação luminosa atingiu valores entre 90 e 95 %; T2 - estádio vegetativo com colheita sete dias após primeiro corte; T3 - estádio vegetativo com colheita quatorze dias após primeiro corte; T4 - estádio pleno vegetativo, segundo corte, quando novamente a interceptação luminosa atingiu valores entre 90 e 95 %; T5 - estádio pleno vegetativo com colheita sete dias após segundo corte; e T6 - estádio pleno vegetativo com colheita quatorze dias após segundo corte. O primeiro corte no estádio vegetativo da aveia preta gerou maior produção de biomassa seca com 2,478 kg ha^{-1} e maior participação de folhas verdes em relação ao segundo corte em estádio pleno vegetativo, assim como a degradabilidade *in situ* das folhas verdes e do colmo foi maior no primeiro corte. O atraso de 7 ou 14 dias a partir do momento ideal da colheita da forragem de aveia preta reduziu a qualidade nutricional. O primeiro corte no estádio vegetativo resultou em maior produção de biomassa seca, maior participação de folhas verdes na matéria seca e melhor degradabilidade das folhas verdes e caule comparado ao segundo corte em pleno estádio vegetativo.

Palavras-chave: *Avena strigosa*. Degradabilidade da matéria seca. Estádio de colheita. Forragem hibernal.

Introduction

The integration between agriculture and livestock, allocating idle agricultural land in part of the year, for cattle farming is a way of improving the livestock production indices and reducing the risks of agriculture, maximizing the use of crop areas during the year. Among the various species to be cultivated in this system, temperate grasses, such as black oat (*Avena strigosa*), are presented as alternatives for use within this context.

The quality of forage plants decreases with maturity, but as the growing time is prolonged the dry matter production per unit area increases (Pereira & Reis, 2001; Moreira et al., 2017). With advancing growth, changes result in the elevation of the contents of structural compounds, such as cellulose, hemicellulose and lignin and, in parallel, decrease cellular content (Van Soest, 1994; Moreira et al., 2017).

In addition to these changes, it is important to note that the decrease in leaf: stem ratio results in changes in plant structure. Thus, it is expected that older plants have lower content of potentially digestible nutrients (Pereira & Reis, 2001).

It has recently been suggested that the use of structural and morphogenic variables of the pasture, such as height and levels of light interception (IL) of the canopy, should be used as a reference for management (Barbosa et al., 2007). These variables are recommended because they are sensitive to variations in the supply of growth factors, allowing forage harvesting at a more constant physiological condition, which would bring benefits to forage productivity and quality (Silva &Nascimento, 2007). Despite this, only in the work of Pedreira, Pedreira and Silva (2007) the harvest based on chronological time (number of days between successive defoliations) with management by interception of light was effectively compared, showing that, under certain circumstances, IL management does not seem to be advantageous, and harvest management using fixed intervals based on technical recommendations, and depending on the climatic conditions yields good results.

Based on this premise, the goal of the present study was to evaluate the agronomic and chemical characteristics of black oat (*Avena strigosa*) under successive cuts harvested at different developmental stages for haylage production.

Material and Methods

The experiment was carried out at the Animal Production Center (NUPRAN), along with the Master's Degree in Agronomy in the Plant Production area, belonging to the Agrarian and Environmental Sciences sector of the *Central Western* Paraná *State University* (UNICENTRO), in the municipality of Guarapuava, State of Paraná, located in the subtropical zone of Paraná, at the geographical coordinates 25º23'02" South latitude and 51º29'43" West longitude, 1.026 m altitude.

The climate of the region according to the classification of Köppen is Cfb (humid, subtropical mesothermal), with mild summers and moderate winter, with no defined dry season and with severe frosts. The average annual rainfall is 1.944 mm, annual average minimum temperature is 12.7 °C, annual average maximum temperature is 23.5 °C and relative humidity is 77.9 %. Figure 1 illustrates the averages of rainfall in mm, as well as the maximum and minimum temperature in ºC during the experimental period.

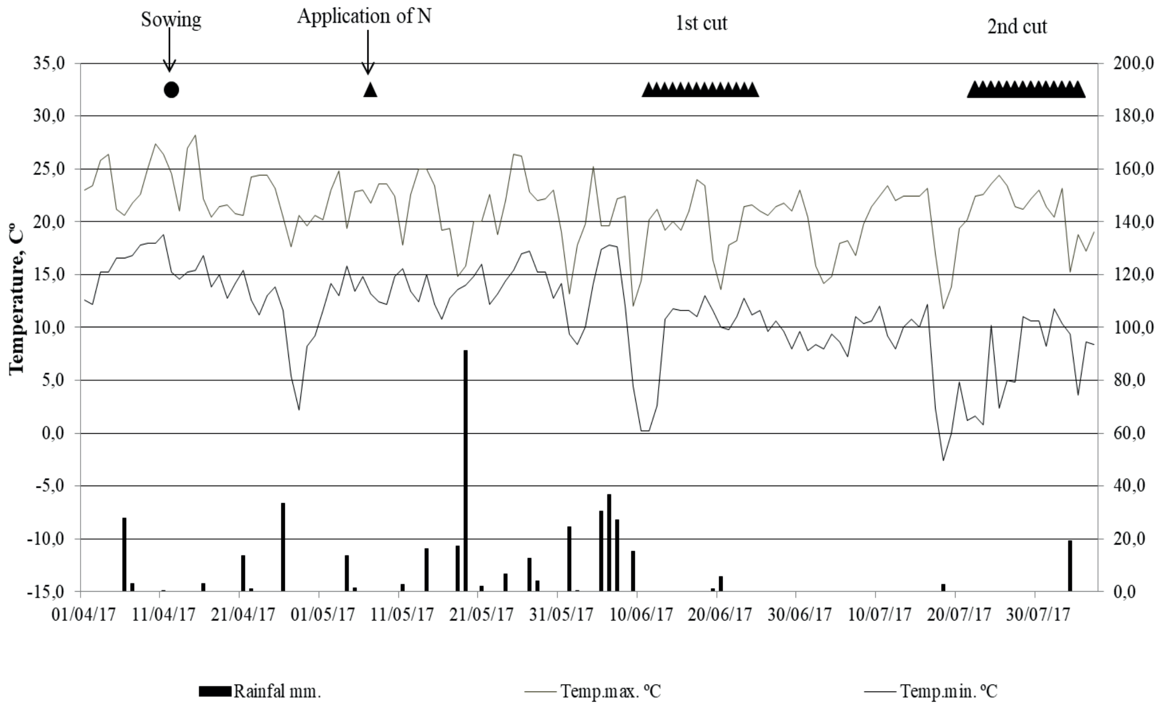


Figure 1. Rainfall averages (mm), maximum and minimum temperature (ºC) during the growing season of the crop

The soil of the experimental area is classified as Latossolo Bruno Típico (Pott, Müller, & Bertelli, 2007) and upon crop implementation, it showed the following chemical characteristics (0 to 20 cm profile): pH: 4.6; $CaCl_2$ 0.01M: 4.7; P: 1.1 mg dm^{-3}; K^+: 0.2 cmolc dm^{-3}; OM: 2.62 g dm^{-3}; Al^{3+}: 0.0 cmolc dm^{-3}; $H^+ + Al^{3+}$: 5.2 cmolc dm^{-3}; Ca^{2+}: 5.0 cmolc dm^{-3}; Mg^{2+}: 5.0 cmolc dm^{-3} and base saturation (V %): 67.3 %.

The black oat cv. Embrapa 139 was sown according to agricultural zoning for the region of Guarapuava, under no-tillage system. The sowing was done with row spacing of 0.17 m, average sowing depth of 2 cm and sowing density of 350 plants m^2. In the experimental area, corn was grown for silage production and constituted 102 m^2, distributed in 12 plots of 8.5 m^2 each (1.70 m x 5.00 m), where each plot represented an experimental unit (repetition).

The experiment was a 2 x 3 factorial randomized complete block design, consisting of six treatments, two developmental stages of the crop (vegetative and full vegetative) associated with three harvest seasons, with four replications: T_1 - vegetative stage, first cut, when light interception reached values between 90 and 95 %; T_2 - vegetative stage with harvest seven days after the first cut; T_3 - vegetative stage with harvest fourteen days after the first cut; T_4 - full vegetative stage, second cut, when again the light interception reached values between 90 and 95 %; T_5 - full vegetative stage with harvest seven days after the second cut; and T_6 - full vegetative stage with harvest fourteen days after the second cut.

At the time of sowing, we used 285 kg ha^{-1} of the fertilizer 08-30-20 (N-P_2O_5-K_2O), respecting the recommendations of Moreira (2017). Nitrogen topdressing fertilization was applied at once with 200 kg N ha^{-1}, as urea, at the full tillering stage of black oat.

Weeds were chemically controlled using glyphosate-based herbicide (Roundup WG® commercial product: 3.0 kg ha^{-1}) for desiccation of the experimental area 15 days before sowing, and in the management of the crop 30 days after planting with the application of Metsulfuron-methyl herbicide (Ally® commercial product: 6.6 g ha^{-1}).

The real sowing density was determined 15 days after emergence of the plants by counting the number of plants per linear meter per plot. Sequentially, 35 days after emergence, tillers were counted per linear meter to estimate the number of tillers plant^{-1}.

In the crop management, for the evaluation of the productive and qualitative traits of the forage, two sequential cuts were made (the first at the vegetative stage and the second at the full vegetative stage), when the light interception reached an average of 90 to 95 % in the plot. Light interception (LI), which is estimated by photosynthetically active radiation (PAR), was measured by the AccuPAR LP-80 digital linear ceptometer (Decagon, Devices). The first and second cuts in the first season were performed at 59 and 107 days after emergence (DAE), in the second season, at 66 and 114 DAE and in the 3rd season, at 101 and 176 DAE, respectively.

The cut of the plants inside the useful area of each plot was performed manually at 10 cm from the ground. The relationship between the weight of the harvested material and the area unit allowed to estimate the fresh biomass production (kg ha^{-1}). A 1 kg sample of each newly harvested material was sent to the laboratory for the physical composition analysis by separation of the structural components and dehydration in a forced air oven at 55 °C to constant weight. This practice allowed to determine the percentage composition of the anatomical structures of the plant as stem, green leaves and senescent leaves.

Immediately after harvesting, a homogeneous sample of 500 g of each plot was collected to determine the dry matter content by means of forced air drying at 55 °C to constant weight. The relationship between fresh biomass yield and dry matter content of the plants allowed to estimate the total dry biomass production (kg ha^{-1}).

The pre-dried samples of the original material were ground in a Wiley mill with a 1 mm sieve, where the total dry matter was determined in an oven at 105 ºC for 4 hours, crude protein (CP) by the micro Kjeldahl method and mineral matter (MM) by incineration at 550 °C for 4 hours according to techniques described in (Association of Official Analytical Chemists International [AOAC], 1995). The contents of neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LIG) were determined according to Silva and Queiroz (2009). From these values, hemicellulose (HEM) content was estimated by difference between NDF and ADF and cellulose (CEL), by difference between NDF and LIG. The total digestible nutrient content (TDN, %) was obtained via equation [TDN, % = 87.84 - (0.70 x ADF)], suggested by Bolsen, Ashbell and Weinberg (1996).

Dry matter degradability of forage and ruminal disappearance of DM from stem, green leaves and senescent leaves was determined by *in situ* technique using nylon bags measuring 12 cm x 8 cm and with 40-60 **μ**m pores containing 5 g dry sample of each material, ground to 1 mm, for later incubation in the rumen (Nocek, 1988). The incubation times used for forage degradability were 0, 6, 12, 24, 36 and 48 hours, in reverse chronological order and for ruminal disappearance of the stem, green and senescent leaves was 48 hours only. For this, two steers with 24 months of age, average body weight of 650 kg, with rumen fistula were used. This study was approved by the ethics committee in animal experimentation number 032/2017.

Data were tested by analysis of variance (ANOVA) and then, when differences were detected, Tukey's test was applied to compare the means at 5 % significance.

Results and Discussions

In general, the only parameter influenced by the harvest season was the production of dry biomass, where it can be observed that by delaying the harvest for 14 days, the crop reached the highest productivity in season 3 with 5.621 kg ha^{-1} dry biomass, differing ($P<0.05$) from seasons 2 and 1 with 3.511 and 3.089 kg ha^{-1} where both did not differ from each other (Table 1).

Table 1
Production of dry biomass, number of plants and tiller per m$^{2-1}$ and number of tillers per black oat plant subjected to successive cuts at different harvest seasons

Harvest season	Cuts		Total/Mean
	Vegetative	Full vegetative	
		Plant population, m$^{2-1}$	
1	317	265	291 A
2	316	237	277 A
3	332	235	284 A
Mean	321 a	246 b	
		Tillers, m$^{2-1}$	
1	568	489	529 A
2	563	515	539 A
3	579	487	533 A
Mean	570 a	497 b	
		Tillers/plant	
1	1.79	1.88	1.83 A
2	1.79	2.19	1.99 A
3	1.75	2.07	1.91 A
Mean	1.77 b	2.04 a	
		Dry biomass production, kg ha^{-1}	
1	2.146	942	3.089 B
2	2.297	1.214	3.511 B
3	2.992	2.629	5.621 A
Mean	2.478 a	15.95 b	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.

Demétrio, Costa and Oliveira (2012) compared black oat cultivars and reported that the yield of black oats subjected to two successive cuts at the vegetative stage reached a mean productivity of 4.290 kg ha^{-1} dry biomass. In turn, Grolli, Gai and Oliveira (2012) evaluated black oat cv. Embrapa 139 in two successive cuts at the vegetative stage and reported a cumulative production of 2.639 kg dry biomass ha^{-1}.

Data in Table 1 also show that the effect of successive cuts in the management of black oat forage, independent of the harvest season, leads to a reduction (P<0.05) in the plant population (321 vs 246 $plants^{2-1}$) and also a decrease in the number of tillers (570 vs 497 $tillers^{2-1}$), but generated an increase in tillering capacity (1.77 vs 2.04 tillers $plant^{-1}$) from the first to the second cut, respectively. Consequently, there was a lower (P<0.05) dry biomass production in the first cut compared to the second cut (2.478 vs 1.595 kg ha^{-1}).

In studies on black oat cultivars, Demétrio et al. (2012) found that the cultivars Preta Comum, IAPAR 61 and EMB 139 produced 1.251 kg ha^{-1}, 1.095 kg ha^{-1} and 1.040 kg ha^{-1} dry matter, respectively, in the first cut; these results are lower than those obtained in the present study. This can be probably related to the combination of factors related to the plant and the favorable soil and climatic conditions, such as relatively uniform distribution of rainfall during the period and high natural fertility of the soil, since the availability of nutrients in the soil is of great importance for forage growth (Primavesi, Primavesi, Cantarella, & Godoy, 2004).

Primavesi, Primavesi, Cantarella and Godoy (2001) working with black oat cultivars, at different cutting and regrowth periods, with the application of 180 kg N ha^{-1}, concluded that the first cut should be done at the stem elongation phase (38-45 day after emergence), because this was the moment the cultivars presented high nutritive value and dry matter production. Rodrigues and Godoy (2000) evaluated the dry matter and crude protein of oats and found dry biomass production at 30 DAE of 1.700 kg dry biomass ha^{-1}, reaching 4.825 kg DM ha^{-1} at 100 DAE, with an opposite relationship as for the CP content, reducing of 13 % with this increase in dry biomass, results that go against those of the present study.

Leão et al. (2019) analyzed the yield of different winter cereals, including black oats, and showed that the DM production in plants not cut at the vegetative stage was higher than those subjected to one or two cuts in this phase.

Values of dry matter content of the plant and its components stem, green and senescent leaves of black oats subjected to successive cuts at different harvest seasons are listed in Table 2. The harvest season, in black oats (P<0.05) influenced the dry matter content of the whole plant and the stem. The dry matter content of the whole plant in season 3 (17.88 %) was higher (P<0.05) than in the other seasons, with 15.48 and 15.41 % for seasons 1 and 2, respectively. However, the dry matter content of the stem in season 1 presented the lowest value, 12.95 %, statistically different from season 3 with 15.00 %, but season 2 did not differ from both, with 14.14 %.

Still on the dry matter content, in the comparison between the cuts at the vegetative and full vegetative stages (Table 2), it can be observed that these increased (P<0.05) from the first to the second cut. The dry matter content of the whole plant obtained in the first cut with 11.70 % increased to 20.81 % in the second cut, similar behavior for dry matter content of green leaves (from 14.00 to 42.02 %) and stems (from 9.45 to 18.61 %), respectively.

Data on the physical composition of the black oat plant managed at different harvest seasons subjected to successive cuts are presented in Table 3, where the participation of green leaves reduced (P<0.05) according to the delay in harvest. In season 1, it reached the highest participation with 60.98%, reducing to 51.78% in season 2 and reached the lowest participation in season 3, 40.30%. The stem participation had an opposite behavior to that of the green leaves, where it increased (P<0.05) according to the delay in harvest, in season 1, it had the lowest participation with 34.52% increasing to 43.71% in season 2 and reaching 55.73% participation of stems in season 3.

Table 2
Dry matter contents of the whole plant, green leaves, stem and senescent leaves of black oat subjected to successive cuts at different harvest seasons

Harvest season	Cuts		Mean
	Vegetative	Full vegetative	
		Whole plant, %	
1	12.76	18.21	15.48 B
2	10.66	20.16	15.41 B
3	11.68	24.08	17.88 A
Mean	11.70 b	20.81 a	
		Green leaves, %	
1	13.13	43.39	28.26 A
2	14.12	42.48	28.30 A
3	14.76	40.20	27.48 A
Mean	14.00 b	42.02 a	
		Stem, %	
1	7.99	17.92	12.95 B
2	9.37	18.91	14.14 AB
3	11.01	19.00	15.00 A
Mean	9.45 b	18.61 a	
		Senescent leaves, %	
1	-	29.31	29.31 A
2	-	28.92	28.92 A
3	-	30.48	30.48 A
Mean	-	29.57	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.

Based on the behavior of green leaf and stem participation, the leaf/stem ratio decreased (P<0.05) after 7 or 14 days after the ideal harvest time, reaching the highest value in season 1 with 1.79, reducing to 1.21 in season 2 and reaching the lowest value in season 3 with 0.72.

The reduction in leaf contribution in black oat was also observed by Leão et al. (2019) when subjected black oats to different cutting regimes, and still infer that cutting reduces the leaf area index, which promotes a reduction in leaf percentage.

The importance of the physical composition of the plant, and especially the leaf fraction is reported by Sbrissia et al. (2003), who argued that larger leaf participation will lead to higher contents of protein and soluble carbohydrates, while the supporting structures like stems have higher contents of structural carbohydrates, which may lead to a decrease in intake during grazing and also lower quality of forage for production of preserved foods, such as haylage.

Stem production in forage plants from the nutritional point of view has little importance, since it has low nutritional value, low digestibility, because it is the most lignified part of the plant, whose main function in the plant is support. The increase in stem production by the forage results in the decrease in the leaf/stem ratio significantly reducing the quality of the resulting forage (Pereira et al., 2012).

Table 3
Participation of green leaves, stem and senescent leaves in the physical composition of the plant and leaf/stem ratio of black oat subjected to successive cuts at different harvest seasons

Harvest season	Cuts		Mean
	Vegetative	Full vegetative	
		Green leaves, % DM	
1	62.78	59.18	60.98 A
2	50.59	52.98	51.78 B
3	44.45	36.16	40.30 C
Mean	52.60 a	49.44 b	
		Stem, % DM	
1	37.22	31.82	34.52 C
2	49.41	38.02	43.71 B
3	55.55	55.91	55.73 A
Mean	47.39 a	41.91 b	
		Senescent leaves, % DM	
1	-	8.92	8.92 A
2	-	9.05	9.05 A
3	-	10.07	10.07 A
Mean	-	9.34	
		Leaf/stem ratio	
1	1.71	1.88	1.79 A
2	1.03	1.40	1.21 B
3	0.80	0.65	0.72 C
Mean	1.18 a	1.31 a	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.

In the comparison between the phenological stages, the first cut at the vegetative stage resulted in the highest participation of green leaves with a mean value of 52.60%, differing from the second cut at the full vegetative stage, with 33.16%, while the stem participation showed a similar behavior, in which at the vegetative stage, it presented 47.39%, reducing to 41.91% ($P<0.05$) at the full vegetative stage (Table 3).

Table 4 lists the ruminal disappearance data of the green leaves, stems and senescent leaves of black oat managed at different harvest seasons and subjected to successive cuts. The only component that was influenced by the harvest time in ruminal disappearance was the green leaves. According to the delay in harvest, there was a reduction in ruminal disappearance ($P<0.05$) at each season; in season 1 there was the highest disappearance with 68.14 %, falling to 60.78% in season 2 and reaching 55.43% in season 3.

Regarding the ruminal disappearance of the plant components between the phenological stages (Table 4), the stem and green leaves presented higher ($P<0.05$) disappearance (68.37 % vs 54.68 % and 59.68 % vs 46.25 %, respectively) in the first cut at the vegetative stage compared to the second cut at the full vegetative stage.

In the evaluation of the nutritional value of the forage (Table 5), the harvest season influenced the contents of neutral and acid detergent fiber. Black oat when harvested in seasons 1 and 2 presented neutral detergent fiber values of 46.00 % and 47.00 % respectively, both differing ($P<0.05$) from season 3 with a value of 50.01% neutral detergent fiber. The contents of acid detergent fiber increased and statistically differed between the seasons according to the delay in harvest; in season 1 the lowest value was observed (28.26 %), increasing in season 2 to 32.13 % and reaching the highest value in season 3 with 34.97 % acid detergent fiber.

Table 4
Ruminal disappearance of stem, green and senescent leaves, under incubation for 48 hours of black oat subjected to successive cuts at different harvest seasons

Harvest season	Cuts		Mean
	Vegetative	Full vegetative	
		Green leaves, %	
1	78.75	57.54	68.14 A
2	66.94	54.62	60.78 B
3	59.44	51.43	55.43 C
Mean	68.37 a	54.53 b	
		Stem, %	
1	63.11	44.83	53.97 A
2	58.06	49.42	53.74 A
3	57.87	44.50	51.18 A
Mean	59.68 a	46.25 b	
		Senescent leaves, %	
1	-	38.03	38.03 A
2	-	39.78	39.78 A
3	-	38.28	38.28 A
Mean		38.69	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.

Gomes and Stumpf (2001) evaluated the crude protein and neutral detergent fiber contents of black oat cv. EMBRAPA 29 under the effects of three cutting intervals (21, 35 and 49 days), and found contents of crude protein of 20.5 %, 18.8 % and 18.0 % and neutral detergent fiber of 42.0 %, 44.1 % and 55.2 %, respectively. Meinerz et al. (2011) examined different cultivars of black oat and subjected them to three cuts found a reduction of 7.12 % in crude protein contents from the first to the third cut.

In the comparison between the phenological stages, independent of the harvest season, the crude protein contents were higher ($P<0.05$) in the first cut at the vegetative stage with 24.68 % compared to the second cut at the full vegetative stage, which reached values of 17.35 %; the mineral matter contents followed the same tendency, at the vegetative stage, it was superior to the full vegetative stage, 8.34% and 5.36% respectively. In turn, the neutral detergent fiber content at the vegetative stage reached values of 55.18 %, which differed ($P<0.05$) from the vegetative stage, with 40.16%. On the other hand, the content of acid detergent fiber followed the same trend and at the vegetative stage presented values of 35.54 % reducing ($P<0.05$) to 28.03 % at the full vegetative stage.

Table 6 presents the contents of hemicellulose, cellulose, lignin, total digestible nutrients and in situ degradability of dry matter of black oat forage managed at different harvest seasons and subjected to successive cuts. Harvest season significantly influenced ($P<0.05$) the contents of hemicellulose, cellulose, total digestible nutrients and in situ degradability of the whole plant. Black oat when harvested in season 1 was superior ($P<0.05$) to season 2 and 3 (17.74% vs. 14.86% and 15.04%, respectively). On the other hand, cellulose contents increased according to the delay in harvest ($P<0.05$) in each season; in season 1, with 21.48% increasing to 24.71% in season 2 and reaching 28.40% in season 3. The total digestible nutrient content revealed the same behavior; in season 1 the highest ($P<0.05$) value was found, 68.05%, reaching 65.34% in season 2 and reaching the lowest value in season 3, with 63.36%.

Table 5
Crude protein (CP), mineral matter (MM), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of black oat subjected to successive cuts at different harvest seasons

Harvest season	Cuts		Mean
	Vegetative	Full vegetative	
		Mineral matter, % DM	
1	8.87	5.32	7.09 A
2	8.55	5.28	6.91 A
3	7.60	5.50	6.55 A
Mean	8.34 a	5.36 b	
		Crude protein, % DM	
1	26.30	16.19	21.24 A
2	24.31	17.19	20.75 A
3	23.43	18.68	21.05 A
Mean	24.68 a	17.35 b	

continue

continuation

		Neutral detergent fiber, % DM	
1	50.42	41.59	46.00 B
2	55.16	38.83	47.00 B
3	59.96	40.07	50.01 A
Mean	55.18 a	40.16 b	
		Acid detergent fiber, % DM	
1	32.33	24.20	28.26 C
2	35.70	28.57	32.13 B
3	38.61	31.33	34.97 A
Mean	35.54 a	28.03 b	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.

When comparing the phenological stages, regardless of the harvest season (Table 6), the contents of hemicellulose, cellulose, lignin and in situ degradability of the whole plant decreased from the first cut at the vegetative stage to the second cut at the full vegetative stage (P<0.05), from 16.63% to 12.13% in hemicellulose, from 27.91% to 21.81% in cellulose, from 7.63% to 6.21% in lignin and from 76.62% to 73.83% in in situ digestibility of the whole plant. The only parameter that increased (P<0.05) in the second cut was the total digestible nutrient content, from 62.95% in the first cut to 68.21% in the second cut.

In relation to the ruminal disappearance rate of the forage (Figure 2), it is possible to observe that the first cut, independent of the harvest season, obtained a higher concentration of soluble nutrients, representing the intercept of the curve, with 46.60% 36.04% and 35.85% for seasons 1, 2 and 3 respectively. The lower concentration of total soluble nutrients in the second cut (full vegetative) in both stands may be related to the higher proportion of stems in this cut.

Table 6
Hemicellulose (HEM), cellulose (CEL), lignin (LIG), total digestible nutrients (TDN) and in situ dry matter degradability of the whole plant under incubation for 48 hours of black oat subjected to successive cuts at different harvest seasons

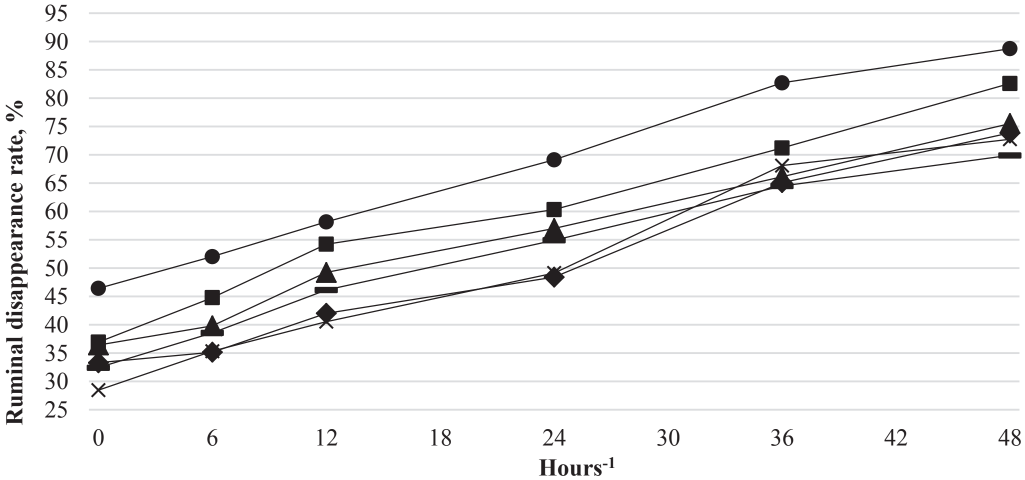
Harvest season	Cuts		Mean
	Vegetative	Full vegetative	
		Hemicellulose, % DM	
1	18.09	17.40	17.74 A
2	19.46	10.26	14.86 B
3	21.35	8.74	15.04 B
Mean	16.63 a	12.13 b	

continue

continuation

		Cellulose, % DM	
1	25.35	17.61	21.48 C
2	27.80	21.63	24.71 B
3	30.59	26.21	28.40 A
Mean	27.91 a	21.81 b	
		Lignin, % DM	
1	6.98	6.59	6.78 A
2	7.90	6.94	7.42 A
3	8.02	5.12	6.57 A
Mean	7.63 a	6.21 b	
		Total digestible nutrients, % DM	
1	65.21	70.90	68.05 A
2	62.85	67.84	65.34 B
3	60.81	65.91	63.36 C
Mean	62.95 b	68.21 a	
		in situ degradability of the whole plant, %	
1	81.62	76.07	78.84 A
2	78.42	75.52	76.97 A
3	69.82	69.92	69.87 B
Mean	76.62 a	73.83 a	

Mean values followed by different uppercase letters in the same column in the comparison between harvest seasons are significantly different by Tukey's test at 5 %.
Mean values followed by different lowercase letters in the same row in the comparison between cuts are significantly different by F-test at 5 %.



● TDMS Season 1 – Vegetative: 46.6057 + 0.9260H (CV: 13.23%; R2: 0.9189; P=0.0001) where H represents hours of incubation, ranging from 0 to 48 hours;
■ TDMS Season 2 – Vegetative: 36.0412 + 0.8959H (CV: 18.23%; R2: 0.9002; P=0.0001);
♦ TDMS Season 3 – Vegetative: 35.8502 + 0.8890H (CV: 10.25%; R2: 0.8905; P=0.0001);
▲TDMS Season 1 – Full vegetative: 30.6851 + 0,8958H (CV: 8.52%; R2: 0.9315; P=0.0001);
x TDMS Season 2 – Full vegetative: 28.4602 + 0.8850H (CV: 14,02%; R2: 0.8845; P=0.0001);
– TDMS Season 3 – Full vegetative: 32.4305 + 0.8605H (CV: 9.25%; R2: 0.8901; P=0.0001).

Figure 2. Ruminal disappearance rate of dry matter of forage of black oat subjected to successive cuts at different harvest seasons.

Paris, Zamarchi, Pavinato and Martin (2015) observed changes in the fiber portion as the oat developmental stage advanced. First, the carbohydrate proportion in the cell wall increases, but simultaneously, the characteristics of the chemical composition and digestion are also altered. Feed intake and digestibility are dependent on the kinetics of digestion in the rumen. This explains the fact that season 3 resulted in a lower nutritional value in relation to the other seasons.

Conclusion

The delay of 7 or 14 days from the ideal harvest time of the black oat forage reduced the nutritional quality.

The first cut at the vegetative stage resulted in higher dry biomass production, greater participation of green leaves in the dry matter and better digestibility of green leaves and stem compared to the second cut at the full vegetative stage.

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