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DYNAMICS OF MILLET STRAW CULTIVATED AT DIFFERENT SOWING DATES IN THE OFF-SEASON

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Abstract – The millet straw dynamics at different sowing dates in the off-season were evaluated in an experiment conducted in Rio Verde-GO. The experimental design used was randomized blocks arranged in a split-plot scheme, with four replications and four sowing dates. Five millet genotypes, two cultivars (ADR300 and ADR500) for biomass production, a dual-purpose hybrid (ADR8010) for grain and biomass production, and two hybrids (ADR9010 and ADR 9020) for grain production were used. Biomass production was performed at 0, 60, 94, 140, and 178 days after grain harvest. The millet cultivars and hybrids showed similar dry biomass production at different sowing dates, with an average production of 8,917 kg ha^{-1}. The ADR300 and ADR500 cultivars and the ADR8010 hybrid showed similar dry biomass decomposition rates at all sowing dates. The hybrids ADR9010 and ADR9020 showed lower rates of straw decomposition in the fourth sowing date than the other genotypes. The hybrids ADR9010 and ADR9020, specific for grain production, have the potential for biomass production similar to the cultivars, regardless of the sowing dates.

Keywords: *Pennisetum glaucum*, direct sowing, modeling, straw half-life.

DINÂMICA DA PALHADA DE MILHETO CULTIVADA EM DIFERENTES ÉPOCAS DE SEMEADURA NA ENTRESSAFRA

Resumo - Com o objetivo de avaliar a dinâmica da palhada de milheto em diferentes épocas de semeadura em safrinha, instalou-se um experimento em Rio Verde-GO. O delineamento experimental utilizado foi o de blocos ao acaso, com parcelas subdivididas, com quatro repetições e quatro épocas de plantio. Foram utilizados duas variedades (ADR300 e ADR500) e um híbrido de milheto de duplo propósito (ADR8010) para produção de grãos e biomassa, e dois híbridos graníferos (ADR9010 e ADR 9020). A produção de biomassa foi realizada nos tempos 0, 60, 94, 140 e 178 dias após a colheita dos grãos. As variedades e híbridos de milheto apresentaram semelhanças na produção de biomassa seca nas diferentes épocas de plantio, com produção média de 8.917 kg ha^{-1}. As variedades ADR300 e ADR500 e o híbrido ADR8010 apresentaram semelhança nas taxas de decomposição de biomassa seca em todas as épocas de plantio. Os híbridos ADR9010 e ADR9020 apresentaram menores taxas de decomposição da palhada na 4ª época de plantio que as variedades. Os híbridos ADR9010 e ADR9020, específicos para a produção de grãos, apresentam potencial para produção de biomassa semelhante às variedades, independente da época de plantio.

Palavras-chave: *Pennisetum glaucum*, semeadura direta, modelagem, meia-vida da palhada.

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Millet is a plant of the grass family (Poaceae) that is highly adapted to the Brazilian Cerrado, where the fertility level is low, and the dry season is well characterized in the off-season. Its high adaptability to Cerrado conditions is due to its high capacity to tolerate prolonged water deficit and low rainfall requirement for its cycle, around 400 mm. Furthermore, millet has a deep root system and can, therefore, recycle nutrients from deeper soil layers, which helps the successor crops (Delazeri et al., 2020). In addition, it has rapid seedling establishment and a significant growth rate, as these are cultures with an early phenological cycle (Assis et al., 2016).

Millet is grown for forage, ground cover, and grain production. During the last 30 years, its use as a cover crop preceding no-till soybean [*Glycine max* (L.) Merrill] has expanded considerably (Assis et al., 2018). Consequently, it generates numerous benefits to production systems in the Cerrado, such as high biomass production and nutrient cycling (Pacheco et al., 2017; Soratto et al., 2019).

Although millet cultivation in Brazil is mainly focused on straw production, great demand for grains, especially in the off-season in the Cerrado region, has given rise to interest in introducing specific hybrids for grain production.

For this, new genotypes have been launched. These genotypes have a lower plant height, thus reducing lodging, but little is known about these materials' biomass producing capacity. Studies involving millet sowing dates in the off-season are still incipient, especially with the new genotypes with grain production aptitude.

The recommendation for optimal biomass production in the Cerrado region is estimated at approximately 10,000 to 12,000 kg ha^{-1} year^{-1} of dry biomass residue (Sá et al., 2015; Andrade et al., 2018), due to the high decomposition rate taking place in tropical regions. Furthermore, considering that the soybean crops biomass production in the summer is around 3,000 kg ha^{-1} (Pittelkow et al., 2012), the millet crop in the off-season gains relevance as an option for the supplementary straw supply to reach the ideal annual production.

Several studies with millet with the objective of biomass production were carried out. Marangoni et al. (2017) obtained 6,000 kg ha^{-1} of dry biomass of millet ADR 300, 120 days after sowing in Urutaí (GO). Costa et al. (2015) got 9,993 and 7,792 kg ha^{-1} of biomass after 45 days of cultivation in two agricultural years in a Cerrado area in Selvíria (MS). Assis et al. (2016), with cultivars ADR 300 and ADR 500 at 50 days after sowing, observed values of 14,189 and 15,396 kg ha^{-1}, respectively. Boer et al. (2008) verified the production of 10,801 kg ha^{-1} of millet ADR500 dry biomass managed in full bloom in the Center-West region of Brazil in the off-season. The evaluation after the desiccation time also influences the biomass amount. In a study by Pacheco et al. (2017), ADR 300 millet biomass values of 10,842, 7,296, and 5,950 were detected after 0, 15, and 30 days after desiccation.

Straw decomposition in the Cerrado is accelerated, whose decomposition rate is higher than in temperate regions (Lal & Logan, 1995, Andrade et al., 2018; Delazeri et al., 2020). When comparing millet with pigeon pea, Marangoni et al. (2017) observed that millet was the most resistant species to decomposition, presenting a percentage of biomass loss of 31% in 70 days. In a review by Andrade et al. (2018), millet had a half-life (t½) ranging from 105-131 days in six agricultural years of evaluation under Cerrado conditions, while Boer et al. (2008) obtained a half-life (t½) of 105 days for ADR500

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when managed at full bloom.

The time length of plant residues on the soil is crucial when choosing cover plant species in Cerrado agricultural systems (Assis et al., 2016; Delazeri et al., 2020). The decomposition rate is directly related to the C/N ratio of plant residues on the soil, whose value below 25 indicates accelerated decomposition (Costa et al., 2015). In this sense, when implementing an experiment in the Center-West region of Brazil to evaluate the green and dry biomass production, Boer et al. (2008) found that the ADR500 millet showed the highest C/N ratio, denoting the potential of this cover plant to maintain the soil cover due to the higher residue permanence in the soil.

This study aimed to evaluate the straw production and decomposition of millet cultivars and hybrids cultivated at different sowing dates in the off-season in Rio Verde-GO.

Material and methods

The experiment was carried out in the 2013 off-season, in the Rio Verde – Goiás, at 18º02'48" S, 55º02'43.54" W, and altitude of 809 meters. In smooth wavy relief, the soil is characterized as a Latossolo Vermelho distrófico, clayey texture, under a no-tillage system for more than five years. Initially, deformed samples from 0-20 cm soil layer were taken for soil chemical and particle-size analyses, according to the methodology proposed by Embrapa (2017).

The experimental design used was randomized blocks arranged in a split-plot scheme, with four replications. The plots corresponded to four sowing dates, as follows: first date (February 12, 2013), second date (February 19), third date (February 27), and fourth date (March 4). Five millet genotypes constituted the subplots. Two cultivars were used (ADR300 and ADR500). ADR300 is recommended for straw production in the no-tillage system, while ADR500 is recommended for grazing. Also, three millet hybrids were evaluated, one of dual-purpose (ADR8010) for grain and straw production and two for grain production (ADR9010 and ADR 9020). The hybrid ADR9020 has an intermediate size, while the ADR9010 has a smaller size. The subplots consisted of 5 rows of 4 m in length, with a spacing between rows of 0.50 m, comprising 960 m^2. The values of monthly rainfall from February 2013 to January 2014 (Table 1) were collected with a rain gauge installed near the experimental area.

Fertilization was carried out according to the soil analysis results using 350 kg ha^{-1} of NPK formulation (2-20-18) in the sowing furrow. After 20 days after seedling emergence, topdressing fertilization with urea (100 kg ha^{-1} of N) was carried out. Sowing was carried out manually, and for the furrow opening, a seed drill was used. Then, the seeds were sown, adding from 10 to 12 kg ha^{-1} of seeds according to the characteristics of each cultivar.

There was no need to use herbicides in the area where millet was sown. The plants were managed in a rainfed system. Before reaching physiological maturity, the panicles were covered with paper bags to avoid losses from bird attacks. Upon reaching physiological maturity, grain yield and plant dry biomass production were determined by collecting two samples of 1.0 m long in the two central rows in each plot. In the harvest, manually carried out, the panicles were threshed with a sieve to facilitate grain removal. Biomass production evaluation in the grain harvest took place on July 06, 2013 (1st date) and the other dates (2nd, 3rd, and 4th) on July 20, 2013. The evaluations of the 2nd, 3rd, and 4th dates occurred on the same date due to the millet cycle anticipation caused by low rainfall in the period.

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Table 1. Monthly rainfall during the experiment, 2013/2014 harvest.

Year	Rainfall (mm)											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2013	-	66	329	128	36	-	-	-	31	66	347	119
2014	137											

The results of soil chemical and particle-size analysis of the experimental area are shown in Table 2.

Table 2. Results of chemical analysis of soil in the experimental area in the 0-20 cm layer

pH	P	$S\text{-}SO_4^{-2}$	K^+	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H + Al	O.M.	SB	CEC
$CaCl_2$	------ mg dm^{-3} --------			----------------cmol$_c$ dm^{-3} --------------					g dm^{-3}	cmol$_c$ dm^{-3}	
5.2	6.64	10.1	46.0	0.12	1.66	0.53	0.03	3.28	41.3	2.31	5.59

BS	m	B	Na	Cu	Fe	Mn	Zn	Sand	Silt	Clay
%		------------------------- mg dm^{-3} ------------------------						--------- g kg^{-1} -----------		
41.3	1.3	0.19	1.00	1.03	50.78	20.81	1.93	510	120	370

O.M. – Organic matter; SB – sum of bases; CEC – cation exchange capacity; BS – Base saturation; m – aluminum saturation.

Then, after the grain harvesting, a disc harrow closed was passed on the area to standardize the straw in the area. Subsequently, straw evaluations were carried out at 0, 60, 94, 140, and 178 days after harvesting, using an iron square of 0.5 m on a side, removing the straw inside, and then placing them in identified paper bags to be sent to the laboratory.

The material was taken to an oven with forced air circulation and renewal at 65ºC for 72 hours for drying and subsequent weighing. For each sampling time, the dry biomass for the species was quantified. The levels of N and C were determined in the plant material (Malavolta et al., 1997). The analyses were carried out on the plant material at time 0, that is, at the grain harvest in all sowing dates.

The data were fitted to an exponential mathematical model to describe the plant residue decomposition, described by Wieder and Lang (1982), where: P = Po exp(-kt) where P is the amount of dry biomass existing at time t, in days; Po is the fraction of potentially decomposable dry biomass, and k the dry biomass decomposition constant. To calculate the straw half-life (t½), that is, the time required for 50% of the remaining biomass to be decomposed, the equation was used, according to Paul & Clark (1989) where: t½ = 0.693/k where t½ is the dry biomass half-life; and k is the dry biomass decomposition constant.

Regression analyses regarding dry biomass decomposition were performed using the Sigma Plot application, version 7.0, from Jandel Scientific. After linearization, the procedure described in Snedecor & Cochran (1989) was used to compare regression equations. The results of the evaluated characteristics were submitted to analysis of variance, applying the F test. For the significant effects of cultivars and hybrids, the means were compared by the Tukey test at 5% probability. The means from sowing dates were submitted to the regression analysis (Ferreira, 2019).

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Results and Discussion

There were no significant differences between millet cultivars and hybrids in dry biomass production at different sowing dates. At different sowing dates, millet cultivars and hybrids' average dry biomass yield was 8,917 kg ha^{-1} (Table 3). This production meets the recommendation of the ideal biomass production for the Cerrado region, estimated at 11,000 to 12,000 kg ha^{-1} year^{-1}. It is necessary to produce around 3,000 kg ha^{-1} of biomass from the soybean crop in the summer and the crop grown in the off-season to produce approximately 8,000 kg ha^{-1} to meet this demand. Even in grain hybrids with grain production aptitude, the biomass production was above 7,000 kg ha^{-1}, evaluated soon after grain harvest (0 days). It is observed that this result is close to the millet biomass values found in the literature under Cerrado conditions. Results reported in the literature show values of 6,000 kg ha^{-1} for ADR 300 (Marangoni et al., 2017), 7,792 kg ha^{-1} for ADR 500 (Costa et al., 2015), 7,900 kg ha^{-1} (Souza et al., 2019), for the BN2 cultivar with a variation of 8,000-11,000 kg ha^{-1} (Votuporanga/SP) and 8,000-12,000 kg ha^{-1} (Selvíria/MS) in two years of cultivation (Borges et al., 2015). However, these values can be even higher, depending on the cultivation situation and location, from 14,189 and 15,396 kg ha^{-1} for ADR 300 and ADR 500, respectively (Assis et al., 2016). These authors reported that the early phenological cycle combined with the growth rate potentiates biomass accumulation in a short growing period.

Table 3 shows that in the biomass assessments (1st to 5th assessment), there was a decrease in the proportional biomass loss, being more pronounced from the 3rd assessment (94 days), corresponding to the beginning of the rainy season (October) (Table 1). This decrease is due to straw decomposition with the initial loss of leaves and less lignified materials. Decomposers quickly use the relatively easy degradation components containing cellulose. In contrast, more resistant materials containing lignin have a relatively lower loss rate, characterizing a fast phase and a slower phase (Costa et al., 2016).

Producing plant residues that decompose slowly promotes soil preservation for a more extended period (Costa et al., 2015). For example, Marangoni et al. (2017), in the off-season period in the Cerrado environment (Urutaí/GO), obtained a reduction of ADR 300 millet biomass of 31 and 19%, respectively in the periods of 70 and 120 days after cultivation. In the current study, the more significant decomposition of the straw can be explained by the considerable rainfall and high temperatures of the region. Temperatures can reach up to 40 °C during the dry season when rains rarely occur, and increased soil water deficits are common (Assis et al., 2018).

Results in Table 4 indicate differences between the cultivars and hybrids evaluated for the content of N, carbon, and C/N ratio in the straw.

The ADR300 and ADR500 cultivars showed, in general, a higher C/N ratio with the advance of the sowing date because they are species with biomass production potential. On the 4th date, the C/N ratio of the cultivars was different from the grain hybrids, with higher values. This increase in the C/N ratio with the sowing date is related to decreased rainfall (Table 1), resulting in a shorter crop cycle and more lignified materials. A study carried out by Petter et al. (2013), combining water deficit conditions found that approximately 40% of the biomass accumulated by the ADR300 cultivar is located in the stem, a more lignified tissue with a higher C/N ratio compared to leaves. This characteristic favors

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Table 3. Remaining biomass (kg ha^{-1}) at different sowing dates and evaluations in millet varieties and hybrids.

Treatments	1st date		2nd date		3rd date		4th date	
Remaining biomass in the 1st evaluation (kg ha^{-1}): 0 days after harvest								
ADR300	10.869	a	9.507	a	8.745	a	7.627	a
ADR500	9.909	a	9.707	a	9.570	a	8.502	a
ADR8010	8.623	a	8.319	a	8.704	a	7.730	a
ADR9010	8.987	a	8.478	a	9.484	a	9.797	a
ADR9020	9.163	a	8.676	a	8.280	a	7.671	a
CV date (%)				20.65				
CV treatment (%)				19.80				
Remaining biomass in the 2nd evaluation (kg ha^{-1}): 60 days after harvest								
ADR300	8.206	a	6.249	b	7.036	a	5.686	a
ADR500	7.706	a	6.823	ab	6.689	a	6.387	a
ADR8010	6.068	a	7.612	ab	6.811	a	6.150	a
ADR9010	6.868	a	9.307	a	5.341	a	6.173	a
ADR9020	7.519	a	7.143	ab	6.405	a	7.439	a
CV date (%)				21.16				
CV treatment (%)				21.13				
Remaining biomass in the 3rd evaluation (kg ha^{-1}): 94 days after harvest								
ADR300	4.925	a	3.588	a	5.054	a	4.390	a
ADR500	5.155	a	3.720	a	3.754	ab	3.606	a
ADR8010	3.781	a	4.289	a	3.569	ab	3.175	a
ADR9010	4.086	a	3.356	a	2.902	b	2.860	a
ADR9020	5.175	a	3.746	a	3.148	b	3.413	a
CV date (%)				29.96				
CV treatment (%)				24.02				
Remaining biomass in the 4th evaluation (kg ha^{-1}): 140 days after harvest								
ADR300	4.838	a	3.358	a	2.435	a	3.635	a
ADR500	3.086	b	3.214	a	2.756	a	3.374	a
ADR8010	3.512	b	3.299	a	3.076	a	2.890	a
ADR9010	3.693	ab	2.864	a	2.711	a	2.765	a
ADR9020	3.172	b	3.599	a	2.681	a	3.229	a
CV date (%)				35.17				
CV treatment (%)				24.42				
Remaining biomass in the 5th evaluation (kg ha^{-1}): 178 days after harvest								
ADR300	2.246	a	3.256	a	2.311	a	3.504	a
ADR500	2.837	a	2.651	a	2.273	a	3.021	ab
ADR8010	2.173	a	2.587	a	2.737	a	2.066	ab
ADR9010	2.206	a	1.950	a	1.814	a	2.020	b
ADR9020	2.661	a	2.302	a	2.168	a	2.221	ab
CV date (%)				36.64				
CV treatment (%)				29.78				

Means followed by the same letter in the column do not differ by the Tukey test at 5% probability.
Sowing dates: 1st date (February 12, 2013), 2nd date (February 19), 3rd date (February 27), and 4th date (March 04).

Table 4. Nitrogen, carbon, and C/N ratio of millet cultivars and hybrids at different sowing dates.

Treatments	1st date	2nd date	3rd date	4th date
		N (g kg-1)		
ADR300	8.4 b	11.2 ab	8.4 b	8.4 b
ADR500	9.8 ab	8.4 b	9.8 ab	8.4 b
ADR8010	8.4 b	14.0 a	12.6 a	11.9 a
ADR9010	11.9 a	11.9 a	10.5 ab	14.7 a
ADR9020	8.4 b	8.4 b	11.2 ab	14.0 a
		C (g kg-1)		
ADR300	508.6 a	493.9 a	491.0 a	470.9 a
ADR500	494.8 ab	502.8 a	506.4 a	487.0 a
ADR8010	487.9 ab	503.4 a	504.4 a	503.6 a
ADR9010	498.5 ab	493.6 a	506.1 a	493.6 a
ADR9020	458.9 b	425.7 b	477.6 a	477.1 a
		C/N		
ADR300	60.5 a	44.1 bc	58.5 a	56.1 a
ADR500	51.3 a	59.9 a	52.8 ab	58.0 a
ADR8010	58.1 ab	36.7 c	40.5 c	42.7 b
ADR9010	44.3 b	44.3 bc	49.0 abc	33.8 b
ADR9020	54.6 ab	50.7 ab	42.6 bc	34.1 b

Means followed by the same letter in the column do not differ by the Tukey test at 5% probability.

Sowing dates: 1st date (February 12, 2013), 2nd date (February 19), 3rd date (February 27), and 4th date (March 04).

a lower decomposition rate, thus contributing to the longer residue permanence in the off-season. These results are analogous to those of the current study.

For this reason, residues with a higher C/N ratio (carbon/nitrogen) gain relevance for soil cover in the off-season because the higher this value is, the slower the residue decomposition. In a study in the off-season, Costa et al. (2015) observed that millet ADR500 had a C/N ratio of 34 at 45 days after emergence. Assis et al. (2016) found C/N ratio values of 20 for millet ADR 300 and 500. In this experiment, ADR500 had a C/N ratio in the four dates above 50 (Table 4). Costa et al. (2016) found a high C/N ratio for millet cv. BN2 45 days after desiccation, higher than the C/N ratio of forages *Panicum maximum* cv. Mombasa and *Urochloa brizantha* cv. Marandu with a high C/N ratio.

Table 5 shows the values of the Po and k coefficients of the regression equation P = Po exp(-kt), the respective coefficients of determination (R^2), and the half-life (t1/2) of the remaining dry biomass up to 178 days after grain harvest, for millet cultivars ADR300 and ADR500 and hybrids ADR8010, ADR9010, and ADR9020. The t½ changes between cultivars and hybrids and among sowing dates, ranging from 69 to 141 days. These variations in t½ are due to the morphological characteristics of genotypes studied, including the leaf/stem ratio, plant

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height, and chemical composition, directly reflecting the biomass decomposition speed and the climatic conditions affecting each material differently (Wieder & Lang, 1982).

The lowest t½ was found in millet ADR9010 on the 3rd date and the highest in millet ADR300 on the 4th date (Table 5). These high values can be explained by the increased capacity of the materials to cover the soil due to the prominent amount of biomass produced, associated with the high C/N ratio. In addition, it was verified that climatic conditions were relevant for plant development, influencing the C/N ratio and, consequently, the soil cover efficiency.

Torres & Pereira (2008) found results like those of this work, when they got a higher t½ for millet, with values of 131 days. The highest t½ was found in the ADR 300 cultivar with 141 days. Marangoni et al. (2017), in an experiment with millet sown in pre-harvest in Cerrado soil and managed up to 120 days, found a half-life for decomposition of ADR 300 residues of 122 days, whose data was similar to that obtained in this study for ADR 500 with a half-life of 120 days in the 2nd evaluation period. In contrast, Delazeri et al. (2020) obtained a higher t½ for millet managed in monoculture and intercropping with *Crotalaria spectabilis* of 73 days.

Efficient soil cover using the straw is one of the factors more limiting the adoption of the no-tillage system, notably due to the rapid decomposition of residues (Andrade et al., 2018). The decomposition rate is directly related to the C/N ratio of crop residues on the soil (Pacheco et al., 2017; Costa et al., 2015). This study found that millet ADR 300 had a higher C/N ratio (Table 4) in the 4^{th} sowing date, favoring the half-life for slower decomposition. This fact denotes these plants' potential as coverage due to the longer time the biomass remains in the soil. Costa et al. (2015) observed that 50% of the forage species straw decomposition (sorghum, millet, and Xaraés grass) occurred at 60 days after desiccation and crop cutting. According to Assis et al. (2016), the highest decomposition rate occurs in the first 60 days after the desiccation process. In a study by Costa et al. (2016), 14 days after desiccation, a decomposition rate of 213.53 kg ha^{-1} day^{-1} was observed for BN2 millet cultivar, whose rapid decomposition was attributed to the high temperature and precipitation after desiccation.

In the present experiment, crop residue decomposition kinetics showed a similar pattern, observing a progressive decrease in dry biomass in all materials studied (Table 5, Figure 1). Figure 1 shows the decomposition of the remaining dry biomass. It is possible to notice the similarity between the materials used, with an average decomposition rate, showing a similar behav ior in the straw decomposition for the cultivars (ADR300 and ADR 500) and hybrids.

Table 6 and Figure 2 show the remaining dry biomass decomposition regression equations for the millet cultivars (ADR300 and ADR500) and hybrids (ADR8010, ADR9010, and ADR9020). They were similar on the 1st, 2nd, and 4th dates. Thus, it can be inferred that straw decomposition has the same behavior for the materials studied. Despite the grain millets having a more remarkable aptitude for grain production, they had high biomass production.

The remaining biomass reduction regarding the evaluation time occurred due to the degradation of crop residues from the decomposition process (Figure 1). The decomposition rate depends on the sowing period, influenced by climatic conditions, mainly temperature and humidity (Costa et al., 2016; Andrade et al., 2018). It also depends on each plant species' chemical characteristics, generating

Table 5. Coefficients of the regression equation, P = Po.exp.(-kt), and half-life, for straw decomposition of ADR300, ADR500, ADR8010, ADR9010, and ADR9020 from 0 to 178 days after harvest at different sowing dates

Dates	Coefficients of the regression equations			
	Po	k	R^2	Half-life (days)
	ADR300			
1st date	11,166.26	0.0072	0.94**	96
2nd date	9,373.39	0.0075	0.94**	92
3rd date	9,217.35	0.0072	0.93**	96
4th date	7,544.71	0.0049	0.98**	141
	ADR500			
1st date	10,278.11	0.0072	0.96**	96
2nd date	9,811.88	0.0080	0.96**	120
3rd date	9,756.31	0.0085	0.97**	82
4th date	8,548.24	0.0067	0.94**	103
	ADR8010			
1st date	8,707.57	0.0073	0.97**	95
2nd date	8,850.13	0.0064	0.88*	108
3rd date	8,908.61	0.0072	0.93**	96
4th date	7,978.65	0.0074	0.92**	94
	ADR9010			
1st date	9,229.81	0.0071	0.95**	98
2nd date	9,471.05	0.0073	0.70*	95
3rd date	9,435.61	0.0101	0.98**	69
4th date	9,858.73	0.0098	0.96**	71
	ADR9020			
1st date	9,609.76	0.0067	0.94**	103
2nd date	9,002.42	0.0070	0.91*	99
3rd date	8,528.56	0.0079	0.92**	88
4th date	8,239.41	0.0065	0.81*	107

(**) and (*) Significant at 1 and 5% probability, respectively.

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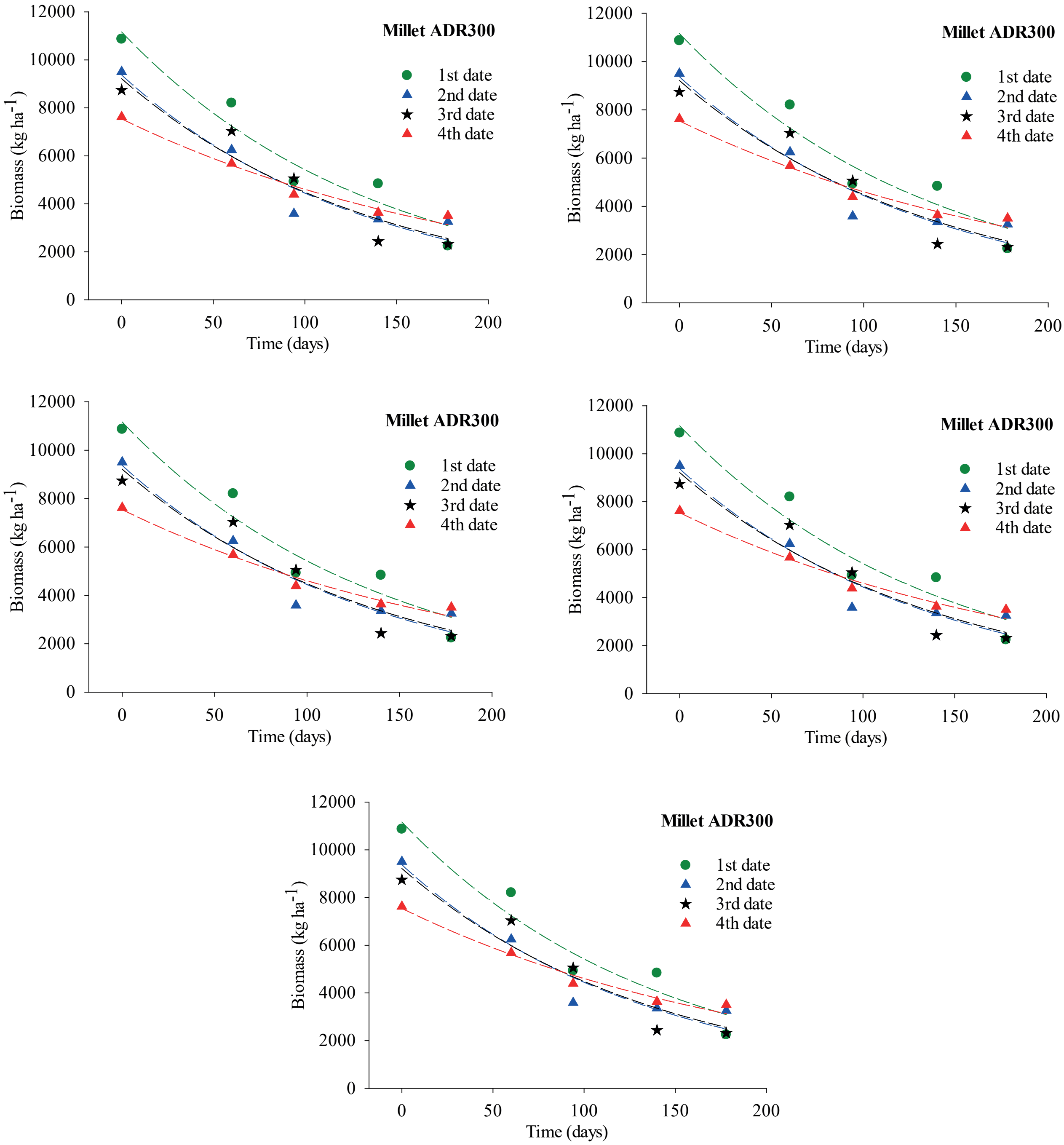

Figure 1. Average remaining dry biomass of ADR300, ADR500, ADR8010, ADR9010, and ADR9020, in the time interval between 0 and 178 days after harvest, at different sowing dates.

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Table 6. Comparison of regression equations, after linearization, for straw decomposition of ADR300, ADR500, ADR8010, ADR9010, and ADR9020 from 0 to 178 days after grain harvest at different sowing dates

Treatments	F			
	1ª	2ª	3ª	4ª
ADR300 vs. ADR500	NS	NS	NS	NS
(ADR300 + ADR500) vs. ADR8010	NS	NS	NS	NS
(ADR300 + ADR500 + ADR8010) vs. ADR9010	NS	NS	*	NS
(ADR300 + ADR500 + ADR8010 + ADR9010) vs. ADR9020	NS	NS	-	NS
Recalculating from the 3rd date				
(ADR300 + ADR500 + ADR8010) vs. ADR9020			NS	
ADR9010 vs. ADR9020			NS	

(*) Significant at 5% probability and (NS) not significant.

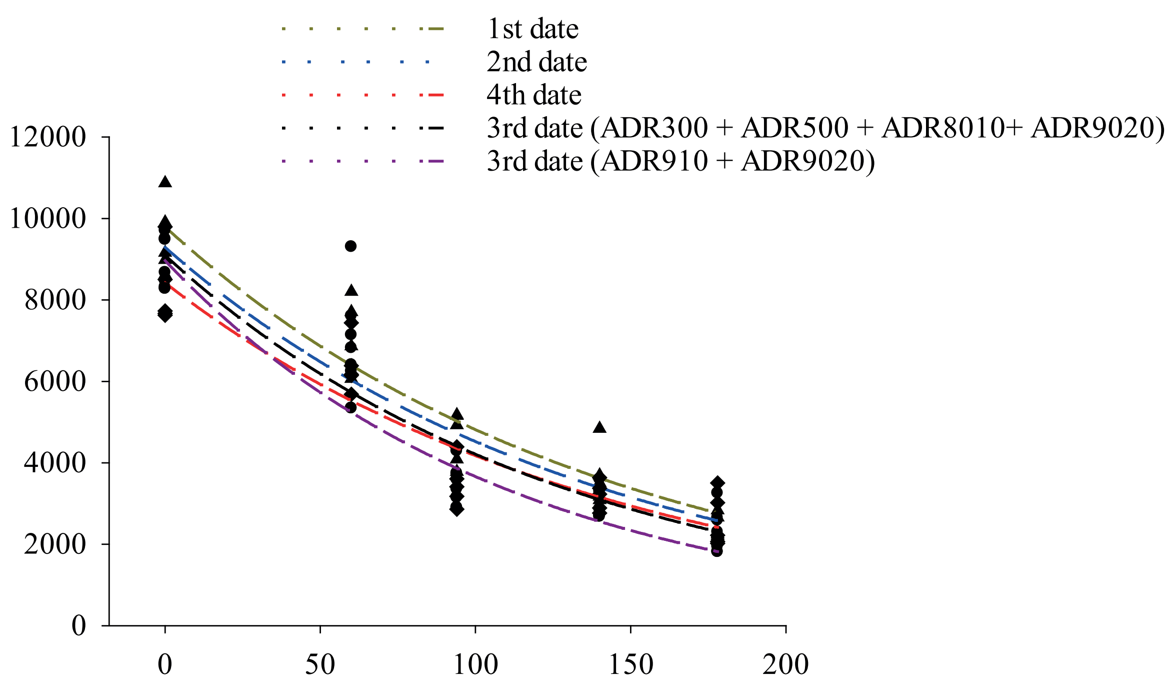

Figure 2. Regression equations fitted for dry remaining dry biomass of crop residues the millet cultivars and hybrids, up to 178 days after grain harvest at different sowing dates

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variability in decomposition rates, aspects agreeing with those found in this study.

Kliemann et al. (2006), in a study in the Cerrado region, evaluated the behavior of grasses: sorghum, Mombasa grass, BN2 millet, Brachiaria, from the intercropping with corn and brachiaria, and observed biomass losses from the straw at 150 days of 80, 64, 58, 56 and 56% respectively. In the present study, an average biomass loss was observed in millet genotypes at 178 days of 75% on the 1st date, 71% (2nd date), 75% (3rd date), and 69% (4th date) (Table 3). It is observed that, regardless of the sowing dates, the decomposition dynamics between the genotypes and in the sowing dates were very alike. Costa et al. (2015), in a study in the Cerrado (Selvíria/MS), with grain sorghum, millet ADR 500 and Xaraés grass for biomass production, desiccated 45 days after emergence, observed at 180 days after management, that the sorghum and millet dry masses showed less decomposition than Xaraés grass. The authors attributed this to the lower contact of the straw produced by these two crops with the soil surface and decomposing agents and the higher total C/N and Lig/N ratio compared with Xaraés grass.

Once the non-significance between the equations (Table 6 and Figure 2) was proven, the values of the evaluation days after management and the remaining dry biomass were then gathered, and a new equation was fitted for millet (ADR300, ADR500, ADR8010, ADR9010, and ADR9020). In the 1st date P = 9796.51 exp(-0.0071t) with R^2 = 0.91**, in the 2nd date P = 9293.50 exp(-0.0072t) with R^2 = 0.86** and in the 4th date epoch P = 8421.32 exp(-0.0070t) with R^2 = 0.87**. In the 3rd date, millets ADR300, ADR500, ADR8010, and ADR9020 did not show significance between the equations, and a new equation was adjusted P = 9098.27 exp(-0.0077t) with R^2 = 0.92**. In the 3rd date, millet ADR9010 and ADR9020 did not show significance between the equations and a new equation was generated: P = 8965.94 exp(-0.0090t) with R^2 = 0.94**.

The decomposition behavior of comparable millet straws in the 1st, 2nd, and 4th dates is due to the high C/N ratio of the genotypes studied. The hybrids ADR9010 and ADR9020 showed similar behavior in straw decomposition in the 4th sowing date (Table 6). This fact can be attributed to the similar C/N ratio between the genotypes, resulting in similar behavior in straw decomposition.

In the Cerrado region, efficient soil cover with straw is one of the factors that most limit direct sowing sustainability, mainly due to the accelerated residue decomposition. Under these conditions, millet represents a strategy to increase soil cover efficiency, especially before summer cultivation.

Conclusions

The millet cultivars and hybrids showed similarities in dry biomass production at different sowing dates, with an average production of 8,917 kg ha^{-1}.

The ADR300 and ADR500 cultivars and the ADR8010 hybrid showed similar dry biomass decomposition rates at all sowing dates.

The ADR9010 and ADR9020 hybrids showed lower straw decomposition than the varieties in the 4th sowing date.

The ADR9010 and ADR9020 hybrids, specific for grain production, have biomass production potential similar to the cultivars, regardless of the sowing date.

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