Australian Journal of Crop Science AJCS
AJCS 16(07):982-989 (2022) ISSN:1835-2707
doi: 10.21475/ajcs.22.16.07.p3652

Cover crops biomass yield grown as a 2nd summer crop in relation to sowing periods

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Abstract

The aim of this study was to evaluate cover crop precocity and biomass yield growth as a 2nd summer crop after soybean at different sowing periods (January 2nd; February 2nd and March 2nd at 2019 and January 27th and March 3rd at 2020). Experiment was laid out as a randomized block design in a 3x3 factorial for each sowing period, in the 2019 and 2020 off-seasons, being factor A represented by the cover crops (*Urochloa brizantha* cultivar Xaraés, *Crotalaria juncea* cultivar IAC-KR-1 and *Pennisetum glaucum* cultivar ANm 38,) and factor B by the evaluation periods along cover crops development cycle. There was an interaction between cover crops and evaluation period for plant height and dry matter yield for both years. *C. juncea* and *P. glaucum* showed faster growth, regardless of the evaluation period and sowing periods, compared to *U. brizantha* in both years. Cover crop biomass yield reduced as sowing period is delayed from January to March to an extend that *P. glaucum* yield dropped from 14.6 to 4.2 t DM ha^{-1} at 2019 and from 14.4 to 6.9 t DM ha^{-1} at 2020 as a result shorter photoperiod and lower temperature. The same was noticed to *U. brizantha* and *C. juncea* which showed yields of 11.676 and 8.800 and 2.220 and 2.555 kg ha^{-1} at April 29th of 2019 and 12.507 and 7.812 and 3.041 and 2.346 kg DM ha^{-1} at June 18th 2020 respectively for January and March sowing periods. *U. brizantha* and *C. juncea* are more viable 90 days, while *P. glaucum* showed the fastest dry matter accumulation rate. All species are viable due to the benefits they provide to the productive system, which becomes more diversified and therefore more sustainable.

Keywords: *Crotalaria juncea;* Dry matter biomass., *Pennisetum glaucum.,* plant height., *Urochloa brizantha.*
Abbreviations: DAS_days after sowing; DM_dry matter biomass; OM_organic matter.

Introduction

The intensive use of soil with cash crops and the increase use of defensives has resulted in high pressure selection and new cases of weed and pest resistance, have appeared with an unprecedented frequency. In this context, it is proposed to introduce cover crops in part of the area in the off-season, to reduce production risks and management problems with resistant weeds, compacted and biologically poor soils, and disease problems due to lack of crop rotation (Spehar and Trecenti, 2011).
Studying and understanding the productive potential of cover crops sowed from January to March will help foster its use. Thus, after summer crop, there are some areas left fallow, which are more prone to soil and nutrients losses by erosion, and weed infestation (Peterson et al., 2019), which over time, has resulted in a shorter productive potential and higher production costs due to the additional use of herbicides, fertilizers, and soil mechanical intervention (Rossetti and Centurion, 2015).
The adoption of cover crops favors other crops in rotation, thanks to the residual effect (Van Westering et al., 2021), and with time, it increases the soil organic matter content (OM), which is directly related to the addition of nitrogen (N) into soil. Besides, the use of cover crops reduces soil compaction and weed occurrence (Debiasi et al., 2011) and provides chemical, physical, and biological soil improvements allowing better soil health fertility (Albuquerque et al., 2013).
One of the premises for success in biomass production is the correct choice of cover crops to be used, which must be adapted to the conditions of the cultivation site, as well as its precocity with rapid establishment capacity (Alvarenga et al., 2001; Pacheco et al., 2013). Also, characteristics that contribute to greater weed suppression and improved soil properties include greater plant height and biomass accumulation, earlier canopy closure, and nutrient uptake and accumulation capacity, important for nutrient cycling in the soil-plant system (Albuquerque et al., 2013; Bajwa et al., 2017; Kunz et al., 2016).
Thus, cover crop biomass production depends mainly on its sowing and growth period length, which is directed affected by the time of the year, since fall and winter weather condition may impair growth due to low temperatures or even frost events. Edaphic, phytosanitary conditions, management practices, and, the aggressiveness of the root

system, also plays an important role on the biomass yield (Carvalho and Amabile, 2006). Therefore, studies that evaluate the growth curve of cover crops species at different periods of the year, as a result of sowing periods after soybean crop, are very important since it can support decision making in choosing the species with the greatest biomass yield potential and when to sow a next crop over these cover crops. In this context, the objective was to evaluate the accumulation curve and final biomass yield of cover crops in relation to different sowing periods along its cycle.

Results and Discussion

Cover crop development and height

When analyzing the accumulation rate and the growth curve of the cover crops throughout its development, in each sowing period, there was an interaction between species x evaluation period for the variables, plant height, and dry matter in both studied years (Table 1 and 2).

Regarding plant height, cover crops showed the tallest height at 100 and 117 days after January sowing period at 2019, except *U. brizantha* that reached the greatest height only in the third evaluation period (117 DAS) (Table 1). It is also possible to observe that *C. juncea* and *P. glaucum* reached greater height than *U. brizantha*, regardless of the evaluation period (Table 1).

Considering the evaluation periods, it is possible to observe at 2020, that *U. brizantha*, showed a different behavior with higher growing rate as earlier as it is sowed. In this way, *U. brizantha* showed height of 79 and 39 cm, respectively, at 70 and 83 DAS for the sowing period of Jan 27th and March 3rd (Table 1). *C. juncea* showed similar results to the previous year with the highest heights in the last evaluation periods at 70 and 119 DAS, and *P. glaucum* showed a stable growth, increasing its biomass as time pass by, although, earlier sowing at the year also resulted in taller height (Table 1). It is important to highlight that days goes shorter and temperature goes down from December 21st to June 21st which represents the beginning of summer and the beginning of winter. This condition direct affect plant development and biomass yield potencial for tropical species.

Similarly to the 2019 off-season, when the behavior of the species is observed within each evaluation period in the 2020 crop, *C. juncea* and *P. glaucum* had higher height compared to *U. brizantha* at 42 and 70 DAS (Table 1). *C. juncea* stood out among the species, showing the greatest height when sown in January of 2020, behavior is also seen when sown in February of the previous year (Table 1). Even tough year are not been compared, it is possible to observe a shorter final height as sowing period was delayed from January up to March. When cover crops were sown in February, according to the evaluation period, the highest height was found at 86 DAS when compared to 69 and 54 DAS for all species, a result similar to what was found for the first sowing period and which is maintained in the third period (Table 1). Also, for this second sowing season of the 2019 off-season, we highlight the growth potential of *C. juncea*, which grew an average of 2.78 cm per day, compared to *P. glaucum* and *U. brizantha*, which grew an average of 2.53 and 1.29 cm per day respectively (Table 1).

Trying to compare height at the similar periods after sowing at the different periods, it may be cited the height values of 201, 205 and 152 cm reached by the *P. glaucum* at 85, 86 and 58 DAS when sowed at January, February and March 2nd. January and February sowing showed a similar development and height, although, March sowing resulted in a lower increase in plants height, probably as a result of lower temperatures reported for this period of the year (Figure 1).

Regarding the behavior of the species when sown in March in both years, it is possible to verify that all cover species showed the same behavior in relation to the evaluation period, with the highest height found at the last evaluation period at 58 and 107 DAS for the years 2019 and 2020 respectively, except *C. juncea* that showed no difference in height when evaluated at 83 and 107 DAS in the second year (Table 1). Among the species, again *C. juncea* and *P. glaucum* stood out to *U. brizantha* in both years, however, *P. glaucum* did not differ from *C. juncea* at 26 and 48 DAS in the first and second year, respectively. However, it stood out from the other species at 41 and 58 DAS in the 2019 off-season. In the second year, only *C. juncea* stood out among the species (Table 1).

This contrasting difference in height between *U. brizantha* and other species can be explained by its straight growth habit (Ribeiro et al., 2016), and thus due to its slower initial growth, resulting from a longer tillering physiological cycle, followed by the elongation phase, where its growth usually becomes more accelerated after 50 days of sowing, when it begins to show accelerated growth increment compared to the other evaluated species, which can be observed in the data of this study. Moreover, it is late sowing (March 02 and 03) significantly reduces its height and therefore, the productive capacity, corroborating with Erasmo et al., (2017) which reported a strong negative impact of sowing delay from summer to fall on the height of *U. brizantha*.

In contrast, *C. juncea* showed to be a species with the fastest initial growth, probably because it is a leguminous plant with an erect growth habit (Calegari, 2019), as well as *P. glaucum*, not presenting tillering, which makes the production of photo-assimilates turned more intensely to the apical growth, generating greater heights (Petter et al., 2013). This fact makes this species interesting as green manure, weed control, and as a cover plant, since it shows a faster canopy closure (Wutke et al., 2007).

Analyzing the height data, it is possible to infer that *C. juncea* is sensitive to photoperiod, with a gradual reduction in height as sowing was delayed from January to March (Table 1). Leal et al. (2012), studying sowing periods effects over *C. juncea* development reported that plants were shorter as sowing periods were delayed from summer to fall, showing that plant are sensitive to the length of the daylight length and therefore that late sowings tend to reduce its final height.

Biomass Yield

When analyzing dry matter biomass yield of the species sown in January, during the respective evaluation periods, it is possible to see similar behavior between *U. brizantha* and *C. juncea* at 85 DAS, although, both species showed lower biomass than *P. glaucum* at the same period. Thus, *U. brizantha* and *C. juncea* showed a biomass increase as evaluation period went from 85 to 100 DAS or from March 28th to April 12th while *P. glaucum* showed it DM yield peak at 85 DAS. These result are important since can support decision making of when to sow a next crop over these cover crops, which can be a cover crop or cash crop such as black oat or wheat (Table 2). At the second year, *P. glaucum* maintained the same behavior as the previous year, showing a greater precocity in relation to the other species, although, as time pass by, the differences between *P. glaucum* and *U. brizantha* got smaller and were higher than the biomass produced by C. *juncea* which stabilized its biomass increase at 70 DAS.

Moreover, as it can be seen in Table 2, dry matter increase has stabilized at 100 DAS for all cover crop species at the January 2nd sowing period, which is represented by the growth period from 01/02 to 04/12/19. This result may be explained by the fact that *P. glaucum* reaches its reproductive stage at 85 DAS, not increasing very much its dry matter biomass after this period. *U. brizantha* and *C. juncea* showed a lower initial biomass increase, what resulted in a bigger difference from the 1st to the 2nd evaluation period. Further, when compared among species, *P. glaucum* showed the highest accumulate rate followed by *U. brizantha* and *C. juncea.*

When compared dry matter biomass yield at the January and February 2nd, sowing periods, it is possible to observe a similar increase at 85 and 86 DAS for all the cover crops, although, when sowing occurs at March 2nd yield reduction appears in a greater extend.

P. glaucum showed a dry matter (DM) accumulate rate of 102 Kg ha^{-1} dia^{-1} at the Feb 2nd sowing period, which occurred from 02/02 up to 03/28/19 and resulted in a yield of 5,517 kg DM ha^{-1} at 54 DAS. This value dropped to 72 kg DM ha^{-1} dia^{-1} at the March 3rd sowing which occurred from 03/02 up to 04/29/19 and resulted in a yield of 4220 kg DM ha^{-1} at 58 DAS. It means that for the same length of time (54 versus 58 days) there as a yield difference of 1,297 kg DM ha^{-1} between February 2nd and March 2nd sowing period. Moreover, February sowing still has part of the summer time to still increase its biomass production, while March sowing period is closer to the winter season, which limit its yield potential.

P. glaucum showed the fastest dry biomass increase and final yield with an accumulation of 14,182 kg ha^{-1} at 85 DAS at the January 1st sowing period, keeping its production higher than the other species along the evaluation periods. *U. brizantha* and *C. juncea* showed at 85 DAS a production of 7,943 and 7,463 kg ha^{-1} respectively, which did not differ in this first period of assessment, however, at 100 and 117 DAS *U. brizantha* becomes superior than *C. juncea*, which showed the lowest dry matter yield among the species (Table 2).

At the 2019 off-season, *C. juncea* sowed on February 2nd showed a dry matter biomass increase from 4,533 to 8,217 kg ha^{-1} from March 28th to April 29th. At 2020 off-season, *C. juncea* sowed on January 27th, showed a similar increase, which went from 3,607 to 6,700 kg ha^{-1} from March 09 to April 6th. These dry matter values are very interesting, since can represent a benefit effect over the next crop, which usually is wheat sowed at the middle of May. Pereira et al. (2017) evaluating *C. juncea* sown in December, reported higher biomass yield at 119 DAS, showing that biomass yield tends to decrease as time pass by from December to June since it goes form summer to winter.

Regarding the species in each evaluation period, it is observed that they do not differ when evaluated at 42 DAS at the January sowing period. In this aspect, *P. glaucum* showed similar results to 2019, with the highest dry matter accumulation rate among the species. Pacheco et al. (2011) highlight that millet (*P. glaucum*) is a species recommended for shorter off-season periods, due to its rapid growth, high biomass production, and nutrient cycling, even under stress conditions, highlighting its use potential.

Moreover, dry matter half live from *P. glaucum* is longer than *C. juncea* since approximately 40% of the accumulated mass of this species is located in the stem, which has more lignified tissues and a higher C/N ratio than the aerial part, which provides a very slow decomposition rate, causing a positive effect on the permanence of these residues for soil coverage in the off-season, which is in accordance with Sodré Filho et al. (2004). In the same way, *U. brizantha* at reproductive stages have a longer dry matter half live than *P. glaucum.*

Thus, the choose among species depends in which crop would be cultivated in sequence. For example, it the interest is for Canola, *P. glaucum* would fit best due to good amount of straw produced earlier in the season. If the interest is for wheat, sowed at 2nd half of May, *C. juncea* would fit best, since it's interesting to use a legume plant before a grass crop such as wheat.

Regarding the sowing performed in February in the 2019 off-season, it is observed that *U. brizantha* provided the highest dry mass accumulations at 69 and 86 DAS, with an average of 8,301 kg ha^{-1} compared to the first period with only 3,384 kg ha^{-1} (54 DAS). For *C. juncea*, the highest yield was obtained at 86 DAS compared to 54 and 69 DAS, with a dry matter increase of 2,227 kg ha^{-1} between the last two evaluation periods. *P. glaucum*, reached the highest accumulation of dry mass only in the third evaluation period (86 DAS) (Table 2). It shows that a latter sowing periods, longer growth length is necessary to reach the same amount of biomass produced at earlier sowing periods, and most of the times, it is not reached due to worse edafoclimatic wheater conditions.

Regarding the productivity of dry mass among the species analyzed for sowing in February in the off-season 2019, *P. glaucum* showed a difference to *U. brizantha* at 54 DAS, however, *C. juncea* showed no significant difference to the other species for this evaluation period. At 69 DAS, *P. glaucum* continues to stand out with the highest productivity of dry matter, followed by *U. brizantha* and *C. juncea*, responsible for the lowest accumulation in this second period. In the third period at 86 DAS, it is possible to verify a similar behavior to the first periods (54 and 69 DAS) for *P. glaucum*, which again showed superiority over other species with an accumulation of dry matter of 165 kg DM ha^{-1} per day. *U. brizantha* and *C. juncea* showed similar values, which produced 99 and 96 kg DM ha^{-1} per day respectively (Table 2).

C. juncea and *U. brizantha* biomass yield did not differ in 2020 when evaluated at 70 and 119 DAS (Table 2), and thus becoming good options for off-season periods longer than 80 days, where they can express the maximum productive potential when sown in January and February. Furthermore, a consortium between these two species, sown in a mix, would be a good alternative to reduce establishment costs from *C. juncea* seeds and allow a better biomass composition for occupying the areas even in winter, when there is no plan to grown wheat, since *U. brizantha* is a perennial specie.

Regarding, the cover species in each evaluation period when sown in March, it is possible to verify that the species did not differ among each other in the first evaluation period in both years of study (26 and 48 DAS respectively) (Table 2). *P. glaucum* was again superior to the other cover crops both in the 2019 and 2020 off-seasons, followed by *C. juncea* and *U. brizantha* at 41 and 58 DAS in the 2019 crop. In the 2020 off-season, *C. juncea* and *U. brizantha* did not differ at 83 and 107 DAS (Table 2).

Table 1. Cover crops height (cm) at different sowing periods in relation to the date of evaluation. Dois Vizinhos - Brazil, UTFPR, 2021.

2019 Off-season			
	January 2nd		
Cover crops	85 DAS[1]	100 DAS	117 DAS
	Mar 28th	Apr 12th	Apr 29th
U. brizantha	95.00 Bc[2]	118.13 Bb	138.00 Ba
C. juncea	205.30 Ab	221.90 Aa	221.90 Aa
P. glaucum	201.37 Ab	220.57 Aa	222.67 Aa
CV (%)[3]	3.32		
	February 2nd		
Cover crops	54 DAS	69 DAS	86 DAS
	Mar 28th	Apr 12th	Apr 29th
U. brizantha	75.23 Bc	88.67 Cb	115.00 Ba
C. juncea	156.80 Ac	191.83 Ab	210.47 Aa
P. glaucum	156.63 Ac	174.47 Bb	205.17 Aa
CV (%)	3.09		
	March 2nd		
Cover crops	26 DAS	41 DAS	58 DAS
	March 28th	Apr 12th	Apr 29th
U. brizantha	11.50 Bc	24.23 Cb	42.17 Ca
C. juncea	25.63 Ac	63.73 Bb	116.10 Ba
P. glaucum	22.63 Ac	71.00 Ab	152.43 Aa
CV (%)	5.52		
2020 Off-season			
	January 27th		
Cover crops	42 DAS	70 DAS	119 DAS
	Mar 09th	Apr 06th	May 25th
U. brizantha	64.63 Bb	79.16 Cab	90.86 Ba
C. juncea	109.33 Ab	174.23 Aa	184.70 Aa
P. glaucum	108.53 Aa	115.40 Ba	104.16 Ba
CV (%)	8.39		
	March 3rd		
Cover Plants	48 DAS	83 DAS	107 DAS
	April 20th	May 25th	Jun 18th
U. brizantha	15.06 Bc	39.80 Cb	60.93 Ba
C. juncea	26.46 Ab	101.93 Aa	122.93 Aa
P. glaucum	35.06 Ac	76.13 Bb	108.80 Aa
CV (%)	17.86		

[1]Days after sowing (DAS). [2] Means followed by the same capital letter in the column and lowercase in the row, within each sowing season, do not differ by the Tukey test (p≤0.05). [3]CV= coefficient of variation.

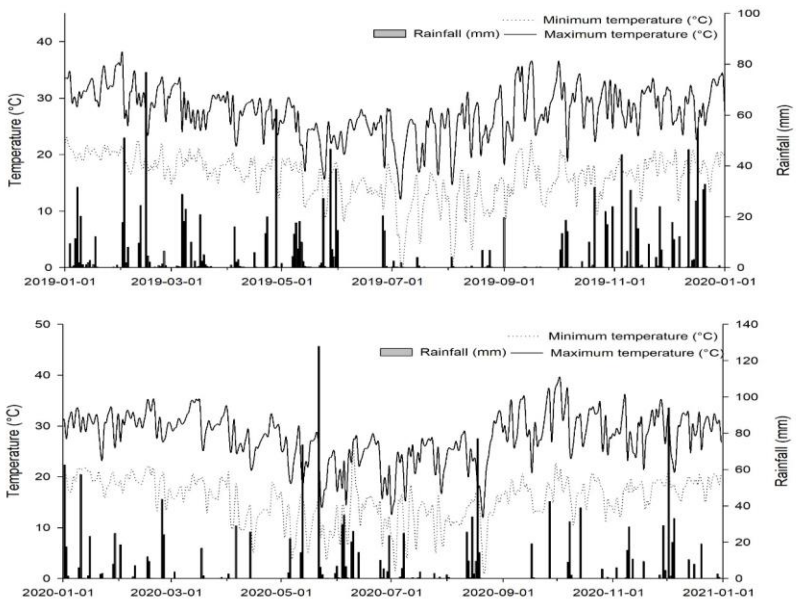

Fig 1. Maximum and minimum temperature (ºC) and rainfall at Dois Vizinhos-PR along the experiment periods. Source: Inmet (2021).

Table 2. Cover crops dry matter (kg ha^{-1}) in relation to the sowing and evaluation periods at the 2019 and 2020 growing season. Dois Vizinhos - Brazil, UTFPR, 2021.

Cover crops	2019 Off-season		
	January 2nd		
	85 DAS[1] Mar/28th	100 DAS Apr/12th	117 DAS Apr/29th
U. brizantha	7,943.04 Bb[2]	11,383.93 Ba	11,676.67 Ba
C. juncea	7,462.68 Bb	9,018.29 Ca	8,800.00 Ca
P. glaucum	14,181.88 Aa	15,021.97 Aa	14,611.46 Aa
CV (%)[3]	4,63		
Cover crops	February 2nd		
	54 DAS Mar 28th	69 DAS Apr 12th	86 DAS Apr 29th
U. brizantha	3,384.04 Bb	8,024.51 Ba	8,577.52 Ba
C. juncea	4,533.55 ABb	5,990.51 Cb	8,217.37 Ba
P. glaucum	5,517.05 Ac	9,914.80 Ab	14,154.56 Aa
CV (%)	9,76		
Cover crops	March 2nd		
	26 DAS Mar 28th	41 DAS Apr 12th	58 DAS Apr 29th
U. brizantha	84.76 Bc	516.27 Cb	2,220.08 Ca
C. juncea	334.85 Ac	1192.66 Bb	2,554.80 Ba
P. glaucum	399.42 Ac	1534.97 Ab	4,200.00 Aa
CV (%)	10,87		
	2020 Off-season		
Cover crops	January 27th		
	42 DAS Mar 09th	70 DAS Apr 06th	119 DAS May 25th
U. brizantha	1,512.56 Bc	8,913.23 Bb	12,507.30 Aa
C. juncea	3,607.87 Bb	6,707.97 Ba	7,812.74 Ba
P. glaucum	6,630.85 Ac	12,774.97 Ab	14,406.00 Aa
CV (%)	32,31		
Cover crops	March 3rd		
	48 DAS April 20th	83 DAS May 25th	107 DAS Jun 18th
U. brizantha	683.52 Ab	1,698.61 Bb	3,041.30 Ba
C. juncea	1,015.15 Ab	1,721.21 Bab	2,345.86 Ba
P. glaucum	1,600.00 Ac	4,352.55 Ab	6,901.71 Aa
CV (%)	22,3		

[1]Days after sowing (DAS). [2] Means followed by the same capital letter in the column and lowercase in the row, within each sowing season, do not differ by the Tukey test ($p \leq 0.05$). [3]CV= coefficient of variation.

It is noticed that cover crops sowed in March in both years resulted in lower dry matter yield in relation to sowing at January and February. In terms of values, *C. juncea* showed a biomass yield of 6,707 kg ha^{-1} at 70 DAS at January 27th in relation to 1,721 kg ha^{-1} at 83 DAS at March 3rd, mainly explained due to climatic conditions. Thus, from May 25th up to June 18th, *C. juncea* increased 624 kg DM ha^{-1}, which means an accumulative rate of 27 kg DM ha^{-1} day^{-1}. If we compare with its growth in January, it is possible to observe a DM accumulative rate of 88 kg DM ha^{-1} day^{-1}. These values may help farmers in the decision make of when to sow the cover crops and when to stop its growth sowing the next crop.

It is important to highlight that daylight length goes shorter, temperature goes down and solar radiation tends to reduce since at fall and winter, there is a greater cloudy and rainy days when compared to spring and summer time, evidencing that even short periods of delay in sowing, coupled with climatic adversities as occurred in the year 2020, is enough to drastically affect the productive potential of the species.

Pacheco et al. (2011) when evaluating cover crops sown in March, reported dry mass productivity for *U. brizantha* and *P. glaucum* of 2,100 and 3,619 kg ha^{-1} respectively at 60 DAS, being similar to the present study, which showed 2,220 and 4,200 kg ha^{-1} and 1,698 and 4,352 kg ha^{-1} at 58 and 83 DAS in the off-season of 2019 and 2020 respectively. Also, the authors point out that the low values of dry biomass found in this period is correlated with the later sowing date of the cover species, due to the persistence of shorter days. Furthermore, it should be noted that this sowing season was strongly affected by the lack of precipitation at the beginning of its development.

In general, *P. glaucum* was the species with the highest accumulation of dry matter regardless of the evaluation periods, sowing times, and off-season, and thus becomes an efficient option for adoption in the short off-season, due to the possibility of desiccation after 85 DAS.

This, it is possible to infer that *U. brizantha* needs a longer establishment period within longer growing periods since it has slower initial development compared to other species as cited by Calegari (2019). However, this behavior does not have a negative effect to the point of making its establishment unviable in sowing situations like those of the present study, since it has a high capacity for dry matter accumulation during its development and its straw has a good persistence over time, and can still be used for grazing. Pacheco et al. (2011) observed that *U. brizantha* shows linear productivity of dry matter, contributing to this species surpassing *P. glaucum* at 180 and 200 DAS.

Dry matter index of *U. brizantha* was considered efficient. Even with slower initial development, this species showed at approximately 90 days after sowing, an accumulation of dry biomass of 7,943 kg ha^{-1} and at 100 days 8,577 kg ha^{-1} when sown in summer and evaluated in autumn. These data corroborate those found by Pacheco et al. (2008) when evaluating this species in Góias (MG) which showed similar data at 90 days after sowing. Still, the same data are higher than those found by Adami et al. (2020), who studied the behavior of *U. brizantha* in the off-season and obtained 5,400 kg ha^{-1} with practically the same cutting age, being cultivated also in autumn. Results like these strengthen the potential use of *U. brizantha* as a cover crop or pasture in the short and long term, becoming a very interesting crop for soil coverage and enrichment of production systems.

In general, *B. brizantha* accumulates greater amounts of biomass from the aerial part (leaves), while *P. glaucum* accumulates in the stem, which may interfere differently in the half-life of the straw, thus, according to Torres and Pereira (2008) and Pacheco et al. (2011), the residual time of millet is higher compared to Brachiaria and Crotalaria, corroborating the data obtained in this study.

C. juncea, did not show the same dry matter yield as the other species when sowing was delayed. *C. juncea* is a legume species with rapid initial development, but presents the characteristic of early flowering, as a result of its sensitivity to the photoperiod and the shortening of the days, which results in a yield reduction when sowed late in the summer (Leal et al., 2012), which is evident in this study, where the *C. juncea,* when evaluated in autumn, showed the lowest dry matter biomass, also justified by the fact that the species has little leaf area compared to other species studied for ground cover. Timossi et al. (2014) suggest that when *C. juncea* is sown in March and April, the cycle is shortened, which also explains the low production of biomass. However, its importance as a biological nitrogen fixation plant keeps it as a species with potential use, specially, when sowed earlier in the year. Thus, it did not differ from the dry matter contribution provided by *U. brizantha*, both having reduced their dry biomass accumulation capacity with later sowing, as reported by Teodoro et al. (2011).

Even though they were not considered for comparison purposes between the sowing seasons, it can be observed that the cover crops sown in March showed less growth, accumulation of green and dry matter during the evaluation periods (Table 1, 2, and 3), a result justified by the reduction in photoperiod and temperature during this sowing season.

Furthermore, sowing in March results in reduced biomass production for all species evaluated (Table 2). Oliveira et al. (2017), when studying the behavior of *U. brizantha*, *C. juncea,* and *P. glaucum* at 45 DAS, sown in April, obtained that dry biomass accumulation of 500, 1,400, and 1,600 kg ha^{-1} respectively, similar results to those recorded in the present work for the sowings of March at 41 and 48 DAS in the 2019 and 2020 off-season respectively, with higher yields for *P. glaucum* to *C. juncea* and *U. brizantha*, reporting reduction in productivity as the sowing season is delayed.

The response that the cover plants deliver to adaptability/behavior in front of the photoperiod, temperature, and adversities to rainfall, is very significant, and from these it is possible to define the best species for each reality in the country, adding productivity, value, and sustainability in the most diverse agricultural production systems.

Material and Methods

Experimental site

Experiment was carried out after soybean harvest at the 2019 and 2020 summer and fall growing season at the Annual Crops Teaching and Research Unit, belonging to the Universidade Tecnológica Federal do Paraná (UTFPR), Campus Dois Vizinhos - Paraná, Brazil (25º42'4'' latitude S and 53º5'43'' longitude W). The experimental area has soil classified as Dystrophic Red Latosol (Bhering et al., 2009) and a humid subtropical mesothermal (Cfa) climate, with an average altitude of 540 m. Average annual temperatures are approximately 20 °C (Alvares et al., 2013), and average annual rainfall between 1,800 to 2,000 mm (INMET, 2021). Minimum and maximum temperature, and rainfall data are presented in Figure 1.

Experimental Desing

Experiment was laid out as a randomized block design in a 3x3 factorial for each sowing period, in the 2019 and 2020 off-seasons, being factor A represented by the cover crops (*Urochloa brizantha* cultivar Xaraés, *Crotalaria juncea* cultivar IAC-KR-1 and *Pennisetum glaucum* cultivar ANm 38,) and factor B by the evaluation seasons (cutting age) during the development cycle of the cover crops (03/28; 04/12 and 04/29/2019 for the three sowing periods and 03/09; 04/06 and 05/25/2020 for the 1st sowing period of the 2nd year and 04/20; 05/25 and 06/18/2020 in the 2nd sowing period) with three replication.

Conduction of experiment and evaluations

Cover crops were sown at three sowing periods (01/02; 02/02 and 02/03) in 2019, and two sowing periods (01/27 and 03/03/2020) in 2020, after soybean harvest (P95R51). Differences between the years may be explained due to climatic conditions differences where the lack of rainfall in the 2020 off-season made early sowings impossible.

Cover crops were sown using a continuous flow sowing seeder with inter-row spacing of 34 cm and sowing depth of 2 cm, without fertilization. *U. brizantha*, *C. juncea*, and *P. glaucum* seeding rate were of 13, 25, and 24 kg ha^{-1}, respectively.

The following variables were evaluated at the different cutting periods: plant height (by measuring the height of 10 plants in the plot and expressed in cm) and dry matter mass (kg ha^{-1}), by cutting and drying a 1 linear meter sample in a forced air oven at 60 °C until constant weight.

After data collection, it was submitted to variance analysis (ANOVA) and when significant, the means of the evaluation period and cover crops were compared using the Tukey test at 5% probability. For statistical analysis, the software SISVAR (Ferreira, 2008) was used.

Conclusions

Total dry matter is reduced as sowing period goes from February to March for all the studied species.

P. glaucum showed the fastest dry matter accumulation rate and reached its dry matter peak earliest after sowing being an ideal species for soil coverage in short off-seasons, when sowing is positioned in the summer and fall.

U. brizantha and *C. juncea* are more viable for off-seasons longer than 90 days.

Acknowledgments

To authors are greatful to AGRISUS (Foundation for Sustainable Agriculture) for providing money resource by the project 2787/19 and to CAPES (Coordination of Superior Level Staff Improvement) for provide a scholarship for the student and to UTFPR-DV. The authors declare that have no conflicts of interest.

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