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Cover crop management in the maize-wheat offseason

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Abstract

This research studied a suitable cover crop considering biomass accumulation and nutrient cycling and its herbicide management to be adopted in the maize-wheat offseason as well as its influence on wheat yield. Experiment was laid out as a randomized block design in a factorial scheme with five cover crops (*Fagopyrum esculentum*, *Crotalaria juncea*, *Pennisetum glaucum*, *Urochloa brizantha* and *Crotalaria spectabilis* at 2017/18 growing season and at 2018/19, *Fagopyrum esculentum* and *Crotalaria spectabilis* were switched for *Dolichos lablab*) and two herbicide management (Desiccation 17 days before and at the wheat Sowing day) with four replications. Fallow was used as a control. *Fagopyrum esculentum* showed the fastest cycle and can be recommended for shorter offseason periods (50 days). *Pennisetum glaucum* showed the highest biomass yield at both years, standing out as the best option for offseason periods of 70 to 80 days. Tradeoff between the additional biomass produced by millet and brachiaria between herbicide desiccation periods does not cover the wheat grain yield reduction, suggesting that its herbicide management should be anticipated. On the other hand, Crotalarias showed a linear increase in biomass along the periods without wheat yield effects and its herbicide dissection at the wheat sowing day is recommended.

Keywords: herbicide management; *Fagopyrum esculentum*; *Crotalaria juncea*; *Pennisetum glaucum*; *Urochloa brizantha*.
Abbreviations: AD_ anticipated desiccation; ANOVA_ analysis of variance; DAS_ days after its sowing; DM_ dry matter; DS_ desiccation immediately before sowing; EU_ experimental unit; FN_ falling number; GBY_ green biomass yield; GWS_ grain weight per spike; HW_ hectoliter weight; NGS_ number of grains per spike; NGSp_ number of grains per spikelet; OM_ organic matter; SP_ spike length; SpS_ spikelets per spike; TGW_ 1000-grain weight; UTFPR_ Federal Technological University of Paraná; Yield_ grain yield;

Introduction

At southern of Brazil, maize is cultivated mainly as a 1st summer crop and usually, farmers grow beans or soybean as a 2nd summer corn. Although, higher pressure of disease (*Phakopsora pachyrhizi*), bugs (*Euschistus heros*) and weed (*Conyza bonariensis*) and difficulties in its management due to resistance (Bunchek et al, 2020) associated with climatic risks (Zilli et al., 2020) (frost) has advocated to the adoption of cover crops.

Maize harvest occurs in February/March and wheat agricultural zoning begins in May/June, therefore, there is an offseason period ranging from 70 to 120 days to be used with some cover crop or forage specie instead of staying in fallow. In this way, selecting a suitable cover crop for this offseason period is important and essential for the success of no-till and soil erosion protection.

Weed suppression, nutrient cycling and reduction in soil erosion stands out among the agronomic feasibility of using these cover crops. In this away, the growth of cover crops in the maize-wheat offseason could reduce these problems, besides improving physical, chemical, and biological soil traits, which may result in higher yields of subsequent crops (Pacheco et al., 2011; Rosolem et al., 2016; Akbari et al., 2019).

Moreover, considering this short offseason period of time, cover crop management at wheat sowing day would improve its dry matter yield, although, the role of grasses and legumes in this ecosystem and its dissection management may effect or not wheat yield potential. Due to it, beyond studying cover crop species biomass accumulation over time, this research aimed to study its effects of cover crop and herbicide desiccation management seventeen days prior and at the day of wheat sowing to better understand the tradeoff between the additional biomass produced between herbicide desiccation periods and its effects on wheat development and grain yield.

Results and discussions

Weather conditions

Regarding to the weather conditions along the experiments, it is noticed that fall and winter of 2018 and winter of 2019 had lower amount of rain than usually occurs for these periods of the year, affecting cover crops and wheat in specific stages of development. At spring (wheat harvest period – Mainly in October), as usual, there was good amounts of rain, affecting wheat grain quality and yield.

One of the water shortage periods was in April of 2018, during the growth period of cover crops, which may have limited its development. On the other hand, at 2019, there were better amounts of rainfall along cover crop growing period, allowing a better cover crops development.

Another period of water shortage happened in July 2018, (less than 20 mm), affecting at this period, wheat development (Figure 1).

As important as rainfall, lower temperature noticed at 2018 in relation to 2019 growing season may explain lower biomass yield of cover crops. Low temperatures (minimum close to 0 °C) at winter may have allowed great wheat yield components differentiation, later on affected by rainfall shortage.

Cover crops

When analyzing the behavior of the cover crops throughout the evaluation periods within each year, an interaction between the factors was evidenced for both experimental years. Even though the water stress evidenced in Figure 1, it is observed that the cover crops grew and produced a good amount of biomass during this period (Tables 1, 2, and 3).

It is noticed that growth (expressed by plant height) was linear and increased as time pass by from the 1^{st} to the last evaluation period (except for *Fagopyrum esculentum*) at both years, indicating that cover crop species still had potential to accumulate biomass if longer periods of time were allowed to do so.

It was found that cover crops grew even at the period of water stress during 2018 (Figure 1), however, at 2019, cover species showed greater biomass yield. Concerning to plant height, it stands out at the 2^{nd} evaluation period, the faster initial growth of buckwheat in the first year (50 cm at 32 DAS) and, pearl millet and sunn hemp, at the 2^{nd} year (Table 1) with an average height of 143.7 and 159.7 cm at 54 days after sowing (DAS).

Buckwheat faster initial development is important for weed suppression, avoiding its germination and development due to limited light interception promoted by cover crops (Oliveira et al., 2014). As noticed on table 1, pearl millet and sunn hemp showed similar growing habit, with similar height along its development, suggesting that it can be cultivated in consortium, which allow at the same time, seed cost establishment reduction (sunn hemp seed is expensive) and nitrogen biological fixation with a final biomass mix which may be more interesting in terms of nutrient release and soil protection for the wheat. In this way, buckwheat could also be use in consortium.

Higher biomass yield showed by the cover crops species at the 2^{nd} growing season may be explained by the fact that species were sowed earlier (beginning of February versus 2^{nd} half of March), and had a longer period at field (Table 2). Plus, as noticed of Figure 1, this provides a higher temperature and a longer photoperiod (days goes shorter form December to July), increasing the photosynthetic rate and biomass accumulation potential, as reported by Pacheco et al. (2011).

Thus, Neto and Campos (2017) reported that as in the fall the photoperiod decreases, the plants tend to shorten its size, producing fewer branches and incorporating less carbon into its tissues. The authors reported DM yields of 1,300 and 2,500 kg ha^{-1} and 1,100 kg ha^{-1} and 1,400 kg ha^{-1} for sunn hemp and buckwheat sown in late February and mid-March, respectively. This aspect highlights the importance of early sowing, although, March sowing also proved to be effective.

Crotalaria spectabilis and *Urochloa brizantha* showed slower initial growth in the first 32 DAS, with 15.8 and 25.8 cm in height (Table 1), respectively. Buckwheat development showed the fastest cycle associate with intermediate biomass yield. According to Görgen et al. (2016), buckwheat has a dry matter production potential of up to 5,000 kg ha^{-1} and respond well to rainfall and high temperature. This fact is seen in this work, where a minimum temperature below 5 °C in May, 2018 resulted in a lower (3,706 kg ha^{-1}) (Table 3), but still very interesting yield.

Crotalaria spectabilis reached the lowest biomass yield (1,662 kg ha^{-1} at 74 DAS), producing only 45% of the total produced by Crotalaria juncea, being mainly affected by the decrease in photoperiod and average temperature (Patterson, 1982). As for *Crotalaria juncea*, at the first year, it did not express its potential, since its DM increased from 2,329 to 3,669 kg ha^{-1} from the 4^{th} to the 5^{th} period (last one). Although, at the 2^{nd} year, these yields were increased from 7,444 to 8,400 kg ha^{-1}.

In the last two-evaluation period in 2018, pearl millet presented the highest dry matter production among cover crops, producing 5,103 and 7,272 kg ha^{-1}, with an average production of 98.3 kg DM ha^{-1} per day. At the 2^{nd} year, pearl millet produced an average of 126 kg ha^{-1} per day, producing 10,895 kg ha^{-1} at 86 DAS, being the species that produced the higher dry matter amount.

Among grasses species, brachiaria showed lower initial development and biomass yield than pearl millet, although, after developing a photosynthetic apparatus, increased rapidly its biomass accumulation rate, reaching values of 89 kg DM ha^{-1} per day between the last two evaluated periods, showing to be interesting in longer offseason periods (more than 80 days).

Concerning Lablab bean, a legume cover crop that was inserted in 2019 due to exchange of *Crotalaria spectabilis* (precocity species with low dry matter production) and buckwheat (problems with seed shattering and later on as a weed in wheat), showed a production of 5,023 kg ha^{-1}, being the cover crop species that produced lesser in the growing season. However, this production is above that reported by Nunes et al. (2006), which was 2,960 kg ha^{-1}.

According to plant height and dry mater yield results along offseason period, it is possible to set up management and choose the species according to its growth habit, since there may be shorter or longer offseason periods between corn and wheat depending on the region where it is considered as a cover crop option. In this way, it can be adopted buckwheat for short offseason periods (50-60 days), pearl millet and sunn hemp for intermediate periods (70-80 days) and brachiaria for longer offseason periods (90 days), considering that grasses demand to be dissected several days before wheat sowing.

Nutrient cycling

Beyond cover crop biomass yield, its ability to absorb nutrients and improve its cycling might be considered. In this way, the carbon content in g kg^{-1} did not differ among the cover crops (Table 4). *Crotalaria spectabilis* presented the highest amount of nitrogen in its tissues, with 44.6 g kg^{-1}. In relation to N accumulation by area, pearl millet and sunn hemp showed higher values at 57 DAS and pearl millet presented higher N accumulation by area at 74 DAS.

In relation to phosphorus, it is verified that pearl millet had the lowest P content in its tissues in both evaluated period, being 2.15 g kg^{-1} at 57 DAS and 2.08 g kg^{-1} at 74 DAS (buckwheat also had 2.08 g kg^{-1} for this period). However, even with the lowest P content in the tissues, pearl millet showed the highest P_2O_5 cycling capacity with 57.5 and 79.2 kg ha^{-1} at 57 and 74 DAS, respectively (Table 4).

The highest concentration of potassium was found in brachiaria at 57 and 74 DAS, with 36.6 and 28.8 g kg^{-1}, respectively. As for the increase in K_2O per hectare, at 57 DAS the highest increases were for brachiaria and pearl millet, with 76.6 and 92 kg ha^{-1}, respectively. However, the highest increase was observed for pearl millet, with 149.2 kg ha^{-1} of K_2O at 74 DAS. In this way, pearl millet is an excellent cover crop for increasing DM and improving K cycling (Pacheco et al., 2011).

Wheat grain yield

Thus, beyond cover crop biomass yield and its nutrient cycling capacity, wheat grain yield should be considered, since these species showed great potential to absorb and transform nutrient into an organic form, which is latter on, more available to wheat crop. According to Grohskopf et al. (2019), the agronomic efficiency index (AEI) of organic P by maize increase in 20% in relation to mineral fertilizer. Moreover, according to Janegitz et al. (2017), sorghum decrease the soil maximum P adsorption capacity, probably by exuding or stimulating microbial production of organic acids and phenolic compounds.

In this way, wheat yield components such as number of grains per spike (NGS) (average of 34,7), number of grains per spikelet (NGSp) (average of 2,5), grain weight per spike (GWS) (average of 12,4g), 1000-grain weight (TGW) (average of 33,6g), Hectoliter Weight (HW) (average of 76) did not differ among cover crops and desiccation management.

Regarding spike length (SP) and the number of spikelet per spike (SpS), it can be noted that buckwheat desiccated immediately before wheat sowing had negative interference on these variables due to buckwheat competition with wheat and its difficult chemical control due to reseeding effect (Table 5).

There was an interaction between cover crops species and desiccation management strategies for wheat yield. There is no difference in wheat yield due to the desiccation management for sunn hemp, buckwheat (even becoming a weed problem at wheat later on at the apply and plant treatment) and fallow, which makes it possible to recommend the desiccation management immediately before wheat sowing for these cover crops. Further, this allows cultivating these cover plants in shorter offseason periods with a satisfactory accumulation of biomass (Table 3).

Anticipated desiccation is not recommended for *Crotalaria spectabilis*, since it is necessary a longer period in the field to express its production potential (Table 1) and also because it has a fast decomposition rate. In addition, when *Crotalaria spectabilis* was desiccated immediately before wheat sowing, wheat produced 305 kg ha^{-1} more than in anticipated desiccation management.

Crotalaria juncea has a high content of lignin, cellulose, and hemicellulose in its stem, being carbonic structures of difficult decomposition, making a plant of slow decomposition, even being a legume. However, when plants are cut by the sowing discs, the nutrient mineralization is faster releasing nitrogen to wheat (Northupl e Rao, 2015).

C onsidering that there was a biomass increase from the last to the prior period, it would be important to keep the plants growing in the field, although, for grasses, this increase in biomass impact wheat grain yield, as shown in table 5. The tradeoff between the additional biomass produced by millet and brachiaria between herbicide desiccation periods does not pay the wheat grain yield reduction, suggesting that its herbicide management should be anticipated.

Thus, this dynamic was different for wheat cultivation after legumes, due to better synchrony between wheat nitrogen supply and demand (Melero et al., 2013). In this away, *Crotalaria juncea* and *Fagopyrum esculentum* showed a linear increase in biomass along the periods without wheat yield effects and its herbicide dissection at the wheat-sowing day appears to be the best management. Thus, in shorter offseason, sunn hemp dissection at the day of wheat sowing might be a useful strategy to explore its yield potential, since its biomass accumulation was linear as time pass by.

Pennisetum glaucum showed rapid growth and the highest biomass yield at both years, standing out as the best option for offseason periods of 70 to 80 days, although, anticipated herbicide management before wheat sowing resulted in higher grain yield. Thus, it was noticed that higher amounts of brachiaria straw (up to 5 t ha^{-1} at the 2nd year) difficult wheat plantability and establishment. Later on, its initial development might be impaired due to high C/N ratio from straw, which may result in a nitrogen deficiency due to immobilization (Neto e Campos, 2017). Due to it, wheat sow immediately after the brachiaria desiccation is not recommended, especially under longer growing season or high amount of straw.

It is noteworthy that cover crops in pre-wheat have a weed suppression potential, such as suppression of wild poinsettia (*Euphorbia heterophylla*), and blackjack (*Bidens pilosa*) by brachiaria (Oliveira et al., 2014) and suppression of pigweed (*Amaranthus powelli*) by buckwheat (Kumar et al., 2009), becoming important control tools in cropping system (Bunchek et al., 2020).

Wheat yield at fallow did not differ from plots with cover crops at the AD treatment. Even so, the effect of cover species is not isolated on wheat but has a beneficial effect on the cropping system, involving soil and subsequent crops. According to Northupl e Rao (2015), the insertion of cover crops in crop rotation with annual cereals crops has been one of the best tools for improving the soil system and thus being a potential for ecosystem diversification. In this away, further studies may explore the beneficial effect of cover crops considering longer periods of time, verifying possible changes in soil traits and also its influence over summer crops yield, such as corn, soybeans, and beans.

Materials and methods

Experimental site

Experiment was carried out at Federal Technological University of Paraná, campus of Dois Vizinhos, Agricultural Research Station, located at 25°41’72” latitude south and 53°05’45” longitude west with an average altitude of 522 m. According to Koppen’s classification, the climate is Cfa, with an annual average rainfall of 2044 mm. Soil at experimental site is classified as a Clayey Oxisol.

Experimental Design

This research evaluated cover crops traits at the 2017/18 and 2018/19 growing seasons and wheat yield at the 2017/18 growing season and it is presented in phase 1, (cover crop) and phase 2 (wheat crop).

Phase 1 (cover crops) was laid out in a randomized block design in a 5 x 5 factorial scheme, with four replications.

Table 1. Cover crops plants height (PH) sowed on 03/15/2018 and 02/02/2019 at different periods after sowing. Federal Technological University of Paraná- Dois Vizinhos, Brazil

Cover crops	Plant height (cm)				
	04/02[1]	abr/16	abr/30	05/nov	mai/28
	18 DAS[2]	32 DAS	46 DAS	57 DAS	74 DAS
Year 2018					
U. brizantha	20.0 cE[3]	25.8 cD	40.5 cC	46.5 dB	61.8 dA
C. juncea	17.3 cE	53.5 aD	101.3 aC	116.0 bB	145.2 bA
P. glaucum	30.0 aE	37.5 bD	103.8 aC	163.4 aB	181.6 aA
F. esculentum	25.0 bC	50.0 aB	65.0 bA	66.6 cA	68.5 cA
C. spectabilis	9.8 dE	15.8 dD	23.0 dC	33.8 eB	44.5 eA
C.V (%)	3.42				
Cover crops	Year 2019				
	fev/28	mar/28	04/dez	abr/29	
	26 DAS	54 DAS	69 DAS	86 DAS	
U. brizantha	21.3 aD	78.9 cC	94.8 cB	109.2 bA	
C. juncea	21.1 aD	143.7 bC	194.4 aB	211.9 cA	
P. glaucum	29.5 aD	159.7 aC	176.8 bB	223.0 cA	
D. lablab	14.7 bC	67.7 cB	80.3 dB	69.2 cA	
C.V (%)	5.33				

[1]Date of the year; [2]DAS- Days after sowing; [3]Means followed by different lowercase in the columns and uppercase in the rows differ by Scott-Knott test (p<0.05).

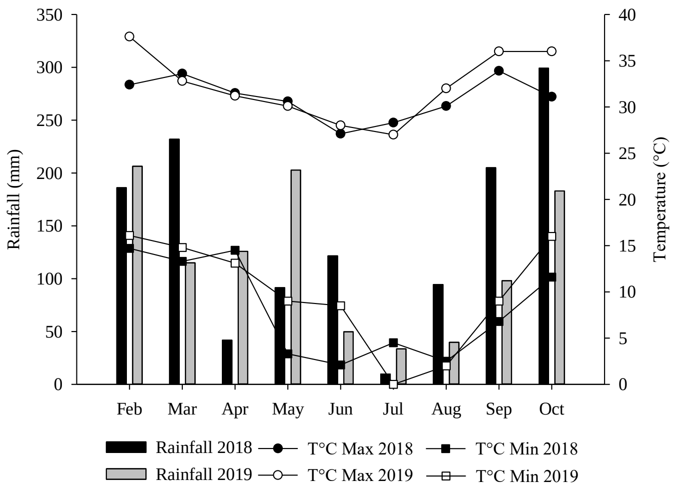

Figure 1. Rainfall (mm), maximum and minimum temperature (°C) observed along the experimental period at 2018 and 2019 growing season (February up to October) - UTFPR-Campus of Dois Vizinhos (Source: INMET, 2019).

Table 2. Green biomass yield (GBY) of cover crops sowed on 03/15/2018 and 02/02/2019. Federal Technological University of Paraná- Dois Vizinhos, Brazil

Cover crops	Green biomass yield (kg ha^{-1})				
	04/02[1]	abr/16	abr/30	05/nov	mai/28
	18 DAS[2]	32 DAS	46 DAS	57 DAS	74 DAS
Year 2018					
U. brizantha	333 dE[3]	6,250 bD	9,949 bC	11,934 bB	17,360 bA
C. juncea	552 cD	3,985 cC	4,507 dC	9,765 cB	12,507 cA
P. glaucum	1,294 bE	5,463 bD	20,051 aC	27,044 aB	31,588 aA
F. esculentum	2,684 aD	7,441 aC	7,294 cC	9,463 cB	11,963 cA
C. spectabilis	202 dD	1,324 dC	1,596 eC	8,382 cB	12,264 cA
C.V (%)	5.74				
Cover crops	fev/28	mar/28	04/dez	abr/29	
	26 DAS	54 DAS	69 DAS	86 DAS	
Year 2019					
U. brizantha	2,318 bD	18,485 cC	39,576 aB	46,182 aA	
C. juncea	1,770 bD	24,985 bC	30,970 bB	36,515 bA	
P. glaucum	7,560aB	34,136 aA	33,303 bA	36,591 bA	
D. lablab	2,757 bD	17,773 cC	22,181 cB	26,728 cA	
C.V (%)	7.4				

[1]Date of the year; [2]DAS- Days after sowing; [3]Means followed by different lowercase in the columns and uppercase in the rows differ by Scott-Knott test (p<0.05).

Table 3. Dry matter (DM) of cover crops sowed on 03/15/2018 and 02/02/2019. Federal Technological University of Paraná- Dois Vizinhos, Brazil

Cover crops	Dry matter (kg ha^{-1})				
	04/02[1]	abr/16	abr/30	05/nov	mai/28
	18 DAS[2]	32 DAS	46 DAS	57 DAS	74 DAS
Year 2018					
U. brizantha	56 cD[3]	735 bC	1,712 bB	1,933 cB	3,390 bA
C. juncea	69 cE	765 bD	1,118 cC	2,329 bB	3,669 bA
P. glaucum	165 bE	926 bD	3,103 aC	5,103 aB	7,272 aA
F. esculentum	316 aE	1,235 aD	1,882 bC	2,484 bB	3,706 bA
C. spectabilis	48 cD	190 cC	360 dB	1,441 dA	1,662 cA
C.V (%)	5.82				
Year 2019					
Cover crops	fev/28	mar/28	04/dez	abr/29	
	26 DAS	54 DAS	69 DAS	86 DAS	
U. brizantha	394 aD	3,703 bC	7,445 bB	9,025 bA	
C. juncea	285 aD	4,166 bC	7,444 bB	8,400 bA	
P. glaucum	932 aD	6,681 aC	8,290 aB	10,895 aA	
D. lablab	553 aD	2,906 cC	3,937 cB	5,023 cA	
C.V (%)	7.50				

[1]Date of the year; [2]DAS- Days after sowing; [3]Means followed by different lowercase in the columns and uppercase in the rows differ by Scott-Knott test ($p<0.05$).

Table 4. Nutrient content and accumulation on cover crops biomass, grown at the 2017/18 maize-wheat offseason, evaluated at two periods after sowing. Federal Technological University of Paraná- Dois Vizinhos, Brazil.

Cover crops	C (%)		N (g kg^{-1})		P (g kg^{-1})		K (g kg^{-1})	
	57 DAS[1]	74 DAS	57 DAS	74 DAS	57 DAS	74 DAS	57 DAS	74 DAS
U. brizantha	41.6 [ns]		30.2 c		4.23 aA[2]	3.23 aB	36.6 aA	28.8 aB
C. juncea	40.8		34.4 b		3.75 aA	3.58 aA	16.6 bA	14.0 cA
P. glaucum	42.5		21.0 d		2.15 cA	2.08 bA	15.0 bA	17.2 bA
F. esculentum	41		20.8 d		3.70 aA	2.08 bB	16.6 bA	14.4 cA
C. spectabilis	41.2		44.6 a		3.10 bA	3.20 aA	17.3 bA	20.4 bA
CV (%)	3.69		10.71		14.03		17.2	
Cover crops	C (kg ha^{-1})		N (kg ha^{-1})		P_2O_5 (kg ha^{-1})		K_2O (kg ha^{-1})	
	57 DAS	74 DAS	57 DAS	74 DAS	57 DAS	74 DAS	57 DAS	74 DAS
U. brizantha	717 cB	1,417 bA	55 bB	98 Ca	38.5 bB	57.5 cA	76.6 aB	116.9 bA
C. juncea	963 bB	1,480 bA	77 aB	132 Ba	45.5 bB	68.3 bA	45.9 bA	62.0 cA
P. glaucum	2,203 aB	3,046 aA	91 aB	175 Aa	57.5 aB	79.2 aA	92.0 aB	149.2 aA
F. esculentum	1,018 bB	1,515 bA	54 bA	73 Db	48.8 bA	40.3 dA	49.6 bA	64.0 cA
C. spectabilis	583 cA	688 cA	63 bA	75 Db	23.0 cA	27.9 eA	30.1 bA	40.5 dA
CV (%)	11.58		15.12		13.02		17.36	

[1]DAS- Days after sowing; [2]Means followed by different lowercase in the columns and uppercase in the rows differ by Scott-Knott test ($p<0.05$). [ns] - not significant

Table 5. Spike length (SP), spikelets per spike (SpS), grain yield (Yield), and falling number (FN) of wheat after two herbicide desiccation management of cover plants in 2018 growing season. Federal Technological University of Paraná- Dois Vizinhos, Brazil.

Cover crops	SP (cm)		SpS		Yield (kg ha^{-1})		FN	
	AD[1]	DS	AD[1]	DS	AD[1]	DS	AD[1]	DS
U. brizantha	7.1 aA[2]	7.2 aA	14.0 aA	14.1 aA	4,092 aA	3,364 bB	183 cB	228 aA
C. juncea	7.2 aA	7.5 aA	13.2 aB	14.8 aA	3,640 aA	3,562 bA	168 cB	251 aA
P. glaucum	7.1 aA	7.3 aA	13.6 aA	14.4 aA	3,661 aA	3,298 bB	211 bA	235 aA
F. esculentum	7.1 aA	6.8 bB	13.8 aA	13.8 bA	3,724 aA	3,696 aA	251 aA	185 cB
C. spectabilis	7.0 aA	7.1 aA	14.1 aA	13.5 bA	3,699 aB	4,004 aA	244 aA	210 bB
Fallow	7.1 aA	7.1 aA	14.1 aA	14.1 a A	3,662 aA	3,697 aA	211 bA	211 bA
CV (%)	6.15		5.18		7.46		7.84	

[1]AD- Anticipated Desiccation; DS- desiccation immediately before sowing. [2]Means followed by different lowercase in the columns and uppercase in the rows differ by Scott-Knott test ($p<0.05$).

Factor A refers to five cover crops [Urochloa brizantha cultivar Xaraés (braquiaria), Pennisetum glaucum cultivar ANm 38 (pearl millet), Fagoryrum esculentum cultivar IPR Baili (buckwheat), Crolaria juncea cultivar IAC-KR-1 (sunn hemp), and Crotalaria spectabilis (showy rattlepod)] and factor B refers to five periods of evaluation along its development. Each experimental plot consisted of 4.5 m wide and 40 m long, totaling 180m^2. At the second growing season, *Crotalaria spectabilis* and buckwheat were switched for *Dolichos lablab* (lablab bean).

At phase 2 (wheat), experimental plots were subdivided (20 x 4.5 m) to establish the herbicide desiccation management arranged in a 6 x 2 factorial scheme, with four replications. Factor A is represented by the cover crops and fallow and factor B by herbicide dissection management so on called as anticipated desiccation (17 days before wheat sowing) and desiccation at the day of wheat sowing.

Conduction of Study

Cover crops were established after a maize crop at different fields between growing seasons. At the first growing season (2017/18), drought conditions delayed maize sowing (10/05/2017) and its harvest occurred on March 15th of 2018. At the 2nd growing season, maize was sowed early (September 2nd of 2018) and harvested on February 02nd of 2019 (more usual date).

These dates are important since cover crops were sowed on the same day as maize was harvested and these dates have a further influence on cover crops development and growth. Seeding was performed using a continuous flow seed-drill with 34 cm row spacing and sowing depth of 2 cm, without fertilization. Regarding to the seed sowing density, were used: 13, 25, 45, 24, 12 and 40 kg ha^{-1} of brachiaria, sunn hemp, buckwheat, pearl millet, showy rattlepod, and lablab bean, respectively.

Weeds were desiccated with glyphosate herbicide (1,000 g a.i. ha^{-1}) just after maize harvest and prior cover crops sowing. At fallow plots, glyphosate and 2,4-D (1,000 g a.i ha^{-1} + 600 g a.i ha^{-1}) was applied at April to control weeds. Cover crops herbicide desiccation management occurred on May 12th and 28th with glyphosate (1,000 g ha^{-1} a.i) associated with metsulfuron-methyl (6 g ha^{-1} a.i). Wheat cultivar TBIO Toruk® was sowed with the aid of continuous flow seed-drill on May 28th of 2018, with 17 cm row spacing and 2,5 cm seed sowing depth at a density of 150 kg ha^{-1}. Wheat fertilization was carried out according to the recommendation of the CQFS (2004) for meeting an expected yield of 5 t ha^{-1} and according to the average values found in the soil analysis in the 0.0-0.1 m layer: pH ($CaCl_2$) 5.1; phosphorus (P) 16.2 mg dm-³; potassium (K) 0.3 cmolc dm^{-3}; organic matter (OM) 4.6 g kg^{-1}; base saturation 59.3%; cation exchange capacity of 13.2 cmol$_c$ dm^{-3}; and, clay content of 53 g kg^{-1}. Base fertilization was performed adding 208 kg ha^{-1} of chemical fertilizer 16-36-00 (DAP) (33.3 kg ha^{-1} of N and 74.9 kg ha^{-1} of P_2O_5). Topdressing fertilization at initial tillering was performed applying 180 kg ha^{-1} of the fertilizer mixture 13-00-28 (YaraBela + potassium chloride) (23.4 kg ha of N and 50,4 kg ha K_2O) and 12 days later 95 kg ha^{-1} of the formula 46-00-00 (Urea) (43.7 kg ha^{-1} of N), totaling 100 kg N ha^{-1}. Weed, bugs, and disease management were carried out based on scouting, applying agrochemicals according to the technical Embrapa recommendations (Pires and Vargas, 2014). Regarding to wheat specific management of weeds, at the tillering phase, 645 g a.i ha^{-1} of 2,4-D was applied. As the buckwheat seed bank re-infested the area, another herbicide (585 g a.i ha^{-1} of MCPA) was applied at the wheat stem elongation. At 2018, cover crops evaluations were performed at 18, 32, 46, 57, and 74 days after its sowing (DAS), respectively on the following dates: April 02nd, 16th and 30th and May 11th and 28th at 2018. At 2019, these evaluations occurred at 26, 54, 69, and 86 days after its sowing respectively on February 28th, March 28th, April 12th and 29th.

Traits measured

Were evaluated: Plant Height, performed in 10 randomized plants/experimental unit (EU), expressed in cm; dry matter yield (kg ha^{-1}), determined by collecting plants at two points of one linear meter per experimental plot of each evaluation period and oven-dried at 60 °C until constant mass. Cover crops dried samples from the last two evaluated periods (at the 2017/18 growing season) were grounded and taken to the laboratory to perform plant tissue analysis. Carbon (% and kg ha^{-1}), nitrogen (g kg^{-1} and kg ha^{-1}), phosphorus (g kg^{-1} and kg ha^{-1}), and potassium (g kg^{-1} and kg ha^{-1}) were determined in accordance the methodology described by Tedesco et al. (1995). Nutrient content multiplied by the dry matter amount of each period resulted in the nutrient accumulation for each cover crop, being phosphorus and potassium converted to P_2O_5 and K_2O, respectively on stage.

Evaluations were carried out at wheat harvesting day. Spike length (cm), number of spikelet per spike, number of grains per spike was performed by evaluating 10 spikes per plot. Number of grain per spikelet was obtained by dividing the number of grain per spike by the number of spikelet per spike; 1000-grain weight (g) was determined by counting four subsamples of 250 grains per plot and weighed to obtain its values; and, grain yield (kg ha^{-1}) was assessed by harvesting and threshing 10 m^2 of plot, then weighed and corrected for the moisture content for 13%.

Statistical Analysis

Data were collected and subjected to analysis of variance (ANOVA) and when verifying the significant effect among treatments, a complimentary analysis was performed using Scott-Knott test at 5% probability. For the analysis of the data, Rbio software was used (Bhering, 2017).

Conclusions

Pennisetum glaucum showed the highest biomass yield, standing out as the best option for offseason periods around 80 days with greater nutrient accumulation.

Crotalaria juncea and *Urochloa brizantha* showed a linear biomass accumulation during the evaluation periods, with high potential for longer offseason for it is fully development.

Although, *Crotalaria juncea* herbicide management can be done at the wheat-sowing day while *Urochloa brizantha* and *Pennisetum glaucum* anticipated herbicide management showed to be better since wheat yield was affected being lower than the fallow treatment.

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