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SOWING STRATEGIES OF COVER CROPS IN NORTHWESTERN SÃO PAULO STATE, BRAZIL

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ABSTRACT

The objective of this work was to evaluate the dry matter yield of *Urochloa ruziziensis*, *U. brizantha*, *Sorghum bicolor* x *S. sudanense* hybrid, *S. sudanense* and *Pennisetum americanum*, in different sowing strategies, and their influence on the soybean crop grown in succession, in the northwest region of São Paulo State, Brazil. The sowing of cover crops was carried out in two phases of the soybean crop, before harvest, in broadcast sod-seeding in the maturation stages R6, R7, and R8, and after harvesting, in broadcast and in no-tillage 2 days after the harvest. The experimental design adopted was the randomized blocks with a 6 (cover plants) x 7 (sowing strategies) factorial scheme and three replications. The sowing strategies of the cover plants interfered in their dry matter yield and the stand and grain yield of the soybean crop in succession, in the northwestern São Paulo State.

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INTRODUCTION

Brazilian agriculture has achieved a great technological advance in the last years, which has resulted in an increase in productivity and improvement in the environmental conditions (Borges *et al*., 2016a). Some of this advance is the result of the use of the no-tillage system in the grain-producing areas. However, to obtain all the benefits that the system provides, it is necessary to, in addition to not disturbing the soil, use crop rotation and keep the soil permanently covered. However, in many Brazilian regions, the biggest obstacle for the sustainability of the no-tillage system is the low straw production in autumn/winter and winter/spring, due to the strong water restriction in this period, as is the case in the northwestern region in the State of São Paulo, which results in many agricultural areas idle for a long period of the year and with low vegetation coverage, compromising the viability of the system (Borges *et al*., 2014a). Thus, there is a need to introduce cover crops within the production systems, with the specific objective of producing phytomass, to keep the soil covered throughout the year.

Among the cover plants, *P. americanum*, *S. bicolor* and *Urochloa* grasses, in Cerrado regions, are considered excellent options for use in no-tillage systems and they have been widely used from autumn to spring to supply forage and/or straw in this productive system (Garcia *et al*., 2014). When examining the use of *S. bicolor*, *P. americanum*, *S. sudanense*, *S. bicolor* x *S. sudanense* hybrid and *U. ruziziensis*, as cover crops in rotation with soybean and maize, for the northwest region of São Paulo State, Borges *et al*. (2015a) found that the use of cover crops was more beneficial than leaving fallow areas, as *U. ruziziensis* and *S. sudanense* reduced weed infestation by more than 90% and maintained coverage of the soil above 80%, until the flourishment of the soybean crop (Borges *et al*., 2014a). Also, *S. sudanense* and *P. americanum* were more efficient in improving the stability of soil aggregates (Borges *et al*., 2016b). As the northwest region of São Paulo State is characterized by high temperatures and irregular rainfall, there are doubts as to the season, sowing method and seed costs of the most appropriate cover plants to the region for achievement of the highest productive potential of the cover plants. The objective of this work was to evaluate the dry matter productivity of different cover crops, using different sowing strategies, and their influence on the soybean crop grown in succession, in northwestern São Paulo State.

MATERIAL AND METHODS

The experiment was carried out in Votuporanga, São Paulo State (SP) (20º20'S, 49º58'W and 510 m altitude), in a Eutrophic Dark-Red Latosol with a sandy texture (according to SiBCS, Santos, *et al*., 2013). The experimental design adopted was the randomized blocks with a 6 (cover plants) x 7 (sowing strategies) factorial scheme and three replications. The cover plants used were as follows:

1 - *U. ruziziensis* (Syn. *Brachiaria ruziziensis*) (common cultivar) with culture value (CV) of 32 in 2010/11 crop and 50 in the 2014/15 crop;
2 - *U. brizantha* (Syn. *B. brizantha*) cultivar (cv.) Marandu with a CV of 33 in the 2010/11 crop and 50 in the 2014/15 crop;
3 - Sorghum (*S. bicolor* (L.) Moench) x Sudan grass (*S. sudanense* (Piper) Stapf) hybrid, cover crop (2010/11 crop) cultivar and Dow SS318 cultivar (2014/15 crop);
4 - Sudan grass (*S. sudanense* (Piper) Stapf);
5 - Pear millet (*P. americanum* (L.) Leek), cultivar BN 2 (2010/11 crop), and BRS 1501cultivar (2014/15 crop).
6 - Control treatment (spontaneous plants as cover), the area is in iddle and made up mainly by *Cenchrus echinatus* L. and *Digitaria horizontalis* Willd in both evaluated crops.

The following are the sowing strategies for cover plants:

1 - Broadcast sod-seeding in soybean crop at R6 maturation stage;
2 - Broadcast sod-seeding in soybean crop at R7 maturation stage;
3 - Broadcast sod-seeding in soybean crop at R8 maturation stage;
4 - Broadcast sowing 2 days after soybean harvest;
5 - Sowing in direct sowing system (DSS), using plot-seeder two days after soybean harvest with the following seed expenditures: *U. ruziziensis*: 960 points of cultural value (CVP) ha^{-1}; *U. brizantha*: 990 CVP ha^{-1}; *S. bicolor* x *S. sudanense* hybrid: 25 kg ha^{-1}; *S. sudanense*: 25 kg ha^{-1}; *P. americanum*: 25 kg ha^{-1};
6 - DSS sowing using plot-seeder two days after soybean harvest with the following seed expenditures: *U. ruziziensis* 800 CVP ha^{-1}; *U. brizantha*: 825 CVP ha^{-1}; *S. bicolor* x *S. sudanense* hybrid: 20 kg ha^{-1}; *S. sudanense*: 20 kg ha^{-1}; *P. americanum*: 20 kg ha^{-1};
7 - DSS sowing using plot seeder two days after soybean harvest with the following seed expenditure: *U. ruziziensis* 400 CVP ha^{-1}; *U. brizantha*: 412,5 CVP ha^{-1}; *S. bicolor* x *S. sudanense* hybrid: 10 kg ha^{-1}; *S. sudanense*: 10 kg ha^{-1}; *P. americanum*: 10 kg ha^{-1}. The seed expenditures in sowing strategies 1, 2, 3, 4, and 5 were the following: *U. ruziziensis*: 800 CVP ha^{-1}; *U. brizantha*: 825 CVP ha^{-1}; *S. bicolor* x *S. sudanense hybrid*: 20 kg ha^{-1}; *S. sudanense*: 20 kg ha^{-1}; *P. americanum*: 20 kg ha^{-1}.

The seeds of *S. bicolor* x *S. sudanense* hybrid, *S. sudanense,* and *P. americanum* were pure and viable.

Sod-seeding was performed manually.

The plots were 5.0 m wide by 10.0 m long.

The cover crops and the standard treatment were managed with herbicides in the pre-sowing of soybean in succession, neither being cut nor mowed. Before soybean sowing, soil samples were collected in the 0.00-0.20 m deep layer for chemical characterization (van Raij *et al*., 2001), and the results are shown in Table 1.

A superficial liming was carried out in September 2015, using 1000 kg ha^{-1} of dolomitic limestone. In the 2010/11 harvest, the area was desiccated on October 20, 2010, using glyphosate (480 g L^{-1}), at a dose of 3.0 L ha^{-1} of the commercial product (c.p.) and 2.4- D (670 g L^{-1}), at a dose of 0.6 L ha^{-1} of c.p. The soybean cultivar used was BRS 184, sown on November 16, 2010, with 20 seeds m^{-1} and 300 kg ha^{-1} of the 04-20-20 formulated fertilizer at a spacing of 0.5 m between rows. The management of cover crops was carried out through desiccation in the pre-sowing of the soybean crop of the subsequent harvest. The cover plants in the area were not mowed or cut. In the 2011/12 harvest, the area was desiccated on December 02, 2011, using glyphosate (480 g L^{-1}), at a dose of 6.0 L ha^{-1} of c.p. and carfentrazone-ethyl (400 g L^{-1}), in the dose of 0.08 L ha^{-1} of c.p. On December 14, 2011, second desiccation was performed, using glyphosate (480 g L^{-1}), at a dose of 3.0 L ha^{-1} of the c.p. The soybean cultivar used was BRS Valiosa RR, sown on January 02, 2012, with 19 seeds m^{-1} and 300 kg ha^{-1} of the fertilizer formulated 04-20-20 formulated fertilizer at the spacing of 0.5 m between rows.

Because of some problems observed in the germination of cover plants sown in the 2011/12 crop, their dry matter yield was not evaluated in this harvest. Also, due to some problems observed in germination in the 2012/13 and 2013/14 crops, the experiment was not carried out. In the 2014/15 crop, the area was desiccated on November 20, 2014, using glyphosate (480 g L^{-1}), at a dose of 6.0 L ha^{-1} of c.p. and carfentrazone-ethyl (400 g L^{-1}), in the dose of 0.1 L ha^{-1} of the c.p. The soybean cultivar used was IAC Foscarin-31, sown on May 12, 2014, with 20 seeds m^{-1} and 300 kg ha^{-1} of the formulated fertilizer 04-20-20 at a spacing of 0.5 m between lines. New sowing of the cover plants was performed and the management of the cover plants was carried out through desiccation in the pre-sowing of the soybean crop of the subsequent harvest, leaving the cover plants in the area without mowing or cutting them. In the 2015/16 crop, the area was desiccated on November 09, 2015, using glyphosate (480 g L^{-1}), in the dose of 4 L ha^{-1} of c.p. and chlorimuron-ethyl (250 g kg^{-1}), in the dose of 0.05 kg ha^{-1} of the c.p. The soybean cultivar used was BMX Potencia RR, sown on November 23, 2015, with 16 seeds m^{-1} and 450 kg ha^{-1} of the 04-20-20 formulated fertilizer, with a spacing of 0.5 m between rows. The dry matter produced by the cover crops was evaluated in the pre-sowing of the soybean crop, on November 29, 2011, and October 19, 2015 by sampling two points of 0.5 x 0.5 m in each plot, with cutting the cover plants close to the ground.

The samples were packed in paper bags and dried in a thermoelectric oven regulated at 65-70ºC. After achieving constant weight, the dry mass of the plant material was determined, and the results were expressed in kg ha^{-1} of dry matter. The parameters evaluated in soybean crop were: height of insertion of the first pod, height of the plants, final stand ha$^{-1,}$ and grain yield ha^{-1}. The evaluations were carried out at harvesting of the soybean crop, on May 15, 2012, and March

16, 2016. Grain yield was obtained by standardizing grain moisture to 13% (wet basis). The sampling of the insertion height of the first pod and plant height was carried out in five plants in each plot, and the sampling of the final stand ha^{-1} and grain yield was carried out in 3 m of two central lines of each plot. The pods were threshed in a mechanical thresher. After threshing, the grains were weighed and their moisture was measured to calculate grain yield. Tables 2 and 3 show the water balance of Votuporanga, SP, during the sowing period of the cover plants in both crops (2010/11 and 2014/15). The data were submitted to the F test and the means were compared using the test of Tukey ($p < 0.05$), using the computer program Assistat (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

A significant interaction was found between cover plants and sowing strategies in relation to the dry matter yield of cover plants, in the 2010/11 and 2014/15 crops (Tables 4, 5 and 6). This type of variation was also observed by Pariz *et al*. (2011) for cover crops *U. brizantha*, *Setaria italica*, *P. americanum* and *S. bicolor*. In the two crops (2010/11 and 2014/15) and the different sowing strategies, the dry matter yield of *P. americanum* and the standard treatment were, respectively, less than 6000 and 4000 kg ha^{-1}, corroborating with Borges *et al*. (2015a). Calvo *et al*. (2010) and Machado and Assis (2010) also found yield of *P. americanum* below 6000 kg ha^{-1}, and attributed this lower yield of straw and forage of *P. americanum* to the short cycle of this crop. It is noteworthy that amounts of dry matter on the soil below 6000 kg ha^{-1} may impair the viability of the no-tillage system. Pacheco *et al*. (2013) did not find any difference between *U. ruziziensis* and *P. americanum*, both sown in sod-seeding with soybean in the 5.5 stage.

In the 2010/11 crop, *U. ruziziensis*, *U. brizantha*, the sorghum hybrid with *S. sudanense* and *S. sudanense* in strategies 1, 5, and 6, had the highest dry matter yields and differed from *P. americanum* and standard treatment. Pacheco *et al*. (2008) also found higher dry matter yields with *U. ruziziensis*, *U. brizantha,* and the sorghum hybrid with *S. sudanense* in the four sod-seeding seasons, and the sorghum hybrid with *S. sudanense* also differed from the standard treatment in all seasons. *U. brizantha* had the highest yield and differed from the other cover plants, in strategy 2; from *U. ruziziensis*, *P. americanum* and from the standard treatment, in strategy 3 and, from *P. americanum*, in strategy 4. It is emphasized that in this period, the soil had 100% of its water storage capacity (Table 2) and, according to Pacheco *et al*. (2008), the greatest use of water supply and photoperiod in the first sod-seeding season contributes to the greater development of *U. brizantha*. For *U. ruziziensis*, strategies 1 and 2 provided greater yield and differed from strategies 3, 4, and 7. For *U. brizantha*, strategy 2 provided the highest yield and differed from strategies 3, 4, 5, 6, and 7. It should be observed that in the period from February 07 to March 13 2011 (stages R6 to R8 of soybeans), the rainfall in Votuporanga totaled 452.9 mm, when the soil showed a water surplus of 290 mm, which favored the development of these cover plants, corroborating with Pacheco *et al*. (2009) who also found that the earliest sowing times of soybean provided increases in the production of phytomass of *U. brizantha* and *U. ruziziensis* in sod-seeding. These authors also mentioned that this occurs due to the better use of soil moisture and the greater coincident photoperiod with the beginning of the development of cover plants. For the hybrid of *S. bicolor* with *S. sudanense*, strategies 1, 2, 3, 5, 6, and 7 provided greater yield and differed from strategy 4. Also, for *S. sudanense*, strategies 1, 6, and 7 provided greater yield and differed from strategy 4.

Table 1. Soil chemical attributes in the 0.00-0.20 m depth layers in the different crops

Crop	P (Resin)	OM	pH ($CaCl_2$)	K	Ca	Mg	H+Al	V
	mg dm^{-3}	g dm^{-3}		---------$mmol_c$ dm^{-3}--------				(%)
2010/11	33	11	4.8	2.6	18	5	20	56
2011/12	39	12	4.8	2.1	18	4	28	46
2014/15	28	12	4.4	2.1	13	7	22	50
2015/16	31	13	5.2	2.5	14	10	18	60

OM - Organic matter.

Table 2. Weekly water balance in Votuporanga from February 07 to April 17, 2011

Period (Week)	AT (ºC)	PP	ETP Storage	ETP	Water deficit	Water surplus
		------------------------ mm ------------------------				
02/07 to 13/02	26.8	87.6	100	36	0	52
02/14 to 20/02	26.1	68.4	100	34	0	35
02/21 to 27/02	27.3	36.9	100	37	0	0
02/28 to 06/03	24.3	175.6	100	29	0	147
03/07 to 13/03	25.0	84.4	100	29	0	56
03/14 to 20/03	25.5	38.2	100	31	0	7
03/21 to 27/03	23.9	23.4	97	26	0	0
03/28 to 03/04	26.1	17.9	85	30	2	0
04/04 to 10/04	23.8	1.0	68	18	5	0
04/11 to 17/04	25.8	37.1	78	27	0	0

Source: CIIAGRO, 2019a.

Table 3. Weekly water balance in Votuporanga from March 16 to May 3 2015

Period (Week)	AT (ºC)	PP	Storage	ETP	Water deficit	Water surplus
		------------------------ mm ------------------------				
03/16 to 03/22	24.2	52.9	100	27	0	26
03/23 to 03/29	25.3	13.7	86	28	1	0
03/30 to 04/05	26.0	44.2	99	31	0	0
04/06 to 04/12	24.2	0.6	79	21	2	0
04/13 to 04/19	26.0	3.8	62	20	7	0
04/20 to 04/26	26.3	21.7	59	25	3	0
04/27 to 05/03	23.2	0.0	48	11	10	0

Source: CIIAGRO, 2019b.

Table 4. Summary of the analysis of variance of dry matter yield by cover plants, Votuporanga, 2010/11 and 2014/15 harvests

Sources of variation	D.F.	F			
		2010/11		2014/15	
Cover plants (F1)	5	64.58	**	38.03	**
Strategies (F2)	6	16.00	**	5.32	**
F1 x F2	30	3.03	**	2.05	**
Treatments	41	12.43	**	6.92	**
Blocks	2	0.06	ns	0.19	ns
Residue	82				
CV		29.20		34.95	

CV - Coefficient of variation (%); D.F. - Degrees of freedom; ns - not significant; * - significant at 5% by the F test; ** - significant at 1% by the F test.

Table 5. Dry matter yield of cover plants (kg ha^{-1}), Votuporanga, 2010/11 harvest

*	Strategies													
	1		2		3		4		5		6		7	
1	13747	aA	12752	bcA	6368	bcB	4086	abB	8161	aAB	9252	aAB	6638	bcB
2	15269	aAB	20041	aA	12273	aB	6642	aC	10567	aBC	11229	aBC	10467	abBC
3	10824	aA	14099	bA	11447	abA	3171	abB	9978	aA	10721	aA	12142	aA
4	12679	aA	7747	cdAB	8473	abAB	4723	abB	8652	aAB	12591	aA	12455	aA
5	3163	bA	4229	dA	2523	cA	1172	bA	1857	bA	3084	bA	5933	bcA
6	2634	bA	2634	dA	2634	cA	2634	abA	2634	bA	2634	bA	2634	cA
LSD (cover plants): 5428.31														
LSD (strategies): 5618.52														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. *Cover plants: 1 - *U. ruziziensis*; 2 - *U. brizantha*; 3 - *S. bicolor* x *S. sudanense*hybrid; 4 - *S. sudanense*; 5 - *P. americanum*; 6 – Standard treatment. LSD: least significant difference.

Table 6. Dry matter yield by cover plants (kg ha^{-1}), Votuporanga, 2014/15 crop

Cover plants	Strategies													
	1		2		3		4		5		6		7	
U. ruziziensis	5764	abA	8542	abA	5673	bcA	6800	bA	7899	abcA	5348	cA	6674	abA
U. brizantha	6153	abB	7293	abcAB	8986	abAB	4987	bB	9164	abAB	11976	abA	4933	bB
Hybrid	5338	abC	5636	bcBC	3451	cC	4993	bC	11407	aA	10534	bAB	7743	abABC
S. sudanense	9829	aB	11030	aAB	11498	aAB	12070	aAB	10028	aB	15574	aA	10208	aB
P. americanum	3232	bA	4174	bcA	2755	cA	4806	bA	5010	bcA	5592	cA	4923	bA
Standard	3657	bA	3657	cA	3657	cA	3657	bA	3657	cA	3657	cA	3657	bA
LSD (cover plants): 4870.19														
LSD (strategies): 5036.57														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. LSD: least significant.

In the 2014/15 crop, dry matter yield of *S. sudanense* was greater than 9800 kg ha^{-1}, and differed from the other cover plants in strategy 4; from *P. americanum* and standard treatment in strategy 1; from the hybrid of *S. bicolor* with *S. sudanense*, *P. americanum* and the standard treatment in strategy 2; from *U. brizantha*, the hybrid of *S. bicolor* with *S. sudanense*, *P. americanum,* and the standard treatment, in strategies 3 and 6; from *U. ruziziensis*, *P. americanum* and the standard treatment in strategy 7. These results corroborate with Borges *et al*. (2014a). For *U. ruziziensis*, strategy 6 provided greater yield, differing from strategies 1, 4, and 7. For *S. bicolor* x *S. sudanense* hybrid, strategy 5 provided greater yield, differing from strategies 1, 2, 3, and 4. For *S. sudanense*, strategy 6 provided greater yield, differing from strategies 1, 5, and 7. In this crop, during the period from March 25 to April 8, 2015 (stages R6 to R8 of soybean), rainfall was 111.4 mm and 26 mm of water surplus was recorded (Table 3), a very different scenario from the 2010/11 (290 mm water surplus), showing that if there is a significant water surplus in the soil during soybean stages R6 to R8, sod-seeding in this phase of *U. ruziziensis* and *U. brizantha* can be promoted. The different seed expenditures of cover crops, in direct sowing after soybean harvest (strategies 5, 6, and 7), interfered in the dry matter yield of *U. brizantha* and *S. sudanense*, in the 2014/15 crop. The use of 412.5 CVP ha^{-1} of *U. brizantha* seeds provided a reduction of 58.8% in dry matter yield, in relation to the use of 825 CVP ha^{-1} and, for *S. sudanense*, the expenditure of 20 kg ha^{-1} of seeds provided an increase of

On the other hand, Correia and Gomes (2015), Borges *et al*. (2014b) and Erasmo *et al*. (2017) found no differences in dry matter yield of cover plants with different seed expenditures; however, Erasmo *et al*. (2017) found that in the single cultivation of cover crops, yield was higher than in the intercropping, showing that cover plants are sensitive to simultaneous cultivation with soybeans. Consequently, sod-seeding was reported as the most suitable alternative to sowing these cover crops, as competition between plants is the major agent in reducing dry matter yield in intercropped crops. In addition, as soybean are at a more advanced stage, they have a greater competitive capacity whether for water, light, or nutrients (Erasmo *et al*., 2017). According to Bilalis *et al*. (2010), plants that develop faster compete more effectively for light and, according to Blank (2010), a combination of plants, whether intra- or interspecific, promotes a reduction in the growth of species, when they occupy the same place, for example, for a certain period. Regarding the cultivation of soybean grown in succession to cover crops, for the parameters height of insertion of the first pod and plant height, no difference ($p < 0.05$) was observed between the cover plants and between their sowing strategies in the 2011/12 and 2015/16 crops (Tables 7 and 8), corroborating with Borges *et al*. (2015b); however, there was a significant interaction between cover plants and sowing strategies, concerning the final stand ha^{-1} and grain yield ha^{-1} (Tables 7, 8, 9, 10, 11 and 12).

Table 7. Summary of analysis of variance of soybean crop agronomic characteristics, Votuporanga, 2011/12 crop

Sources of variation	D.F.	F							
		I.H.		P.H.		STA		G.Y.	
Cover plants (F1)	5	23001.00	ns	1.1186	ns	2.73	*	8.09	**
Strategies (F2)	6	10932.00	ns	0.3921	ns	3.62	**	1.83	ns
F1 x F2	30	0.9645	ns	0.8378	ns	2.47	**	2.07	**
Treatments	41	11463.00	ns	0.8068	ns	2.67	**	2.76	**
Blocks	2	91112.00	**	4.9163	**	18.73	**	6.67	**
Residue	82								
CV		6.64		11.48		7.46		17.14	

CV - Coefficient of variation (%); D.F. - Degrees of freedom; I.H. - Insertion height of the first pod (m); PH - Plant height (m); STA - Final stand ha^{-1}; GY - Grain yield (kg ha^{-1}); ns - not significant; * - significant at 5% by the F test; ** - significant at 1% by the F test

Table 8. Summary of analysis of variance of the soybean crop agronomic characteristics, Votuporanga, 2015/16 crop

Sources of variation	D.F.	F							
		I.H.		P.H.		STA		G.Y.	
Cover plants (F1)	5	5.6248	**	3.1581	*	6.23	**	7.53	**
Strategies (F2)	6	2.0927	ns	2.0211	ns	3.79	**	2.96	**
F1 x F2	30	1.0648	ns	0.9678	ns	3.01	**	2.03	**
Treatments	41	1.7714	**	1.3891	ns	3.52	**	2.83	**
Blocks	2	0.065	*	0.2227	ns	1.81	ns	0.05	*
Residue	82								
CV		21.59		11.63		16.38		22.57	

CV - Coefficient of variation (%); D.F. - Degrees of freedom; I.H. - Insertion height of the first pod (m); P.H. - Plant height (m); STA - Final stand ha^{-1}; G.Y. - Grain Yield (kg ha^{-1}); ns - not significant; * - significant at 5% by the F test; ** - significant at 1% by the F test.

Table 9. Soybean Crop final stand ha^{-1}, 2011/12 crop

Cover plants	Strategies													
	1		2		3		4		5		6		7	
U. ruziziensis	230000	bc	244444		227778		240000	ab	232222		251667		233333	ab
U. brizantha	208889	c	241667		233333		236667	ab	217778		230000		226667	ab
Hybrid	262222	abA	252222	AB	240000	ABC	208889	bC	216667	BC	217778	BC	245000	aABC
S. sudanense	271667	aA	238889	ABC	217778	BC	257778	aAB	242222	ABC	226667	BC	206667	abC
P. americanum	258333	abA	246667	AB	237778	AB	227778	abABC	228889	ABC	213333	BC	193333	bC
Standard	221482	bc	221482		221482		221482	ab	221482		221482		221482	ab
LSD (cover plants): 15542.72														
LSD (strategies): 17376.29														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. LSD: least significant difference.

Table 10. Soybean Crop final stand ha^{-1}, Votuporanga, 2015/16 crop

Cover plants	Strategies													
	1		2		3		4		5		6		7	
U. ruziziensis	223333	AB	250000	A	225000	AB	225000	AB	208333	aAB	151667	bcB	208333	abAB
U. brizantha	250833	A	240833	A	246667	A	214167	AB	130833	bC	105833	cC	152222	bBC
Hybrid	240833		193333		248333		260833		229167	a	265000	a	231667	a
S. sudanense	245833		225000		212500		257500		197500	ab	250000	a	228889	a
P. americanum	218333		213333		198333		261667		226667	a	234167	a	238333	a
Standard	211667		211667		211667		211667		211667	a	211667	ab	211667	ab
LSD (cover plants): 73470.22														
LSD (strategies): 75980.15														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. LSD: least significant difference.

Table 11. Soybean grain yield (kg ha^{-1}), Votuporanga, 2011/12 crop

Cover plants	Strategies													
	1		2		3		4		5		6		7	
U. ruziziensis	861	a	839	ab	722		783		572	ab	725	ab	767	ab
U. brizantha	828	abAB	1067	aA	858	AB	761	AB	783	aAB	1017	aA	617	bB
Hybrid	556	bB	667	bAB	817	AB	728	AB	633	abAB	867	abAB	925	aA
S. sudanense	875	a	672	b	744		728		856	a	756	ab	667	ab
P. americanum	767	ab	625	b	600		589		467	b	639	b	533	b
Standard	767	ab	767	ab	767		767		767	ab	767	ab	767	ab
LSD (cover plants): 304.15														
LSD (strategies): 314.81														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. LSD: least significant difference.

Table 12. Soybean grain yield (kg ha^{-1}), Votuporanga, 2015/16 crop

Cover plants	Strategies													
	1		2		3		4		5		6		7	
U. ruziziensis	2371		2852	ab	2611		2026		2392	ab	2469	ab	1950	ab
U. brizantha	2433	AB	2301	abAB	2297	AB	2685	A	1530	bB	1658	bAB	1545	bB
Hybrid	2620		2291	ab	2588		2511		2422	ab	2463	ab	2183	ab
S. sudanense	2856	A	1861	bAB	2105	AB	2954	A	1417	bB	2446	abAB	1450	bB
P. americanum	2318		3069	a	2145		2974		3151	a	2747	a	2771	a
Standard	2039		2039	ab	2039		2039		2039	b	2039	ab	2039	ab
LSD (cover plants): 1065.19														
LSD (strategies): 1101.58														

Means followed by the same lower-case letter in the columns and upper-case letter in the lines are not different from each other by the test of Tukey at 5%. LSD: least significant difference.

On the other hand, Garcia *et al*. (2014), Machado and Assis (2010), and Machado (2012) did not observe the influence of cover crops on the grain yield of the soybean crop in succession and attributed this fact to the rates of decomposition and mineralization of forage straws being similar. Also, they mentioned that the variations caused by the different coverages may have been smaller than that of other factors related to soil, sowing, and the evaluation of the experiment. The insertion heights of the first pod ranged from 0.14 to 0.18 m in the 2011/12 crop and from 0.09 to 0.16 m in the 2015/16 crop. Moreover, the plant heights ranged from 0.48 to 0.58 m in the 2011/12 crop and from 0.56 to 0.76 m in the 2016/16 crop. For the parameter final stand ha^{-1} of the soybean crop, in the 2011/12 crop, in strategy 1, *S. sudanense* provided a higher final stand ha^{-1} and differed from *U. ruziziensis*, *U. brizantha,* and standard treatment. In strategy 4, *S. sudanense* also provided a greatest and and differed from the *S. bicolor* x *S. sudanense* hybrid. In strategy 7, the *S. bicolor* x *S. sudanense* hybrid provided a higher stand and differed from *P. americanum*. On the other hand, Krutzmann *et al*. (2013) found no difference between sowing dates in relation to the stand of the soybean grown in succession, and Pacheco *et al*. (2009) found that the stand of the soybean grown in succession to the cover crops suffered less interference from the straws on the soil surface, even under a large quantity of the produced phytomass.

The authors mentioned that in the sowing of soybeans, the cutting system and the deposition of fertilizer and seed from the seeder-fertilizer are sufficient to leave a furrow between the straws in the sowing line, which favors the incidence of light, therefore, contributing to the germination and growth of the annual crop. Cover plants that support adequate soil coverage promote the germination and development of seedlings of the next crop. In the northwest region of São Paulo, it is common the occurrence of Indian summer in October and November, the recommended period for sowing most soybean cultivars. If the soil does not have a good layer of straw and the seed does not have a good vigor, the stand may be affected and, consequently, there will be a reduction in grain yield. For the grain yield parameter, in the 2011/12 crop, it ranged from 467 kg ha^{-1}, on the *P. americanum* straw with strategy 5, to 1067 kg ha^{-1}, on the *U. brizantha* straw with strategy 2. In the 2014/15 crop, yield ranged from 1417 kg ha^{-1}, on the *S. sudanense* straw; to 3151 kg ha^{-1}, on the *P. americanum* straw, both with strategy 5. It is noteworthy that the soybean cultivars used in the two crops were different. In the 2011/12 crop, for logistical reasons, soybean sowing was carried out on January 02, 2012, off the recommended season for sowing the cultivar BRS Valiosa RR, which impaired its yield. In the 2011/12 crop, the highest dry matter yield of *U. brizantha*, in strategy 2, 20041 kg ha^{-1} (Table 5) responded with a higher grain yield of soybean in succession (Table 11) and, the lower dry matter yield of *P. americanum*, in strategy 5, 1857 kg ha^{-1} (Table 5), reflected in lower soybean yield in succession, showing the importance of using cover crops with high dry matter yield before the soybean crop, in the northwestern São Paulo State. For *U. brizantha*, strategies 2 and 6 provided greater grain yield, differing from strategy 7. For the sorghum x *S. sudanense* hybrid, strategy 7 provided greater yield, therefore, differing from strategy 1. In the 2015/16 crop, *P. americanum* provided the highest grain yields in strategies 2, 5, 6, and 7, and differed from *S. sudanense* in strategy 2, from *U. brizantha* and *S. sudanense* in strategies 5 and 7, and *U. brizantha* in strategy 6. It is emphasized that the *P. americanum* cultivar used in this crop was different from that used in the 2010/11 crop, showing the importance of choosing the cultivar of the cover plant to be used. Borges *et al*. (2014b) found accumulations of up to 163; 52; 196; 45; 28 and 23 kg ha^{-1} for N, P, K, Ca, Mg and S, respectively, for *P. americanum*. As the degradation of pearl millet straw in the northwest region of São Paulo is very fast because of the high temperatures, with a reduction of 53.6% in the quantity of dry matter produced at flowering, in relation to the pre-sowing of soybean in succession (Borges *et al*., 2015a), soybean in succession benefited from the nutrients accumulated by *P. americanum* and made available after its degradation, which was reflected in the higher grain yields in strategies 2, 5, 6 and 7. Regarding *U. brizantha*, strategy 4 provided greater grain yield, differing from strategies 5 and 7.

For *S. sudanense*, strategies 1 and 4 provided greater productivity, differing from strategies 5 and 7. On the other hand, Andrade *et al*. (2017) found a difference in soybean grain yield in only one of the two crops and Pacheco *et al*. (2008) found no differences in relation to the yield since the sod-seeding of the cover plants was done in the physiological maturation of soybean. Besides, according to the authors, the interference of the late intercropping in grain yield is null because, in the physiological maturation, the soybean has already defined its productivity. Also, the growth of cover crops only starts after a high defoliation rate of soybean, almost at the harvest point. Unlike the work of Andrade *et al*. (2017) and Pacheco *et al*. (2008), this study aimed to verify the effect of cover crops on soybean grown in succession, so the interference of cover crops on the soybean that received sod-seeding (BRS 184 and IAC Foscarin-31) was not evaluated. The different seed expenditures of *U. brizantha* (strategies 5, 6, and 7) interfered in the soybean grain yield in the 2011/12 crop. The use of 412.5 CVP ha^{-1} of seeds provided a reduction of 39.3% in grain yield in relation to the expenditure of 825 CVP ha^{-1}.

Conclusions

The sowing strategies of cover plants interfered in their succession in the northwest region of São Paulo State. In the 2010/11 crop, the broadcast sod-seeding of *Urochloa brizantha* cultivar Marandu, with the soybean crop at the R7 maturation stage, provided the highest dry matter yield and the highest grain yield of the soybean cultivar BRS Valiosa RR in the following crop. In the 2014/15 crop, *Sorghum sudanense* sown in a direct sowing system, using plot-seeder 2 days after the soybean harvest with 20 kg ha^{-1} of seed expenditure resulted in the highest dry matter yield. The highest grain yields of the soybean cultivar BMX Potencia RR in the 2015/16 crop were provided by the *Pennisetum americanum* cultivar BRS 1501 in the broadcast sod-seeding with the soybean crop at the R7 maturation stage and in sowing under no-tillage system using plot-seeder 2 days after soybean harvest, with 25, 20 and 10 kg ha^{-1} of seed expenditure.

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