Effects of intercropping on temperate grasses canopy architecture and nutritive profile

Efeitos do consórcio na arquitetura do dossel forrageiro e perfil nutricional de gramíneas de clima temperado

Efecto de los cultivos intercalados en la arquitectura del dossel forrajero y el perfil nutricional de las gramíneas templadas

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Abstract
This paper aimed to evaluate the impact of intercropping between oats and triticale species, over three defoliation cycles. The experiment occurred in two winters in a row, and was in split-plot randomized complete blocks design (20 plots) with five species combination, four blocks and three defoliations. The main plots were the species combination: black oat (*Avena strigosa* cv. IAPAR 61) – BO, white oat (*Avena sativa* cv. IPR Emerald) – WO, triticale (*X Triticosecale* Wittmack cv. Tpolo 981) – T; and the intercropping: black oat + triticale – BOT, and white oat + triticale - WOT. The sub-plots were the three defoliations cycles initially scheduled to be every 28 days. The intercropping between oats and triticale did not affect the accumulated dry matter yield (DM), but it also improved the pastures, as an increase on crude protein content (CP) (about 1.85% greater in WOT than WO; and 2.7% greater in BOT than BO). The number of leaves was also increased by the intercropping, from 4.2 (WO) and 3.7 (BO) to 7.6 (WOT) and 7.2 (BOT) leaves per main stem. Over the defoliation cycles, the maximum average of growth rate (2.72 t DM ha^{-1} ºCd^{-1}), tiller per plant (10 tillers plant^{-1}) and main tiller height (53.2 cm) were unanimously observed at third defoliation. The changes observed did not reduced the nutritional quality of the pastures, therefore both are highly indicated to these conditions.
Keywords: *Avena sativa* L. IPR Emerald; *Avena strigosa* Schreb IAPAR 61; Competition; Tiller density; *X Triticosecale* Wittmack Tpolo 981.

Resumo
O objetivo deste trabalho foi avaliar o impacto do consórcio entre aveias e triticale, ao longo de três ciclos de pastejo. O experimento ocorreu em dois invernos seguidos, em delineamento em blocos casualizados com parcelas subdivididas no tempo (20 parcelas) com cinco combinações de espécies, quatro blocos e três pastejos. As parcelas principais foram as combinações de espécies: aveia preta (*Avena strigosa* cv. IAPAR 61) - BO, aveia branca (*Avena sativa* cv. IPR Esmeralda) - WO, triticale (*X Triticosecale* Wittmack cv. Tpolo 981) - T; os consórcios aveia preta + triticale – BOT, e aveia branca + triticale – WOT. As subparcelas foram os três ciclos de pastejo inicialmente agendados para ocorrerem a cada 28 dias. O consórcio entre aveias e triticale não afetou a produção de matéria seca (MS), mas aumentou a concentração de proteína bruta (PB) (cerca de 1.85% superior em WOT comparado a WO; e 2.72% superior em BOT do que BO). O número de folhas vivas também foi aumentado, de 4.2 (WO) e 3.7 (BO) para 7.6 (WOT) e 7.2 (BOT) folhas no perfilho principal. Durante os ciclos de pastejo, a média máxima de taxa de crescimento (2.72 t DM ha^{-1} ºCd^{-}

^{1}), perfilhos por planta (10 perfilhos planta^{-1}) e altura do perfilho principal (53.2 cm) foram unanimemente obtidos na terceira desfolhação. As mudanças observadas não reduziram a qualidade nutricional das pastagens, sendo assim ambos consórcios são indicados para estas condições.

Palavras-chave: *Avena sativa* L. IPR Esmeralda; *Avena strigosa* Schreb IAPAR 61; Competição; Densidade de perfilhos; *X Triticosecale* Wittmack Tpolo 981.

Resumen

Este artículo tuvo como objetivo evaluar el impacto de los cultivos intercalados entre especies de avena y triticale, durante tres ciclos de defoliación. El experimento se llevó a cabo en dos inviernos consecutivos, en un diseño de bloques al azar con parcelas divididas en el tiempo (20 parcelas) con cinco combinaciones de especies, cuatro bloques y tres de pastoreo. Las principales parcelas fueron combinaciones de especies: avena negra (*Avena strigosa* cv. IAPAR 61) - BO, avena blanca (*Avena sativa* cv. IPR Esmeralda) - WO, triticale (*X Triticosecale* Wittmack cv. Tpolo 981) - T; los consorcios avena negra + triticale - BOT, y avena blanca + triticale - WOT. Las subparcelas fueron los tres ciclos de pastoreo inicialmente programados para ocurrir cada 28 días. El cultivo intercalado entre avena y triticale no afectó la producción de materia seca (MS), pero aumentó la concentración de proteína cruda (CP) (aproximadamente 1.85% más alta en WOT en comparación con WO; y 2.72% más alta en BOT que BO). También se incrementó el número de hojas, de 4,2 (WO) y 3,7 (BO) a 7,6 (WOT) y 7,2 (BOT) hojas en la macolla principal. Durante los ciclos de pastoreo, la tasa máxima promedio de crecimiento (2,72 t MS ha^{-1} ºCd^{-1}), macollos por planta (10 macollos planta^{-1}) y altura de macollos principales (53,2 cm) se obtuvieron por unanimidad en la tercera defoliación. Los cambios observados no redujeron la calidad nutricional de los pastos, por lo que ambos consorcios están indicados para estas condiciones.

Palabras clave: *Avena sativa* L. IPR Esmeralda*; Avena strigosa* Schreb IAPAR 61; Competência; Densidad de macollos; *X Triticosecale* Wittmack Tpolo 981.

1. Introduction

The temperate grasses are used to fill the winter gap produced by the dormancy of *Cynodon* spp. and as soil winter cover in crop-livestock systems. The main characteristic of these species is frost resistance (Poirier et al., 2012), very common in this area from May to August.

Although known as highly nutritive feed, these grasses have a lower yield compared with tropical ones, which leads producers to reduce the area of their cultivation, and the use of silage and grains supplementation to animals, etc. To optimize the cultivation area, some researchers have been trying to enhance the productivity of temperate grasses by mixture different genotypes and species (Carvalho et al., 2011; Duchini et al., 2016; Ferrazza et al., 2013).

The intercropping of species with different growth patterns and rates can be synchronized to increase the persistence (Carvalho et al., 2011) of high digestible fibre in the field, stimulate the leaf emergence and elongation rates, promote the yield in different horizons in the canopy (Duchini et al., 2016), increase the crude protein levels of the pasture and produce a maximum of 9 t DM ha^{-1} (Ferrazza et al., 2013). The most used intercropping in South Brazil is between black oat (*Avena sativa* L.*) + ryegrass (*Lolium multiflorum* Lam.)

However, it also can increase the leaf senescence and stem elongation when the species are not in balance (Duchini et al., 2016), which may result in a decrease of nutritional quality, depending on the damage level. The process of genotype choice is essential to achieve the producer objective, associated with the right management to optimize the soil use.

The objective of this paper was to determine the effects of intercropping white oat IPR Emerald and black oat IAPAR 61 with triticale Tpolo 981, by evaluating the productivity, canopy structure and nutritive quality of the canopy compared with their monocrop over three defoliations cycles.

2. Methodology

The experiment was established at the Experimental Farm of Western Parana State University - UNIOESTE, campus Marechal Cândido Rondon, Parana, Brazil (24º 33' 22'' S and 54º 03' 24'' W, 400 m of altitud) in a Cfa humid subtropical weather, with 22 ºC as the highest average temperature and 18 ºC as the lowest average temperature, with frequent frosts over winter (Bhering & Santos, 2008). The rainfall and temperature data were obtained from the local weather station situated 100 m

far from the field experiment (Figure 1), from which the accumulated thermal-time (ºCd) was counted using the "threshold broken-stick" method (Moot et al., 2001), adapted for temperate grasses, with basal temperature (T_b) equals to 1 ºC. The experiment was performed over the winters of two consecutive years.

Figure 1. Mean temperature and accumulate rainfall in Marechal Cândido Rondon, Paraná, Brazil, during the winter of Years 1 and 2.
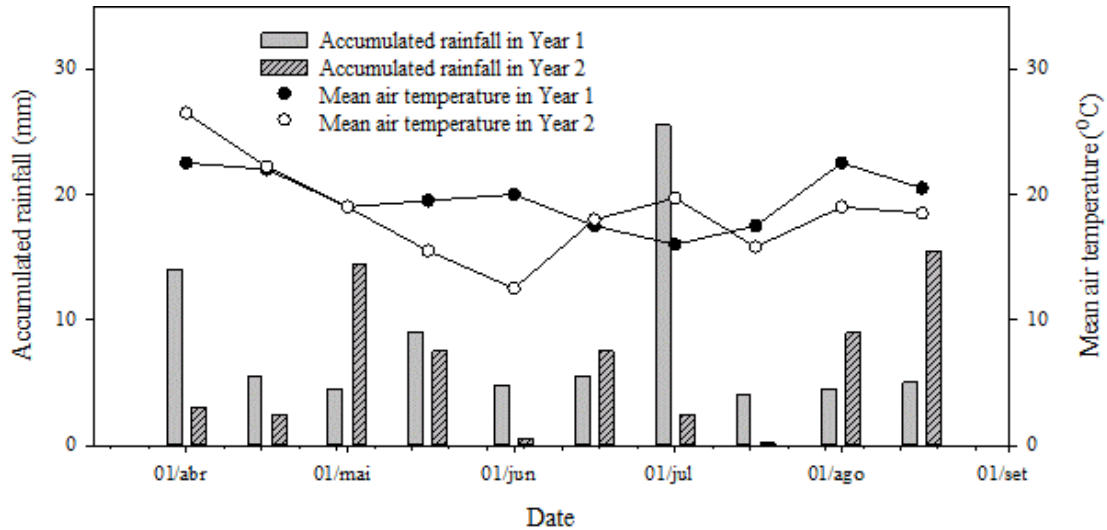
Source: Authors.

The area (0.10 ha) had been cultivated in a crop-livestock system with corn and soybeans during the spring/summer and temperate grasses in the cold seasons for the past eight years. The soil is classified as Latosoil Red Eutoferric (EMBRAPA, 2006) and initially presented pH ($CaCl_2$) of 4.95, 21.87 g dm^{-3} of organic matter, 0.32 cmol$_c$ dm^{-3} of K, 2.30 cmol$_c$ dm^{-3} of Ca^{2+}, 2.30 cmol$_c$ dm^{-3} of Mg^{2+}, 5.50 cmol$_c$ dm^{-3} of Al+H, 0.15 cmol$_c$ dm^{-3} of Al^{3+}, 38.08 mg dm^{-3} of P, 1.60 mg dm^{-3} of Zn and 3.87 mg dm^{-3} of Al, at 20 cm of depth.

The experiment was in split-plot randomized complete blocks design (20 plots of 52.8 m^2) with five species combination, four blocks and three defoliations. The main plots were the species combination: black oat (*Avena strigosa* cv. IAPAR 61) (60 kg seed ha^{-1}) – BO, white oat (*Avena sativa* cv. IPR Emerald) (60 kg seed ha^{-1}) – WO, triticale (X *Triticosecale* Wittmack cv. Tpolo 981) (140 kg seed ha^{-1}) – T; and the intercropping: black oat (50 kg ha^{-1}) + triticale (120 kg seed ha^{-1}) – BOT, and white oat (50 kg ha^{-1}) + triticale (120 kg seed ha^{-1}) - WOT. The sub-plots were the defoliations cycles initially scheduled to be every 28 days, as performed by farmers in this region.

The species were sown in April of 2015 using no-tillage seeding, with 17 cm between rows and 3-5 cm of seed depth. The plants emerged about seven days later. An establishment period of 25 days was settled, followed by a nitrogen (N) application (60 kg N ha^{-1}), like urea. After the establishment phase the cycle period (28 days) started to be counted, but due to the weather conditions took about 28, 32 and 38 days for the 1st, 2nd and 3rd regrowth cycles, respectively.

The structural and phenological measurements were performed at the end of each regrowth cycle. The number of tillers and plants were counted using a frame of 0.25 m² twice per plot randomly chosen, where all tillers and plants were counted by species. A non-marked tiller morphometric evaluation adapted from Carrère et al. (1997) was performed by taken 10 tillers of each species, randomly chosen, and the height from soil to the curve of the highest leaf, or the top of inflorescence when present, number of live and dead leaves and stem diameter (using a digital caliper below the first node) were measured. The SPAD index was measured in 10 random mature leaves of each species, by a chlorophyllometer (SPAD-502, Minolta, Osaka, Japan).

Biomass yield was measured with the use of a 0.5 m² frame randomly chosen per plot, where all the content was hand-cut. A straw residue of 8-12 cm remained to consider only the available forage to animals, once this was the output height. Right after the measurements, the defoliations were performed by dairy cows using the "put-and-take" technique (Mott & Lucas, 1952) until the output height was achieved. From the slope between biomass yield and accumulated thermal-time data, the values of linear growth rate were obtained.

The biomass samples were dried in a forced-air oven at 60 ºC for 72 h to determine biomass yield dry matter (DM). The dried samples were ground in a knife mill to ~1 mm of particle size, and then analyzed for neutral detergent fibre (NDF_{pa}), acid detergent fibre (ADF) and lignin in 72% sulphuric acid (Van Soest et al., 1980), and crude protein (CP, micro Kjeldahl) (AOAC, 1995).

Attributes were analyzed separately by year to determine the interaction between treatments and defoliations according to the following model:

$$Y_{ijk} = \mu + T_i + B_j + e_{ij} + d_k + \delta_{ik} + e_{ijk}$$

Where Y_{ijk} is the ith species combination value in the jth block at the kth defoliation, having μ as overall model average, T_i being the treatment fixed effect, B_j the block fixed effect and e_{ij} the experimental error between treatment and block. The d_k represents the defoliations as a random effect, while δ_{ik} represents the interaction between treatment and defoliation, with e_{ijk} as the experimental error between the ith treatment value, the jth block value and the kth defoliation value. Means were compared by Tukey's honestly significant difference test (α=0.05) by ANOVA. Statistical analyses were performed using the software SAS® On Demand. The graphics were produced using SigmaPlot Software®, version 14.0.

3. Results

The accumulated dry matter (DM) yield differs ($P<0.05$) among systems only in Year 2 (Table 1). The systems with oat in a single crop had higher ($P<0.05$) yield than triticale, with no differences to the intercropping. The greatest ($P<0.05$) DM yield occurred in the third cut when plants entered in reproductive stage. The growth rate maintained ($P>0.05$) 1.64 and 2.45 t DM ha^{-1} ºCd^{-1} in Years 1 and 2. The increase of temperatures from the second defoliation on allowed the plants to increase ($P<0.05$) the growth rate and, probably, enter on the reproductive stage.

Table 1. Accumulated dry matter yield (t DM ha^{-1}), linear growth rate (t DM ha^{-1} ºCd^{-1}), number of tillers (tillers m^{-2}) and number of live leaves of white oat IPR Emerald (WO), black oat IAPAR 61 (BO) and triticale Tpolo 981 (T) in single crop or intercropping (WOT and BOT) defoliated three times over two years at Marechal Cândido Rondon, Parana, Brazil.

	Accumulated DM yield (t DM ha^{-1})		Growth rate (t DM ha^{-1} ºCd^{-1})		Tiller m^{-2}		Number of live leaves	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
WO	3.70	2.93a	1.90	2.59	218.17a	330.09ab	3.99b	4.44b
WOT	4.04	2.70ab	1.87	2.83	203.70b	370.74ab	7.27a	7.96a
BO	2.97	2.84a	1.26	2.15	253.83a	396.72ab	3.63b	3.83c
BOT	3.64	2.14ab	1.77	2.68	262.73a	457.03a	6.87a	7.64a
T	2.87	1.91b	1.41	2.00	265.06a	252.98b	3.44b	3.85c
SE	281.6	167.8	0.15	0.18	14.08	36.61	0.31	0.09
P	0.0435	0.0002	0.0015	0.48	0.66	0.56	<0.0001	<0.0001
1st	0.58c	0.84c	0.80b	1.13b	290.36a	267.85b	5.97a	5.49b
2nd	1.90b	1.43b	2.03a	3.29a	284.57a	410.62a	4.60b	5.24c
3rd	3.44a	2.50a	2.26a	3.19a	147.16b	406.05a	4.54b	5.89a
SE	50.99	72.12	0.09	0.12	10.90	28.35	0.24	0.07
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0012	<0.0001	<0.0001
Species combination x defoliation								
SE	0.12	0.14	0.26	0.32	24.38	63.41	0.54	0.16
P	0.85	0.73	0.97	0.64	0.02	0.13	0.82	0.03

Averages followed by the same letter in column did not differ by Tukey's test (α=0.05). Source: Authors.

The phenology results presented contrary patterns between the years. There was a sharp reduction in tiller population, from 284 tillers m^{-2} in the second regrowth cycle, to 147 tillers m^{-2} on the third cycle of Year 1. However, Year 2 showed an average of 408 tiller m^{-2} in a similar period, with no differences (P>0.05) among species systems. As the number of tillers is dependent on the number of leaves, a similar pattern was obtained over the defoliations, a reduction (P<0.05) in Year 1 and a gradual increase (P<0.05) in Year 2. However, the number of live leaves was higher (P<0.05) in intercropped systems, and in Year 2 it was even lower (P<0.05) for black oat and triticale in a single crop, compared with the other systems.

Another important phenology variable tested was the stem diameter, and it presented interaction between species and the number of defoliations (P<0.05) in both years (Figure 2). In general, the triticale presented thinner (P<0.05) stems, mainly compared to white oat, whereas the black oat ranged between the two extremes. Two interesting points to bring up are 1) the thicker (P<0.05) stem of black oat intercropped with triticale at second defoliation (about 0.07 mm greater than the single crop); and 2) the reduction of oats stem diameter from >3.8 mm in the second to a maximum of 3.5mm in the third defoliation.

Figure 2. Stem diameter (mm) of white oat (WO), black oat (BO) and triticale (T) in single crop or intercropping and defoliated three sequential times over two winters at Marechal Cândido Rondon, Parana, Brazil.
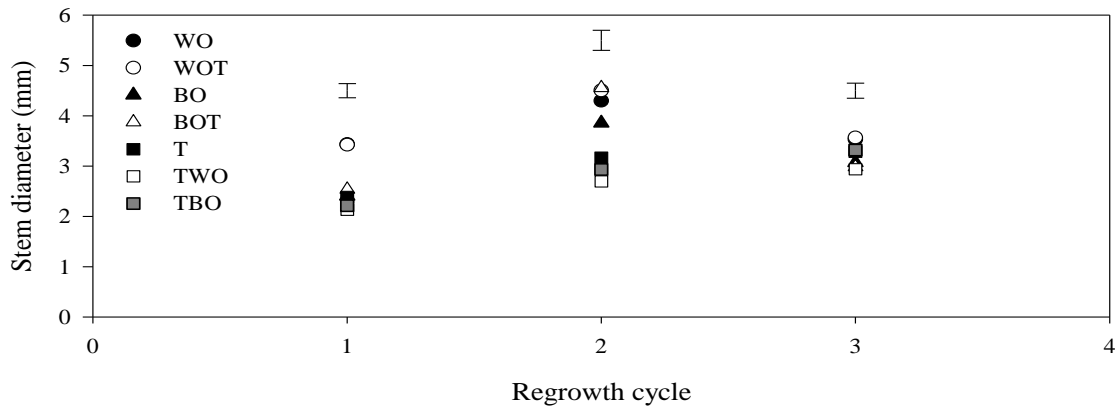
WOT represents the results of white oat intercropped to triticale; BOT represents the results of black oat intercropped to triticale; TWO and TBO represent triticale results intercropped to white oat and black oat, respectively. Error bars represent standard error when differences were noticed by Tukey's test (α=0.05). Source: Authors.

Contrary to tiller m^{-2}, the number of tillers per plant increased over the defoliations in both years, from 4.8 and 6.4 tiller plant^{-1} at the first defoliation to 9.2 and 10.6 tillers plant^{-1} at the third defoliation (Table 2). There were no differences ($P>0.05$) among genotypes and systems, with total averages of 7.1 and 9.1 tillers plant^{-1}, irrespective of Years 1 and 2.

The black oat main tiller height was affected ($P<0.05$) by the intercropping, which caused the increase of the main tiller compared to its single crop. Among different species, there were differences ($P<0.05$) as the white oat IPR Emerald is naturally taller than the Triticale Tpolo 981. The increase in tiller height at the third defoliation reinforces the entering of plants on the reproductive stage, when the temperature was favourable to it. With the increase in tiller height, the number of senescent leaves also increased ($P<0.05$) by the defoliations, and achieved 2.3 and 1.6 leaves plant^{-1} at the end of both experiments.

The SPAD index presented differences ($P<0.05$) among species in Year 2, with the triticale as the highest values, independent of the system (> 60), and by the defoliations it fluctuated with a pattern of increase from ~40 to ~50. As a non-destructive indication of nitrogen (N) content, the SPAD index obtained a similar response of crude protein (CP). It was noticed by the greater ($P<0.05$) concentration of CP on triticale systems (Table 3).

Even with the greatest CP content, the triticale CP yield (0.57 and 0.29 t CP ha^{-1}, at Years 1 and 2) was lower than the WO at the single crop (0.58 and 0.41 t CP ha^{-1}, respectively), due to the lower shoot yield obtained in those treatments (Table 3). The black oat IAPAR 61 had the CP yield increased when intercropped with triticale T at Year 1 (from 0.55 to 0.68 t CP ha^{-1}, for BO and BOT treatments), a fact that has not occurred in Year 2 when the maximum was 0.37 t CP ha^{-1} achieved by BO.

The fibre variables (NDF and ADF) exalted the tallest plants of white oat IPR Emerald and shown the greatest ($P<0.05$) values of 38% (NDF of WOT at Year 1) and 18.6% (ADF of WO at Year 1). Over the defoliations, as the plants entered on reproductive stage, the fibre content was increased ($P<0.05$), to a maximum of 40% of NDF, 17.2% of ADF, and 5.6% of lignin.

Table 2. Phenological characteristics of white oat IPR Emerald (WO), black oat IAPAR 61 (BO) and triticale Tpolo 981 (T) in single crop and intercropped, defoliated sequential times over two years at Marechal Cândido Rondon, Parana, Brazil.

	Tiller plant[-1]		Main tiller height (cm)		Number of dead leaves		SPAD index	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
WO	8.26	8.06	55.26a	42.87	1.23	0.68	46.25	47.41b
WOT	6.56	6.82	56.58a	43.07	1.52	0.62	48.77	48.76b
BO	9.56	10.79	39.24b	43.08	0.89	0.57	44.18	50.51b
BOT	7.35	8.72	49.43a	35.53	1.44	0.72	44.20	50.56b
T	8.10	12.77	33.42bc	37.35	1.19	0.60	50.92	67.82a
TWO	4.45	7.93	28.34c	34.77	1.37	0.64	46.97	65.34a
TBO	5.67	8.90	26.19c	35.94	1.46	0.62	53.72	63.63a
SE	0.62	0.68	2.03	3.78	0.22	0.05	1.36	2.28
P	0.14	0.82	0.0002	0.41	0.60	0.09	0.24	0.0255
1st	4.82c	6.43b	32.43c	27.25b	0.11c	0.06c	-	49.24c
2nd	7.32b	10.35a	40.62b	33.67b	1.48b	0.20b	43.04b	64.30a
3rd	9.22a	10.65a	50.57a	55.91a	2.31a	1.64a	52.67a	55.33b
SE	0.42	0.45	1.33	2.48	0.14	0.03	0.72	1.49
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Species combination x defoliation								
SE	1.08	1.18	3.51	6.56	0.39	0.09	1.92	3.94
P	0.25	0.90	0.13	0.56	0.95	0.80	0.41	0.08

WOT represents the results of white oat intercropped to triticale; BOT represents the results of black oat intercropped to triticale; TWO and TBO represent triticale results intercropped to white oat and black oat, respectively. SE: standard error. Averages followed by similar letter in column did not differ by Tukey's test (α=0.05). Source: Authors.

4. Discussion

This study aimed to compare the morphological plasticity of intercropped grasses and its impact on dry matter yield and nutritional profile. We also accessed the effects of continuous defoliations on these plants through the winter and vegetative-reproductive stages.

The white oat IPR Emerald proved to be more ($P<0.05$) productive than the black oat IAPAR 61 and the triticale Tpolo 981, by its highest ($P<0.05$) and thickest ($P<0.05$) stems. In addition, its precocity, that allowed the earlier defoliation with almost 1.0 t DM ha^{-1} at 42 days after emergence (DAE). The results are still lower than the obtained by Demétrio et al. (2012), but those authors evaluated the temperate grasses over the spring, in greater photoperiod and temperatures. Oliveira et al. (2015) achieved the 5.8 t DM ha^{-1} year^{-1} when intercropped white oat IPR Emerald with triticale Tpolo 981. It may imply the low tolerance of these species to soil aluminium content (Al) that reduces the development of the roots and, consequently, the regrowth plant ability.

The low DM yield, which hardly exceeded 4 t DM ha^{-1} year^{-1}, might be a reflex of seeding date. Ferrazza et al. (2013) and Pin et al. (2011) indicate that seeding of temperate grasses in Southwest of Parana is not economically worthy when performed after the second half of April, once long-cycled plants as black oat IAPAR 61 can express the whole potential and supply the demand of feed in the off-season. As the regrowth cycles in this experiment were settled by time, not canopy characteristics, it influenced a lower production linked to self-thinning resulted from a turnover within the canopy (Pin et al., 2011; Duchini et al., 2018).

Table 3. Nutritional values of white oat IPR Emerald (WO), black oat IAPAR 61 (BO) and triticale Tpolo 981 (T) in single crop and intercropped (WOT and BOT, respectively to the oats), defoliated three sequential times over two years at Marechal Cândido Rondon, Parana, Brazil.

	CP (%)		NDF (%)		ADF (%)		Lignin (%)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
WO	15.6c	14.1bc	37.6a	16.2	18.6a	11.2a	2.0	4.7b
WOT	16.5bc	16.9a	38.0a	15.9	18.2ab	11.4a	1.8	4.7b
BO	18.5ab	13.2c	34.0b	13.8	16.5c	10.1b	1.8	5.7a
BOT	18.8ab	15.9ab	30.6bc	15.0	15.4bc	9.8bc	1.8	5.5ab
T	19.9a	15.3abc	30.1c	11.3	15.1c	9.1c	2.0	5.8a
SE	0.64	0.59	0.78	1.14	0.46	0.22	0.07	0.19
P	0.06	0.15	0.0008	0.87	0.0001	0.0007	0.96	0.0087
1st	19.3a	15.6a	29.8c	13.9	16.7	9.4c	1.94a	5.3a
2nd	19.1a	14.1b	32.6b	14.4	17.2	10.1b	1.73b	5.6a
3rd	15.0b	16.7a	40.0a	15.9	16.5	11.7a	2.02a	4.7b
SE	0.42	0.39	0.51	0.75	0.30	0.14	0.05	0.13
P	<0.0001	<0.0001	<0.0001	0.16	0.29	<0.0001	<0.0001	<0.0001
Species combination x defoliation								
SE	1.12	1.03	1.35	1.98	0.81	0.38	0.12	0.33
P	0.81	0.0003	0.17	0.0309	0.95	0.41	0.29	0.94

SE: standard error. Averages followed by similar letter in column did not differ by Tukey's test (α=0.05). Source: Authors.

White oats are known for higher canopies compared to other temperate grasses (Neres et al., 2012), which could imply greater light interception by the top canopy and shading on the lower leaves. However, the number of dead leaves and tillering results express the WO balance within the canopy, with no differences between a single crop and intercropping. The adjustment between tiller height, tiller density and stem diameter corroborates Sbrissia et al. (2018) results and indicates that in WO canopies the DM yield is more dependent on tiller weight than tiller population, contrary to triticale and black oat swards. On the other hand, Ducati et al. (2015) obtained greater tiller density (771 tillers m^{-2} of black oat IAPAR 61), but with lower number of live leaves (average of 2.15), which suggests another via to balance the canopy and keep the tiller size/density.

The growth rate responded to defoliation stimuli, increasing with positive photoperiod and flowering. The aerial biomass removal of grasses, mainly when it involves the apical meristem, causes an increase in basal tiller emission. These basal tillers tend to be shorter than the main tillers, as long as thinner and work as a balance between tiller size/density (Duchini et al., 2013). In this case, as the DM yield increased with it, the balance was positive and caused no loss to the canopy. On the contrary, the regular removal increased the leaves emission at Year 2, and the digestible fibre content.

The use of different growth pattern plants can optimize not only the horizontal space but also the vertical profile, with a greater number of leaves in different canopy horizons (Zhu et al., 2016). For that, the triticale is highlighted by its shorter height but greater photosynthetic capacity, proved by the SPAD index (Silva et al., 2013; Sim et al., 2015), which means the same production ability in a lower light environment. The triticale leaf angle also participated in this process, which allowed the plants to increase the light interception (Zhu et al., 2016).

The higher tiller density in the intercropping BOT appeared to have forced the black oat to increase their stems in second defoliation, a natural process to searchlight mainly in canopies with more than one growth pattern (Dordas & Lithourgidis, 2011). This plasticity can imply nutritional quality reduction by the leaf:stem ratio changing (Castagnara et al. 2010), but in this case,

it increased the CP yield without affecting the fibre and lignin content, and also the number of live leaves. According to Baxevanos et al. (2017) the high density, and the mixture of genotypes, is essential to force plants to express their whole production capacity. Without this light competition, the plants have a suitable situation at lower levels and find no difficulty to survive, but the boundaries must be defined to not reduce the nutritive quality.

A reduction on tiller m^{-2} within the defoliations in Year 1 (significant interaction, P=0.02), is associated with a drought period right after the second defoliation (Figure 1). Australian temperate grasses have shown tiller population reduction with a decrease in water availability (Assuero & Tognetti, 2010; Poirier et al., 2012), which is associated with specific leaf area (SLA) reduction in the meantime (Wellstein et al., 2017) and causes the early collapse of the canopy. Nevertheless, Duchini et al. (2018) suggested that this tillering reduction is a dormancy process in most sensitive plants, and, in a further adequate environment, they can recover and return to increase the tillering.

As seen in Year 2, a minimum post-defoliation water supply can avoid these low results. In that year the increase of the tiller population over the defoliations was supported by the continued crescent of black oat and triticale tillering, the most perennial species (Ferrazza et al., 2013). The intercropping WOT showed a synchronized pattern, the association of an early cycle plant (WO) and a perennial one (T) (Oliveira et al., 2015) where the persistence can be optimized and guarantee feed through the winter.

The CP achieved a maximum of 21.8% of DM for T at the first defoliation in Year 1, whereas the oats ranged between 12% (WO at 3rd defoliation in Year 1) and 21.2% of DM (BO at 2nd defoliation in Year 1). These results are much smaller than Neres et al. (2012) that obtained 24% and 19.6% at 1st and 3rd defoliations, respectively. Nevertheless, similar to those reported by Ducati et al. (2015) between 9.33 and 26.6% of DM. In that situation the authors found that, the intercropping between black oat and birdsfoot can cause the reduction of CP content over the time by the more intense competition for light. The NDF and ADF are also lower than reported in that paper, however, the lignin content is coherent (minimum of 2.9 and maximum of 6.3% of DM). The similar lignin results may indicate that the plants in this experiment entered in reproductive stage at first (WO) and third regrowth cycles. The former due to its precocity (Oliveira et al., 2015), the latter is a result of all treatments led to flowering by the drought stress in that stage (Poirier et al., 2012). In Year 2, the gradual crescent of lignin content was similar to the expressed in Neres et al. (2012) reports, which still characterized the results as from high nutritional quality grasses.

5. Conclusion

The intercropping between white oat IPR Emerald + triticale Tpolo 981 was effective to improve the different canopy horizons by the number of live leaves and the nutritional profile, with the increase in crude protein concentration.

The intercropping between black oat IAPAR 61 + triticale Tpolo 981 increased the dry matter yield compared with a single triticale crop. It also increased the crude protein content, tiller population and number of live leaves, in comparison with the black oat in a single-use.

The SPAD index associated with the number of live leaves proved the high efficiency of triticale Tpolo 981 to produce with a lower light interception

In future studies, the persistence of these treatments shall be studied over the spring, to determine the longevity of the systems and comprehend the full cycle of these plants intercropped.

Acknowledgments

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