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Dynamics of yield and nutritional value for winter forage intercropping

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ABSTRACT. The work was carried out to assess mass production and nutritional content of winter forages using lopsided oat (*Avena strigosa*) and white oat (*Avena sativa*) intercropped with ryegrass (*Lolium multiflorum*) and vetch (*Vicia sativa* L.). The species were intercropped as the following treatments: lopsided oat with ryegrass (LO+RG); white oat with ryegrass (CO+RG); lopsided oat with vetch (LO+V); white oat with vetch (CO+V); lopsided oat, vetch and ryegrass (LO+RG+V); and white oat, ryegrass and vetch (CO+RG+V). The study evaluated total forage mass production of each intercropping and crude protein levels, neutral detergent fiber and *in vitro* digestibility coefficient of dry matter. The results indicate that forage yield of oats was higher in early assessments, and ryegrass and vetch were higher in the final evaluation period. The crude protein levels and neutral detergent fiber were higher at the start of the experiment for all evaluated treatments, and those including vetch intercropped with oats showed an increase in these parameters in the final period due to the presence of vetch, which has a more delayed cycle.

Keywords: intercropping, grasses, legumes, pasture quality.

Dinâmica da produção e do valor nutritivo do consórcio de Forrageiras Hibernais

RESUMO. O trabalho foi realizado com o objetivo de verificar a produção de massa e teores nutritivos de espécies forrageiras de estação fria, utilizando pastagens de aveia preta (*Avena strigosa*) e aveia branca (*Avena sativa*) consorciadas com azevém (*Lolium multiflorum*) e ervilhaca comum (*Vicia sativa* L.). As espécies foram consorciadas conforme os tratamentos: Aveia Preta com Azevém (AVP+AZ); Aveia Branca com Azevém (AVB+AZ); Aveia Preta com Ervilhaca (AVP+E); Aveia Branca com Ervilhaca (AVB+E); Aveia Preta, Azevém e Ervilhaca (AVP+AZ+E) e Aveia Branca com Azevém e Ervilhaca (AVB+AZ+E). Foram avaliados a massa total de forragem de cada espécie e os teores de proteína bruta, fibra em detergente neutro e o coeficiente de digestibilidade "in vitro" da matéria seca. Os resultados indicam que a produção de forragem das aveias foi maior no início das avaliações e de azevém e ervilhaca no período final. Foram maiores os teores de proteína bruta e fibra em detergente neutro no início do experimento para todos os tratamentos avaliados, sendo que os que continham ervilhaca consorciada com aveia apresentaram aumento desses teores no período final pela presença exclusiva de ervilhaca que possui ciclo mais tardio.

Palavras-chave: consorciação, gramíneas, leguminosas, qualidade de pastagem.

Introduction

Cattle production in Brazil is traditionally based on grazing production systems, which are the main feed source for animals. The main winter cycle cultivars used in southern Brazil are lopsided oat (*Avena strigosa*), common oat (*Avena sativa*) and ryegrass (*Lolium multiflorum*). When intercropped, these species have great benefits on animal production, as they provide different usage periods due to their speed of establishment and growth/development stage (ROCHA et al., 2004).

The intensification of cattle production and the search for improved results have motivated new alternatives for pasture management. In that regard, grass-legume intercropping emerged and contributes to increase the numbers and longevity of forage production. Intercropping promotes improved diet nutritional value from the presence of the legume, combined with nitrogen fixation in the soil through symbiosis with *Rhizobium* genus bacteria (SILVA; SALIBA, 2007), reducing costs with urea application on pastures, as nitrogen fertilizers increase the cost of production (CARVALHO; PIRES, 2008).

Among the studied species, oat is one of the main forage species used in winter grazing, and can be grown by itself or intercropped with other temperate-climate forage species, given its high dry matter yield and forage quality, resistant to stomping and featuring low production cost (MACARI et al., 2006). Ryegrass shows high potential during that period as well. The greatest advantages of this grass are its natural re-sowing ability, as well as resistance to disease and versatility when intercropped (FRIZZO et al., 2003).

Studying the quality of forage species is of great importance in nutritional management, and animal performance will depend on the quality of available forage; it is important to evaluate not only bromatological quality, but also the digestibility of pastures (BENEVIDES et al., 2007). Crude protein levels can vary according to sowing season; however, the main factor for that variation is the plant's physiological stage. Fiber values usually increase when the plant is cut; this usually happens as the result of plant maturation, with increased cell content (FEROLLA et al., 2008).

The objective of this work was to assess the yield of mass and nutritive levels of winter forage species, using pastures of lopsided oat (*Avena strigosa*) and common oat (*Avena sativa*) intercropped with ryegrass (*Lolium multiflorum*) and vetch (*Vicia sativa* L.).

Material and methods

The experiment was carried out at the Dois Vizinhos campus of the Federal Technology University of Paraná (UTFPR), elevation 520 m, latitude 25°44" South and longitude 54°04" West, in a dystroferric red Nitosol soil. The predominant climate is mesothermic humid subtropical (Cfa), according to the Köppen classification (MAAK, 1968). Average temperature in the warmer months is higher than 22°C, and lower than 18°C in the colder months, with 65% relative air humidity and annual rainfall of 2,100 mm.

Rainfall and high/low temperature data recorded in the period between April and October 2008 in the region of the Dois Vizinhos UTFPR campus are shown in Figure 1, according to the weather station of INMET (2008).

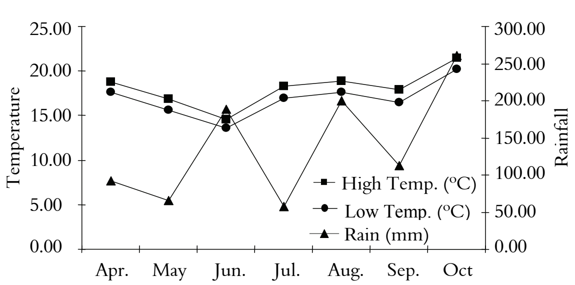

Figure 1. Rainfall and high/low temperature in the municipality Dois Vizinhos, Paraná State, in the period between April and October 2008 (INMET).

Sowing was done manually in April 2008, on the remaining straw from the soy crop, in rows spaced 20 cm apart. No fertilization was used at seeding time; 30 kg ha^{-1} of nitrogen in urea form were applied after tillering. The experimental design was entirely randomized, consisting of 18 plots with 9 m² each (3 x 3 m), with six treatments and three replications. The species were intercropped according to the treatments: Lopsided Oat with Ryegrass (LO+RG); Common Oat with Ryegrass (CO+RG); Lopsided Oat with Vetch (LO+V); Common Oat with Vetch (CO+V); Lopsided Oat with Ryegrass and Vetch (LO+RG+V) and Common Oat with Ryegrass and Vetch (CO+RG+V).

To determine sowing density, the seed germination test was carried out for each treatment and the respective numbers of seeds were calculated, with 60 kg ha^{-1} lopsided oat, 80 kg ha^{-1} common oat, 40 kg ha^{-1} ryegrass and 30 kg ha^{-1} vetch in treatments LO+RG, CO+RG, LO+V and CO+V; in treatments LO+RG+V and CO+RG+V, the amounts were 50 kg ha^{-1} lopsided oat, 60 kg ha^{-1} common oat, 30 kg ha^{-1} ryegrass and 20 kg ha^{-1} vetch.

The analyzed variables were forage total dry matter (FTDM), individual yield of the studied species (YLO, YCO, YRG and YV), crude protein (CP) levels, neutral detergent fiber (NDF) and *in vitro* digestibility coefficient of dry matter (IVDCDM). Collections were performed on July 1st, August 4, September 9 and October 10, 2008. Four cuttings were carried out, collecting two samples per plot 10 cm from the soil, with the aid of a 0.25 m² metal square, with the exception of the last collection performed close to the ground, to verify total forage production. After each collection, the remainder of the plot was lowered entirely at 10 cm from the ground.

The samples removed from each plot were immediately weighed and homogenized. A subsample was taken for botanical separation of the different intercropped species in order to assess the rate of each evaluated species, and another sample was used for chemical analyses. The separated material was dried in a forced-air oven at 65 ºC for 72h, in order to determine the production of the structural components of each species. Crude protein levels were given by the micro Kjeldhal method (AOAC, 1995), neutral detergent fiber (NDF) by the fiber partition method of Van Soest (1994), and *in vitro* digestibility of dry matter (IVDCDM) according to the methodology of Tilley and Terry (1963).

The data were submitted to analysis of variance (*f*-test), evaluated over time through regression tested and fitted to the 3rd degree, according to degree of significance, using SOC-NTIA software (EMBRAPA, 1997).

Results and discussion

Table 1 shows the phenological behavior of the studied species, observing that oats show high growth rates in the months of July and August, whereas ryegrass and vetch have high growth potential in September and October. Nevertheless, when intercropped with oat and ryegrass, vetch does not fulfill its productive potential due to competition with ryegrass, as these two species are not complementary.

The average forage total dry matter (FTDM) between treatments as a function of days after sowing is shown in Figure 2. It was observed that the interaction between treatments and period was not significant. The featured cubic behavior can be evidenced by the increased production until about 85 days after sowing, reaching 1,594 kg ha^{-1}; after that, production declined. Initial production is due to the presence of lopsided and common oat, which have high yield during that stage due to their earlier productive cycle, as explained by Fontanelli and Freire Junior (1991), who obtained 90.2% of oat compared to 9.8% of ryegrass in the month of July, reaching 0% of oat and 100% of ryegrass in December.

The drop in production occurred until 142 days after sowing, reaching 552 kg ha^{-1}. From that point on, production began to increase due to growth of late species such as ryegrass and vetch, reaching 1,403 kg of dry matter per hectare 168 days after sowing - until October 2008. This demonstrates that this type of intercropping prolongs the grazing period, starting in the month of April and extending until October, as indicated by Rocha et al. (2004), when tropical forage species already showed high rates of accumulation.

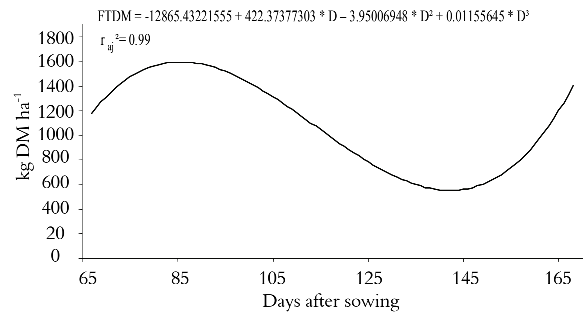

Figure 2. Forage total dry matter as a function of days after sowing. FTDM: Forage total dry matter; DM: Dry matter.

It is possible to observe that during the period between 125 and 156 days after sowing, available forage mass was lower than 800 kg ha^{-1}. That period was critical to using the intercrops studied for grazing - if managed inadequately, animals can ingest young ryegrass tillers or vetch during early development, not allowing these species to reach their full productive potential. This can be avoided b controlling animal load on the pasture, or using supplements for animals during this critical stage.

Table 1. Dry matter production and standard deviation of each species within the intercrops (kg ha^{-1}).

Species	Collection date				Total
	Jul. 1, 2008	Aug. 4, 008	Sep. 9, 2008	Oct. 10, 2008	
			LO+RG		
LO	1105	868	0.0	0.0	3501
RG	30	135	413	925	
Total	1135 ± 242 a	1003 ± 475 a	413 ± 122 b	950 ± 375 ab	p = 0.017
			CO+RG		
CO	1289	1268	0.0	0.0	4447
RG	41	188	525	1114	
Total	1330 ± 682	1456 ± 117	525 ± 61	1136 ± 49	p = 0.120
			LO+V		
LO	904	1236	63	0.5	4408
V	46	79	545	1512	
Total	950 ± 107 ab	1315 ± 96 a	609 ± 261 b	1535 ± 218 a	p = 0.008
			CO+V		
CO	1172	1594	86	97	5294
V	78	123	518	1608	
Total	1250 ± 31 ab	1717 ± 80 a	604 ± 155 b	1723 ± 29 a	p = 0.031
			LO+RG+V		
LO	1376	863	0.0	0.0	
RG	18	176	642	1319	5038
V	36	100	151	306	
Total	1430 ± 182	1139 ± 19	794 ± 33	1677 ± 140	p = 0.523
			CO+RG+V		
CO	915	1509	7	0.0	
RG	21	127	329	1042	4690
V	34	172	181	324	
Total	970 ± 177 bc	1808 ± 271 a	516 ± 305 c	1396 ± 40 ab	p = 0.0005
Prob.*	0.52	0.19	0.26	0.09	0.36

Lowercase letters in the rows differ between periods by Tukey's test. LO: Lopsided oat; RG: Ryegrass; CO: Common oat; V: Vetch. *Prob: Probability between treatments.

The yields of lopsided oat (YLO), common oat (YCO) and ryegrass (YRG) did not show significant interactions, either, as can be seen in Figure 3. It can be observed that common oat showed cubic behavior, and the average was high until 86 days after sowing, with 1,698 kg ha^{-1}; from then on, it decreased until 137 days, when its productive cycle ended.

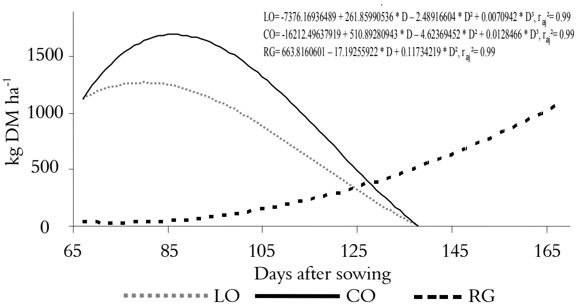

Figure 3. Yield of lopsided oat, common oat and ryegrass as a function of days after sowing. LO: Lopsided oat; CO: Common oat; RG: Ryegrass; DM: Dry matter.

A similar behavior was observed for lopsided oat, although its yield was 25% lower, resulting from the precociousness of that species, providing earlier grazing as compared to more delayed forage species.

The results found for both oats demonstrate that grazing on this species alone by animals is not sufficient to fulfill all forage requirements during the winter period. Thus, the use of species featuring more delayed development intercropped with oat is beneficial for the productive system.

Ryegrass showed quadratic behavior, inverse to the oats - reduced yield at the start of evaluations (about 50 kg ha^{-1} 85 days after sowing), increasing until 168 days, with 1,087 kg ha^{-1} (Figure 3). The data observed in the present study demonstrate that when intercropped with oat, ryegrass increases the pasture utilization period, allowing greater animal load for a longer period of time.

The production of vetch showed difference between treatments and periods (Figure 4). In the treatments in which vetch was intercropped with lopsided oat and common oat, the curves showed quadratic behavior, noting that yield was minimal at the start when oats showed high yield, increasing at the end of the period and reaching approximately 1,500 and 1,580 kg of DM ha^{-1}, respectively. Thus, vetch helps prolong the grazing period because it has a more delayed cycle.

In the treatments in which vetch was intercropped with oat and ryegrass, linear behavior was observed, with lower yield at the start of the evaluation period and a slight increase until the end (approximately 275 and 305 kg of DM ha^{-1}, respectively), as shown in Figure 4. This was likely due to the competitive effect of vetch with ryegrass, reducing the productive potential of the legume when compared to intercrops with oat only, which at that time had already ended their growth stage. It is known that grasses are more competitive than legumes, as grasses are more efficient users of water and certain mineral nutrients, which results in higher growth rate and potentially higher forage yield than legumes, as well as having a more extensive and diffused root system (ANDRADE et al., 2003). For that reason, vetch did not show satisfactory development when intercropped with ryegrass.

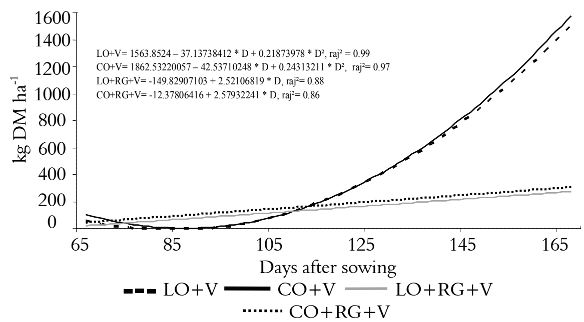

Figure 4. Production of vetch as a function of days after sowing in the different intercrops. LO+V: Lopsided oat + Vetch; CO+V: Common oat + Vetch; LO+RG+V: Lopsided oat + Ryegrass + Vetch; CO+RG+V: Common oat + Ryegrass + Vetch.

Crude protein levels, shown in Figure 5, here highest at the start of the evaluation (65 days after sowing) for the lopsided oat-ryegrass intercrop. This was because oat features superior quality during that development stage due to the large number of leaf blades. CP values in that intercrop showed quadratic behavior, with values consistently above 20% until 99 days after sowing, as ryegrass was in its full development stage, whereas oat was in the final stage of the cycle.

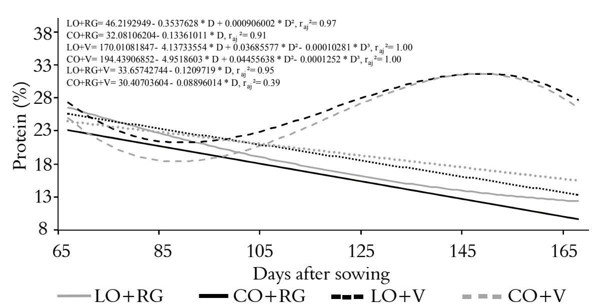

Figure 5. Protein levels (CP) in the different treatments as a function of days after sowing. LO + RG: Lopsided oat + Ryegrass; CO+RG: Lopsided oat + Ryegrass; LO+V: Lopsided oat + Vetch; CO+V: Common oat + Vetch; LO+RG+V: Lopsided oat + Ryegrass + Vetch; CO+RG+V: Common oat + Ryegrass + Vetch.

The 26.58% CP level found during the first days of evaluation can provide optimum animal production indices. However, when the plant's vegetative stage is extended, a reduction is observed in CP levels, reaching values of 12.36% CP at 168 days after sowing. During that period, only ryegrass was in the reproductive stage. Soares et al. (2001) found a similar occurrence while evaluating the intercropping of oat and ryegrass, starting with values above 22% CP in June and reaching approximately 15% in November, as ryegrass was at the end of its productive cycle and showed great amounts of stems and reproductive structures.

A similar behavior was also observed for the common oat-ryegrass intercrop. However, this combination showed a linear curve, starting at 23.12% CP in the 65th day after sowing, falling until 168 days to a CP level of 9.63%. It can thus be observed that lopsided oat has higher protein levels than common oat, differently from the value found by Barro et al. (2008), who observed 12.0 and 11.3% CP for common oat and lopsided oat, respectively.

In the same Figure 5, it can be seen that the oats-vetch intercrops without ryegrass showed cubic behavior, with CP values at 27.33 and 25.02%, respectively, 65 days after sowing. Until around 85 days, there was a decline resulting from plant aging, increasing thereafter due to the higher rates of vetch (Table 1), which has higher levels of CP. The intercrops reached a CP peak around 149 days, with 31.69 and 31.65% CP, respectively, as vetch was practically by itself due to the fact that the senescence of oats disappeared around 137 days after sowing, as can be seen in Figure 3. The great potential of vetch thereby becomes evident, as reported by Fontanelli and Freire Junior (1991), who observed a 40% increase in CP level when vetch was intercropped with oat and ryegrass, compared to grass intercropping alone.

For oats intercrops with ryegrass and vetch, the highest levels of CP were observed 65 days after sowing with 25.55 and 24.44% CP (Figure 5). The values decreased linearly, finishing the evaluations with levels of 13.33 and 15.46% CP for lopsided and common oat intercropped with ryegrass and vetch, respectively - also due to the senescence of oats and the advanced reproductive stage of ryegrass in that period. They nevertheless showed higher values when compared to intercrops without vetch, even with low participation of that species (Table 1).

For neutral detergent fiber (NDF) levels, intercrops of lopsided oat with ryegrass and common oat with ryegrass and vetch displayed quadratic behavior (Figure 6). At 65 days after sowing, values were 46.67 and 45.23% NDF, respectively. The highest values were observed around 144 days after sowing, with 63.87 and 61.89%, respectively. After that period, levels declined slightly due to the presence of ryegrass and/or vetch in the treatment. Ferolla et al. (2008) found higher values in the month of April (first cutting) compared to June (third cutting), with 64.28 and 52.10% NDF, respectively, for lopsided oat, explained by the advanced vegetative state of ryegrass in the first cutting, as plants at the end of stages show higher NDF values due to the increased incidence of stems.

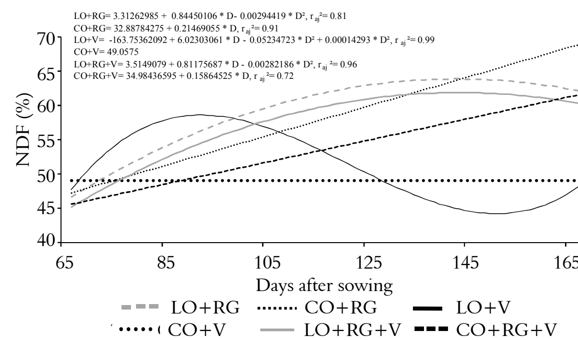

Figure 6. Neutral detergent fiber (NDF) levels in the different intercrops as a function of days after sowing. LO + RG: Lopsided oat + Ryegrass; CO+RG: Lopsided oat + Ryegrass; LO+V: Lopsided oat + Vetch; CO+V: Common oat + Vetch; LO+RG+V: Lopsided oat + Ryegrass + Vetch; CO+RG+V: Common oat + Ryegrass + Vetch; NDF: Neutral Detergent Fiber.

The treatments featuring common oat intercropped with ryegrass and common oat with ryegrass and vetch showed similar results, with NDF levels at 65 days after sowing at 47.27 and 45.61%, increasing linearly until the end of the study, reaching values of 68.96 and 61.93%, respectively, as shown in Figure 6. This may be due to the absence or small participation of vetch and lower quality of ryegrass in the final evaluation stages, evidencing the lower quality of forage species as the phenological stage advances.

When comparing the treatments of common oat intercropped with ryegrass and lopsided oat intercropped with ryegrass, it is observed that NDF levels of the former are lower than those of the latter at the start of the developmental stage. However, at the end of the cycle this behavior is reversed, possibly due to botanical composition of the treatments - in this case, there no longer was a considerable amount of lopsided oat, with only ryegrass in its composition, which during that period had higher quality than oat.

For the intercrop between oat and vetch, cubic behavior was observed, showing at 65 days after sowing values of 47.79% NDF, quickly increasing until reaching 58.60% at 93 days due to the earlier senescence of lopsided oat compared to the other species (including common oat), as ryegrass was absent in that treatment. However, NDF began to decrease with the onset of vetch, reaching 44.25% at 152 days, resulting in a less fibrous feed at the end of the pasture use period. Lastly, common oat intercropped with vetch showed no variation in NDF level from the start to the end of the experiment, with average value of 49.06%. This evidences that common oat has lower fiber levels, maintaining the lower NDF levels until vetch growth.

In Figure 7, it can be seen there was no significant difference in the interaction between treatments and periods, and that the average of the *in vitro* digestibility coefficient of dry matter (IVDCDM) showed quadratic behavior. There was no great variation in IVDCDM throughout the experiment, ranging from 77.20% down to 60.85% 168 days after sowing at the end of the experimental period, as a consequence of the presence of vetch, which had a large share at that stage. As occurred with NDF, this variation was due to plant development, which over time became more indigestible and featured lower quality. Olivo et al. (2009), evaluating the digestibility of ryegrass between the months of July and October, found average IVDCDM of 71.4%, ranging from 76.97% at the start to 57.02% at the end of the evaluation period.

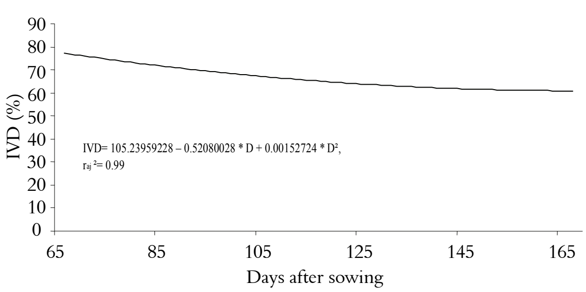

Figure 7. *In vitro* digestibility coefficient of dry matter (IVDCDM) as a function of days after sowing.

The observed values for IVDCDM are sufficient for optimal performance of pasture-reared animals. However, the values for digestibility and crude protein are combined, it can be seen that the factor limiting higher yield would be energy, especially in the treatments in which vetch has higher yield, as digestibility values are positively correlated with total digestible nutrients (NDT), which express the energy level of diet items.

Conclusion

Oats showed higher yield around 85 days after sowing. Ryegrass and vetch had higher yield starting at 142 days, which shows they are not complementary species.

The intercrops showed high levels of protein and low NDF at the start of the grazing period, decreasing throughout the evaluation period, with the exception of the vetch- oat intercrop, with ryegrass, as vetch had a more delayed cycle and high quality, extending the pasture utilization period. IVDCDM levels remained high throughout the grazing period.

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