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Mixtures of rye cultivars to improve forage yield, distribution and nutritive value

Misturas de cultivares de centeio para melhora da produção, distribuição estacional e valor nutritivo da forragem

Mezclas de cultivares de centeno para mejorar la producción, la distribución estacional y el valor nutricional del forraje

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Abstract
The search for forage cultivars that provide higher yields with quality in periods of forage shortage, whether in isolated or mixed management, is essential for livestock stability. Thus, the objective was to evaluate the forage performance and nutritive value of rye cultivars mixtures (BRS Progresso, BRS Serrano and Temprano) from different production cycles compared to the isolated management of rye, dual-purpose wheat cvs. (BRS Tarumã and BRS Pastoreio) and black oat cv. Embrapa 139 Neblina as controls. The experiment was conducted at a randomized complete block design, with four rye associations and the isolated cultivation of wheat, oat, and rye. Dry matter (DM) yield and nutritive value, such as content of neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) content were evaluated for each cut and total values. There was difference (P<0.001) in total DM, the highest yield was in single cultivation as well as mixtures with Temprano. BRS Serrano and BRS Progresso and their mixture had lower leaf blade percentage in the total DM. There were differences (P<0.05) in NDF concentration (55.1 to 70.60%), ADF (15.2 to 34.7%), and CP (27.4 to 36.8%) levels along harvests. Among cultivars, Temprano showed the highest proportion of leaf blades and total DM yield.
Keywords: *Secale cereale*; Forage yield; Nutritional quality.

Resumo
A busca por cultivares de forrageiras que proporcionem maiores rendimentos com qualidade em períodos de escassez de forragem, seja em manejo isolado ou em mistura, é essencial para a estabilidade pecuária. Com isso, objetivou-se avaliar o desempenho forrageiro e o valor nutritivo de misturas de cultivares de centeio (BRS Progresso, BRS Serrano e Temprano) de diferentes ciclos de produção em relação ao manejo isolado de centeio, trigo de duplo propósito cvs. BRS Tarumã e BRS Pastoreio e a aveia-preta cv. Embrapa 139 Neblina como testemunhas. O experimento foi conduzido em delineamento de blocos completamente casualizados, com quatro associações de centeio e cultivo isolado de trigo, aveia e centeio. Foram avaliados o rendimento de matéria seca (MS) e o valor nutritivo, como teor de fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e teor de proteína bruta (PB) para cada corte e valores totais. Houve diferença (P<0,001) na MS total, o maior rendimento foi no cultivo solteiro, bem como nas misturas com Temprano. BRS Serrano e BRS Progresso e sua mistura apresentaram menor porcentagem de lâmina foliar na MS total. Houveram diferenças (P<0,05) nos teores de FDN (55,1 a 70,60%), FDA (15,2 a 34,7%) e PB

(27,4 a 36,8%) ao longo das colheitas. Entre as cultivares, a Temprano apresentou a maior proporção de lâminas foliares e produtividade total de MS.
Palavras-chave: *Secale cereale*; Rendimento de forragem; Qualidade nutricional.

Resumen
La búsqueda de cultivares forrajeros que proporcionen mayores rendimientos con calidad en períodos de escasez de forraje, ya sea en manejo aislado o mixto, es fundamental para la estabilidad del ganado. Así, el objetivo fue evaluar el comportamiento forrajero y el valor nutricional de mezclas de cultivares de centeno (BRS Progresso, BRS Serrano y Temprano) de diferentes ciclos productivos en relación al manejo aislado de centeno, trigo de doble propósito cvs. (BRS Tarumã y BRS Pastoreio) y avena negra cv. Embrapa 139 Neblina como testigos. El experimento se llevó a cabo en un diseño de bloques completamente al azar, con cuatro asociaciones de centeno y cultivo aislado de trigo, avena y centeno. Se evaluó el rendimiento de materia seca (MS) y el valor nutricional, así como el contenido de fibra detergente neutro (FDN), fibra detergente ácida (FDA) y proteína cruda (PC) para cada corte y valores totales. Hubo diferencia (P<0,001) en la MS total, el mayor rendimiento fue en el monocultivo, así como en las mezclas con Temprano. BRS Serrano y BRS Progresso y su mezcla presentaron menor porcentaje de lámina foliar en MS total. Hubo diferencias (P<0,05) en los niveles de FDN (55,1 a 70,60%), FDA (15,2 a 34,7%) y PC (27,4 a 36,8%) a lo largo de las cosechas. Entre los cultivares, Temprano presentó la mayor proporción de láminas foliares y productividad de MS total.
Palabras clave: *Secale cereale*; Rendimiento de forraje; Calidad nutricional.

1. Introduction

Integrated crop-livestock systems (ICLS) can contribute to cattle farming, mainly through the use of inactive areas (Tonato et al., 2014), which can be occupied with winter pastures (Silveira et al., 2017). In grass-feeding systems, fluctuations in forage availability throughout the year make the activity challenging, however, planting forage in idle areas and storing the surplus allows for greater stability (Santos et al., 2010).

Different attempts have been analyzed seeking adapted species that allow a longer period of forage supply along with high nutritive value (Oliveira et al., 2014). Due to animal performance being impacted by the nutritive value of forages (Mattews et al., 2019), it is relevant, along with quality, to improve new alternative systems that seek to combine lower costs with high DM yield (Orth et al., 2012), contributing to the farms income with the use of these plants (Carr et al., 2021), in order to minimize the pressure on pastures and protecting natural resources (Tan & Yolcu, 2021).

Amongst the possibilities, there is the use of intercropping systems, in which two or more species are implanted in the same area, growing simultaneously for a significant period of their development (Lithourgidis et al., 2011). However, different factors must be considered when choosing the forages that compose the system (Meccage et al., 2019), for example, factors such as management and climatic conditions of each region affect the phenological aspects of crops (Martin, 2010). In this study, intercropping was performed by mixing cultivars.

Due to all these circumstances, it is essential to evaluate forage yield and distribution along seasons, together with nutritive value, an aspect that depends on the phenological stage of plant development (Meinerz et al., 2011), varying amid genotypes of the same species (Bruckner & Raymer, 1990). The success of mixtures depends, among other factors, on the choice of cultivars that compose this strategy. Therefore, the objective of this study was to evaluate the forage performance and nutritive value of mixtures of rye cultivars from different production cycles compared with rye, dual-purpose wheat (DP) and black oat managed as single crops.

2. Methodology

This study was conduted at Passo Fundo, Rio Grande do Sul state, experimental station of Embrapa Trigo (longitude 28° 15' S, latitude 52°, 24' W and altitude of 684 m) during the cool-season of 2018, from April 13 to October 8. The climate of the region is classified as subtropical humid (Cfa) (Kuinchtner & Buriol, 2001), and the soil as humic dystrophic Red

Latosol (Streck et al., 2008), in a randomized complete block design (RCBD) with four replicates. The plot size was 5 m by 1.6 m (eight 5 m rows by 0.2 m row spacing) planted at 3 to 5 cm seeding dept. Seeding rate was 400 seeds/m^2 for all treatments.

The treatments consisted of three cvs. of rye (*Secale cereale* L.) BRS Progresso (P), BRS Serrano (S) and Temprano (Te), two wheat (*Triticum aestivum* L.) cvs. BRS Tarumã (Ta) and BRS Pastoreio (Pa) and one black oat (*Avena strigosa* Schreb.) cv. Embrapa 139 (Neblina) (E). The rye cultivars were managed in mixtures and as single crops, the other species as single crops only. The treatments were as follows: P= BRS Progresso (rye); S= BRS Serrano (rye); Te= Temprano (rye); P+S= BRS Progresso + BRS Serrano; P+Te= BRS Progresso + Temprano; S+Te= BRS Serrano + Temprano; P+Te+S= BRS Progresso + BRS Serrano + Temprano; E= Embrapa 139 (Neblina) (black oat); Pa= BRS Pastoreio (DP wheat) and Ta= BRS Tarumã (DP wheat).

Seeding date was on April 13, using a no-till drill. The mixture of two cvs. was seeded 50% of each one, and three cvs. was seeded 1/3 of each one. Before planting, 350 kg ha^{-1} of 05-25-25 (N-P_2O_5-K_2O) was applied, according to soil analysis (Table 1). Also 40 kg ha^{-1} of N, as urea, was applied at tillering stage, stage 2 on the Feeks & Large scale (Large, 1954), for all treatments.

Table 1- Physical-chemical soil attributes at 0-20 cm depth at the trial area.

P	K	MO	pH	Ca	Mg	H + Al	CEC	V	Clay
(mg/dm³)		(g/dm³)	water	(mmol$_c$/dm³)				(%)	(g/dm³)
29.85	266	27.0	5.9	55.8	28.7	39.0	130.3	69.2	580

Source: Embrapa Wheat.

Forage DM yield was obtained by cutting 6 m² of each treatment. Plots were harvested using a sickle-bar mower (Wintersteiger®) when forage was 30 cm tall and stubble height was at 7 cm. After each harvest, 30 kg ha^{-1} of N as urea was applied. Samples were taken to evaluate DM concentration and nutritive value.

The samples were oven dried at 60 °C for 72 h or achieve constant weigh, for DM determination and ground in a Willey mill to pass a 1 mm screen sieve. It was analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude protein (CP) concentration by the infrared radiation reflectance (NIRS) method, described by Marten et al. (1985).

Data was submitted for analysis of variance and means were compared by Tukey's test, at the level of 5% error probability. The analyzes were performed using the SISVAR statistical package (Ferreira, 2011).

3. Results and Discussion

It was observed that, during the evaluation period, some treatments supported seven cuts Ta and Pa, about eight cuts P, S, E, P+S and P+TE+S and others supported nine cuts Te, Te+S and Te+P. Two of the treatments with the highest number of cuts occurred in the autumn season, five in the winter and two in the spring, with an average rest period of 24, 15 and 14 days, respectively (Table 2).

The duration of the cultivars development cycles are different, ranging from medium to late. The cultivar BRS Progresso has a medium cycle (60 to 75 days until heading and 125 to 145 days until maturity) (Nascimento Junior et al., 2014). The complete cycle of BRS Serrano lasts about 160 days, being considered medium/late (75 to 90 days to heading and 145 to 160 days to maturation) (Nascimento Junior et al., 2006). The cultivar Temprano has a late cycle (approximately 175 days to maturity) (Chaves et al., 2018).

The black oat cv. Embrapa 139 Neblina has an early cycle of about 157 days from emergence to maturation (Gaudencio et al., 1998). The wheat cv. BRS Pastoreio is a late/early cycle cultivar (103 days to head and 156 days to maturity). The cycle of cv. BRS Tarumã is classified as late (110 days to heading and 162 days to ripening) (Fontaneli, 2007).

The BRS Tarumã cultivar is highly sensitive to vernalization (Alberto et al., 2009), therefore, the difference in cycle duration is related to the vernalization need of each cultivar (Walter et al., 2009). In addition, the rate of development increases with the increase in photoperiod, causing a reduction in the cycle to flowering (Craufurd & Cartwright, 1989). Authors describe that the duration of the total cycle is directly linked to the duration of the vegetative phase, from emergence to anthesis, with little relation to the reproductive phase, as it is similar in cultivars (Walter et al., 2009).

Table 2 - Forage yield (kg ha^{-1} of DM) by harvest dates of rye cultivars in single cultivation or mixtures, with black oat and dual-purpose wheat as controls.

Treatments	Number of forage cuts/evaluation dates									TDM[1] (kg ha^{-1} of DM)
	1	2	3	4	5	6	7	8	9	
	05/23	06/6	07/3	07/23	08/6	08/27	9/10	9/25	8/10	
P	867	713	833	512	386	862	439	401	NC	5013 b
S	899	634	820	574	453	926	610	489	NC	5405 b
Te	612	679	561	1022	932	1396	990	699	182	7073 a
P+S	769	607	796	566	465	921	530	505	NC	5159 b
P+Te	810	652	527	922	811	1373	1050	724	168	7037 a
S+Te	891	561	594	956	880	1249	1172	731	216	7250 a
P+Te+S	797	665	685	835	720	1353	1129	792	NC	6976 a
E	918	709	511	896	470	838	571	643	NC	5556 b
Pa	NC[2]	907	612	1185	830	1211	542	420	NC	5707 b
Ta	NC	897	457	1026	903	1218	515	474	NC	5490 b
									P-value	<0.001
									SEM[3]	90.53

[1]TDM = total dry matter production; [2]NC = not clipped; Statistical analysis of separate cuts was not performed. [3]SEM= standard error of mean. Means followed by the same lower case letter in the column are not different (P>0.05) by Tukey test. P: BRS Progresso (rye); S: BRS Serrano (rye); Te: Temprano (rye); P+S: BRS Progresso + BRS Serrano; P+Te: BRS Progresso + Temprano; S+Te: BRS Serrano + Temprano; P+Te+S: BRS Progresso + BRS Serrano + Temprano; E: Embrapa 139 (Neblina) (black oat); Pa: BRS Pastoreio (DP wheat) and Ta: BRS Tarumã (DP wheat). Source: Authors (2022).

The dual-purpose wheat cultivars were cut for the first time at 48 days after emergence, unlike the other treatments that were cut at 34 days. It should be noted that the first cut of rye and black oat took place 14 days before the first cut of DP wheat, representing an economic advantage in order to minimize forage shortage. Landry et al. (2019) reported 7 to 10 days anticipation in rye forage harvest compared to wheat, triticale and barley. Meinerz et al. (2012) observed that rye is one of the most precocious annual temperate grasses, and amongst the later genotypes, BRS Tarumã wheat, was first cut 72 days after sowing. In addition, black oat develops rapidly at the beginning of its cycle (Marques et al., 2014). These results indicate the precocity of these two species (rye and black oat) and their collaboration in forage production in shortage periods.

There was a difference (P<0.001) between treatments for TDM (Table 2). The rye cultivar Temprano was the most productive both as a single crop and in mixture with other cultivars, surpassing the isolated crops of rye P and S, black oat and dual-purpose wheat.

Forage production ranged from 7250 kg ha^{-1} of DM to a minimum of 5013 kg ha^{-1} of DM, for the mixture S + Te and P, respectively. Results similar to those of Ferrazza et al. (2013) with the BRS Serrano (5882 kg ha^{-1} of DM), common black oat (4277 kg ha^{-1} of DM) and wheat BRS Tarumã (5981 kg ha^{-1} of DM) when sown in April. Whereas the values found in this experiment were higher than those found by Kirchner et al. (2010) that obtained 5147 and 4550 kg ha^{-1} of DM, respectively for dual-purpose wheat and black oat.

Manfron et al. (2022) observed in wheat cultivars (BRS Pastoreio and BRS Tarumã), 1067 and 1237 kg ha^{-1} of DM, respectively, in the first cut. The same authors also evaluated rye cultivars (BRS Serrano, BRS Progresso and Temprano) and a black oat (Embrapa 139 Neblina) in isolated cultivation, showing forage yield of 1589; 1472; 1192 and 1384 kg ha^{-1} of DM in the first cut, respectively, values higher than in this study.

Within the mixtures, the species must not harm the development of each other so that this management is efficient and that maximizes productivity (Roso et al., 2000). When plants compete with each other for available resources in the environment it is called intraspecific competition and with other plants, it is described as interspecific competition (Zanine & Santos, 2004). The mixtures of cultivars P+Te, S+Te and P+Te+S were statistically equal to the isolated cultivation of the cultivar Temprano and in the mixture S+P, the production was similar to the isolated cultures of the cultivars BRS Progresso and BRS Serrano.

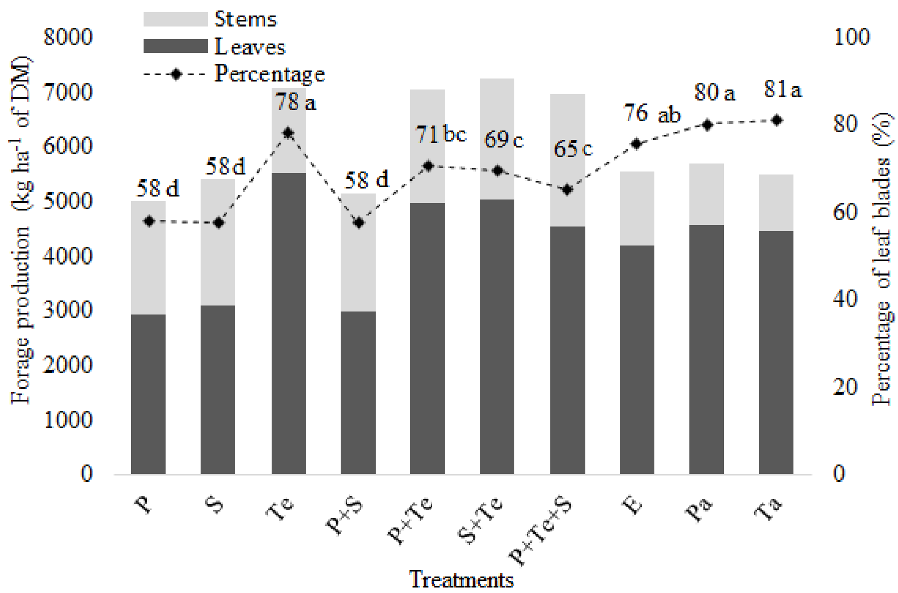
Intercropping tends to increase forage availability in relation to the isolated cultivation (Barducci et al., 2009). However, in this work, there was no mutual cooperation, when the production of both species is superior to that of monoculture (Willey, 1979).

It is recommended the use of cultivars with a long vegetative cycle when the objective is to obtain forage in shortage periods (Lehmen et al., 2014). The isolated Temprano cultivar and its mixtures tolerate 9 cuts, unlike other treatments that tolerate 8 cuts. In general, the later materials present higher forage production, due to greater tillering when compared to early materials (Meinerz et al., 2012). This characteristic is clear for Te cultivar, which has a late cycle (Chaves et al., 2018). This constitutes an alternative that can provide forage in periods of scarcity and reduce the need for stored forages and concentrated supplements (Mullenix & Rouquette, 2018).

Leaf production is the attribute that expresses the highest nutritive value and digestibility, being critical for forage selection (Tafernaberri et al., 2012). Rye and wheat can present high nutritive value (Coblentz et al., 2020), if the growth stages indicated for cutting and/or harvesting are respected, differing according to each species (Meccage et al., 2019).

The results observed for the average leaf blade percentage (Figure 1) showed a difference (P<0.001) between treatments, which are directly related to the botanical characteristics of each treatment. Temprano, BRS Pastoreio and BRS Tarumã were statistically superior to the others. Wheat cultivar BRS Tarumã had 81% of leaf blade, which represents 4448.6 kg ha^{-1} of DM. On the other hand, the rye cultivar BRS Serrano presented 58% of leaf blades, constituting a production of 3115.8 kg ha^{-1} of DM. These values were equivalent to 1.36 to 4.27 of leaf/stem ratio, respectively, close to those of Meinerz et al. (2012), where the ratio ranged from 0.73 to 2.57 for rye BRS Serrano and from 0.67 to 4.46 to BRS Tarumã wheat, decreasing along with cuts.

Figure 1 - Total forage yield, leaf blades and stem fractions, and percentage of leaf blades of rye cultivars in single cultivation or in mixtures, with black oat and dual-purpose wheat as controls.



Notes: Different letters on the percentage line in each column indicate a significant difference between treatments by Tukey's test (P<0.05). Treatments: P: BRS Progresso (rye); S: BRS Serrano (rye); Te: Temprano (rye); P + S: BRS Progresso + BRS Serrano; P + Te: BRS Progresso + Temprano; S + Te: BRS Serrano + Temprano; P + Te + S: BRS Progresso + BRS Serrano + Temprano; E: Embrapa 139 Neblina (black oat); Pa: BRS Pastoreio (wheat) and Ta: BRS Tarumã (wheat). Source: Authors (2022).

For neutral detergent fiber (NDF), there were significant differences between treatments at the first cut. The values varied between 64.0% and 56.5% of NDF for P and E, respectively (Table 3), wheats were not cut on that date. In the second cut, the maximum NDF values were 70.6% for BRS Progresso and the minimum values in this content were 58.1% for BRS Tarumã. For the third, eighth and ninth cuts, the values were similar.

In the fourth cut, wheat BRS Tarumã obtained the lowest value in relation to P, S, and P+S. In the fifth cut, the values varied between 67.9% for Ta and 60.1% for P + Te+ S. Differently in the sixth cut, whose maximum value was 67.9% for Ta and the lowest being 57.6% for cv. E. Finally, in the seventh cut, the black oat had lower (P<0.05) values in relation to S and S+Te. Similarly, Meinerz et al. (2011) obtained 53.78 to 68.9% for S, 55.1 to 68.2% for Ta and 55.1 to 58.2% for black oat.

Table 3 - Neutral detergent fiber (% NDF) concentration of rye cultivars in single cultivation or mixtures, with black oat and dual-purpose wheat as controls.

Treatments	Number of forage cuts/evaluation dates								
	1	2	3	4	5	6	7	8	9
	05/23	06/06	07/03	07/23	08/06	08/27	09/10	09/25	10/08
P	64.0[1] a	70.6 a	65.3	61.7 a	63.3 ab	61.7 bc	63.6 ab	66.2	NC
S	62.3 a	67.8 ab	62.9	61.5 a	63.8 ab	61.0 bc	69.1 a	68.2	NC
Te	59.2 ab	58.7 c	57.4	58.3 ab	62.0 ab	62.5 abc	67.3 ab	64.9	62.3
P+S	63.9 a	64.0 abc	63.4	61.3 a	64.1 ab	61.0 bc	66.5 ab	66.8	NC
P+Te	62.5 a	61.6 bc	58.6	58.8 ab	60.7 b	63.6 abc	65.8 ab	67.0	61.8
S+Te	61.8 a	63.1 abc	60.5	58.3 ab	60.5 b	62.7 abc	70.2 a	65.9	62.5
P+Te+S	60.0 ab	62.9 bc	60.8	59.0 ab	60.1 b	64.4 ab	66.5 ab	68.6	NC
E	56.5 b	61.7 bc	56.5	58.5 ab	60.2 b	57.6 c	62.1 b	67.9	NC
Pa	NC[2]	60.1 c	60.8	58.6 ab	67.9 a	67.1 ab	67.1 ab	66.8	NC
Ta	NC	58.1 c	59.4	55.1 b	62.4 ab	67.9 a	67.3 ab	69.9	NC
P-value	<0.001	<0.001	0.073	0.016	0.013	<0.001	0.047	0.452	0.954
SEM[3]	1.06	1.55	1.91	1.17	1.40	1.29	1.41	1.44	1.46

[1]In percentage (%); [2]NC = not clipped. Means followed by the same lower case letter in the column are not different (P>0.05) by Tukey test. [3]SEM= standard error of mean. P: BRS Progresso (rye); S: BRS Serrano (rye); Te: Temprano (rye); P+S: BRS Progresso + BRS Serrano; P+Te: BRS Progresso + Temprano; S+Te: BRS Serrano + Temprano; P+Te+S: BRS Progresso + BRS Serrano + Temprano; E: Embrapa 139 (Neblina) (black oat); Pa: BRS Pastoreio (DP wheat) and Ta: BRS Tarumã (DP wheat). Source: Authors (2022).

For acid detergent fiber (ADF) (Table 4), significant differences were observed only from the fourth to the sixth cut. Wheat BRS Tarumã presented higher content in the fourth cut, in relation to intercropping and isolated rye crops, except for P. In the fifth cut, this higher content was found in wheat BRS Pastoreio being superior in relation to isolated crops of S, Te, E and all rye intercrops. In the 6th cut, both wheats outperformed the isolated crops S, Te, E and the other intercropping, except P+Te. Similar conditions were observed by Meinerz et al. (2011), when evaluating small grain genotypes as single crops, among them, cultivars of black oat, rye and dual-purpose wheat, which presented average values of ADF, after three cuts, of 26.7; 27.4 and 28.6%, respectively.

Table 4 - Acid detergent fiber (% ADF) concentration of rye cultivars in single cultivation or in mixtures, with black oat and dual-purpose wheat as controls.

Treatments	Number of forage cuts/evaluation dates								
	1	2	3	4	5	6	7	8	9
	05/23	06/06	07/03	07/23	08/06	08/27	09/10	09/25	10/08
P	17.4[1]	21.6	31.2	21.2 abc	23.0 abc	22.7 ab	25.1	24.9	NC
S	15.7	19.9	31.7	19.3 cd	21.9 cb	21.9 b	25.9	25.0	NC
Te	15.2	16.4	25.9	19.4 cd	21.7 cb	20.9 b	21.5	22.1	20.8
P+S	19.0	21.1	34.7	20.8 bc	21.0 cb	19.9 b	23.5	20.4	NC
P+Te	17.6	18.2	26.2	15.2 d	20.0 c	22.3 ab	24.6	20.3	18.4
S+Te	19.6	16.2	26.5	16.4 d	22.2 bc	21.8 b	22.8	20.9	20.0
P+Te+S	18.4	19.6	26.7	17.0 cd	18.7 c	20.3 b	23.2	20.1	NC
E	15.8	16.2	28.3	23.8 ab	20.1 c	20.5 b	22.7	20.1	NC
Pa	NC[2]	22.7	31.1	24.7 ab	28.3 a	27.8 a	25.3	24.5	NC
Ta	NC	20.4	27.9	25.1 a	25.8 ab	27.7 a	23.8	23.0	NC
P-value	0.146	0.324	0.072	<0.001	<0.001	<0.001	0.112	0.063	0.071
SEM[3]	1.22	2.14	2.08	0.89	1.13	1.15	1.01	1.11	0.61

[1]In percentage (%); [2]NC = not clipped. Means followed by the same lower case letter in the column are not different (P>0.05) by Tukey test. [3]SEM= standard error of mean. P: BRS Progresso (rye); S: BRS Serrano (rye); Te: Temprano (rye); P+S: BRS Progresso + BRS Serrano; P+Te: BRS Progresso + Temprano; S+Te: BRS Serrano + Temprano; P+Te+S: BRS Progresso + BRS Serrano + Temprano; E: Embrapa 139 (Neblina) (black oat); Pa: BRS Pastoreio (DP wheat) and Ta: BRS Tarumã (DP wheat). Source: Authors (2022).

Plant maturity influences forage quality, with yield throughout development tending to increase while quality decreases (Zhao et al., 2020), so later cuts increase NDF concentrations and reduce total digestible nutrients (Sadeghpour et al., 2022).

As for crude protein (CP) (Table 5), there were no significant differences in the first, second, seventh and ninth cuts. However, for the third cut, the cultivar Te showed higher ($P<0.05$) CP content in relation to intercropping with the cultivars P + S with levels of 33.7% and 28.5%, respectively. For the fourth cut, the highest ($P<0.001$) values were from isolated rye crops and the intercropped treatments with the Te cultivar. For the fifth cut, only black oat presented a higher value than the dual-purpose wheats, the same was repeated for the sixth cut, but only for cv. BRS Pastoreio. These high levels are associated with N fertilization, as 30 kg ha^{-1} of N were applied after each cut, totaling 180 kg ha^{-1} of N plus previous fertilization.

Finally, in the eighth cut, the intercropping with the three rye cultivars had a higher ($P<0.05$) value compared to the isolated cultivation of cv. BRS Progresso, 31.4% and 27.7% respectively. Values higher than those of Soares et al. (2016) and Piazzetta et al. (2009) who found 21.1% in black oat. Similar to those observed by Meinerz et al. (2011) with mean values after three cuts of 22.42 and 21.24% for common black oat and Ta wheat, respectively, and 19.63% for S rye.

The high protein contents found in this study possibly occurred because the cuts were performed according to the plant height criterion and not on pre-established days. This method allows a greater number of tillers and new leaves, resulting in higher protein content, in addition to the contribution of nitrogen fertilization (Soares et al., 2013), that is, the CP levels in forages can be altered according to nitrogen fertilization (Moreira et al., 2007). The treatments with 9 cuts received 270 kg ha^{-1} of N plus previous fertilization.

Table 5 - Crude protein (% CP) concentration of rye cultivars in single cultivation or mixtures, with black oat and dual-purpose wheat as controls.

Treatments	Number of forage cuts/evaluation dates								
	1	2	3	4	5	6	7	8	9
	05/23	06/06	07/03	07/23	08/06	08/27	09/10	09/25	10/08
P	31.7[1]	30.7	30.5 ab	33.2 abc	33.5 ab	30.9 ab	27.5	27.7 b	NC
S	32.2	31.8	30.8 ab	34.3 abc	32.6 ab	30.7 ab	27.5	29.1 ab	NC
Te	33.7	33.4	33.7 a	33.7 abc	32.3 ab	31.8 ab	28.9	29.5 ab	30.1
P+S	31.0	30.2	28.5 b	32.7 bc	33.2 ab	31.4 ab	27.8	28.7 ab	NC
P+Te	31.8	32.4	33.3 ab	36.8 a	33.4 ab	30.5 ab	28.5	30.6 ab	30.6
S+Te	30.2	33.5	32.8 ab	36.2 ab	33.3 ab	30.6 ab	29.3	30.3 ab	31.5
P+Te+S	30.8	31.3	32.9 ab	36.0 ab	33.4 ab	31.2 ab	27.4	31.4 a	NC
E	33.6	33.7	32.4 ab	31.9 c	35.1 a	32.7 a	29.2	29.1 ab	NC
Pa	NC[2]	33.5	32.9 ab	30.6 c	29.9 b	27.7 b	29.2	28.9 ab	NC
Ta	NC	31.6	33.0 ab	31.3 c	30.1 b	28.5 ab	29.5	28.1 ab	NC
P-value	0.350	0.255	0.039	<0.001	0.003	0.006	0.356	0.046	0.223
SEM[3]	0.76	1.09	1.05	0.83	0.80	1.02	0.78	0.76	0.50

[1]In percentage (%); [2]NC = not harvested. Means followed by the same lower case letter in the column are not different (P>0.05) by Tukey test. [3]SEM= standard error of mean. P: BRS Progresso (rye); S: BRS Serrano (rye); Te: Temprano (rye); P+S: BRS Progresso + BRS Serrano; P+Te: BRS Progresso + Temprano; S+Te: BRS Serrano + Temprano; P+Te+S: BRS Progresso + BRS Serrano + Temprano; E: Embrapa 139 (Neblina) (black oat); Pa: BRS Pastoreio (DP wheat) and Ta: BRS Tarumã (DP wheat). Source: Authors (2022).

The reduction in forage consumption can be caused by deficiency or excess of protein in the animals' diet (Cavalcante et al., 2005), requiring at least 12% of CP in the feeding of ruminants (Brito et al., 2003). Thus, the values presented are in accordance with this requirement. In conclusion, all cultivars present values above the necessary to not affect ruminal fermentation and microbial growth.

4. Conclusion

Rye Temprano is the best for DM yield and leaf blade percentage. Forage yield does not change when the cultivar Temprano is mixtured with the other rye cultivars, but leaf blade production decreases and stem production increases. In this scenario the precocious cultivars can be used in mixtures to increase DM yield while maintaining nutritive value levels from the fall to spring seasons.

Finally, we suggest for future work that the production, the nutritive value of each genotype at different sowing dates, together with the cost of seeds in single cultivation and in mixtures should be considered so that there is a greater adoption of single cultivation or mixtures of annual winter grasses in rural properties.

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