Journal of Agricultural Sciences Research

ISSN 2764-0973 vol. 5, n. 7, 2025

ARTICLE 13

Data de Aceite: 23/12/2025

YIELD AND NUTRITIONAL VALUE OF THREE SMALL GRAIN FORAGES FROM AUTUMN-WINTER, ALONE AND IN MIXTURES, IN NORTHERN COAHUILA

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Thanks to INIFAP for facilitating this work.

Abstract: The experiment was conducted during the 2017/18 fall-winter growing season to evaluate the effect of three small--grain fall-winter forage crops— —in monoculture and in mixture on the availability of timely forage, production period, dry matter yield, and nutritional value of the forage. The study consisted of five treatments with the following densities: T1: Avena Tamo 397 (100 kg ha^{-1}), T2: Wheat Coahuila S-92 (100 kg ha^{-1}), T3: Ryegrass (35 kg ha^{-1}), T4: Oats 50 kg ha^{-1}+ Ryegrass 17.5 kg ha^{-1}, T5: Wheat 50 kg ha^{-1}+ Ryegrass 17.5 kg ha^{-1}; conducted in a randomized block design with four replicates. There was no difference ($p<0.05$) in plant height at first cut between treatments. The first cut was obtained at 45 days. On average, 5 cuts and 159 days of production were obtained. The analysis reported differences ($P< 0.05$) in dry matter (DM) yield. Ryegrass with the highest yield, 14.97 t DM ha^{-1}, was equal ($p<0.05$) to mixtures, oats + ryegrass and wheat + ryegrass with 14.27 and 13.47 t DM ha^{-1}, respectively. The increase compared to oats was 16.11 and 5%. Oats alone and the oats + ryegrass mixture provided higher DM yield in the first and second cuts. The contribution of ryegrass in mixture with oats in the first and second cuts (27:73% and 31:69%) and with wheat (42:58% and 68:32%), respectively. The yield of PC, NDT, and DMS was higher in ryegrass and similar to the wheat + ryegrass and oats + ryegrass mixture with a PC range (2,339 to 2,159 kg ha^{-1}). NDT (10,566 to 9,288 kg ha^{-1}) and MSD (13,991 to 12,618 kg ha^{-1}). These results suggest that to obtain timely forage, a longer production period, higher DM yield, and nutritional yield, mixtures and ryegrass monoculture are the best options.

Keywords: Monoculture, mixture, dry matter, crude protein, digestibility.

INTRODUCTION

Forage is the main source of feed in ruminant production systems (Navarro *et al.*, 2021). The production of calves for export, goat milk, and lamb are the most important systems in the northern region of Coahuila, as their feed is based on pasture forage, a resource that represents 90.1% of the regional area of 3.1 million ha-[1](INEGI, 2022). However, during the period from November to April, low availability and quality of forage in this resource is common due to the low temperatures and low rainfall that characterize this period, which compromises the productivity of livestock in the physiological state of pre- and post-calving, stages with greater demands on forage and its quality (Hernández *et al.,* 1997). Faced with this situation, some producers supplement their feed with forage crops from the fall-winter (F-W) cycle, where oats (*Avena fatua* L) are the main crop, with a planting area of 2,718 ha^{-1}, representing 58% of the 4,652 ha^{-1} sown in the 2023 O-W cycle in the region (SIAP, 2023). The preference for oat cultivation is due to the fact that it provides forage for grazing in November, 30 days faster than the ryegrass variety (*Lolium multiflorum* L) cv Gulf, which is recommended for the region (Osuna *et al.,* 1987b), as there are no other alternatives and this is what agro-input companies sell in the region. A poor choice of what companies offer can represent a 22.25% reduction in yield, due to the effect of the environment interacting with the genotype in the same locality and between localities (Fang *et al.*, 2017; Pan *et al.*, 2018; Lin *et al.*, 2018; Godisa *et al.*, 2023, Nuñez *et al.,* 1997). There are even 40% reductions in the yield of Cuauhtémoc oats due to rust (*Puccinia avenae*), a recurring disease in northern Coahuila, as conditions are conducive to its development (Osuna *et al.,* 1987a; Silva, 2007). Under these conditions, one option could be the late-cycle Coahuila S-92 wheat variety, with yields of 8.4 t DM $^{ha^{-1}}$ and good tolerance to rust and frost in early stages (Silva, 2007). There are annual tetraploid ryegrass varieties on the market that grow quickly at first, offering earlier forage, higher yields, and better nutritional quality than diploid ryegrass (Goyal *et al.*, 2017; Bostan *et al.*, 2022). Sowing cereals mixed with ryegrass extends the grazing period due to the rapid development of cereals in the initial growth stage, allowing earlier and later grazing by extending the cycle with ryegrass, increasing yield and dry matter quality per unit area (Waghray *et* al., 1980; Oliver. 1980; Lozano *et al.,* 2002; Lizárraga *et al.*, 1980; Duffau *et al.,* 2020). Due to the limited forage options available in the region, the objective of this study was to evaluate the effect of three small-grain autumn-winter forage crops in monoculture and in mixture on the availability of timely forage, production period, dry matter yield, and nutritional value of forage under irrigated conditions.

MATERIALS AND METHODS

Study area

The experiment was conducted during the 2017/18 fall-winter growing season at the Zaragoza-INIFAP Experimental Site in Zaragoza, Coahuila, Mexico. Located at coordinates 28° 59' 79" north latitude and 100° 90' 77" west longitude, at 350 meters above sea level. The climate is Bs0xh' (dry--hot), with rainfall in summer and scarce rainfall during the rest of the year, and an average annual temperature of 21.4 °C (SEP, 1982). Average annual precipitation is 375 mm, with a bimodal distribution, originating in May and September, the months with the highest precipitation. The soil in the study area is characterized by a loamy--clay texture, with an apparent density of 1.08 g/cm³, moderate organic matter content (1.83%), and no salinity problems. It is very poor in nitrogen (N), medium in phosphorus (P) and potassium (K), with low to medium trace element content, which is limited in availability due to the alkaline pH (8.39) and high total carbonate content (68.1%) (Fertilab, 2017).

Description of treatments

The experiment consisted of five treatments, three in monoculture and two mixtures at 50% of the recommended density in monoculture: T1: Oats cv Tamo 397), T2: Wheat cv Coahuila S-92, T3: Annual tetraploid ryegrass cv Jumbo), T4: Oats + Ryegrass, and T5: Wheat + Ryegrass. Conducted in a randomized block design with four replicates. The experimental unit was 9 $^{m^2}$(3 m x 3 m) and the usable plot was 4 $^{m^2}$(2 m x 2 m).

Soil preparation and management

The soil was left fallow, two cross-shaped harrowing passes were made, and it was leveled with a rail behind the harrow. Fertilizer was applied according to the formula 90-100-00 kg ha^{-1}. Urea (46-00-00) was used as a commercial source of nitrogen (N) and monoammonium phosphate (11-52-00) was used for P. Fifty percent of the N and 100% of the P were applied prior to the second harrow pass. The remaining 50% of the N was broadcast during the second emergency irrigation.

After each cut, 65 kg N $^{ha^{-1}}$ was applied. Sowing was carried out on October 5, manually in dry conditions at the bottom of the furrow, and the seed was covered with a hoe. For monoculture crops, such as Oats (T1) and Wheat (T2), a density of 100 kg SPV $^{ha^{-1}}$ was used, and 35 kg $^{ha^{-1}}$ for Ryegrass (T3). In the case of mixtures T4: Oats 50 kg + Ryegrass 17.5 kg SPV ha^{-1} and T5: Wheat 50 kg + Ryegrass 17.5 kg SPV ha^{-1}. During the study period (October to May), a total of seven to eight irrigations were carried out at intervals of 17 to 25 days, with an application of 12 cm of water per irrigation.

Variables evaluated

Plant height (PH) was measured just before each cut using a ruler 1 m long and accurate to 1.0 mm. Four readings were taken within each usable plot, on randomly selected plants, with the ruler held completely vertical from the base of the plant to the youngest upper leaf (Hodgson *et al.*, 1990). Days to first cut (DPC) were estimated by counting the days between the date of the first cut (made at a plant height of 35 to 40 cm, a criterion established at the beginning) and the date of the first irrigation after sowing. The number of cuts (NC) was recorded by noting the date of each cut. Days between cuts (DBC) were obtained by recording the days between cut dates. Days of production (DP) were obtained by counting the days between the dates of the first and last cuts. The DM content was determined in a sample taken from 0.85 m of five of the central furrows of a 4 m^{2}plot, at a plant height of 35 to 40 cm. At the time of sampling, two samples were taken from the usable plot (an extra 250 g per usable plot from the mixed treatments, to estimate the participation of the crops in the plot), weighed fresh, then dried at 65 °C in a forced--air oven for 48 to 72 hours until a constant weight was reached. Subsequently, the DM yield was obtained by multiplying the fresh forage yield by the DM percentage of the forage in each useful plot. The plants monitored to estimate DM content were used to analyze the nutritional value of the forage (for budgetary reasons, a representative sample per treatment was analyzed). The dry matter forage samples were ground in a Wiley® mill (Thomas Scientific, Swedesboro, NJ, USA) with a 1 mm mesh.

The nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation, and titration procedures (AOAC, 2005), and the PC content was estimated by multiplying the N content by 6.25. The structural components of the plant (FDN, FDA, and NDT) were determined according to the procedure of Goering and Van Soest (1970). The in vitro digestibility of DM (IVDDM) was determined according to Tilley and Terry (1963). The yields of CP, TDN, and MSD $^{ha^{-1}}$were obtained by multiplying the CP, TDN, and IVDDM contents by the DM yield $^{ha^{-1}1}$.

Statistical analysis

Analysis of variance (P < 0.05) was performed for the variables of plant height at first cut and DM yield, according to the randomized block experimental design with four replicates using the GLM procedure of the SAS statistical package (SAS Institute, 2009). The comparison of means between treatments was performed using the Tukey test (P<0.05). For agronomic variables (DPC, NC, DEC, DP), concentrations (PC, FND, FAD, and DIVMS), and nutritional yield (PC, NDT, MSD), the statistics of means and standard deviation were used.

RESULTS AND DISCUSSION

Plant height at first cut

The analysis of variance for plant height at first cut (APC) did not report a significant difference (p<0.01) between treatments (Table 1). This was due to the plant height criterion of 35 to 40 cm, established prior to the study. The lower plant height in wheat is explained by damage caused by the leafcutter ant *Atta mexicana* Smith in two replicates during one day in the first 40 days after sowing, which was controlled by applying the commercial product Lorsban 450 EC at a dose of 1 liter ha^{-1}.

Days to first cut

The first cut was obtained 45 days after the sowing date (ddfs) (Table 1). This is lower than the range of 60 to 90 dps at which Gulf ryegrass reaches a plant height of 35 to 40 cm, the recommended criterion for first grazing in northern Coahuila (Osuna *et al.*, 1987b). The results obtained are 5 to 10 ddfs lower than those indicated for oats + ryegrass in Argentina (Duffau *et al.*, 2020). They are 27 to 37 days earlier than in Sonora (Lizárraga *et al.*, 1980) for the barley + ryegrass mixture. The variation is due to the pre-established harvest criteria, as well as the genetic characteristics of the cultivars evaluated and their ability to respond to the environment (Velasco *et al.*, 2005; Lizárraga *et al.*, 1980; Duffau *et al.*, 2020).

Number of cuts

During the growing cycle, there were 4 to 6 cuts between treatments, with an average of 5± 0.83. (Table 1). Wheat and ryegrass in monoculture and the wheat + ryegrass mixture (T5), with 6 cuts, exceeded the oat + ryegrass mixture by 1 cut and the oat control, the only one below average, by 2 cuts (Table 1). The lower number of cuts in oats was due to the use of a short-cycle variety, compared to the intermediate-cycle ryegrass and late-cycle wheat.

Days between cuts

The oat control and the oat + ryegrass mixture reported the highest frequency between cuts (46 and 40 days), respectively, in a range of 35 to 46 days and with an average of 38± r 4.9 days (Table 1). This is 5 to 11 days longer than the rest of the treatments. This indicates that oats alone and the oats + ryegrass mixture take longer to recover after cutting.

Days of production

Production days (PD) varied from 138 to 168 days (Table 1), with an average of 159± 13.2 days. The wheat + ryegrass mixture, ryegrass alone, and wheat alone, with values above the average, obtained the highest number of PD. This was 17 and 30 days more than the oat + ryegrass mixture and oat Tamo 397 (Table 1). The shorter production period for oats alone and the oat + ryegrass mixture was due to their higher frequency between cuts, lower number of cuts, and the short cultivation cycle of oats (Table 1). The results are the same as 168 days for ryegrass and oats + ryegrass in Argentina (Daffau *et al.*, 2020); they exceed 18 days for ryegrass in La Laguna, Co-

Treatments	Plant height**	Days to first cut	Number of cuts	Days between cuts	Production days
T1: Oats*	39.6ª	45	4	46	138
T2: Wheat	36.9 ª	45	6	35	168
T3: Ryegrass	37.7 ª	45	6	35	168
T4: Oats + Ryegrass	38.9 ª	45	5	40	155
T5: Wheat + Ryegrass	39.4 ª	45	6	35	168
Average	38.5	45	5	38	159
DS ±	1.6	0	0.89	4.9	13.2

*Control. **MSD = Minimum Significant Difference of 1.79 (Tukey <0.05). **C.V (%): Coefficient of variation of 6.03. **Means in the plant height column with the same letter are not statistically different.

Table 1. Agronomic performance of small-grain forage crops with a cycle of autumn-winter cultivation in monoculture and mixed cultivation. SEZAR - CIRNE - INIFAP.

Yield	T3: Ryegrass	T5: Wheat + ryegrass	T4: oats + ryegrass	T1: oats	T2: wheat	DMS	CV %
t DM ha-¹	14.97 a	14.27 ab	13.49 ab	12.88 b	8.99	1.79	6.03

DMS: Minimum Significant Difference

abc: Different letters indicate significant differences (Tukey p≤0.01).

Table 2. DM yield of small-grain forage crops with an autumn-winter growing cycle in monoculture and mixed cropping. S.E. Zaragoza- CIRNE-INIFAP.

Treatments	DM yield (t ha⁻¹) per cut						Prom	DE (±)
	1	2	3	4	5	6		
T1: Oats	2.20	3.90	3.45	3.33	0.0	0.0	3.22	0.726
T2: Wheat	0.90	1.85	1.74	1.60	1.20	1.70	1.50	0.369
T3: Ryegrass	1.42	2.26	3.92	2.89	2.39	2.09	2.50	0.845
T4: Oats + Ryegrass	1.72	3.76	2.95	2.09	2.97	0.0	2.70	0.805
T5: Wheat + Ryegrass	1.57	2.73	2.87	2.24	2.68	2.18	2.38	0.483

DM: Dry matter; Avg = Average; SD = Standard deviation.

Table 3. Productive distribution (t DM $^{ha^{-1}}$) of the treatments under study during the SEZAR-CIRNE-INIFAP.

ahuila (Nuñez *et al.,* 1997); but are 32 days lower for ryegrass alone and in a mixture of barley and ryegrass in Sonora (Lizárraga *et al.*, 1980). The variation may be due to the sowing date, plant condition at harvest, cutting frequency, temperatures and solar radiation, and the crop cycle of the genotypes used (Nuñez *et al.*, 1997; Lizarraga *et al.*, 1980; Dufau *et al.*, 2020; Alende *et al.*, 2020).

Dry matter yield

MS yield showed significant differences ($p<0.05$) between treatments (Table 2), with a mean value of 12.92 t $^{ha^{-1}}$, ranging from 8.99 to 14.97 t $^{ha^{-1}}$.

The ryegrass with a yield of 14.97 t $^{ha^{-1}}$ was higher and equal ($p<0.01$) to the oat + ryegrass mixture and the wheat + ryegrass mixture. The increase over oats (12.88 t DM ha^{-1}) was 16.11 5% and over wheat (8.99 t DM ha^{-1}) was 50 to 60%, respectively. This is because oats have a shorter phenological cycle than wheat and ryegrass, with a higher frequency of cuts, fewer cuts, and a shorter production period; and the effect of ants in the case of wheat and the temperatures that occurred during the crop cycle. The increase was less than the 25% increase in ryegrass over the oat + ryegrass mixture reported in India (Puri *et al.,* 2010), perhaps due to the lower sowing density used for oats (37.5 kg $^{ha^{-1}}$of seed) in the mixture with ryegrass.

The DM yields obtained exceed by 58% (5,399 kg DM $^{ha^{-1})}$those reported by Celis *et al.* (2017) for oats in the State of Mexico. They exceed by 27% (9,355 kg DM ha^{-1}) those obtained in oats and by 26.3% (10,523 kg DM ha^{-1}) those obtained in the oats + ryegrass mixture in Argentina (Duffau *et al.,* 2020). In contrast, they are 25.6% lower than those reported by Nuñez *et al.* (1997) in annual ryegrass (17.8 to 20.1 t DM ha-^{1}) in Laguna, Coahuila, and 33.3% lower than those reported by Lizárraga *et al.* (1980) in Sonora of 20.89 t DM ha^{-1} in the barley + ryegrass mixture. The variation can be explained by differences in environments and genetics of the cultivars. In this regard, Gadisa *et al.* (2023) found that the variation in DM yield in eight oat cultivars evaluated in different locations in India was explained by 23.2% by the environment between locations and 7.5% by genetic variability.

Production distribution

The productive distribution of the treatments under study during the fall-winter growing cycle is presented in Table 3. Oats in monoculture and the oats + ryegrass mixture produced the highest yield in 1er . cut (2.20 and 1.72 t DM ha^{-1}) and 2nd cut (3.90 and 3.76 t ha^{-1}), reaching its highest production in the 2nd , as did wheat (1.85 t DM ha^{-1}). On the other hand, ryegrass and the wheat + ryegrass mixture obtained their highest production in the^{3rd}cut (3.92 and 2.87 t DM $^{ha^{-1}}$), respectively.

The highest yields obtained in the^{1st}and^{2nd}cuts in this study were for oats alone, followed by the oats + ryegrass and wheat + ryegrass mixtures; contrary to what was reported by Daffau *et al.* (2020), who in Argentina obtained the highest production from ryegrass alone, followed by the oats + ryegrass mixture and, lastly, oats in monoculture, possibly due to the density in climatic conditions and the lower sowing density of oats in the mixture with ryegrass.

In terms of average yield per cut, the wheat + ryegrass mixture, ryegrass alone, and the oats + ryegrass mixture had average yields per cut of 2.38 to 2.70 t DM ha^{-1} (Table 3), with a difference between the two of 0.320 t DM ha^{-1} and an SD of 0.483 to 0.845 t DM ha^{-1}, had intermediate yields similar to oats, which had the highest average yield (3.33 t DM ha^{-1}), but with a higher SD than the wheat + ryegrass mixture (0.483 t DM ha^{-1}), which positions the latter as the option with the best DM distribution throughout the cycle (Table 3).

Productive share of crops in mixtures

The productive share of oats and ryegrass in the mixture during the crop cycle is shown in Figure 1. In the first two cuts, the average DM contribution of oats was 65.4% (72.7 and 58.2%) and that of ryegrass was 34.6% (27.3 and 41.8%); the opposite occurred from the 3rd to the 5thcut, where ryegrass, with an average contribution of 84%, exceeded the 16% contributed by oats by 4.25 times.

In the wheat + ryegrass mixture, wheat accounted for an average of 50.4% (69.4 and 31.5%) in the 1st and 2nd cuts, and ryegrass accounted for 49.6% (30.6 and 68.5%), respectively (Figure 2). In contrast, from the 3rd to the 6th cut, the proportion of wheat decreased steadily to a minimum average of 9.3% (13.0 to 7.1%), while ryegrass, on the contrary, increased its contribution with an average of 90.7% (87.0 to 92.9%). The proportion obtained for oats and wheat mixed with ryegrass does not agree with that reported by Puri *et al.* (2010), who, in a study on ryegrass + oat mixtures conducted in India, with a sowing density of 37.5 kg ha^{-1} for each, found a more balanced share for both crops (49.9% ryegrass and 50.1% oats). However, the proportion from the second cut onwards was similar (90:10) to that obtained in the current study (84:26).

The productive participation (MS) of oats and wheat shown in mixture with ryegrass during the crop cycle (Figures 1 and 2) may be due to the rapid growth and increase in leaf coverage of each crop in response to the optimal temperatures for each of them. As reported by Sapkota *et al.* (2020), who, when evaluating the competition of ryegrass in wheat sowing, found that for each unit of increase in ryegrass aerial coverage, wheat yield is reduced by 18 grams; this could also occur in the mixture of ryegrass with oats, only to a lesser degree. It could also be due to ryegrass's greater response to nitrogen when under optimal temperature conditions (Vilojen *et al.*, 2020).

Nutritional composition of forage

The nutritional composition evaluated in monoculture and mixed crops, at the stem elongation stage (plant height 35 to 40 cm) in the first cut, is shown in Table 4.

Crude protein (CP) content

Wheat and oats in monoculture and the oats + ryegrass mixture, with a difference of 10.7 g kg^{-1} (184.1 vs. 173.4 g kg^{-1}), equivalent to 5.76% between the two and in favor of wheat, had the highest PC contents, above the average of 167.3 g kg^{-1} (Table 4); as well as 12% more PC than the wheat + ryegrass mixture and 17% more than ryegrass. The PC values found in this study exceed by 8.62% those of oats cv Saia, harvested 72 days after sowing in the State of Mexico (Celis *et al.*, 2017). Likewise, they exceed those reported by Duffau *et al.* (2020) for the first cut of 16.0% in oats, 12.0% in ryegrass, and 12.2% in oats + ryegrass, at a

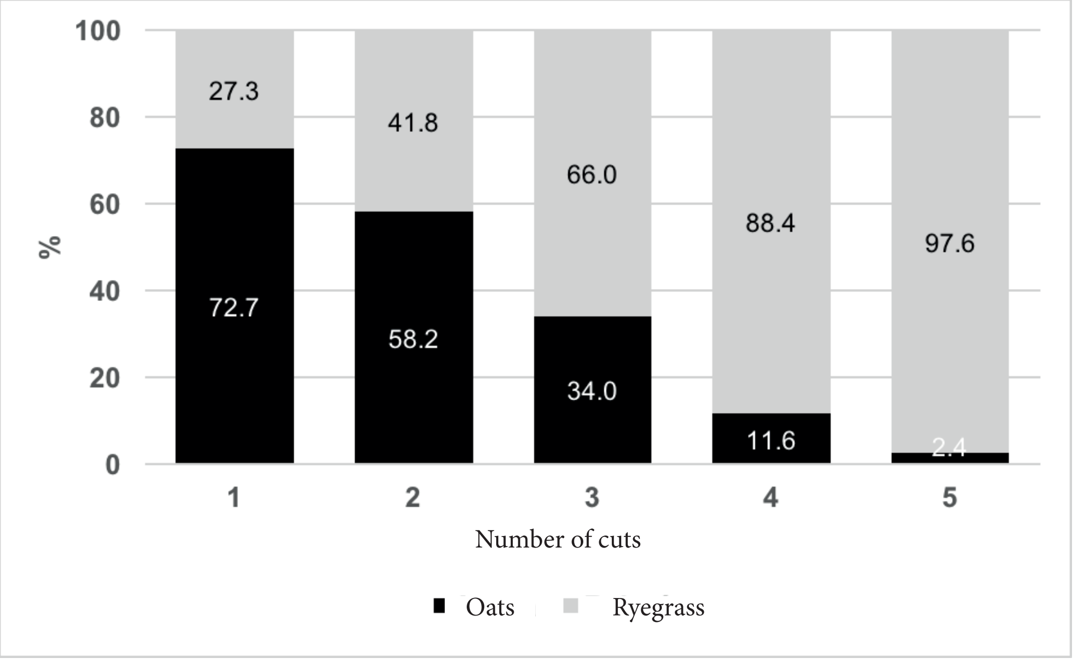

Figure 1. Percentage share of oats + ryegrass in the mixture in each cut during the fall-winter-spring crop cycle. SEZAR-CIRNE-INIFAP.

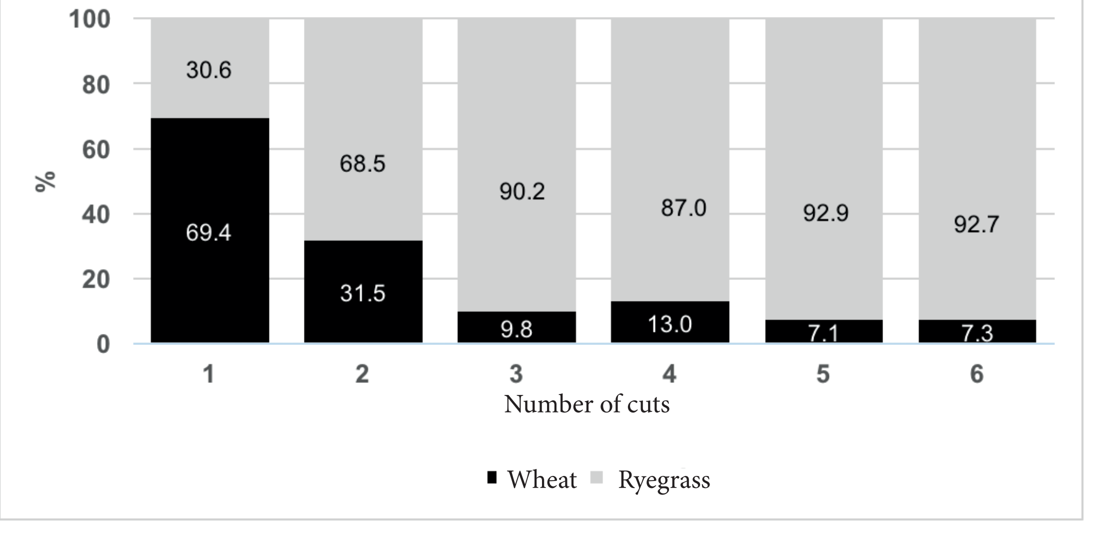

Figure 2. Percentage share of wheat + ryegrass in the mixture in each cut during the fall-winter crop cycle. SEZAR-CIRNE-INIFAP.

sowing density of 37:37 kg SPV $^{ha^{-1}}$in Argentina and harvested at 35 days. The low PC content in the wheat + ryegrass mixture could be due to the lower proportion of wheat in the mixture (Figure 2), since it had the highest content in monoculture. In contrast, the low PC content in ryegrass could be due to a lower leaf and stem content in the plant, as reported by Shrivastava *et al.* (2020) when evaluating oats and ryegrass in India and finding that ryegrass with 147 g PC kg^{-1} DM, exceeded oats (126 g PC kg^{-1}DM) by 14.3% ( ) because it produced fewer leaves (32.7%) and stems (33.7%) than ryegrass in the ^{first}cut, under the climate and management conditions presented at their study site.

NDF and ADF content

The neutral detergent fiber (NDF) content ranged from 493.9 to 419.9 g $^{kg^{-1}}$DM, with an average of 448.9± 29.6 g $^{kg^{-1}}$DM; while the ADF ranged from 293.2 to 231.9± 24.8 g $^{kg^{-1}}$DM) (Table 4). Wheat and the wheat + ryegrass mixture obtained the highest FND (493.9 and 462.7 g $^{kg^{-1}}$DM) and FAD (293.2 and 269.2 g $^{kg^{-1}}$DM) values above the average, respectively (Table 4). Meanwhile, the oats + ryegrass mixture and oats and ryegrass monocultures had below-average FND (3.9, 2.8, and 9.4%) and FAD (1.3, 7.5, and 9.8%) values, respectively (Table 4). The higher NDF and ADF content in the aforementioned treatments could be explained by the fact that wheat and oats showed faster growth, which may have led to higher cellulose, hemicellulose, and lignin content in their structural composition, contributing to the obtained values. As a result, they would be the least digestible and least consumed (Stroh, 2025).

In a study conducted in Coahuila (Ochoa *et al.,* 2020), Cuauhtémoc oats were reported to have FND and FAD values (581 and 389 g kg^{-1}DM), and Karma oats were reported to have FND and FAD values (621 and 387 g kg^{-1}DM). For Salamanca wheat,

Treatments	PC (g kg^{-1})	FND (g kg-^{1})	FAD (g kg^{1})	NDT (g kg^{1})	DIVMS (g kg^{1})
T3: Ryegrass	154.0	419.9	231.9	705.8	934.6
T5: Wheat + Ryegrass	151.3	462.7	269.2	676.0	919.2
T4: Oats + Ryegrass	173.4	431.6	253.8	688.5	935.4
Q1: Oats	173.6	436.5	238.0	701.0	937.8
T2: Wheat	184.1	493.9	293.2	657.5	927.9
Average	167.3	448.9	257.2	685.8	930.5
DE ±	14.1	29.6	24.8	19.6	75

CP = Crude protein**;** NDF = Neutral detergent fiber; ADF = Acid detergent fiber; TDN = Total digestible nutrients

total; DIVMS= In vitro digestibility of dry matter; SD= Standard deviation

Table 4. Chemical and quality parameters in the different treatments under study. SEZAR-CIRNE-INIFAP.

FND and ADF values were 584 and 356 g kg^{-1}DM, respectively, and for AN 265 wheat, FND and ADF values were 628 and 410 g kg^{-1}DM, respectively. The values for oats are 27.3% (FND) and 38.0% (FAD) higher, and for wheat 18.4% (FND) and 20.7% (FAD) higher than those found in this study for Tamo 397 oats and Coahuila S-92 wheat (Table 4).

However, they are similar to those reported in India (Goyal *et al.,* 2017) for oats (FND 457 and FAD 343 g $^{kg^{-1}}$DM) and for ryegrass (FND 418 and FAD 266 g $^{kg^{-1}}$DM), as well as those mentioned for intermediate tetraploid ryegrass (FND 450 and FAD 280 g kg^{-1}DM, (Alende *et al*., 2020). The differences can be attributed to the phenological state at harvest, different climatic conditions, and genetic characteristics of the cultivars (Celis *et al.,* 2017; Ochoa *et al*., 2020; Goyal *et al.,* 2017; Alende *et al*., 2020).

Total digestible nutrients (TDN) content

The TDN content ranged from 705.8 in ryegrass to 701.0 g kg^{-1}in oats, with an average of 685.8+19.6 g kg^{-1}. The ryegrass, oat, and oat + ryegrass mixture cultivars, with similar values (705.8, 701.0, and 688.9 g kg^{-1}), were higher than the average value (Table 4), exceeding the wheat + ryegrass mixture by 29.8 to 12.5 g $^{kg^{-1}}$and wheat by 48.3 to 31.0 g kg^{-1}. The treatments with the highest TDN content were those with the lowest CP, NDF, and ADF contents, where these last three s were related in the treatments, except in the wheat + ryegrass mixture, where the NDF and ADF values showed no relationship with CP.

DIVMS content

The DIVMS content ranged from 937.8 g kg^{-1}for the control oats to 919.2 g kg^{-1}for the wheat + ryegrass mixture, with an average of 930.5± 75 g kg^{-1}(Table 4). The trend shown by the control oat cultivars, the oat + ryegrass mixture, and ryegrass alone in TDN content was repeated in DIVMS with values of 937.8, 935.2, and 934.6 g kg^{-1}DM, respectively, above the average (Table 4). Below this average, the wheat crop and the wheat + ryegrass mixture again had the lowest contents (927.9 and 919.2 g $^{kg^{-1}}$), respectively.

The wheat + ryegrass mixture showed high and consistent values for FND and FAD, but the lowest values for PC and DIVMS. In contrast, wheat, which obtained the highest and most consistent values for PC, FND, and FAD, ranked second with the lowest DIVMS content. This relationship does not agree with Oscar *et al.* (2020), who report a consistent relationship between CP, NDF, and ADF with DIVMS in wheat. The high digestibility values in the present study could be explained by the fact that it was cut at the stem elongation stage at 45 days with an average height of 39 cm and by the high dose of phosphorus applied at the time of sowing, which could have led to an increase in phosphorus and this increase in digestibility, as reported by Sandoval *et al.* (2016), who found a correlation between DIVMS and the mineral content of P, FND, FAD, PC, and EE, cellulose, and lignin in a study of the fermentation and digestibility of star bermuda grass. Based on the digestibility results (g kg^{-1}DM), the cultivars evaluated in monoculture and in mixture ( ) are of good quality, exceeding 700 g kg DM, the amount considered as a classification criterion (Chamberlain and Wilkinson, 2002).

Nutritional yield of forage

The yield (kg ha^{-1}) of PC, NDT, and MSD showed a similar trend among treatments (Table 5). In relation to PC yield, oats, oats + ryegrass mixtures, ryegrass, and wheat + ryegrass mixtures, with a difference between the two of 0.003 to 7.2%, obtained the highest PC yields above the average (2,139± 279 kg ha^{-1}). Both treatments exceeded the lowest wheat yield (1,655 kg ha^{-1}) by 23.3 to 29.3%. This difference was due to wheat obtaining the lowest DM yield (Table 2), despite obtaining the highest CP values in the nutritional composition (Table 4).

As for NDT yield, it fluctuated between 5,910 kg ha^{-1}(wheat) and 10,566 kg ha^{-1}(ryegrass), with an average of 8,888± 1,763 kg ha^{-1}(Table 5). The treatments with the highest PC yield values are the same as those with the highest NDT values (kg ha^{-1}). Ryegrass and the wheat + ryegrass mixture, with values of 10,566 and 9,646 kg NDT ha^{-1} are slightly higher by 8.7% (920 kg ha^{-1}) than the oat + ryegrass mixture and, in a range of 14.6% to 44.1% (9,028 to 5,910 kg ha^{-1}) than the oat and wheat controls, respectively. The difference in higher NDT yield is due to higher DM yield, higher nutritional value of PC (g kg^{-1}) and lower FND and FAD contents (g kg^{-1}) (Table 4).

MSD yield ranged from 8,409 kg ha^{-1}to 13,991 kg ha^{-1}(for wheat and ryegrass), with an average of 11,981± 2,081 kg ha^{-1} (Table 5). Ryegrass, wheat + ryegrass mixtures, and oat + ryegrass mixtures, with above-average values, exceeded the oat control by 6.2 to 14.6% and wheat by 14.6 to 39.9%, respectively. The difference in MSD yield in favor of the treatments with higher values is due to the nutritional value of NDT (g kg^{-1}) and its higher DM yield.

CONCLUSIONS

Under the growing conditions in which the study was conducted, the three small-grain cereals in monoculture and in mixture, when sowing is established early and under the cut criterion, mixtures of oats with ryegrass, wheat with ryegrass, and ryegrass in monoculture are the options for obtaining timely forage for grazing purposes, a longer period of use and/or production,

Treatments	PC (kg ha^{-1})	NDT (kg ha^{1})	MSD (kg ha^{1})
T3: Ryegrass	2,305	10.566	13,991
T5: Wheat + Ryegrass	2,159	9,646	13,117
T4: Oats + Ryegrass	2,339	9,288	12,618
T1: Oats	2,336	9,028	11,951
Q2: Wheat	1,655	5,910	8,409
Average	2,139	8,888	11,981
DE±	279	1,763	2,081

Table 5. DM yield and nutritional value of small-grain forage crops in autumn-winter crop cycle in monoculture and mixture. S.E. Zaragoza-CIRNE-INIFAP.

higher r DM yield, and higher nutritional yield per hectare. However, it is suggested to continue evaluating other cultivars and Coahuila S-92 wheat due to ant damage and its effect on yield.

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