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Productivity and nutritional quality of forage sorghum cultivars in northeastern Argentina

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ABSTRACT

The objective of the work reported in this paper was to evaluate the productivity and nutritional quality of ten sorghum cultivars in the northeastern region of Argentina, with and without the application of basic fertilizers. The types studied were the following: fodder sorghum, dual-purpose, biomass sorghum (silage sorghum), sudan grass (Sorghum × drummondii (Steud.) Millsp. & Chase) and multipurpose sorghum. A split-plot design was carried out considering these factors: cultivar, fertilization and the interaction of both. The evaluated cultivars presented differences in productivity and quality. Two dual-purpose cultivars, one silage and one multipurpose, showed the highest potential for green and dry matter accumulation. However, the last two presented a lower energy contribution, mainly due to their large proportion of acid detergent fiber (ADF). The application of basic phosphorus and nitrogen fertilizer was favorable for the development of the crop, observing differences in yield up to 5,000 kg ha^{-1} of dry matter in the means of the treatments. Among all the fodder sorghum cultivars studied, the fertilized BMR (Brown Middle Rib) 500 Peman cultivar presented the highest digestibility values, although it showed the lowest yield. Finally, it should be point out that, to select a genotype in a specific productive approach, all the productive and nutritional quality variables must be analyzed together.

Keywords: yield, digestibility, fertilization.

RESUMEN

El objetivo del presente trabajo fue evaluar la productividad y la calidad nutricional de diez cultivares de sorgo en la región nordeste argentino, con y sin aplicación de fertilización de base. Se analizaron diez cultivares de tipo forrajeros, doble propósito, sileros, sudan grass y multipropósito. Se realizó un diseño de parcelas divididas considerando los siguientes factores: cultivar, fertilización y la interacción de ambos. Los cultivares evaluados presentaron diferencias de productividad y de calidad. Dos cultivares doble propósito, uno silero y uno multipropósito mostraron el mayor potencial de acumulación de materia verde y seca. No obstante, los dos últimos presentaron un menor aporte energético debido, principalmente, a su gran proporción de FDA. La aplicación de fertilizante de base de fósforo y nitrógeno fue favorable para el desarrollo del cultivo, ya que se observaron diferencias en rendimiento de hasta 5.000 kg ha^{-1} de materia seca en las medias de los tratamientos. El cultivar BMR (Brown Middle Red) 500 Peman fertilizado presentó los mejores valores de digestibilidad, aunque mostró la cuantía más baja de rendimiento. Para seleccionar un genotipo en un planteo productivo específico todas las variables de productividad y calidad nutricional deberían ser analizadas en conjunto.

Palabras clave: *rendimiento, digestibilidad, fertilización.*

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INTRODUCTION

In the northeast of Argentina, different types of sorghums (Sorghums sp) are cultivated with various possibilities of use, allowing forage-livestock producers greater flexibility in the management of these resources (Giorda and Ortiz, 2011; Gambín *et al.*, 2012; Bolsa de cereales, 2023). The possibilities of use are the following: grain for domestic and foreign markets, sorghum for cattle feed in form of wet grain silage, whole-plant silage, for direct or deferred grazing, and ethanol production (Bolsa de Cereales, 2021; Peña *et al*., 2023).

The variability of this crop allows it to be classified in: a) grain sorghum, which has a high grain production, b) dual-purpose sorghum, a high-yield crop, both grains and stem biomass, c) silage sorghum, which has a high biomass production and good digestibility, d) Sudan grass/Sudanese sorghum, used for direct grazing or for making rolls, e) photosensitive sorghum, a plant with a strong photoperiod response, which can be late or no flowering; and finally, sweet sorghum (*Sorghum bicolor* (L.)), used for bio-ethanol production (Agro Spray, 2021).

In Argentina, the first grazing of sorghum is generally done when it reaches a production close to 2000 kg Dry Matter ha^{-1}, with a height between 60 and 70 cm, using an animal stocking rate that varies from 4 to 6 Cow Equivalent (CE) in marginal areas and from 7 to 8 EV in typical grazing areas (Gallarino, 2018).

The studies carried out by Barbera and Benítez (2016) in the south of the Corrientes province (Argentina) are consistent with these assessments in terms of dry matter production for the first grazing. On the other hand, the studies on the early grazing of sorghum by Villalba and Villalba (2023) indicate that, when looking for higher energy and protein contents, which is considered a key characteristic for productivity, the first grazing should be done at 30 cm of height with a content of 24% of Crude Protein (CP). On the contrary, if it is done at 60 cm, there is an increase in Dry Matter (DM), but a 12% decrease in the amount of CP.

Tranier Pérez and Mayo (2017) indicate that Sudan grass sorghums are the most used for direct grazing because they are considered more adapted to this type of use, with a high volume of forage per hectare and great re-growth capacity. Secondly comes photosensitive sorghums, because they are good for direct grazing and are the ones that generate the largest volume of forage. Nonetheless, studies conducted by Montossi *et al*. (2020) conclude that hybrid sorghum (HS) with the BMR gene (Brown Middle Rib) presents greater advantages in terms of production and nutritional value compared to Sudan grass sorghums (S). This indicates that HS presented a higher production (69 vs 21%), a higher CP level (9.9 vs 8.9%), and higher digestibility (64.7 vs 59.7%).

Among the forage sorghums, silage or Sudan grass type, the presence of the BMR cultivars or brown mid-rib sorghums stands out, since they are characterized by having a lower lignin content in all their tissues. This quality translates into a material that can be used more efficiently by cattle, since lignin is a recalcitrant component, that is, it is difficult to degrade (Alessandri, 2012; Diaz, 2020).

Regarding fertilization in sorghum, in studies carried out by Fariza *et al*. (2017), fractional fertilization with nitrogen and phosphorus in silage cultivars determined 16,144.6 kg ha^{-1}; therefore, it is considered a recommended technique, especially in soils with little organic matter. Studies by Damanet Filippi and Canales Cartes (2020) indicate that nitrogen fertilization conducted in three stages (pre-sowing, sowing and plants with 4-6 expanded leaves) increases yields in impoverished soils.

The different types of sorghum will present a notable variation in their quality, so it is important to take this into account when choosing the material to be used. The quality also varies with the distribution of the total dry weight of the plant among the different fractions. Carrasco *et al*. (2011) point out that the differences in the morphological composition and in the proportion of stems, leaves and panicles that the different types have could generate disparities in the chemical composition and, consequently, in the nutritional value of the forage resource.

The objectives of this work were to evaluate the productivity and nutritional quality of ten sorghum cultivars (forage, dual-purpose, silage, sudan grass and multipurpose) by contrasting their development with and without the application of base fertilization.

METHODS AND MATERIALS

Location of the study. Edaphic and climatic characteristics

The experiment was conducted in Las Breñas, an experimental agricultural station of the National Agricultural Technology Institute (27°04'26.5"S and 61°03'56.5"W) in 2020 and 2021. The soil is classified as OxicHaplustol (Soil Survey Staff, 2014). It is moderately deep, and the main problems are moderate water erosion, imperfect drainage, moderate sodium and low organic matter content. Despite these constraints, it is an important agricultural soil. Use Classes II, III and IV. Tizón soil series. (LEDESMA 2003). Figure 1 shows the typical soil profile.

The climatic conditions of the two years of research are detailed in table 1.

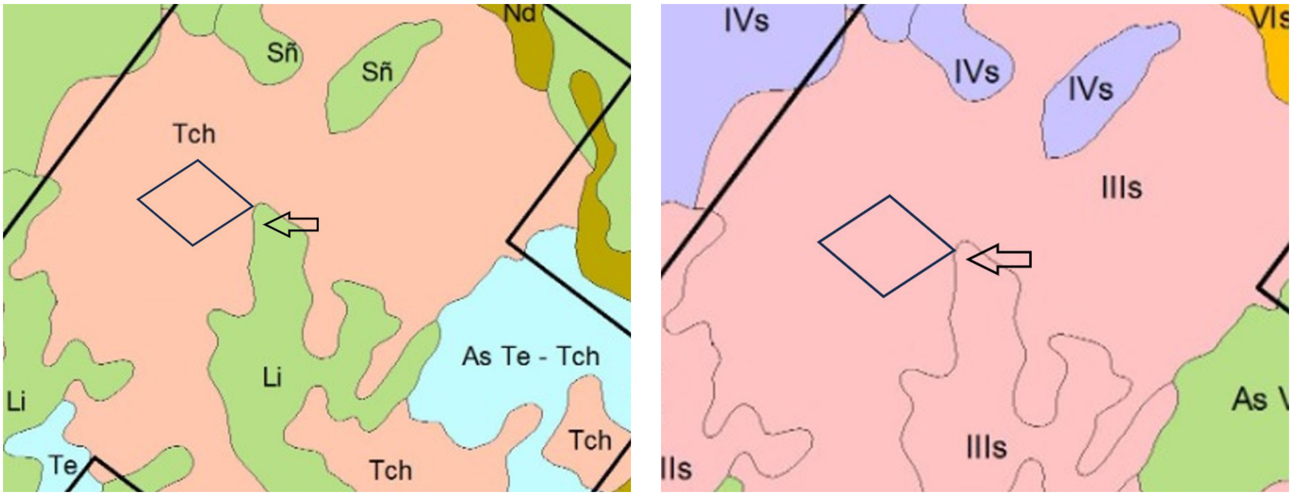
Experimental material

The ten sorghum cultivars used in this trial are: Takuri Peman (Dual-Purpose: DP), VT Seed 1616 (DP), 417 Genesis (DP), BMR 500 Peman (Forage: F), Silage INTA Peman (Silage: S), AR-SE 35 Kioto 1 (Multipurpose: MP), Pegual Genesis (Sudan grass: SG), AR-SE 23 Kioto 2 (MP), CH 744 Chromatin (S) and CH 546 Chromatin (F).

The evaluated cultivars have different maturation cycles, that is, from sowing to harvest (from milky to pasty grain stage). Some have a short cycle (approximately 70-75 days), others have an intermediate cycle (80-85 days), and the rest have a long cycle (up to 97 days). Considering these characteristics, the harvest dates were different. The sowing in 2020 was carried out on March 6, and the harvest of the short cycle cultivars was conducted on May 22; for those of the intermediate cycle, on May 29 and for those of the long cycle, on June 8. In 2021, the sorghums were planted on March 3, the short-cycle sorghums were harvested on May 15, the intermediate-cycle sorghums on May 27, and the long-cycle sorghums were harvested on June 10.

Experimental design

The experimental design was a split-plot design where the main plots were the cultivars (ten levels) and the subplots were the fertilized plots (two levels: with and without), which resulted in 20 treatment combinations with three repetitions (see table 2).



Place off rehearsal

Figure 1. Location and soil series of the test lot.

	Jan	Feb	Mar	Apr	May	June
Min. T year 2020	20.5	20.1	18.6	15.4	12.3	9.7
Min. T year 2021	22.0	20.0	19.2	15.7	13.0	10.4
Max T. year 2020	34.0	32.6	30.6	27.0	24.3	21.4
Max. T year 2021	33.6	33.0	29.8	28	24.0	22.4
PP year 2020	139.0	128.2	124.4	101.8	39.7	22.4
PP year 2021	125.0	130.0	110.6	98.3	28.6	24.2

References: Min. T= minimum temperature. Max. T= maximum temperature. PP = Precipitation.

Table 1. Average data of minimum temperatures, maximum temperatures expressed in degrees Celsius and precipitation expressed in millimeters.

Sixteen 90-meter-long rows of each cultivar were planted at a distance of 0.52 meters between rows. Therefore, each plot was 702 m^2 (figure 2). Eight rows were fertilized with 80 liters of UAN (urea-ammonium nitrate) and 20 liters of phosphate (P2O5) from the BlackSoil company (https://blacksoilglobal.com/) (accessed on 28 November 2022) on the same planting line, and the other eight rows had no fertilizer applied.

Measured Response Variables

The analyzed and measured response variables in this essay can be divided into two categories: 1) productivity and 2) nutritional quality.

The productivity variables were measured in the phenological state of the milky-pasty grain, corresponding to the moment of chopping the sorghum for its conservation using the silage method. The samples were collected using the destructive sampling method, which is based on the cutting and weighing of the samples. To do this, pruning shears were used, making the cut at a height of 15 centimeters with respect to the ground, in the plants included in the 2 linear meters along the furrow, which constitutes the sampling unit.

The distribution of the sampling units was randomly conducted within each subplot, carrying out the three repetitions of each treatment in different furrows. Subsequently, the samples obtained were weighed, dried and sent to the Agricultural Chemistry laboratory of the Faculty of Agricultural Sciences of the National University of the North-East (UNNE), where the digestibility analyses were carried out.

Productivity parameters

The yields expressed in green or fresh matter and dry matter were used as productivity indicator variables. Both determinations were made for the different fractions of the plants, thus obtaining data on: a) Leaf wet weight (LWW), b) Panicle wet weight (PWW), Stem wet weight (SWW). Subsequently, the samples were dried in an oven and the following vari-

Treatments	Cultivars	Fertilization
1	Takuri Peman	With
2	Takuri Peman	Without
3	VT Seed 1616	With
4	VT Seed 1616	Without
5	417 Genesis	With
6	417 Genesis	Without
7	BMR 500 Peman	With
8	BMR 500 Peman	Without
9	Silage INTA Peman	With
10	Silage INTA Peman	Without
11	AR -SE 35 Kioto 1	With
12	AR -SE 35 Kioto 1	Without
13	Pegual Genesis	With
14	Pegual Genesis	Without
15	AR - SE 23 Kioto 2	With
16	AR - SE 23 Kioto 2	Without
17	CH 744 Chromatin	With
18	CH 744 Chromatin	Without
19	CH 546 Chromatin	With
20	CH 546 Chromatin	Without

References: With = with fertilization. Without = without fertilization.

Table 2. Identification of treatment combinations.

ables were obtained: a) Dry weight of the leaves (DWL), b) Dry weight of the panicles (DWP) and c) Dry weight of the stems (DWS). From the sum of these last three variables, which were expressed in kg per 2 linear meters of furrow, the total dry weight of the samples (TDW) was obtained. The TDW was expressed in kg ha^{-1} and was used to estimate the yield that the cultivars would have when chopped for silage. The calculation of TDW= ((DWL+PWP+DWS)*19230.77)/2, where the constant 19230.77 is the number of linear meters per ha, with a distance between rows of 0.52 meters and the value 2 is considered since the samples were collected from 2 linear meters of furrow.

Nutritional quality parameters

Crude Protein (CP): Theoretical value assigned to the protein content of a food; its determination is inferred from the total nitrogen content of the sample. Nitrogen is determined using the Kjeldahl method multiplied by a correction factor (6.25) or dividing by 0.16 (Ferret, 2003). The Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) correspond to the Van Soest method and are based on the use of detergents to separate two nutritional fractions of the forage, which correspond to the cell content and the cell wall, which is composed of cellulose, lignin and hemicellulose mainly (Caravaca Rodríguez *et al*., 2005). During the ADF determination, the lignin and cellulose are separated from the hemicellulose, since they are indigestible in the acid detergent. This method allows to have an approximation of the degree of digestibility of the fibers in the food because they are not directly correlated.

The NDF is a useful measure of the factors that determine the consumption of dry matter and vegetable fibers in food. It has the ability to separate soluble nutritional components from

Figure 2. The constitution of the plot at the time of sowing.

those that are not fully usable or that depend on biological fermentation for their use. This measurement (NDF) presents certain limitations in its precision when the protein values are very high and the fiber values are low (Hidalgo *et al*., 2013).

Total Digestible Nutrients (TDN): this measurement indicates the relative energy value of the feed for the animal expressed in %, and it is determined by adding the values of digestible crude protein, digestible crude fiber, digestible ethereal extract and digestible fat 2.25 times, since it is considered that fats release 2.25 times more energy than proteins and carbohydrates (Gaggioti *et al*., 2001).

Digestible Energy (DE): it is the part of the food energy consumed that does not appear in the animal's feces. It is measured as the difference between the content of gross energy and of the energy lost in the animal's feces. It is considered a good indicator of the energy available to the animal (Aponte, 2010).

Fert.	Cultivar (*)	LDW (Kg)
With	AR - SE 23 Kioto 2 (MP)	0.411 a
With	AR -SE 35 Kioto 1 (MP)	0.333 b
With	Takuri Peman (DP)	0.310 bc
With	Silage INTA Peman (S)	0.289 bcd
With	Pegual Genesis (SG)	0.289 bcd
Without	417 Genesis (DP)	0.267 cde
Without	AR -SE 35 Kioto 1 (MP)	0.254 cdef
With	VT Seed 1616 (DP)	0.248 def
Without	AR - SE 23 Kioto 2 (MP)	0.244 def
With	CH 744 Chromatin (S)	0.243 def
Without	Takuri Peman (DP)	0,242 def
With	417 Genesis (DP)	0.240 def
Without	Silage INTA Peman (S)	0.235 def
Without	Pegual Genesis (SG)	0.208 ef
Without	CH 744 Chromatin (S)	0.206 f
With	BMR 500 Peman (F)	0.205 f
Without	VT Seed 1616 (DP)	0.204 f
With	CH 546 Chromatin (F)	0.196 f
Without	BMR 500 Peman (F)	0.193 f
Without	CH 546 Chromatin (F)	0.128 g
C.V.		**18.11**

Averages with a common letter are not significantly different (p > 0.05)

References: (*) MP = multipurpose. DP = dual-purpose. S = silage. SG = sudan grass. F = forage. (Kg) = Kilograms. C.V. Coefficient of variation. With = with fertilization. Without = without fertilization.

Table 3. Results of Duncan's test of the means by cultivar of leaf dry weight (LDW) in kilograms (kg), average of the two years. Coefficient of variation (CV).

Statistic analysis

It is important to highlight that, with the exception of the DWL variable, the other measured variables did not present a normal distribution. Therefore, in order to carry out the analysis of variance of the split-plot design, transformations had to be performed on them.

The DWP variable was transformed by applying a logarithm in base ten, and the dry weight of the stem was modified by applying the transformation of Box and Cox, λ=0.25 (Peña Sánchez, 1986). To describe the joint behavior of the production and quality variables, a Principal Component Analysis (PCA) was carried out and later a biplot graph.

The statistical analyzes were carried out with the InfoStat program, 2019 version (Di Renzo *et al*., 2019).

RESULTS

Yields parameters

Leaf Dry Weight (LDW): The analysis of variance indicated a significant interaction (p value = 0.0003) between the factors Cultivar and Fertilization. Due to this, we proceeded to perform the analysis of interactions (table 3).

The fertilized multipurpose cultivar AR - SE 23 Kioto 2 showed significant differences with the rest. Furthermore, the fertilized multipurpose cultivar AR -SE 35 Kioto 1 showed high values of leaf dry weight without significant differences with fertilized dual-purpose Takuri Peman, Silage INTA Peman and Pegual Genesis (SG).

The lowest value was observed in the forage cultivar CH 546 Chromatin, which was significantly different from the rest of the cultivars. It was observed that there was no significant interaction with the Year Factor.

Panicle Dry Weight (PDW): The interaction between years and the factors Cultivar and Fertilization was not remarkable (p-value=0.1325). Therefore, it was decided to analyze the factors separately. Significant differences were observed between cultivars. It can be seen in table 4 that the dual-purpose cultivars differed significantly from the forage cultivars, Sudan Grass and multipurpose cultivars. The cultivar Silage INTA Peman (S) does not differ from the dual-purpose cultivars. The lowest value of PDW corresponded to the multipurpose cultivar AR -SE 35 Kioto 1.

It is important to note that a significant difference was observed in panicle production when fertilizer was added at sowing time (table 5).

Stem Dry Weight (SDW): The interaction between years was not significant. However, the interaction between the factors Cultivar and Fertilization was noteworthy (p-value<0.0001). Therefore, it was decided to analyze the interactions. The cultivars CH 744 Chromatin, AR - SE 23 Kioto 2, 417 Genesis, VT Seed 1616 and Pegual Genesis, two of which were dual-purpose, are the ones that presented the highest stem dry weight, differing significantly from the rest. BMR 500 Peman (F), Takuri Peman (DP) and Silage INTA Peman were the cultivars with the lowest values (table 6).

Total Dry Weight (TDW): The interaction between years was not significant, while that of the factors Cultivar and Fertilization was remarkable with a pv (<0.0001). Therefore, it was decided to analyze the interactions. Similarly to the variables ana-

Cultivar (*)	DWP (kg)
VT Seed 1616 (DP)	0.461 a
Takuri Peman (DP)	0.416 ab
417 Genesis (DP)	0.389 abc
Silage INTA Peman (S)	0.369 bc
CH 744 Chromatin (S)	0.321 cd
AR - SE 23 Kioto 2 (MP)	0.315 cde
BMR 500 Peman (F)	0.266 def
Pegual Genesis (SG)	0.236 ef
CH 546 Chromatin (F)	0.213 f
AR - SE 35 Kioto 1 (MP)	0.192 f
C.V.	**29.93**

Averages with a common letter are not significantly different (p > 0.05)

References: (*) MP = multipurpose. DP = dual-purpose. S = silage. SG = sudan grass. F = forage. (Kg) = kilograms. C.V. Coefficient of variation.

Table 4. Duncan's panicle dry weight (DWP) means test results. Average two years.

Fertilization	DWP (kg)
With	0.38 a
Without	0.25 b

Averages with a common letter are not significantly different (p>0.05)

References: (Kg) = Kilograms

Table 5. Duncan's panicle dry weight (DWP) means results, fertilization and non-fertilization treatments.

Fert.	Cultivar (*)	SDW (Kg)
With	AR - SE 23 Kioto 2 (MP)	2.28 a
With	CH 744 Chromatin (S)	2.21 a
With	VT Seed 1616 (DP)	2.07 ab
With	417 Genesis (DP)	1.98 b
With	Pegual Genesis (SG)	1.60 c
Without	417 Genesis (DP)	1.54 cd
With	CH 546 Chromatin (F)	1.53 cd
With	AR -SE 35 Kioto 1 (MP)	1.48 cd
With	Takuri Peman (DP)	1.46 cde
Without	AR - SE 23 Kioto 2 (MP)	1.44 cde
Without	VT Seed 1616 (DP)	1.43 cde
With	Silero INTA Peman (S)	1.33 def
With	BMR 500 Peman (F)	1.30 def
Without	Pegual Genesis (SG)	1.29 def
Without	CH 744 Chromatin (S)	1.23 efg
Without	Takuri Peman (DP)	1.17 fg
Without	Silero INTA Peman (S)	1.06 g
Without	CH 546 Chromatin (F)	1.05 g
Without	BMR 500 Peman (F)	1.04 g
Without	AR -SE 35 Kioto 1 (MP)	1.01 g
C.V.		**12.55**

Averages with a common letter are not significantly different (p > 0.05).

References: (*) MP = multipurpose. DP = dual purpose. S = silero. SG = sudan grass. F = forage. (Kg) = Kilograms. C.V. Coefficient of variation. With = with fertilization. Without = without fertilization.

Table 6. Duncan's stem dry weight (SDW) Mean test results.

lyzed above, it was observed in table 7 that the cultivars AR - SE 23 Kioto 2 (MP), CH 744 Chromatin (DP), 417 Genesis (DP) and VT Seed 1616 (DP) were the ones with the highest TDW values, differing significantly from the cultivars Takuri Peman (SG), CH 546 Chromatin (F), AR - SE 35 Kioto 1 (MP), Silage INTA Peman (S) and BMR 500 Peman (F).

Nutritional quality parameters

In all the quality variables, the interactions with the Year Factor were not significant. Nevertheless, the interaction of cultivar and fertilization was significant for the variables CP, ADF, NDF and TDN with a p-value <0.0001 and not significant in DE with p-value=0.2059. Tables 8 and 9 show the results of each of the nutritional quality variables of the different cultivars with and without fertilization.

The BMR 500 Peman cultivar, with and without the addition of fertilizer, presents the highest values of Crude Protein (CP), Total Digestible Nutrients (TDN) and the lowest values of Acid Detergent Fiber (ADF). Within the multipurpose materials, the cultivar AR - SE 35 Kioto 1 presented high values of Total Digestible Nutrients (TDN) and Digestible Energy (DE), but with a lower protein intake, possibly due to less panicle development. Analyzing the DE, the cultivars with the lowest values were CH546 Chromatin, CH744 Chromatin, Pegual Genesis and AR - SE 23 Kioto 2, presenting a higher proportion of stem close to 70% (see table 6). These materials also registered high ADF values.

Analysis of the main parameters of cultivars with and without fertilization

The biplot graphics (3 and 4) provide a quick understanding and description of the variability in the parameters of productivity and nutritional quality of the different cultivars studied. In general, a different response to the addition or no addition of fertilizer was found.

Without fertilization (figure 3), the cultivar BMR 500 Peman (F) presented adequate contents of Crude Protein (CP), To-

Fert.	Cultivar (*)	TDW (Kg DM/ha)
With	AR - SE 23 Kioto 2 (MP)	21887.82 a
With	CH 744 Chromatin (S)	21269.23 a
With	VT Seed 1616 (DP)	19927.89 ab
With	417 Genesis (DP)	19027.24 b
With	Pegual Genesis (SG)	15427.89 c
Without	417 Genesis (DP)	14762.82 cd
With	CH 546 Chromatin (F)	14674.68 cd
With	AR -SE 35 Kioto 1 (MP)	14251.61 cd
With	Takuri Peman (DP)	14006.41 cde
Without	AR - SE 23 Kioto 2 (MP)	13810.90 cde
Without	VT Seed 1616 (DP)	13761.22 cde
With	Silero INTA Peman (S)	12788.46 def
With	BMR 500 Peman (F)	12453.53 def
Without	Pegual Genesis (SG)	12397.44 def
Without	CH 744 Chromatin (S)	11850.96 efg
Without	Takuri Peman (DP)	11285.26 fg
Without	Silero INTA Peman (S)	10155.45 g
Without	CH 546 Chromatin (F)	10068.91 g
Without	BMR 500 Peman (F)	9975.96 g
Without	AR -SE 35 Kioto 1 (MP)	9717.95 g
C.V.		**12.55**

Averages with a common letter are not significantly different (p>0.05).

References: (*) MP = multipurpose. DP = dual purpose. S = silero. SG = sudan grass. F = forage. (Kg) = Kilograms. C.V. = Coefficient of variation. With = with fertilization. Without = without fertilization.

Table 7. Duncan's test results for total dry weight of sample (TDW) equivalent to average yield per cultivar. Average two years.

tal Digestible Nitrogen (TDN) and Digestible Energy (DE), low amounts of Neutral Detergent (NDF) and ADF. In contrast, the Total Dry Weight (TDW) is observed as an indicative factor of productivity. The arrangement of these parameters in the graph shows that this cultivar presented a good nutritional quality but a low yield in kilograms of dry matter per hectare.

The cultivars AR - SE 35 Kioto 1 and CH 546 Chromatin presented good DE and TDN contents, but lower protein intakes (CP) and low productivity (TDW).

Silage INTA Peman (S) and Pegual Genesis (SG) presented higher amounts of NDF and ADF, a high content of CP and TDW, low proportions of DE and TDN, factors indicative, at least for this study, that both types of sorghum had a low performance, both in terms of productivity and nutritional quality.

The cultivars 417 Genesis, AR-SE 23 Kioto 2, Takuri Peman, CH 744 were characterized by low TDN and DE contents but good yield performance (TDWS).

With the addition of fertilizers (figure 4), a similar behavior was observed in BMR 500 Peman (F), registering adequate proportions of CP, TND and DE and low amounts of TDW. These parameters indicate that fertilization did not change the performance of this cultivar, it only contributed to a greater increase in these variables. Similar conditions were observed in 417 Genesis (DP). The nutritional quality of the AR - SE 35 Kioto 1 cultivar is also noteworthy, with satisfactory proportions of the indicative variables (CP, TND and DE) increased with fertilization. These two cultivars differed from the rest, registering a better nutritional quality, but to the detriment of yield (lower TDW content).

Regarding the effect of fertilization on the increase in the nutritional quality of the Takuri Peman cultivar, a significant increase was found, but in productivity, no major changes were observed. VT Seed 1616 presented an increase in nutritional quality and a positive effect on productivity, observing adequate proportions of CP, TND, DE and TDW. The cultivars that presented high NDF and ADF contents and low CP, TND and DE contents were CH 744 Chromatin and CH 546 Chromatin.

These variables are indicative of low nutritional quality due to the presence of a large proportion of indigestible cell wall. Regarding productivity, the Biplot graph indicates the effect of the addition of fertilizer on the increase in yield in the cultivars AR – SE 23 Kioto 2 and CH 744 Chromatin.

DISCUSSION

Yields parameters

Leaf Dry Weight (LDW): Fertilization increased the LDW values in the two multipurpose cultivars (AR – SE 23 Kioto 2 and AR -SE 35 Kioto 1), while lower amounts were recorded for the forage sorghums. It is expected that these MP-type cultivars stand out in respect to this yield variable and respond to fertilization because they combine good tiller size and density with high leaf production.

It is important to highlight the effect of fertilization on Pegual Genesis, which had an increase of 47.4% (0.28 kg vs 0.19 kg). This cultivar is characterized by having a long, thin and sweet cane with good leaf content and an average height of 2.8 m. In the CH 546 Chromatin cultivar, a null response to fertilization was observed, perhaps because it is a conventional forage cultivar with high forage production, with an adequate stem-leaf ratio and a high regrowth speed. Possibly adverse weather conditions at the end of the cycle, which delayed the harvest, produced an increase in senescence and leaf drop.

Panicle Dry Weight (PDW): The dual-purpose cultivars exhibited higher grain production compared to the others, followed by silage sorghums, which showed similar panicle production values. The cultivar with the highest production value was VT Seed 1616. On the contrary, the multipurpose cultivars AR - SE 35 Kioto 1 and AR - SE 23 Kioto 2, together with CH 546 Chromatin (F) and Pegual Genesis, were the ones with the lowest production value and panicle production. The first two are sugary sorghums, and, together with Sudan Grass (SD), they are of late cycle. According to Coria (2010), there is a positive correlation between late maturation and high yield; however, this does not occur when conditions are not favorable (excess rain or drought). During the entire

Cultivar (*)	CP (%)	ADF (%)	NDF (%)	TDN (%)	DE (Mcal/kg))
Pegual Genesis (SG)	6.17 a	36.79 a	59.97 b	63.60 de	2.80 bc
BMR 500 Peman (F)	5.82 b	24.68 e	53.62 de	72.36 a	3.17 a
Silage INTA Peman (S)	5.12 c	32.55 bc	66.50 a	65.73 cd	2,90 abc
417 Genesis	4.73 d	32.34 c	58.42 bc	67.72 bc	2.67 c
CH 546 Chromatin	4.63 d	35.47 a	57.71 bc	57.13 e	2.64 c
VT Seed 1616 (DP)	4.50 de	29.53 d	56.47 c	68.42 b	3.02 ab
AR –SE 35 Kioto 1 (MP)	4.43 def	26,09 e	52.35 e	69.63 b	3.08 ab
Takuri Peman	4.40 def	32.76 bc	55.86 cd	62.05 ef	2.82 ab
AR - SE 23 Kioto 2 (MP)	4.25 ef	33.96 b	56.21 cd	64.88 d	2.86 abc
CH 744 Chromatin (DP)	4.11 f	31,57 c	57.11 c	60.09 de	2.81 bc
C.V.	**4.96**	**3.98**	**3.76**	**2.87**	**8.34**

Means with a common letter are not significantly different (p > 0.05). Analysis by column.

References: (*) MP = multipurpose. DP = dual-purpose, S = silage, SG = Sudan Grass, F = forage. C.V. = Coefficient of variation.

Table 8. Results of the Duncan's test for nutritional quality without fertilization for the means of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), digestible energy (DE), average of the two years.

Cultivar (*)	CP (%)	ADF (%)	NDF (%)	TDN (%)	DE (Mcla/kg)
BMR 500 Peman (F)	7.55 a	24.13 e	50.61 h	72.58 a	3.21 a
AR –SE 35 Kioto 1 (MP)	6.16 b	25.54 e	61.67 b	68.94 b	3.06 ab
Pegual Génesis (SG)	5.91 bc	34.65 c	59.34 d	66.43 de	2.89 ab
Takuri Peman	5.81 cd	33.84 c	54.73 f	66.99 cd	3.14 a
AR - SE 23 Kioto 2 (MP)	5.70 cd	34.23 c	53.26 g	65.35 e	2.91 ab
417 Genesis	5.65 cd	31.88 d	57.22 e	67.77 bcd	3.00 ab
VT Seed 1616 (DP)	5.60 d	30.91 d	55.06 f	68.16 bc	3.00 ab
Silage INTA Peman (S)	5.06 e	33.42 c	67.19 a	66.20 de	2.90 ab
CH 546 Chromatin	4.58 f	37.08 b	61.06 bc	58.84 g	2.45 c
CH 744 Chromatin (DP)	4.41 f	38.51 a	59.89 cd	61.90 f	2.78 b
C.V	**4.06**	**3.47**	**1.78**	**1.92**	**8.80**

Means with a common letter are not significantly different (p > 0.05),

References: (*) MP = multipurpose. DP = dual-purpose, S = silage, SG = Sudan Grass, F = forage. C.V. = Coefficient of variation.

Table 9. Results of the Duncan's test for nutritional quality with fertilization for the means of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), digestible energy (DE), average of the two years.

growth period, the hybrids with early or intermediate maturation showed a better performance. Miñón *et al*. (2009) indicated that forage cultivars have a low proportion of grain, less than 10% of the whole plant. These statements explain, to some extent, the behavior of these types of sorghums.

Stem Dry Weight (SDW): Contrasting values were observed in the two silage cultivars (S), 1.22 and 0.56 kg for CH 744 Chromatin and Silage INTA Peman, respectively. This difference was expected considering the characteristics of these two types of sorghum. The first is a sweet-type silage material, with high dry matter production and stability, with an average height of 3 m, while the second is a conventional forage sorghum, with high forage production and a high stem-leaf ratio, but susceptible to adverse climatic conditions that affect its development and, therefore, the production of dry matter. This indicates that the TDW demonstrates a differential response to fertilization.

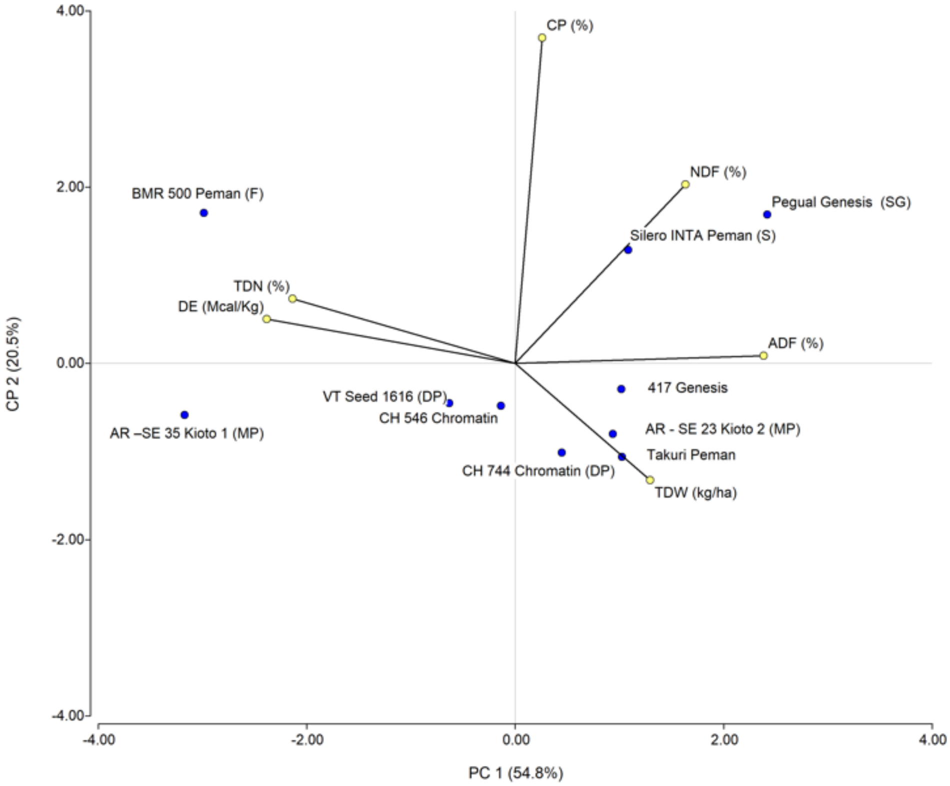


Figure 3. Biplot graph of unfertilized cultivars and quality variables: crude protein (CP), digestible energy (DE), total digestible nitrogen (TDN), acid detergent fiber (ADF), neutral detergent fiber (NDF) and productivity: total sample dry weight (TDW) without fertilization.

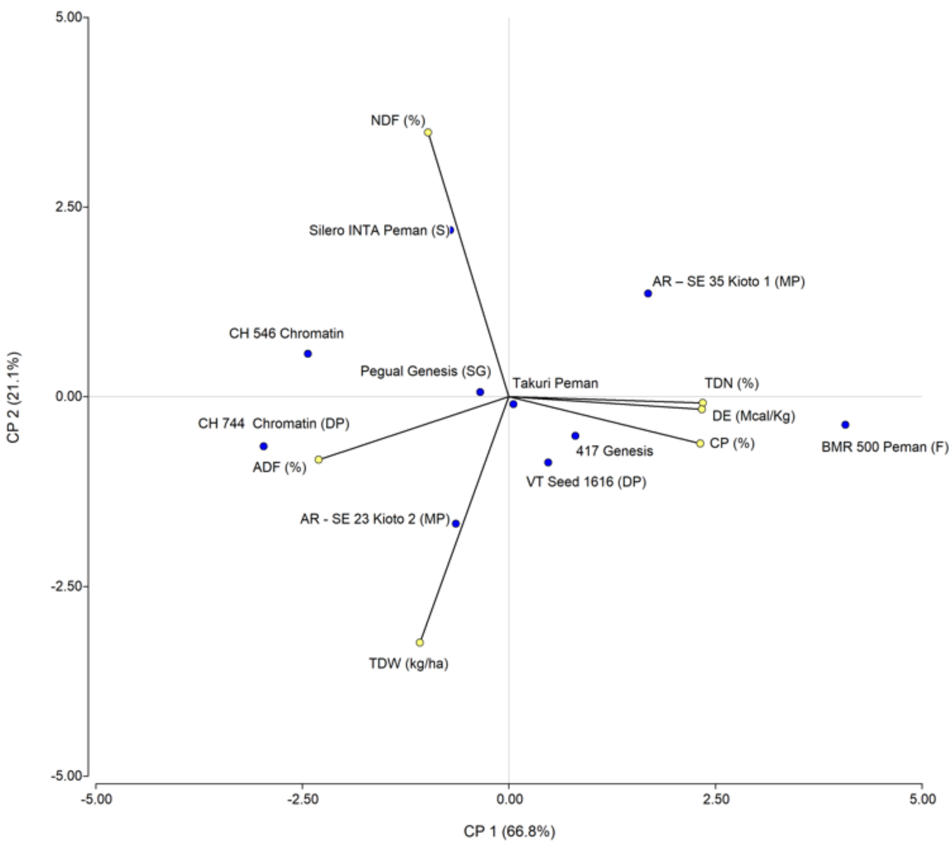


Figure 4. Biplot graph of the cultivars with fertilization. Quality values: Crude protein (CP) Digestible energy (DE), Total digestible nitrogen (TDN), Acid detergent fiber (ADF), Neutral detergent fiber (NDF) and productivity: Total dry weight of sample (TDW).

The Silage INTA Peman and Takuri Peman cultivars had lower values compared to the other cultivars studied. Comparing with the study carried out by Loizaga (2017), it can be seen that the former had a lower stem development in the present study 0.56 kg against 0.626 kg, for the latter, the values were 0.64 kg higher than the previous ones (0.516 kg from the previous study). The Silage INTA Peman cultivar is probably more susceptible than the rest to the adverse climatic conditions mentioned above.

Total Dry Weight (TDW): The yield data obtained in this study on the Takuri Peman, Pegual Genesis, VT Seed 1616 and Silage INTA Peman cultivars were all higher than those obtained in a previous trial carried out by Loizaga (2017). Regarding the cultivar Silage INTA Peman, the yield obtained was lower than that described in the trial carried out by Fariza *et al*. (2017).

The TDW values, in all cultivars, were much higher than those obtained by Gallarino (2018), who points out that the first sorghum grazing is generally done when it reaches a production close to 2,000 kg DM/ha in similar altitude conditions (60-70 cm), using average loads that vary from 4 to 6 Cow Equivalent (CE) in marginal areas and from 7 to 8 EV in typical grazing areas. Similar results were described by Barbera and Benítez (2016) for the south of the Corrientes province.

Fertilization produced a 38% increase in the average yield. A trend of lower dry matter production was observed for the brown mid-rib sorghum BMR 500 Peman (F), obtaining an average of 10,865.39 kg DM ha^{-1}, values that coincide with those determined in the studies carried out by Oliver *et al*. (2005).

It is known that the particular characteristics of the genes that brown mid-rib sorghums possess also affect plant height and, therefore, yield. These particularities are the possible causes of the lower biomass values (Lus, 2020). In addition, a greater partition of photoassimilates was observed towards the stems and panicles, and less towards the leaves, obtaining values of 61.45% in stems, 21.705% in panicles and 17.34% in leaves.

Nutritional quality parameters

The BMR 500 Peman cultivar with brown veins, with and without fertilization, presented the lowest ADF values. The recorded values were 24.56% without fertilization and 25.28% with fertilization, both lower than those recorded by Romero *et al*. (2002) and Corral-Luna *et al*. (2011). This variable determines what fraction of the cell wall corresponds to indigestible lignin and cellulose. Consequently, these characteristics explain why this material obtained the highest TDN and DE values.

Considering the aforementioned and that this material with fertilization showed the highest value of Crude Protein (CP), it can be said that it is the one with the best nutritional quality.

Regarding the results of (CP), for this fertilized cultivar, the average value was 7.41%, similar to that obtained by Romero *et al*. (2002) and higher than those obtained by Corral-Luna *et al*. (2011). It should be noted that the data obtained for the same cultivar without fertilization (5.84%) were lower than those determined by both researchers. Possibly, a lower rainfall record affected this result.

The dual-purpose cultivars presented intermediate to low CP values, with CH 744 Chromatin being the one with the lowest values both with and without fertilization. The preceding descriptions justify this behavior.

With respect to the multipurpose materials, the AR - SE 35 Kioto 1 cultivar presented adequate values of Total Digestible Nutrients (TDN) and Digestible Energy (DE) but higher amounts of ADF, which caused lower protein intake added to a lower panicle development.

Analyzing this last variable (DE), the cultivars with the lowest values were CH 744 Chromatin, Pegual Genesis and AR - SE 23 Kioto 2, presenting higher data for ADF, which explains the low DE and a higher proportion of stems than leaves, possibly due to an increase in lignification and leaf drop due to senescence produced by a delay in the cutting time due to adverse weather conditions.

CONCLUSIONS

1. The fertilized BMR 500 Peman sorghum variety presented lower ADF contents than normal sorghum cultivars, achieving the best values in terms of digestibility. However, this line showed the lowest yield value.

2. The application of starter fertilizer based on phosphorus and nitrogen is very favorable for the crop development, since an average yield difference of almost 5,000 kg/ha of dry matter was found for the treatments with and without fertilization, although it is necessary to carry out a cost/benefit analysis.

3. The joint analysis of the quality and productivity variables allows the selection of a genotype for a specific productive approach.

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