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A comparison of the dry matter yield and nutritional value of different corn hybrids for silage production

[*Comparação do rendimento de matéria seca e do valor nutricional de diferentes híbridos de milho para produção de silagem*]

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ABSTRACT

The aim of this study was to evaluate the forage yield and nutritional value of eight corn hybrids for silage production: P3565 PWU (Pioneer®), CERES 310, CERES 312, CERES 405, CERES 412 (Nova Ceres Sementes®), 2A521 PW, 2B533 PW and FS620 PWU (Forseed®), with 4 repetitions each. The plants were harvested at the dough grain phenological stage (R4). Hybrid CERES 312 showed higher dry biomass production, however, with no significant difference from CERES 310 (30,919 and 27,662kg ha^{-1}, respectively), and higher grain yield (14,365 kg ha^{-1}). The participation of stem and leaves of hybrid CERES 405 was higher than the other hybrids (22.3% and 20.2%). Hybrid CERES 405 presented higher CP content (8.38%) however, it did not differ from CERES 310, CERES 312 and 2B533 PW. The 2B533 PW hybrid had lower LDA content (2.94%). Hybrids P3565 PWU and 2B533 PWU presented higher values of NEl (1.511 and 1.499 Mcal kg DM^{-1}, respectively) and the hybrid CERES 312 presented lower value (1.412 Mcal kg DM^{-1}). Differences in the participation of plant components were inconsistent on the nutrients obtained, proving that structural and nutritional evaluations of corn hybrids should be complementary.

Keywords: bromatology, digestibility, productivity, preserved feed, silage

RESUMO

O objetivo deste estudo foi avaliar a produção e o valor nutritivo da forragem de oito híbridos de milho para silagem: P3565 PWU (Pioneer®), CERES 310, CERES 312, CERES 405, CERES 412 (Nova Ceres Sementes®), 2A521 PW, 2B533 PW e FS620 PWU (Forseed®), com quatro repetições cada. As plantas foram colhidas em estádio fenológico de grão farináceo (R4). O híbrido CERES 312 apresentou maior produção de fitomassa seca, sem diferir estatisticamente do CERES 310 (30.919 e 27.662kg ha^{-1}, respectivamente), e também maior produção de grãos (14.365 kg ha^{-1}). A participação de colmo e folhas do híbrido CERES 405 foi superior aos demais híbridos (22,3% e 20,2%). O híbrido CERES 405 apresentou maior teor de PB (8,38%), sem diferir dos híbridos CERES 310, CERES 312 e 2B533 PW. O híbrido 2B533 PW apresentou menor teor de LDA (2,94%). Os híbridos P3565 PWU e 2B533 PWU apresentaram maiores valores de NEl (1,511 e 1,499 Mcal kg de MS^{-1}, respectivamente), e o híbrido CERES 312 apresentou menor valor (1,412 Mcal kg de MS^{-1}). As diferenças nas participações estruturais da planta foram inconsistentes aos nutrientes obtidos, o que prova que as avaliações estruturais e nutricionais de híbridos de milho devem ser feitas de forma complementar.

Palavras-chave: bromatologia, digestibilidade, produtividade, alimentos conservados, ensilagem

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INTRODUCTION

Forages preserved as silage appear as one of the most used and timely sources in the diet for cattle on feedlot (Wilkinson and Rinne, 2017), in which corn (*Zea mays*, L.) is the main crop used for silage production in Brazil due to its satisfactory adaptation to a large part of the national territory and for high dry biomass yield per area and high energy content (Silva *et al*., 2018).

The choice of hybrid has a direct influence on the quality of the resulting silage (Moraes *et al*., 2013), as each hybrid has a different agronomic and nutritional behavior (Silva *et al.*, 2018). For Moraes *et al.* (2013), silage quality is related to structural composition of the corn plant and the number of grains present in the material to be ensiled. A study on the productive performance of corn hybrids carried out by Klein *et al.* (2018) showed that greater participation of stem in the plant is related to a lower percentage of ear, grains and other structural components. Opsi *et al.* (2013) showed an increase in the contribution of grains as the plant matures, as well as a reduction in the content of fiber carbohydrates during this process.

Characterization of corn hybrids with potential for silage making is an important tool to help technicians and producers during forage, nutritional and economic planning. Knowing the average values of crop productivity, the participation and quality of fractions of the corn plant, added to the identification of the most adapted hybrids through the expression of their productive potential, allows to establish the correlation of these variables with crop productivity and the quality of corn intended for silage production (Silva *et al*., 2018). Therefore, the goal of this study was to evaluate the production and nutritional value of forage of eight corn hybrids for silage production.

MATERIAL AND METHODS

The experiment was carried out at the State University of the Midwest (UNICENTRO), located in the municipality of Guarapuava, state of Paraná, Brazil (25º23'02"S and 51º29'43"W). According to the Köppen classification, the climate of the region is Cfb (mesothermal humid subtropical), with mild summers and moderate winters, no defined dry season, severe frosts. The average annual rainfall is 1,944 mm, average minimum annual temperature of 12.7°C, average maximum annual temperature of 23.5°C and relative humidity of 77.9%.

The soil of the experimental area is classified as Latosol Bruno Típico. The area had been used in recent years for annual cycle pasture in the winter season, and corn crops in the summer season, receiving phosphorus and potassium fertilization at each growing season.

At the time of sowing, the chemical characteristics of the soil were evaluated (0 to 20 profile): pH $CaCl_2$, 0,01M: 5,98; Phosphorus: 15,30 mg dm^{-3}; K^+: 0,43 $cmol_c$ dm^{-3}; MO: 23,73%; Al^{3+}: 0,21 $cmol_c$ dm^{-3}; H^+Al^{3+}: 6,42 $cmol_c$ dm^{-3}; Ca^{2+}: 6,33 $cmol_c$ dm^{-3}; Mg^{2+}: 1,67 $cmol_c$ dm^{-3} and base saturation: 56,75%.

This was a randomized block experimental design was, consisting of 8 treatments, and each treatment represented by a hybrid: P3565 PWU (Pioneer®), CERES 310, CERES 312, CERES 405, CERES 412 (Nova Ceres Sementes®), 2A521 PW, 2B533 PW and FS620 PWU (Forseed®), with 4 repetitions each.

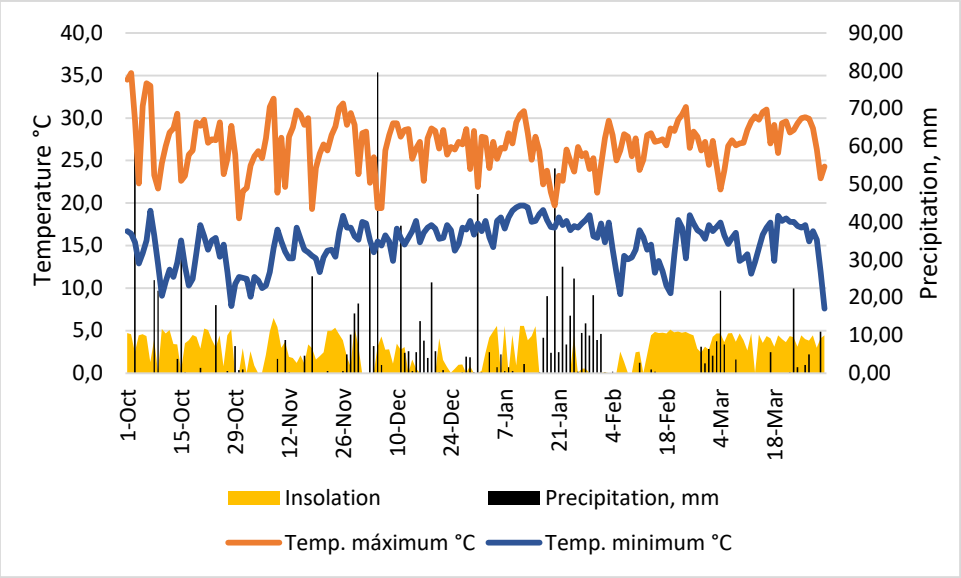
Crops were planted on October 10, 2020, after ryegrass (*Lolium multiflorum* L.), in a no-till system, using 55cm row spacing, 4cm sowing depth, and linear seed distribution to a final population of 70 thousand plants per hectare. Hybrids were planted in plots of 2.2 m × 6.0 m, totaling an area of 13.2 m^2, and for quantitative-qualitative evaluations, a central useful area of 5.5 m^2 (1.1 m × 5.0 m) was considered.

Basal fertilization was carried out with 400kg ha^{-1} with the fertilizer 8-20-20 (N-P-K) and nitrogen as topdressing was applied 20 days after emergence, at a dose of 450kg ha^{-1} urea (46% nitrogen).

Plants were harvested at the dough grain stage (R4), between February 25 and March 8, 2021, to evaluate the accumulation of the dry matter content of the plant and its structural components. In the evaluation, 10 homogeneous, representative, whole corn plants were harvested (original material), inside the useful area of each plot, manually cut at 25cm from the ground. In the physical composition, first ear height and

plant height (m), number of dry leaves and the potential of dry phytomass production (kg ha^{-1}) were determined at the time of ensiling, in samples composed of plants from the plots, by relating individual plant weight and plant population per unit area.

The weather data for the experimental period (01/10/2020 to 31/03/2021), shown in Figure 1 was characterized by average maximum temperatures of 26.9°C and minimum averages of 15.3°C. The occurrence of 89 rains was observed, determining an average rainfall of 10.55mm, with maximum and minimum variations between 79.60 mm and 0.20 mm, respectively.



Source: SIMEPAR/UNICENTRO experimental station, Guarapuava, PR, 2024.

Figure 1. Precipitation, insolation, maximum temperature and minimum temperature during the experimental period.

Whole plant samples were weighed and pre-dried in a forced air oven at 55°C. After drying for 72 hours, samples were weighed again to determine the dry matter content, and then ground in a Wiley mill, with a sieve with a mesh size of 1 mm. The pre-dried samples were analyzed for total dry matter (DM) in an oven at 105ºC, crude protein (CP) by the micro Kjeldahl method, ether extract (EE) and ash by incineration at 550ºC for 4 hours, according to AOAC (Official…, 1995). Neutral detergent fiber (NDF) content was determined using heat-stable α amylase (Termamyl 120L, NovozymesLatin América Ltda.), according to Van Soest *et al.* (1991), and acid detergent fiber (FDA) and acid detergent lignin (LDA), according to Goering and Van Soest (1970). Ethereal extract (EE) plus non-fiber carbohydrates (NFC) content was calculated by difference: $EE + NFC = 100 -$ (CP + ash + NDF); hemicellulose and cellulose values were estimated by difference between NDF and ADF and between ADF and ADL, respectively. Total digestible nutrients (TDN) was obtained via equation $[TDN, \% = 87.84 - (0.70 \times ADF)]$.

To determine the *in situ* ruminal digestibility (DMD) of whole plants, two male, neutered, Jersey bulls, 65 months of age, mean body weight of 750 kg and with permanent rumen cannula were used. For incubation in the rumen, 5 g samples were packed in nylon bags of known weight (10 × 12 cm in size, with 50 µ porosity). Bags were sealed and attached to a nylon thread with a lead weight (100 g) at the end.

Ruminal incubation was performed at fixed times of 24 and 48 hours. Subsequently, bags

were washed, dried in a forced air oven at 55 ℃ for 72 hours and weighed, to obtain the results regarding rumen disappearance. The determination of indigestible NDF (iNDF) was performed through NDF analysis, of the residue after ruminal incubation (168 hours), according to Van Soest *et al*. (1991). Treatment evaluations at different incubation times and with four repetitions were performed in duplicate.

Data collected for each parameter were tested by analysis of variance, with comparison of the means at a significance level of 5% by Duncan's test, using the statistical program SAS (Institute…, 1993).

RESULTS

According to Table 1, hybrid CERES 412 presented the highest plant height (2.55 m), however, it did not differ from hybrids CERES 312, CERES 405 and 2A521 PW, while the hybrids 2B533 PW and FS620 PWU presented the lowest heights (2.25 and 2.20m, respectively). Following the same behavior, hybrid CERES 412 also presented the highest ear height among the evaluated hybrids (1.44m).

Hybrids CERES 312 and CERES 412 had the highest number of dry leaves at harvest, and CERES 312 had the highest dry biomass production, however, without statistical difference from CERES 310 (30,919 and 27,662kg ha^{-1}, respectively). The grain yield of CERES 312 was also expressive (14,365kg ha^{-1}), while hybrid CERES 405 presented the lowest grain yield (9,445kg ha^{-1}). There was also an influence of the hybrid ($P<0.05$) on the DM content of the whole plant, where CERES 312 and FS620 PWU had higher levels at harvest.

Table 1. Plant height, first ear height, number of senescent leaves per plant, dry biomass yield, grain yield and dry matter (DM) content of different corn hybrids for silage production

Hybrid	Plant height	Ear height	Dry leaves	Dry biomass yield	Grain yield	DM
	m	m	n°	kg ha^{-1}	kg ha^{-1}	%
P3565 PWU	2.40b	1.28ab	1.83cd	23,198b	11,876b	38,08b
CERES 310	2.32bc	1.25ab	3.01ab	27,662ab	12,923ab	40.40ab
CERES 312	2.41ab	1.22ab	3.57a	30,919a	14,365a	44.69a
CERES 405	2.45ab	1.18ab	1.77cd	23,368b	9,445c	39.39ab
CERES 412	2.55a	1.44a	3.18a	25,984b	11,822b	41.56ab
2A521 PW	2.42ab	1.16b	2.66abc	26,673b	13,498ab	43.42ab
2B533 PW	2.25c	1.20ab	1.87bcd	23,521b	11,974b	42.17ab
FS620 PWU	2.20c	1.14b	1.24d	25,289b	12,789ab	44.44a
Average	2.37	1.23	2.39	25,827	12,336	41.77
P-value	<0.01	0.29	<0.01	<0.01	<0.01	0.12
CV	3.98	13.39	20.97	10.52	10.31	8.28
SEM	0.01	0.02	0.54	73.93	16.20	11.96

[a-d] Mean values followed by different letters are significantly different from each other by Duncan's Test at 5%.

The stem participation of hybrid CERES 405 was superior to the other hybrids (22.3%). This same hybrid also presented the highest percentage of leaves (20.2%), while the 2A521 PW hybrid presented the lowest percentage of this component (16.1%).

Hybrids CERES 310, CERES 312, CERES 405, CERES 412 and 2A521 PW showed the highest participation of bracts and cob, while P3565 PWU presented the lowest participation of this fraction (17.9%; 17.7%; 17.2%; 17.6%, 17.8%

and 14.1%, respectively), and there was no significant difference between the others. Hybrids P3565 PWU, 2A521 PW, 2B533 PW and FS620 PWU showed the highest participation of grains in dry matter (51.4%; 50.6%; 50.8% and 50.7%), followed by hybrids CERES 310, CERES 312 and CERES 412 (46.9%; 46.5% and 45.6%), respectively.

Regarding the chemical composition of the plant, there was a significant difference ($P<0.05$) for ash, CP, EE+NFC and ADL (Table 2). Hybrid CERES 412 showed the highest concentration of ash, not differing from P3565 PWU and CERES 310. The 2A521 PW had the lowest value for this parameter, not differing from CERES 312, CERES 405, 2B533 PW and FS620 PWU.

Table 2. Whole plant chemical composition of different corn hybrids for silage production

Hybrid	Ash	CP	EE+NFC	NDF	ADF	ADL	TDN
	% DM						
P3565 PWU	2.82ab	6.96b	35.03ab	55.20	30.85	4.27abc	66.15
CERES 310	2.80ab	7.36ab	30.09b	59.74	33.93	5.65a	63.99
CERES 312	2.56bc	7.61ab	33.02ab	56.80	31.26	4.78ab	65.86
CERES 405	2.66bc	8.38a	32.31ab	56.65	32.70	5.10a	64.85
CERES 412	3.23a	6.57b	35.68ab	54.51	30.28	4.09abc	66.54
2A521 PW	2.21c	6.45b	35.11ab	56.23	33.05	3.33bc	64.61
2B533 PW	2.60bc	7.01ab	35.79ab	54.60	29.95	2.94c	66.77
FS620 PWU	2.52bc	6.27b	36.61a	54.61	29.66	3.38bc	66.97
Average	2.68	7.08	34.21	56.04	31.46	4.19	65.72
P-value	0.03	0.04	0.20	0.49	0.50	0.0167	0.50
CV	13.28	12.18	10.32	6.48	10.41	14.99	3.48
SEM	0.12	0.74	12.47	13.22	10.72	1.0981	5.25

[a-c] Mean values followed by different letters are significantly different from each other by Duncan's Test at 5%.

Hybrid CERES 405 presented the highest content of CP (8.38%), however, it did not differ from hybrids CERES 310, CERES 312 and 2B533 PW. The latter also had the lowest ADL content (2.94%). Regarding the content of NFC+EE, hybrid FS620 presented the highest content observed, and hybrid CERES 310 presented the lowest among the evaluated hybrids (36.61 and 30.09%, respectively), and neither differed from the others.

The DMD of the whole plant for the incubation time of 24 hours was higher for hybrid FS620 PWU, which showed the highest digestibility (44.52%; Table 3), however it did not differ from hybrids P3565 PWU and 2B533 PW. After 48 hours of incubation, 2B533 hybrid presented the highest DMD (62.71%). There was no significant difference between the hybrids evaluated for iNDF.

Hybrids P3565 PWU and 2B533 PWU presented the highest values of NEl (1.511 Mcal kg DM^{-1} and 1.499 Mcal kg DM^{-1}, respectively), while hybrid CERES 312 presented the lowest estimated value (1.412 Mcal kg DM^{-1}). However, both did not differ from hybrids CERES 310, CERES 405, CERES 412, 2A521 PW and FS620 PWU. Hybrids 2A521 PW, 2B533 PW and FS620 PWU presented the highest estimated values for DMI (Table 4).

The estimate for milk yield was higher for hybrid P3565 PWU (1,504 g kg DM^{-1}), while hybrid CERES 312 presented the highest estimated production value in kilograms per hectare (42,325 kg milk ha^{-1}).

Table 3. *In situ* ruminal digestibility of dry matter (DMD) and indigestible neutral detergent fiber (iNDF) of whole corn hybrid plants for silage production

Hybrid	Ruminal incubation time		
	DMD 24h	DMD 48h	iNDF 168h
	DMD, % DM		iNDF %, NDF
P3565 PWU	42.33ab	55.53bc	34.98
CERES 310	38.73bc	54.42bc	36.18
CERES 312	34.20c	54.78bc	36.84
CERES 405	37.86bc	48.26d	42.81
CERES 412	38.50bc	51.96cd	36.53
2A521 PW	37.62bc	58.05ab	42.39
2B533 PW	41.72ab	62.71a	36.39
FS620 PWU	44.52a	57.32abc	34.38
Average	39.44	55.38	25.22
P-value	<0.01	<0.01	0.20
CV	8.36	6.38	16.89
SEM	10.89	12.50	18.14

[a-c] Mean values followed by different letters are significantly different from each other by Duncan's Test at 5%.

Table 4. Estimates of silage energy, dry matter intake and milk yield by Milk2006

Hybrid	NEl-3×	DMI	Milk yield	
	Mcal kg DM^{-1}	kg day^{-1}	g kg DM^{-1}	kg ha^{-1}
P3565 PWU	1.511a	12.2ab	1,504a	34,959b
CERES 310	1.425ab	11.0b	1,382bc	38,100ab
CERES 312	1.412b	11.7ab	1,369c	42,325a
CERES 405	1.469ab	11.6ab	1,443abc	33,625b
CERES 412	1.465ab	12.3ab	1,445abc	37,625ab
2A521 PW	1.482ab	12.5a	1,476abc	39,300ab
2B533 PW	1.499a	12.9a	1,502ab	35,325b
FS620 PWU	1.460ab	12.7a	1,446abc	36,375ab
Average	1.465	12.1	1,446	37,203
P-value	0.17	0.08	0.12	0.10
CV	3.57	7.28	5.04	10.60
SEM	0.01	0.78	53.22	15.57

[a-d] Mean values followed by different letters are significantly different from each other by Duncan's Test at 5%.

DISCUSSION

All materials evaluated were characterized as medium-sized plants (2.20 to 2.80m). According to Domingues *et al*. (2013), larger plants can contribute to phytomass productivity, however, it does not necessarily contribute to a better quality of the silage produced (Buso *et al.*, 2018). In the present study, there was no relationship between higher plant height and higher dry biomass production.

As well as plant height, the first ear height is also a quantitative characteristic of importance, which seems to be related to the tolerance of the hybrid to lodging, so that plants with a high relationship between ear height and plant height are more susceptible to lodging (Souza *et al.*, 2021).

According to Lupatini *et al*. (2004), dry leaf count at harvest is an efficient method to determine plant staygreen, which is classified as low (6-7 dry leaves), intermediate (4-5 dry

leaves) and high (2-3 dry leaves). Hybrids with a lower number of dry leaves, with high staygreen, may have greater vigor at the time of ensiling, due to their greater ability to remain green and consequently expand the harvest season (Klein *et al*., 2018). In addition, a greater number of green leaves favors grain filling, while a high number of dry leaves can make it difficult to chop and compact at the time of ensiling (Klein *et al.*, 2018).

Phytomass production is a characteristic that allows to reduce costs and increase the profitability of the system (Pedrazzi *et al*., 2017), therefore, hybrids with high phytomass production are increasingly sought, in addition to other quantitative traits, such as grain yield. This, in turn, is closely linked to silage quality, and according to results obtained from Horst *et al.* (2020), under favorable ensiling conditions, grain yield potential influences silage quality even if vegetative fractions do not differ between hybrids. Hybrid CERES 312 presented higher production of phytomass and grains, however, it showed an intermediate staygreen. Hybrid FS620 PWU, despite having lower plant height and phytomass production, had a lower number of dry leaves, that is, a lower proportion of senescent material and a higher dry matter content.

Furthermore, the quality and participation of each structural component of the plant, as well as the digestibility of the vegetative portion, also has a great influence on the nutritional value and quality of the silage (Horst *et al*., 2020). The P3565 PWU, in addition to presenting a lower participation of bracts + cob, presented a high participation of grains, which is positive, because hybrids destined for silage production are sought, which present higher grain production and lower participation of stem, bracts and cob, which are the fractions that contain the most low-quality fibers (Pedrazzi *et al*., 2017).

The highest leaf: stem ratio is also sought after in hybrids for silage production, as according to Klein *et al.* (2018), there is a higher concentration of crude protein and soluble carbohydrates in leaves, which help in fermentation and in the final quality of the silage. Hybrid CERES 405, which obtained the highest percentage of CP in DM, also showed a greater participation of leaves in its proximate structure.

Although there was no statistical difference for ADF between the hybrids studied, it was observed that numerically the CERES 310 hybrid presented the highest lignin content and also presented a higher percentage of ADF, intrinsic characteristics of the plant itself (Garcez *et al.*, 2016). In DMD-24h, digestion of components of easy degradation by ruminal microorganisms occurred, which may explain the behavior of hybrid FS620 PWU, which had higher DMD and high participation of grains in the whole plant. The lower DMS-48h of hybrid CERES 405 suggests that it reflects its greater participation of stem in the plant structure, which is characterized by the fiber fraction of lower digestibility. According to Souza Filho *et al.* (2011), the whole plant digestibility depends primarily on the quality of each structural component and then on the participation of each fraction in the dry matter of the plant, and thus, we can attribute the low digestibility of this hybrid to this lower quality of the fiber fraction. The higher DMD-48h of the 2B533 PW hybrid may be indicative that it has better quality fiber, consequently leading to greater use of this fraction by the animals (Paziani *et al*., 2019).

Although CERES 312 presented higher production of phytomass and grains, it did not present adequate ruminal digestibility of the whole plant, both in 24h and in 48h, which may indicate the greater participation of bracts and cob. Only the evaluation of phytomass production seems little for choosing hybrids, as DMD can equate hybrids of different yield levels (Horst *et al*., 2020). When evaluating a hybrid for silage production, it is necessary to analyze several factors, as well as the reality of the production system where it will be inserted, in this way, all the characteristics should be observed and which are the most relevant for that system (Paziani *et al.*, 2019).

The forage NEl can be influenced by some factors, such as a lower amount of non-digestible fiber and a higher participation of grains. Observing Tab. 5, hybrids that presented higher NEl content also presented greater participation of grains in the structure of the whole plant and smaller participation of stem.

Table 5. Plant structural composition of different corn hybrids for silage production

Hybrid	Stem	Leaves	Bracts + Cob	Grains
	% whole plant			
P3565 PWU	17.6 c	16.9 cd	14.1 b	51.4 a
CERES 310	17.3 c	17.9 bc	17.9 a	46.9 b
CERES 312	16.9 cd	18.9 ab	17.7 a	46.5 b
CERES 405	22.3 a	20.2 a	17.2 a	40.3 c
CERES 412	19.3 b	17.4 bcd	17.6 a	45.6 b
2A521 PW	15.5 de	16.1 d	17.8 a	50.6 a
2B533 PW	15.4 de	18.0 bc	15.8 ab	50.8 a
FS620 PWU	15.0 e	18.5 b	15.8 ab	50.7 a
Average	17.4	18.0	16.7	47.8
P-value	<0.01	<0.01	<0.01	<0.01
CV	6.42	5.11	8.27	4.21
SEM	1.25	0.84	1.91	4.05

[a-d] Mean values followed by different letters are significantly different from each other by Duncan's Test at 5%.

There are several factors influencing the DMI, such as the DM content, the NDF percentage and the energy density (Nutrient…, 2021). Observing the results, hybrid FS620 PWU, one that presented the highest estimate of DMI, also presented higher DM of the whole plant and lower NDF content, even with no significant difference.

Regarding the productive potential of hybrids, the first parameter (g kg DM^{-1}) is related to the partial nutritional value of all forage components, while the production per hectare is related, in addition to the nutritional value, also to the production of DM per hectare, where a lower nutritional value can be compensated for higher DM production. This explains the behavior of hybrid CERES 312, which presented the lowest milk yield in grams per kilogram of forage DM (1.369), which also had the lowest NEl, however, it presented the highest milk yield in kilograms per hectare, which may have been compensated for higher production of DM.

CONCLUSION

Under the conditions of the present study, hybrid CERES 312 had the highest dry matter yield, which allowed obtaining a high estimated milk yield per area. Nevertheless, nutritional differences provided the P3565 PWU hybrid with a higher energy estimate and, consequently, a higher estimated milk yield per kg of DM.

Differences in the participation of the plant components were inconsistent on the nutrients obtained, proving that the structural and nutritional evaluations of corn hybrids should be complementary.

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