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Agronomic characteristics of maize hybrids (*Zea mays*, L.) at different maturity stages

Características agronômicas de híbridos de milho (*Zea mays*, L.) silageiros em diferentes estádios de maturação

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Highlights:
Phenological stage does not define harvest moment.
The vegetative fraction of plant should be considered as much as the grain.
Simple hybrids appear to be superior for silage production.

Abstract

The objective of this study was to evaluate the production and physical composition of three maize hybrids (*Zea mays*, L.) for silage production at six maturity stages. The hybrids evaluated were Maximus VIP3, Defender VIP and Feroz VIP. The experiment was conducted in a completely randomized block design with four replicates. The mean plant heights observed at harvest time (2.33 m, 2.45 m and 2.40 m) demonstrated that all materials were medium-sized hybrids. A positive correlation was observed between plant height and height of the ear insertion, varying from 0.86 for the Feroz VIP hybrid to 0.88 for the Maximus VIP3 hybrid, but these two variants had no correlation with the productivity data. There was a significant difference for the production of fresh biomass at the R1, R2 and R5 stages, with Maximus VIP3 obtaining the highest yields. The proportion of grains in the physical composition of plant varied between hybrids, where Maximus VIP3 and Defender VIP (482.2 and 461.7 g kg^{-1}, respectively) were superior to Feroz VIP (429.7 g kg^{-1}). With the advancement of maturity, there was a decreasing linear behavior for stem and leaf participation, with reductions of 3.8 g kg^{-1} and 4.5 g kg^{-1}, respectively, per day (R^2 = 0.79 and 0.80, respectively), quadratic behavior for bracts and corncob and a linear increase in grain participation in the plant structure, with an increase of 7.7 g kg^{-1} per day (R^2 = 0.88). In general, the three hybrids present good characteristics for silage production and permit harvesting in the hard grain stage, allowing the addition of starch in relation to the farinaceous grain stage.

Key words: Phenological stage. Physical composition. Production. Silage.

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Resumo

O objetivo do trabalho foi avaliar a produção e a composição física de três híbridos de milho (*Zea mays*, L.) para produção de silagem, em seis estádios de maturidade. Os híbridos avaliados foram o Maximus VIP3, Defender VIP e Feroz VIP. O experimento foi conduzido em delineamento de blocos inteiramente casualizados com quatro repetições e três tratamentos. A média de altura de planta observada no momento da colheita (2,33m, 2,45m e 2,40m, respectivamente) classifica todos os materiais como híbridos de porte médio. Foi observado correlação positiva, variando de 0,86 para o híbrido Feroz VIP a 0,88 para o híbrido Maximus VIP3, entre a altura de planta e altura de inserção da espiga, porém, essas duas varáveis não tiveram correlação com os dados de produtividade. Houve diferença significativa para produção de biomassa fresca nos estádio R1, R2 e R5, tendo o Maximus VIP3 obtido as maiores produtividades. A proporção de grãos na composição física da planta variou entre os híbridos, onde o Maximus VIP3 e o Defender VIP (482,2 e 461,7 g kg^{-1}) foram superiores ao Feroz VIP (429,7 g kg^{-1}). Com o avanço da maturidade notou-se comportamento linear decrescente para participação de colmo e folha, com redução de 03,8 g kg^{-1} e 04,5 g kg^{-1} (R^2=0,79 e 0,8; respectivamente) ao dia, quadrático para brácteas e sabugo, e linear crescente para participação de grãos na estrutura da planta, com aumento de 7,7 g kg^{-1} ao dia (R^2=0,88). De forma geral, os três híbridos apresentam boas características para produção de silagem e permitem a colheita em estádio de grão duro, possibilitando acréscimo de grãos em relação ao estádio de grão farináceo.

Palavras-chave: Estágio fenológico. Composição física. Produção. Silagem.

Introduction

The concept that the best hybrids for grain production are also the best for silage production is being demystified since the vegetative fraction of grain represents more than 50% of the dry matter of the silage (Zopollatto et al., 2009). Pereira, Mizubuti, Pinheiro, Villarroel and Clementino (2007) assert that ideal maize hybrids for silage production should have a good percentage of grains, together with a highly digestible vegetative fraction. Older studies show that the genetic improvements of maize hybrids increase productivity and nutritional quality, with the vegetative fraction being important at this point (Lavezzo, Lavezzo, & Campos Neto, 1997).

The development of these hybrids with a silage purpose has resulted in maize silage being a common food for cattle throughout the country. However, the choice of the most suitable hybrids has been the subject of discussions due to the scarcity of information on their qualitative aspects (Zeoula et al., 2003), which are highly relevant as they determines the quality of an animal's final diet (Domingues et al., 2012).

The existence of a large number of hybrids available on the market, with distinct phenotypic and nutritional characteristics, makes it fundamentally important to identify those that offer the best animal response. Countless studies show nutritional differences in maize silage from different hybrids (Lupatini Maccari, Zanette, Piacentini, & Neumann, 2004; Jaremtchuk et al., 2005; Restle et al., 2006), but these differences do not normally interfere with animal performance. However, Neumann et al. (2003) reported differences in silage bromatology, as well as dry matter intake in different periods and in the final weight gain of confined steers.

The selection of a hybrid is important, but other factors also affect the final quality of silage, and the maturity stage of the harvest is one of the most discussed points (Oliveira et al., 2010). Beleze et al. (2003) evaluated the maturity stages of verified leaves and stem reductions and the percentage increase in grains and corncobs with the progress of the stages. The same authors also showed that a greater proportion of grains does not always provide better quality silage, but the percentage combination of each of the fractions of the plant determines such a variable.

The objective of this study was to evaluate the production and physical composition of three maize hybrids (*Zea mays*, L.) for silage production at six maturity stages.

Materials and Methods

The experiment was developed in Guarapuava, Paraná, located at 25° 23' 36 "south latitude and 51° 27' 19" west longitude. The climate of the region is high altitude temperate (Cfb - humid mesothermic subtropical), without a dry season, with mild summers and moderate winters according to the classification of Köppen, at an altitude of approximately 1,100 m. Figure 1 shows the mean values of sunshine (hours day^{-1}), rainfall (mm), maximum and minimum temperatures (°C) and relative humidity (%) in the decennial during the experimental period.

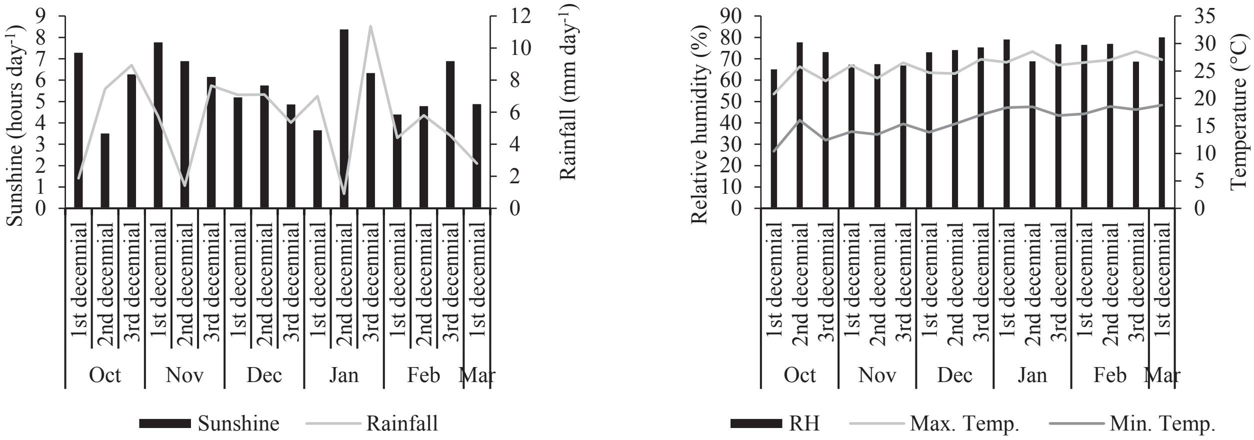

Figure 1. Mean of sunshine (hours day^{-1}), rainfall (mm), maximum and minimum temperature (ºC) and relative humidity (%). Harvest 16/17.
Source: SIMEPAR / UNICENTRO experimental station, Guarapuava –PR.

The soil of the experimental area is classified as Latossolo Bruno Tipico (Pott, Müller, & Bertelli, 2007). The area where the maize was grown was used in recent years with annual cycle pastures in the winter season and maize and soybean crops in the summer season, receiving phosphorus and potassium fertilizers at each season, according to Comissão de Química e Fertilidade do Solo [CQFS RS/SC] (2004).

In the present experiment, the production of fresh and dry biomass and grains, the physical composition of the plants, and the dry matter content of the plants and the structural components of the maize hybrids, Maximus VIP3, Defender VIP and Feroz VIP (Syngenta®) as simple, triple and double hybrids, respectively, were evaluated.

The maize crops were planted in the first half of October, under a no-tillage system. At the planting, row spacing was 0.5 m, the approximate seed depth was 0.04 m, and seed distribution per linear meter was used, aiming at final densities of 65 thousand plants ha^{-1}.

The basic fertilization consisted of 500 kg ha^{-1} of the NPK fertilizer in the formulation 08-20-20 (N-P_2O_5-K_2O), and in the cover, urea (45-00-00) was used in the dose of 400 kg ha^{-1} between vegetative stages of 4 to 6 fully expanded leaves.

The maize plants of the different hybrids were evaluated successively in the reproductive stages of grain formation, R1; milky grain, R2; pasty grain, R3; farinaceous grain, R4; hard grain, R5; and mature grain, R6 to evaluate the accumulation of the dry matter content of the plant and its structural components in addition to the physical composition of the plant. At each evaluation, ten whole plants contained in the plot area were manually harvested at 20 cm from the soil, using the triple pairing method, and the adoption of this practice allowed the determination of the dry matter content and the percentage physical composition of the structures of the plant by segmentation of the components: stem, leaves, bracts, corncob and grains. The insertion of the first ear and the plant (m), number of dry leaves and the productive potential of green and dry biomass and grains (kg ha^{-1}) were evaluated. The final production of fresh biomass, dry biomass and grain yield was determined at the time of silage (hard grain phase, R5) by samples that contained plants of the plots by relating individual plant weight and plant population per unit area.

The reproductive stages and development of the maize plants were determined according to Ritchie, Hanway and Benson (2003): stage R1 - full flowering (flowering - day 0); stage R2 - milky grain (8 days after flowering); stage R3 - pasty grain (21 days after flowering); stage R4 - farinaceous grain (31 days after flowering); stage R5 - hard grain (53 days after flowering); and stage R6 - physiological maturity (73 days after flowering).

The experiment was conducted in a completely randomized block design with four replications and three treatments (Maximus VIP3, Defender VIP and Feroz VIP).

The data were submitted to the Shapiro-Wilk and Bartlett tests to verify the assumptions of normality and homogeneity of variance, respectively. Once these assumptions were met, the F-test was applied with a 5% probability of confidence, through analysis of variance (ANOVA) and then the Tukey test of the comparison of multiple means at 5% significance. The data were also submitted to polynomial regression analysis, considering the variable days of evaluation, using the "proc reg" procedure of the SAS program (SAS, 2009).

Results and Discussion

Table 1 shows the agronomic characteristics of the different hybrids during the maturity stages. Plant height of the Maximus VIP3 hybrid was lower ($P < 0.05$) from the R3 stage until the R6 stage when compared to the other treatments, while the Defender VIP and Feroz VIP hybrids were statistically similar along the maturation stages. The average plant height at harvest time (2.33 m, 2.45 m and 2.40 m) demonstrated that all materials were medium-sized hybrids (Pinto, Lançanova, & Bernardo, 2010). A similar result was described by Paziani et al. (2009), while Pinto et al. (2010) evaluated 12 hybrids and obtained lower values with an average plant height of 2.13 m.

The same trend can be observed for ear height, where the different hybrids presented insertion heights at 1.40 m, 1.51 m and 1.48 m at the time of harvest (R5). Santos et al. (2010) also observed different ear insertion heights when evaluating seven distinct hybrids; however, the mean height described by the authors was 0.90 m, although the mean plant height was 2.20 m.

A positive correlation was observed between the plant height and height of the ear insertion, varying from 0.86 for the Feroz VIP hybrid to 0.88 for the Maximus VIP3 hybrid, but these two variants had no correlation with the productivity data.

Table 1 also shows a constant decrease and increase ($P < 0.05$) in the number of green and dry leaves, respectively, with the advancement of the maturity stages. In the general average, the hybrids had 14 leaves in their structure that were all green until the R3 stage, and there was no significant difference among the hybrids for the number of dry leaves at the R5 stage, with a mean of 1.9 per plant. This low number of dry leaves allows the classification of the three hybrids as high stay green (Lupatini et al., 2004).

Table 1
Agronomic characteristics of different corn hybrids for silage between R1 to R6 stages

Hybrids	Phenological stage					
	R1	R2	R3	R4	R5	R6
	Plant height, m					
Maximus VIP3	2.30 a	2.32 a	2.30 b	2.29 b	2.33 b	2.38 b
Defender VIP	2.32 a	2.39 a	2.44 a	2.44 a	2.45 a	2.44 a
Feroz VIP	2.37 a	2.38 a	2.40 a	2.42 a	2.40 a	2.45 a
Average	2.33 B	2.36 AB	2.38 AB	2.38 AB	2.39 AB	2.42 A
CV, %	2.35	3.82	1.58	3.78	2.63	2.15
	Ear height, m					
Maximus VIP3	1.35 a	1.39 a	1.33 b	1.36 b	1.40 b	1.45 b
Defender VIP	1.44 a	1.47 a	1.50 a	1.53 a	1.51 a	1.56 a
Feroz VIP	1.42 a	1.44 a	1.46 a	1.54 a	1.48 a	1.54 a
Average	1.41 B	1.43 B	1.43 B	1.48 AB	1.46 AB	1.52 A
CV, %	3.75	5.78	2.81	5.18	4.07	2.85
	Number of green leaves					
Maximus VIP3	14.9 a	15.0 a	14.3 a	14.5 a	12.8 a	5.9 b
Defender VIP	14.4 a	14.9 a	14.2 a	14.0 ab	12.2 a	7.1 a
Feroz VIP	15.0 a	14.7 a	13.7 a	13.6 b	12.1 a	7.7 a
Average	14.7 AB	14.8 A	14.1 B	14.0 B	12.4 C	6.9 D
CV, %	2.58	2.33	2.34	2.54	3.46	8.00
	Number of dry leaves					
Maximus VIP3	0.0 a	0.0 a	0.0 a	0.1 a	1.8 a	8.1 a
Defender VIP	0.0 a	0.0 a	0.1 a	0.3 a	2.1 a	7.3 a
Feroz VIP	0.0 a	0.0 a	0.1 a	0.6 a	1.7 a	5.6 b
Average	0.0 C	0.0 C	0.0 C	0.3 C	1.9 B	7.0 A
CV, %	0.00	0.00	174.35	97.97	27.03	9.64

Averages, in the column, followed by different lowercase letters, differ by the Tukey Test at 5%.
Averages, in the row, followed by different capital letters, differ by the Tukey Test at 5%.

The increase in the number of dry leaves observed between the R5 and R6 stages (Table 1) generated a significant reduction in the average fresh biomass production of the hybrids (77509 versus 59395 kg ha^{-1}, respectively) but did not interfere in dry biomass production (Table 2).

The average production of fresh biomass showed quadratic behavior, reaching the highest yields between the R3 and R5 stages (Table 2). Regarding the hybrids, there was a significant difference in the R1, R2 and R5 stages, with Maximus VIP3 obtaining the highest yields. As the harvest occurred at the R5 stage, it should be analyzed with greater importance. The same trend cannot be noted for the production of dry biomass, where the hybrids differed only in the R1 stage, and the average behavior was linear, with the dry matter accumulation varying from 214.8 to 260.7 kg ha day^{-1}.

Most studies in the literature, such as Santos et al. (2010) and Pinto et al. (2010), show productive results of the hybrids harvested at the R4 stage similar to those of the present study at the same stage (18286 kg ha^{-1}). Harvesting at an advanced stage is only permitted if the dry matter content is compatible (Cox & Cherney, 2005). As in the present study, Souza et al. (2011) evaluated dry biomass production in the R5 stage that averaged 21489 kg ha^{-1}, which was lower than the 24929 kg ha^{-1} reported here.

Table 2
Production of fresh and dry biomass, and grains of different maize hybrids for silage between R1 to R6 stages

Hybrids	Phenological stage					
	R1	R2	R3	R4	R5	R6
	Fresh biomass, kg ha^{-1}					
Maximus VIP3	69,431 a	77,942 a	83,174 a	84,076 a	82,466 a	58,396 a
Defender VIP	59,283 c	70,654 b	74,415 a	79,159 a	76,464 ab	58,596 a
Feroz VIP	63,573 b	67,203 b	72,188 a	76,388 a	73,597 b	61,194 a
Average	64,096 C	71,933 B	76,592 AB	79,874 A	77,509 AB	59,395 C
CV, %	2.62	3.23	6.70	6.32	10.50	12.44
	Dry biomass, kg ha^{-1}					
Maximus VIP3	10,994 a	12,815 a	15,666 a	18,294 a	25,558 a	25,141 a
	Y=11,439+214.8D (R^2=0.8522; CV: 13.12)					
Defender VIP	9,547 c	12,550 a	14,526 a	17,532 a	25,026 a	26,155 a
	Y=10,151+239.9D (R^2=0.9138; CV: 11.27)					
Feroz VIP	10,244 b	11,588 a	14,788 a	19,032 a	24,202 a	27,372 a
	Y=10,003+260.7D (R^2=0.9116; CV: 12.09)					
Average	10,262 D	12,318 D	14,993 C	18,286 B	24,929 A	26,222 A
CV, %	3.07	4.80	5.40	15.68	13.26	8.16
	Grains, kg ha^{-1}					
Maximus VIP3	124 a	711 a	1,299 ab	4,677 a	12,431 a	13,891 a
	Y=-937+204.1D (R^2=0.8282; CV: 26.42)					
Defender VIP	168 a	547 b	857 b	4,534 a	11,585 a	13,896 a
	Y=-1,245+213.7D (R^2=0.9400; CV: 26.20)					
Feroz VIP	181 a	520 b	1617 a	4,558 a	10,391 a	14,789 a
	Y=-1,282+212.3D (R^2=0.8636; CV: 21.78)					
Average	158 D	593 D	1,258 D	4,590 C	11469 B	14,222 A
CV, %	24.57	12.01	23.43	22.41	20.61	21.48

Averages, in the column, followed by different lowercase letters, differ by the Tukey Test at 5%.
Averages, in the row, followed by different capital letters, differ by the Tukey Test at 5%.

Grain production did not differ (P> 0.05) among the hybrids at the most important stages, with production of 12431, 11585 and 10391 kg ha^{-1} for the Maximus VIP3, Defender VIP and Feroz VIP hybrids, respectively, in the harvest. For the general average, there was a linear increase in grain, with increments varying between 204.1 to 213.7 kg (Maximus VIP3 and Feroz VIP, respectively) for each day of advancement of maturity. Although grain production provides a prediction of silage quality (Allen, Oba, & Choi., 1997), grain production cannot be considered in isolation. Beleze et al. (2003) affirm that the selection of maize hybrids for silage production depends on many factors, including the participation and quality of each component present in the plant, and dry matter content directly interferes with these variables.

Table 3 shows that there was no difference (P> 0.05) in the dry matter contents of any components between stages R1 and R3. In the R5 stage, the Maximus VIP3 hybrid differed (P <0.05) in the dry matter content of the stem in relation to the Feroz VIP hybrid (160.4 versus 202.8 g kg^{-1}, respectively), while the other components were statistically the same, with averages of 179.9, 324.4, 298.2, 389.2, and 620.5 g kg^{-1} for stem, leaves, bracts, corncob and grains, respectively. This result suggests that the crop of this hybrid could be extended for a few more days. In general, the dry matter contents of the whole plant were kept within the range recommended by Cox and Cherney (2005), favoring anaerobic conditions (Lupatini et al., 2004) and avoiding clostridic fermentation (Bernardino, Rodriguez, Santana, Gonçalves, & Zago, 1997).

Table 3
Dry matter content (g kg dry matter^{-1}) of structural components and of whole plant, of different maize hybrids for silage between R1 to R6 stages

Hybrids	Phenological stage					
	R1	R2	R3	R4	R5	R6
			Stem			
Maximus VIP3	148.7 a	171.6 a	182.7 a	199.4 a	160.4 b	215.5 b
Defender VIP	157.9 a	186.0 a	174.1 a	194.3 a	176.6 ab	267.5 a
Feroz VIP	160.6 a	177.1 a	188.5 a	180.5 a	202.8 a	246.1 ab
Average	155.7 C	178.2 BC	181.8 B	191.4 B	179.9 B	243.0 A
CV, %	4.74	7.64	7.95	9.17	9.49	9.08
			Leaves			
Maximus VIP3	202.5 a	232.9 a	272.4 a	245.0 a	349.3 a	628.9 a
Defender VIP	228.2 a	230.3 a	218.9 a	255.9 a	314.3 a	578.9 a
Feroz VIP	197.9 a	207.4 a	262.7 a	238.7 a	309.6 a	602.8 a
Average	209.5 C	223.5 C	251.3 C	246.5 C	324.4 B	603.5 A
CV, %	2.29	7.95	10.62	5.68	9.92	6.98
			Bracts			
Maximus VIP3	106,6 a	178.8 a	225.8 a	218.6 b	282.9 a	643.4 a
Defender VIP	125.0 a	177.3 a	225.2 a	252.5 a	320.6 a	597.9 a
Feroz VIP	110.3 a	169.7 a	242.9 a	242.8 ab	290.9 a	596.0 a
Average	114.0 E	175.3 D	231.3 C	238.0 C	298.2 B	612.4 A
CV, %	9.01	7.13	4.41	5.02	10.33	8.98
			Corncob			
Maximus VIP3	113.1 a	156.0 a	211.5 a	291.5 b	379.5 a	469.0 ab
Defender VIP	193.8 a	124.6 a	196.7 a	325.7 a	389.6 a	427.6 b
Feroz VIP	139.2 a	141.2 a	229.5 a	273.8 b	398.6 a	491.4 a
Average	148.7 E	140.6 E	212.6 D	297.0 C	389.2 B	462.7 A
CV, %	32.25	6.97	4.47	3.36	10.39	4.50

continue

continuation

			Grains			
Maximus VIP3	121.2 a	144.4 a	175.1 a	375.3 a	624.5 a	765.1 a
Defender VIP	123.0 a	164.7 a	234.1 a	417.1 a	623.8 a	772.8 a
Feroz VIP	129.7 a	163.3 a	200.7 a	387.7 a	613.2 a	779.9 a
Average	124.7 E	157.4 E	203.3 D	393.4 C	620.5 B	772.6 A
CV, %	16.98	11.45	19.34	6.30	2.66	2.30
			Plant			
Maximus VIP3	158.3 a	164.4 a	188.4 a	217.6 a	309.9 a	430.5 a
Defender VIP	161.0 a	177.6 a	195.2 a	221.5 a	327.3 a	446.4 a
Feroz VIP	161.1 a	172.4 a	204.9 a	249.1 a	328.8 a	447.3 a
Average	160.2 E	171.5 E	196.1 D	229.4 C	322.0 B	441.4 A
CV, %	1.29	4.22	6.15	14.47	5.09	4.07

Averages, in the column, followed by different lowercase letters, differ by the Tukey Test at 5%.
Averages, in the row, followed by different capital letters, differ by the Tukey Test at 5%.

Initially, up to the R4 stage, the leaf did not undergo major changes in its dry matter content, ranging from 209.5 g kg^{-1} at the R1 stage to 246.5 g kg^{-1} at the R4 stage. According to Zopollatto et al. (2009), at that moment, there is no reduction in the water content in this fraction because its photosynthetic rate is high and exceeds the respiratory rate. The same authors also evaluated the dry matter content of the leaves in two harvests and described values of 284 g kg^{-1} in the first harvest and 323 g kg^{-1} in the second harvest.

Russell (1986) evaluated the vegetative fractions of maize hybrids for silage and found an increasing linear effect of the maturity stage on leaf dry matter content, with a daily increase of 8.50 g kg^{-1}. Figure 2 shows similar behavior to that reported, however, with gain of 4.30 g kg^{-1} per day after flowering (R^2 = 0.79).

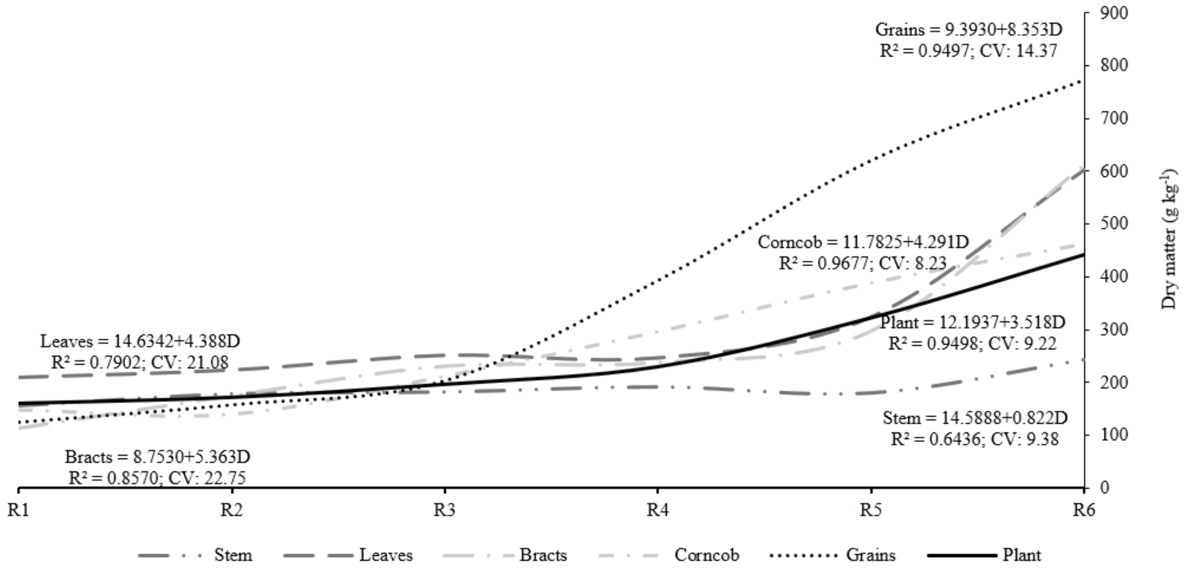

Figure 2. Average dry matter content of plant and components: stem, leaves, bracts, corncob and grains harvested between R1 to R6 stages.
D = Days after flowering.

From the regression equations of Figure 2, it was clear that with the advancement of the maturity stage, the dry matter content of all the components increased linearly, with a daily increase of 0.8, 5.3, 4.2, and 8.3 g kg^{-1} for stem, bracts, corncob and grains, respectively. The drying rate of the plant, 3.5 g kg^{-1} per day, shows the high stay green of the hybrids. After reaching the ideal dry matter for harvest until losing this same amount of dry matter would take 14 days, considering the window of harvest.

The proportion of grains varied ($P<0.05$) between hybrids, where Maximus VIP3 and Defender VIP (482.2 and 461.7 g kg^{-1}) were higher than Feroz VIP (429.7 g kg^{-1}); however, all of the proportions of grains of the hybrids were above the 400 g kg^{-1} as recommended by Rosa et al. (2004) for high quality silage, which classifies the three hybrids as suitable for this purpose. Corroborating the data of the present study, Beleze et al. (2003) show a positive correlation between the advancement of the maturation stage and the increase in the proportion of grains. The average proportions of grains at different maturation stages are similar to those reported by Johnson, Monson e Petligrew (1985) and higher than the values reported by Hunt et al. (1993).

It is clear that the grain fraction has a great influence on the quality of silage (Neumann, Restle, & Brondani, 2010), however, the vegetative fraction is responsible for more than half of the silage composition, indicating that this fractions needs to be taken into account. No difference was observed between hybrids for the other components at harvest time (Table 4).

Table 4
Physical composition of plant (g kg of dry matter^{-1}) of different maize hybrids for silage between R1 to R6 stages

Hybrids	Phenological stage					
	R1	R2	R3	R4	R5	R6
			Stem			
Maximus VIP3	449.6 a	392.0 ab	347.8 a	291.8 a	198.5 a	182.3 a
Defender VIP	467.7 a	436.1 a	326.7 a	311.4 a	210.3 a	207.5 a
Feroz VIP	479.5 a	381.8 b	321.0 a	272.7 a	185.3 a	190.8 a
Média	465.6 A	403.3 B	331.8 C	292.0 C	198.0 D	193.5 D
CV, %	14.71	5.73	14.03	10.11	16.32	15.31
			Leaves			
Maximus VIP3	534.5 a	436.1 a	379.5 a	320.2 a	243.0 a	190.7 a
Defender VIP	536.5 a	416.1 ab	306.3 a	320.7 a	219.1 a	171.2 a
Feroz VIP	533.9 a	370.6 b	354.6 a	287.4 a	209.2 a	163.3 a
Average	535.0 A	407.6 B	346.8 C	309.4 C	223.8 D	175.1 E
CV, %	11.84	6.33	9.77	10.03	11.07	14.38
			Bracts			
Maximus VIP3	106,1 a	174.5 a	207.1 a	173.8 a	105.4 a	77.2 a
Defender VIP	86.7 a	167.6 a	145.0 b	153.3 a	98.5 a	74.2 a
Feroz VIP	114.6 a	147.9 a	178.2 ab	125.0 a	85.8 a	72.7 a
Average	102.4 B	163.3 A	176.8 A	150.7 A	96.6 B	74.7 B
CV, %	17.65	10.39	14.74	18.17	21.06	17.18

continue

continuation

			Corncob			
Maximus VIP3	13.6 a	47.2 a	138.3 a	137.7 a	93.6 a	79.1 a
Defender VIP	14.7 a	53.5 a	144.8 a	151.7 a	98,9 a	76.6 a
Feroz VIP	16.5 a	51.5 a	150.5 a	122.1 a	108.7 a	90.5 a
Average	14.9 D	50.8 C	144.5 A	137.1 A	100.4 B	82.1 B
CV, %	22.08	10.23	14.09	17.04	20.98	12.50
			Grains			
Maximus VIP3	11.3 a	55.3 a	83.5 b	260.0 a	482.2 a	512.0 a
Defender VIP	17.8 a	43.9 a	89.3 b	258.6 a	461.7 a	531.7 a
Feroz VIP	17.9 a	45.1 a	109.7 a	244.2 a	429.7 b	519.7 a
Average	15.7 C	48.1 C	94.2 C	254.3 B	457.9 A	521.1 A
CV, %	27.06	12.43	22.27	29.35	20.72	17.44

Averages, in the column, followed by different lowercase letters, differ by the Tukey Test at 5%.
Averages, in the row, followed by different capital letters, differ by the Tukey Test at 5%.

It is also worth noting the decreasing behavior of leaf participation with the advancement of physiological maturity, from 535 g kg^{-1} in the first reproductive stage to 175.1 g kg^{-1} in the sixth. During the vegetative stages, the photoassimilates and water are destined to the leaves and stem. From the first reproductive stage, with the ear formed, the photoassimilates gradually move towards the new structure (Zopollatto et al., 2009). This fact is confirmed by the regression equations of Figure 3, where there was a decreasing linear behavior for stem and leaves, with a reduction of 3.8 g kg^{-1} and 4.5 g kg^{-1}, respectively, per day (R^2 = 0.79 and 0.81, respectively), quadratic behavior for bracts and cob, and a linear increase in grain participation in the plant structure, with an increase of 7.7 g kg^{-1} per day (R^2 = 0.88). Similar results were reported by Beleze et al. (2003), demonstrating the increase in the proportion of grains and relating it to the translocation of substances from their formation.

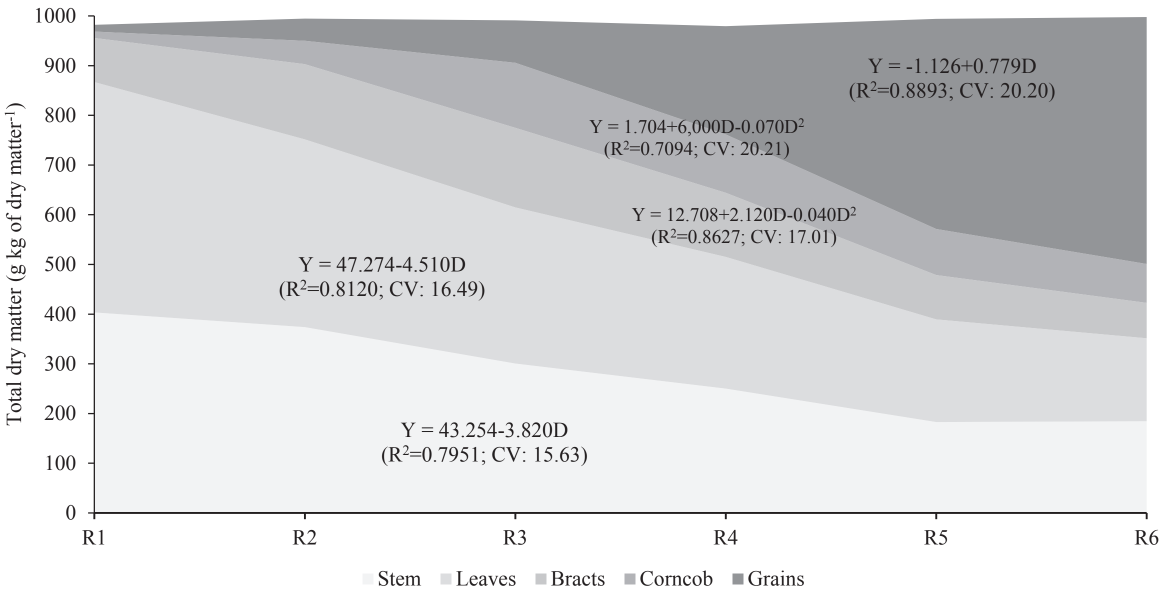

Figure 3. Average participation of components of plant during the advance of maturity stages.

Quadratic behavior, which is a dilution effect where the grain fraction increases during the different stages of maturation, in the bracts and corncob was also reported by Beleze et al. (2003). As indicated by Caetano (2001), the data show that the harvesting time of maize for silage production is a very important factor since it directly affects the silage composition, which will directly interfere with the quality and consumption of the silage obtained.

Conclusion

In general, the three hybrids present good characteristics for silage production and permit harvesting in the hard grain stage, allowing the addition of grains in relation to the farinaceous grain stage. The hybrid Maximus VIP3 stood out for its greater productivity.

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