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Bromatological characterization of maize genotypes for silage

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ABSTRACT. Since every year public and private companies bring many genotypes of maize to the market, the suitability of these genotypes for the production of silage should be evaluated. Current study evaluates the agronomic and chemical characteristics of early-normal cycle maize genotypes as well as assesses whether the genetic bases (single, double, and triple hybrids, as well as varieties and intervarietal genotypes) and the grain hardness (hard, semi-hard and dentate) modify the indication of maize genotypes for silage. The experiment was conducted at the Universidade Tecnológica Federal do Paraná, campus Dois Vizinhos, Paraná State, Brazil. Thirty-six genotypes were evaluated by a simple lattice design. Grains were harvested at the pasty to farinaceous stage and stored in micro-silos of 100-mm PVC, for 60 days. Neither the different genetic bases nor the different textures of the genotypes influenced the indication of maize genotypes. The early-normal cycle maize genotypes behave similarly for most characteristics assessed, except for the stem diameter and stem dry matter. Moreover, most maize genotypes have suitable characteristics for the production of high-quality silage.

Keywords: genetic bases, grain hardness, cultivars indication, *Zea mays* L.

Caracterização bromatológica de genótipos de milho para silagem

RESUMO. As empresas públicas e privadas disponibilizam, anualmente, diversos genótipos de milho no mercado. A avaliação desses genótipos quanto a sua aptidão para a produção de silagem é fundamental para o seu uso adequado. O objetivo deste trabalho foi avaliar as características agronômicas e bromatológicas dos genótipos de milho de ciclo precoce-normal, bem como avaliar se a base genética (híbridos simples, duplos, triplos, variedades cultivadas e intervarietais) e a dureza dos grãos (duro, semiduro e dentado) alteram a indicação de genótipos de milho para silagem. O experimento foi realizado na área experimental da Universidade Tecnológica Federal do Paraná, *Campus* Dois Vizinhos. Foram avaliados 36 genótipos no delineamento látice simples. A colheita foi realizada quando as plantas apresentavam estádio pastoso a farináceo, ensiladas em microssilos de PVC de 100 mm, e desensilados após 60 dias. Verificou-se que as diferentes bases genéticas, bem como genótipos de diferentes texturas não influenciam na indicação de genótipos de milho. Os genótipos de milho do ciclo precoce-normal comportam-se de maneira similar para a maioria das características avaliadas, exceto para o diâmetro de colmo e matéria seca do colmo. Além disso, os genótipos de milho têm características indicadas para a produção de silagem de qualidade.

Palavras-chave: base genética, dureza do grão, indicação de cultivares, *Zea mays* L.

Introduction

Forage production in southern Brazil is determined by seasonality and reduced quantity and quality, which put at risk animal performance. Thus, it is necessary to produce and store forage for animals' nutritional supplementation, mainly in the Fall and Spring production gaps.

In southern Brazil, maize is the crop most widely used for silage, followed by sorghum as a second option (NEUMANN et al., 2008). Beleze et al. (2003) highlight the average characteristics necessary for the maize plant to be considered an excellent source of forage for silage production. The silage dry matter should vary between 30 and 38%, due to the direct relationship between voluntary consumption, digestibility, grains and fiber proportions in the silage.

During the 2009/2010 crop year, 429 maize genotypes, including 104 transgenic ones, were available on the seed market. The existence of variability among genotypes may be observed in the production of dry matter, the production of grains and the quality of silage (MELO et al., 1999; OLIVEIRA et al., 2007). These characteristics are affected by the genotypes' interaction with the environment, which requires their evaluation in different locations that represent the main regions of silage production.

Several studies demonstrate the existence of significant alterations in genotype classification according to crop location (MITTELMANN et al., 2005; NEUMANN et al., 2008; FERREIRA et al., 2011). Balbinot Junior and Fleck (2005) found significant differences among genetic groups (double hybrids versus cultivars; simple hybrids versus intervarietal genotypes) with regard to grain productivity. They attributed these morphology differences (a tall variety with decumbent leaves – 'traditional' architecture; the simple hybrid with low height and upright leaves – 'modern' architecture) to plants which were conditioned to different spacing. In this context, a continuous search occurred for genotypes with better bromatological characteristics of interest for silage production (BELEZE et al., 2003; FLARESSO et al., 2000; JAREMTCHUK et al., 2005).

Each genetic base is adapted to the specific conditions of the environment according to the plants' genetic constitution. The genetic variability of maize plants increases from simple hybrids to triple hybrids and from double hybrids to cultivars (FANCELLI; DOURADO NETO, 2000). Paterniani (1978) showed not only that crops with a larger genetic base (varieties) were more stable than those with a smaller one, but also found that this greater stability of heterogeneous materials was due to the large number of base-composing genotypes.

Maize may be classified according to grain texture, or rather, it may be either dentate or hard. The dentate grains have low density and consist of soft and porous starch. Hard grains, on the other hand, have a rigid endosperm that almost occupies the entire volume of the grain. There are reports in the literature that grain texture influences the degradability of the starch in the rumen (CORRÊA et al., 2002). Nevertheless, most studies have been performed with a limited number of genotypes, and many of these genotypes are not the most commonly cultivated.

Current assay evaluates the bromatological characteristics of maize genotypes for silage production in the early-normal South Trial of the National Network of Corn Genotypes in Dois Vizinhos, Paraná state, Brazil. It was also assessed whether the genetic basis (simple, double, and triple hybrids as well as cultivars and intervarietal genotypes) or the hardness of the grains (dentate, hard, or semi-hard) alter the suitability of maize genotypes for silage.

Material and methods

The experiment was conducted in the experimental area of the Universidade Tecnológica Federal do Paraná (UTFPR), campus Dois Vizinhos, Paraná State, Brazil. The region lies within the third plateau of the state of Paraná (520 m; 25°44" S and 53°04" W); predominant climate is humid and subtropical (Cfa), according to Köppen classification (MAACK, 1968); soil classified as Distroferric Red Nitosol, with clay texture in the subtropical evergreen forest phase and hilly terrain (EMBRAPA, 2006).

The evaluated genotypes (Table 1) were provided by Embrapa Maize and Sorghum (Sete Lagoas, Minas Gerais State, Brazil) and belong to the south Brazilian maize genotype trials, in which 36 genotypes of the early and normal cycles were evaluated. These trials were performed in several Brazilian regions using a methodology standardized by the National Center for Research on Maize and Sorghum (NCRCS). The experiment started by sowing on the 28th October 2009, placing two seeds in each hole; on the 20th November 2009, when the plants were trimmed when they displayed two to three definite leaves, adjusting the crop layout to 60,000 plants per hectare.

Table 1. Genotypes (Gen), commercial name, genetic base (GB), grain hardness (GH), and producing company (COM) of the genotypes belonging to the Early-Normal South Trial.

Gen	Commercial Name	GB*	GH**	COM***
1	30A91	SH	SemH	AGN
2	AS 1573 YG	SH	H	AGR
3	30A86HX	SH	SemH	AGN
4	BG 9619	SH	N/A	AGN
5	30A95	SH	SemH	AGN
6	AS 1578 YG	TH	SemH	AGR
7	2B655HX	TH	H	DOW
8	2B604HX	TH	SemH	DOW
9	CD 388	DH	SemH	CD
10	DX 809	SH	SemH	DS
11	BRS 1040	SH	SemH	BRS
12	DSS 2002	TH	SemH	DS
13	XBX 70202	SH	H	SM
14	SHS-5121	TH	SemH	CATI
15	BRS 1002	SH	N/A	BRS
16	SHS 7222	SH	H	SHS
17	SHS 7323	SH	H	SHS
18	P30R50	SH	N/A	BRS
19	CD327	SH	H	CD
20	CD 384	TH	H	CD
21	CD 321	SH	D	CD
22	CD 308	DH	SemH	CD
23	BMX 822	N/A	N/A	N/A
24	20A55	TH	SemH	AGN
25	30B39Y	TH	SemH	PS
26	EMBRAPA Caimbe	Cult	SemH	BRS
27	GNZX 9505	SH	SemH	GNZ
28	GNZX 8132	SH	SemH	GNZ
29	BG 7060 Y	TH	SemH	PS
30	EMBRAPA synthetic 1x	Cult	SemH	BRS
31	AL Avare	Cult	SemH	CATI
32	AL Bandeirante	Cult	SemH	CATI
33	EMBRAPA 1D2195	SH	SemH	BRS
34	EMBRAPA 1F6265	SH	SemH	BRS
35	HPS 0219	SH	SemH	BRS
36	EMBRAPA 3E482	TH	SemH	BRS

*Genetic Base: SH: Simple Hybrid, TH: Triple Hybrid, Cult: Cultivar, DH: Double Hybrid, IH: Intervarietal Hybrid; **Grain hardness: N/A: information not available, SemH: Semi hard, H: Hard, D: Dentate; ***Companies: Agroeste (AGR); Coodetec (CD); Information not available (N/A); DI SOLO (DS); Embrapa (BRS); Santa Helena Sementes (SHS); Pioneer Sementes (PS); Agromen Tecnologia (AGN); Gêneze Sementes (GNZ); Dow AgroSciences (DOW); DSMM/CATI (CATI); and Semeali (SM).

The plots consisted of two rows, 5 m long, 75 cm space between rows, and approximately 23 cm between plants. Base fertilization was performed 15 days before sowing and consisted of 20 kg of urea ha^{-1}, 100 kg of simple superphosphate ha^{-1}, and 20 of potassium chloride kg ha^{-1}. When the plants displayed five to six expanded leaves, cover fertilization was undertaken with 80 kg ha^{-1} of nitrogen in the form of urea. Weed control was performed on 23rd November 2009, by applying herbicide (6-chloro-N2-ethyl-isopropyl-1,3,5-triazine-2,4-diaminotriazine) at a dosage of 5 L ha^{-1}. An insecticide (((S-methyl-N (methylcarbamoyl)-oxy)-thioacetamide) Methomyl) was applied on 24th November 2009, at a dosage of 0.3 L ha^{-1}.

The number of days until flowering (DF) was evaluated. Further, Plant height (PH, m), first cob insertion height (FCH, m), and diameter of stem (DS, cm) were measured one day prior to harvest. The harvest, performed on the 31st January 2010, consisted of cutting the 5-m plant rows at 30 cm above the soil surface. The collection point was established when the kernels on the cob appeared to be between the pasty and the farinaceous stage. After harvest, the plants were weighed and one plant was separated for morphological evaluation (fractioning of stalk, leaves, and cob). The following characteristics were evaluated: green matter (GM, kg ha^{-1}), percentage of dry matter in the stalk (DMSTALK, %), dry matter of the green leaves (DMGL, %), dry matter in the cob (DMCOB, %), dry matter of the plants crushed for silage (DMCP, %), release of effluents (EF, L tDM^{-1}), dry matter of the total plant (DMPL, %), and dry matter per hectare (DMH, t ha^{-1}). The remaining material was crushed, using a JF 90 silage chopper attached to a tractor, and regulated for a particle size of 5 mm. Dry weight was calculated by placing a sample in a forced-circulation stove at 55°C until it reached a constant mass. The silage was made with a silage chopper attached to a tractor and was stored in experimental silos, measuring 500 mm in length and 100 mm in diameter, containing 350 grams of sand on the silo bottom. Compression was performed manually, using 550 kg of green matter per cubic meter. Silage was then stored for 60 days.

The bromatological characteristics of the silage were chemically analyzed, according to the *Sindirações* Compendium of Animal Nutrition (ANFAR, 2009), performed in the laboratory of Nuvital Alimentos S/A and in the bromatological laboratory of the Federal University of Paraná (UFPR). The following characteristics were taken into account: pH, dry matter content of the silage material (DMSM, %), crude protein (CP, %), ether extract (EE, %), mineral material (MM, %), neutral detergent fiber (NDF, %), acid detergent fiber (ADF, %), crude fiber (CF, %), total digestible nutrients (TDN, %), and net energy of lactation (NEL, kcal kg^{-1} of MS). TDN was estimated when the value of the net energy was assessed and ADF regression equation (COCHRAM et al., 1986) was applied: TDN = (53.1*(NEL/2.2)+31.4). The net energy of lactation was estimated by the following regression equation: NEL= 1.044-(0.0124*ADF))*2.2.

Data underwent the mathematical model assumption analysis (additivity, normality, homogeneity of variance and independence of errors), according to the applications of Martin and Storck (2008). Subsequently, an analysis of variance (SAS, 1996) was performed by the simple lattice design, and the averages were compared by contrasts (Scheffé) between the genetic bases (simple hybrid, triple hybrid, double hybrid, intervarietal hybrid, and cultivar) and between the groups of corn (hard, semi-hard, and dentate). Subsequently, the averages for the genotypes were compared by a Scott-Knott test, at a 5% error probability, by Genes (CRUZ, 2006).

Results and discussion

As a result of the efficiency of the chemical control applied, the experiment was not jeopardized by pests, diseases or weeds. The assumptions of the mathematical model (additivity, normality, homogeneity of variance and independence of errors) were not violated for any of the evaluated characteristics and thus the quality of the data used in the statistical analysis was ensured. Genotype stratification indicates that the companies' genetic improvements have been directed toward the production of hybrids for grain production. Semi-hard or hard grain genotypes were more widely available than the materials of the dentate group (Table 1).

No significant differences ($p > 0.05$) were observed among the genotype groups (simple hybrids, double hybrids, triple hybrids, and other varieties) for any of the characteristics; the differences between the means of groups were lower than the minimum significant differences (MSD) (Table 2). This fact may be explained by the similar crop management practices in all the experimental units (assumption of experimental management), where the genotypes with the greatest genetic potential (simple hybrids) may not have expressed their entire potential because they were limited by the crop management or by the environment.

However, the genotypes with a broader genetic base (double hybrids and cultivar varieties) may be favored by their lower management or environmental requirements.

Table 2. Estimated means for the genotypes of each genetic base and the minimum significant difference (MSD) of contrast estimated by Scheffé method, early normal^{-1} south trial.

Characteristics	SH	TH	MSD	SH	DH	MSD	SH	CULT	MSD
DF	70.5	70.8	2.7	70.5	69.0	2.7	70.5	70.4	3.8
PH	2.3	2.3	0.2	2.3	2.3	0.2	2.3	2.3	0.3
FCH	1.3	1.2	0.2	1.3	1.3	0.2	1.3	1.2	0.3
SD	2.3	2.3	0.4	2.3	2.3	0.4	2.3	2.3	0.6
GM	48.6	50.6	19.2	48.6	46.3	19.2	48.6	44.6	27.0
DMSTALK	26.4	28.4	7.0	26.4	24.2	13.2	26.4	28.3	10.0
DMGL	33.1	33.0	24.6	33.1	38.6	46.9	33.1	39.3	34.7
DMCOB	49.9	49.9	18.6	49.9	49.1	35.4	49.9	46.7	26.2
DMCP	33.5	33.1	9.3	33.4	33.1	17.7	33.5	32.2	13.1
EF	3.3	3.4	3.1	3.3	3.8	3.1	3.3	3.7	3.2
DMPL	34.9	36.2	6.1	34.9	35.5	14.5	34.9	35.7	10.7
DMH	16.3	16.6	7.5	16.3	15.4	7.5	16.3	14.5	10.6
pH	3.7	3.7	0.6	3.7	3.7	0.6	3.7	3.8	0.9
DMSM	33.0	33.2	6.9	33.0	33.9	6.9	33.0	33.5	9.8
CP	8.0	8.2	3.1	8.0	8.6	3.1	8.0	7.8	4.3
EE	2.4	2.2	1.7	2.4	2.8	1.7	2.4	2.0	2.4
MM	4.0	4.8	2.2	4.0	4.4	2.2	4.0	4.6	3.1
NDF	56.8	55.7	12.0	56.8	54.9	12.0	56.8	57.1	16.9
ADF	32.1	31.1	14.4	32.1	29.1	14.4	32.1	34.0	20.2
CF	22.3	22.1	8.5	22.3	21.5	8.5	22.3	22.2	11.9
TDN	65.7	66.4	9.5	65.7	67.7	9.5	65.7	64.5	13.3
NEL	1.4	1.4	0.4	1.4	1.5	0.4	1.0	1.4	0.6
	TH	DH	MSD	TH	CULT	MSD	DH	CULT	MSD
DF	70.8	69.0	5.3	70.8	70.4	4.0	69.0	70.4	5.9
PH	2.3	2.3	0.4	2.3	2.3	0.3	2.3	2.3	0.4
FCH	1.2	1.3	0.4	1.2	1.2	0.3	1.3	1.2	0.5
SD	2.3	2.3	0.9	2.3	2.3	0.7	2.3	2.3	1.0
GM	50.5	46.3	38.1	50.5	44.6	29.1	46.3	44.6	42.5
DMSTALK	28.4	24.2	13.8	30.0	28.3	10.1	24.2	28.3	15.43
DMGL	33.0	38.6	48.9	33.0	39.3	37.3	38.6	39.3	54.7
DMCOB	49.9	49.1	36.9	49.9	46.7	28.2	49.1	46.7	41.2
DMCP	33.1	33.1	18.4	33.1	32.0	14.1	33.1	32.0	20.6
EF	3.4	3.8	3.1	3.4	3.7	0.5	3.8	3.7	3.1
DMPL	36.2	35.5	15.1	36.2	35.7	11.5	35.5	35.7	15.3
DMH	16.6	15.5	14.9	16.6	14.5	11.4	15.5	14.5	16.7
pH	3.7	3.7	1.3	3.7	3.8	3.1	3.7	3.8	1.4
DMSM	33.2	33.9	13.7	33.2	33.5	10.5	33.9	33.5	15.4
CP	8.2	8.6	6.1	8.2	7.8	4.7	8.6	7.8	6.8
EE	2.2	2.8	3.4	2.2	2.0	2.6	2.8	2.0	3.8
MM	4.8	4.4	4.4	4.8	4.6	3.3	4.4	4.6	4.9
NDF	55.7	54.9	23.7	55.7	57.1	18.1	54.9	57.1	26.5
ADF	31.1	29.1	28.5	31.1	34.0	21.8	29.1	34.0	31.9
CF	22.1	21.5	16.8	22.1	22.2	12.8	21.5	22.2	18.8
TDN	66.4	67.7	18.8	66.4	64.5	14.3	67.7	64.5	21.0
NEL	1.4	1.5	0.8	1.4	1.4	0.6	1.5	1.4	0.9

SH: simple hybrid; TH: triple hybrid; DH: double hybrid; CULT: cultivar variety; number of days until flowering (DF), plant height (PH, m), first cob height (FCH, m), stalk diameter (SD, cm), green mater (GM, kg ha^{-1}), dry stalk matter (DMSTALK, %), dry matter of green leaves (DMGL, %), cob dry matter (DMCOB, %), dry matter of plants crushed for silage (DMCP, %), liberation of effluents (EF L tDM^{-1}), total plant dry matter (DMPL, %), dry matter (DMH, t ha^{-1}), pH, dry matter of the silage material (DMSM, %), crude protein (CP, %), ether extract (EE, %), mineral matter (MM, %), acid detergent fiber (ADF, %), neutral detergent fiber (NDF, %), crude fiber (CF, %), total digestible nutrients (TDN, %), net energy of lactation (NEL, kcal kg^{-1} of DM).

In studies on different genetic bases, Von Pinho et al. (2009) showed that simple hybrids are the more responsive to improvements in management and, therefore, have better productivity than the other genetic bases (cultivars, double hybrids or triple hybrids), which was not found in this study.

The analysis of the contrasts of the genotypes grouped by grain texture (Table 3) did not display a significant difference for any of the characteristics ($p > 0.05$) when analyzed by Scheffé test. Rossi Júnior et al. (2006), evaluating two maize cultivars (dentate and semi-hard), did not observe a significant difference in the evaluated characteristics. Similar results were found by Ribas et al. (2007) when they assessed the bromatological characteristics of maize hybrids with hard, semi-hard, and dentate textures.

The number of plants per hectare did not vary among the genotypes when compared by contrast or individually (average: 56.508, minimum: 52143 and maximum: 63572; data not shown).

With regard to the genotypes' individual characteristics, significant differences ($p > 0.05$) were found only for SD and DMSTALK, with rates between 1.9 cm and 2.7 cm and between 21.2 and 30.2%, respectively (Table 4). Beleze et al. (2003) evaluated five maize hybrids and obtained significant differences with rates ranging between 2.12 and 2.33 cm for SD. Jaremtchuk et al. (2005) also observed a significant difference for DMSTALK, which varied between 18.6 and 25.5% in corn genotypes.

Table 3. Estimated means for genotypes of each class of grain hardness and the minimum significant difference (MSD) of the contrast estimated by Scheffé method, early-normal South trial.

Variable	SH	H	MSD	SH	D	MSD	H	D	MSD
DF	70.5	70.4	2.9	70.5	69.0	7.0	70.4	69.0	7.3
PH	2.3	2.3	0.2	2.3	2.2	0.5	2.3	2.2	0.5
FCH	1.2	1.2	0.2	1.2	1.2	0.5	1.2	1.2	0.6
SD	2.3	2.3	0.5	2.3	2.5	1.1	2.3	2.5	1.2
GM	47.6	52.1	21.1	47.6	46.4	50.1	52.1	46.4	52.5
DMSTALK	27.9	25.0	7.6	27.9	22.2	18.2	25.0	22.2	19.1
DMGL	33.9	33.6	27.1	33.9	26.3	64.2	33.6	26.3	67.5
DMCOB	49.7	49.7	20.4	49.7	49.4	48.6	49.7	49.4	50.9
DMCP	32.7	33.5	10.2	32.7	34.2	24.3	33.5	34.2	25.5
EF	3.6	2.8	3.31	3.6	3.7	2.5	2.8	3.7	3.1
DMPL	35.6	35.1	8.4	35.6	32.5	19.9	35.1	32.5	20.8
DMH	15.6	17.6	8.3	15.6	14.7	19.6	17.6	14.7	20.6
pH	3.7	3.7	0.7	3.7	3.5	1.7	3.7	3.5	1.7
DMSM	33.2	33.1	7.6	33.2	28.9	18.1	33.1	28.9	19.0
CP	7.9	8.3	3.4	7.9	7.8	8.0	8.3	7.8	8.4
EE	2.3	2.2	1.9	2.3	2.9	4.5	2.2	2.9	4.7
MM	4.2	4.9	2.4	4.2	3.8	5.7	4.9	3.8	6.0
NDF	56.5	54.5	13.2	56.5	56.0	31.3	54.5	56.0	32.8
ADF	31.6	29.8	15.8	31.6	29.4	37.5	29.8	29.4	39.3
CF	21.9	21.6	9.3	21.9	23.8	22.2	21.6	23.8	23.2
TDN	66.0	67.2	10.4	66.0	67.5	24.7	67.2	67.5	25.9
NEL	1.4	1.5	0.4	1.4	1.5	1.0	1.5	1.5	1.1

SH: semi-hard; H: hard; D: dentate; number of days until flowering (DF), plant height (PH, m), first cob height (FCH, m), stalk diameter (SD, cm), green mater (GM, kg ha^{-1}), dry stalk matter (DMSTALK, %), dry matter of green leaves (DMGL, %), dry matter of the cob (DMCOB, %), dry matter of plants crushed for silages (DMCP, %), liberation of effluents (EF L tDM^{-1}), total plant dry matter (DMPL, %), dry matter (DMH, t ha^{-1}), hydrogen potential (pH), dry matter of the silage material (DMSM, %), crude protein (CP, %), ether extract (EE, %), mineral matter (MM, %), acid detergent fiber (ADF, %), neutral detergent fiber (NDF, %), crude fiber (CF, %), total digestible nutrients (TDN, %), net energy of lactation (NEL, kcal kg^{-1} of DM).

Table 4. Means of the maize genotype (Gen) characteristics evaluated for silage production.

Gen	DF*	PH	FCH	SD		GM	DMSTALK		DMGL	DMCOB	DMCP	EF
1	71	2.5	1.4	2.7	a*	67.4	28.6	a	43.4	53.7	41.0	4.7
2	69	2.2	1.2	2.1	b	43.7	30.2	a	32.1	51.3	32.8	2.8
3	71	2.5	1.4	2.3	a	70.5	30.2	a	36.7	48.8	31.3	4.2
4	70	2.4	1.4	2.1	b	58.3	25.4	b	278	44.6	32.4	3.5
5	70	2.3	1.2	2.0	b	49.5	28.6	a	25.3	51.5	35.8	2.7
6	70	2.3	1.2	2.0	b	52.9	25.4	b	27.5	51.2	37.6	3.0
7	71	2.3	1.2	2.2	b	45.5	31.2	a	25.4	52.3	30.6	3.8
8	69	2.3	1.3	2.6	a	45.5	24.3	b	45.0	49.3	41.3	3.5
9	69	2.3	1.2	2.5	a	46.4	22.2	b	26.4	49.4	34.3	3.0
10	72	2.2	1.3	2.3	b	46.8	23.0	b	26.3	46.1	30.6	2.8
11	70	2.1	1.0	2.0	b	55.1	26.7	b	28.3	50.6	32.4	2.9
12	69	2.2	1.2	2.5	a	48.0	21.2	b	35.5	50.7	31.8	3.8
13	69	2.4	1.4	2.2	b	44.5	27.2	b	41.9	47.7	34.5	2.3
14	69	2.1	1.1	2.0	b	48.0	28.7	a	41.7	54.8	35.1	2.7
15	73	2.2	1.1	2.7	a	43.8	27.5	a	29.1	51.4	33.5	2.6
16	73	2.3	1.3	2.3	b	41.7	27.9	a	26.0	42.0	30.5	3.2
17	72	2.5	1.3	2.1	b	59.2	25.6	b	28.0	55.5	34.2	3.0
18	71	2.4	1.2	2.3	a	68.3	26.4	b	28.5	49.6	36.5	3.1
19	72	2.3	1.2	2.2	b	50.0	25.9	b	49.9	41.2	30.0	3.6
20	71	2.3	1.2	2.5	a	45.4	32.0	a	34.0	44.9	30.2	3.6
21	72	2.3	1.3	2.3	b	56.7	33.1	a	26.2	49.6	29.0	3.7
22	72	2.3	1.2	2.1	b	48.5	33.0	a	33.9	47.4	31.3	2.4
23	71	2.4	1.3	2.7	a	43.7	25.0	b	31.9	48.3	29.5	3.1
24	72	2.3	1.3	1.9	b	47.1	30.3	a	34.0	55.5	33.8	3.1
25	70	2.4	1.2	2.3	a	49.3	25.7	b	26.6	45.1	34.1	3.0
26	69	2.3	1.2	2.1	b	33.8	29.9	a	47.1	55.8	34.1	2.4
27	70	2.4	1.2	2.6	a	56.2	22.4	b	34.7	54.4	32.4	3.1
28	70	2.2	1.1	2.0	b	35.3	28.9	a	31.1	64.2	35.0	3.5
29	70	2.6	1.4	2.6	a	56.3	30.0	a	28.2	47.0	32.7	2.3
30	71	2.3	1.2	2.2	b	38.0	26.4	b	62.2	38.9	33.5	2.8
31	69	2.2	1.2	2.3	b	50.6	25.4	b	49.1	51.2	28.2	3.4
32	69	2.2	1.2	2.3	b	31.9	23.7	b	33.0	47.2	33.5	3.7
33	71	2.2	1.2	2.5	a	47.9	29.5	a	35.2	48.0	31.4	2.9
34	72	2.2	1.2	2.4	a	44.7	22.0	b	27.4	49.7	32.7	3.1
35	72	2.3	1.2	2.2	b	37.2	24.1	b	49.0	48.5	34.3	2.3
36	70	2.4	1.4	2.5	a	36.3	25.0	b	32.6	47.3	42.0	2.7
Mean	70.4	2.3	1.2	2.3		47.5	26.6		32.8	49.5	33.2	3.0
CV	1.7	4.6	7.5	9.6		18.9	11.9		25.8	9.5	9.6	17.0

*Means not followed by the same letter differ at 5% probability by Scott-Knott test. DF = days until flowering; PH = plant height (m); FCH = first cob height (m); SD = stalk diameter (cm); GM = green matter, t ha^{-1}; DMSTALK = dry matter of the stalk (%); DMGL = dry matter of the green leaves (%); DMCOB = dry matter of the cob (%); DMCP = dry matter of the material crushed for silage (%); EF = release of effluents (L tDM^{-1}); CV = coefficient of variation (%).

Table 5. Means of the maize genotypes (Gen) characteristics evaluated for silage production.

Gen	DMPL	DMH	pH	DMSM	CP	EE	MM	NDF	ADF	CF	TDN	NEL
1	40.0	25.8	3.8	28.9	7.6	2.5	2.9	48.0	27.6	16.9	68.7	1.6
2	38.2	16.0	3.6	29.1	7.5	2.6	4.3	54.3	29.3	20.2	67.6	1.5
3	36.7	22.9	3.6	29.4	10.7	1.7	4.3	64.4	43.3	34.8	58.3	1.1
4	31.2	17.6	3.5	29.7	6.3	2.2	3.7	55.8	27.3	23.9	68.9	1.6
5	35.5	16.1	3.7	29.8	7.6	2.8	4.0	56.2	32.8	23.7	65.2	1.4
6	34.2	18.7	3.4	29.9	6.4	2.3	3.4	51.8	31.3	21.6	66.2	1.4
7	37.9	14.3	3.6	31.1	7.9	2.1	5.1	58.3	31.5	22.4	66.1	1.4
8	36.9	17.5	4.0	31.5	8.1	3.0	2.6	47.2	25.6	15.8	70.0	1.6
9	32.6	14.6	3.5	31.5	7.8	2.9	3.9	56.0	29.5	23.8	67.5	1.5
10	29.4	14.2	3.7	31.6	7.6	3.7	4.4	56.1	28.2	24.7	68.3	1.5
11	35.5	18.9	3.6	31.7	9.2	1.6	8.2	51.6	24.6	20.4	70.7	1.6
12	34.9	15.8	3.6	31.8	8.8	3.2	4.8	56.0	29.0	22.4	67.8	1.5
13	36.2	15.1	3.7	31.9	8.3	2.4	4.1	53.8	29.2	20.6	67.6	1.5
14	39.9	17.6	3.4	32.0	7.9	2.4	3.6	58.7	30.8	20.0	66.6	1.5
15	34.3	14.1	3.6	32.5	8.3	2.3	4.1	55.2	29.3	24.1	67.6	1.5
16	31.3	11.7	3.7	32.7	8.2	2.3	4.1	58.6	31.3	20.8	66.3	1.4
17	36.2	20.3	4.0	33.4	7.5	2.2	4.1	54.9	31.1	21.6	66.4	1.5
18	35.8	21.6	3.7	33.6	9.7	2.3	5.0	52.8	28.7	22.8	67.9	1.5
19	32.4	16.1	3.5	33.8	7.3	1.4	5.3	54.6	30.4	22.6	66.8	1.5
20	35.8	13.8	3.5	33.9	7.2	1.7	4.6	62.3	44.0	24.1	57.9	1.1
21	36.3	17.4	3.7	34.0	7.9	1.9	4.7	60.3	37.7	22.5	62.1	1.3
22	34.2	15.7	3.9	34.0	8.1	1.8	4.0	58.9	33.7	20.6	64.7	1.4
23	34.7	14.3	3.8	34.3	8.5	1.8	4.5	56.2	29.3	22.8	67.6	1.5
24	39.4	15.8	3.7	34.3	8.1	1.7	3.9	56.7	33.5	21.3	64.8	1.4
25	31.2	15.5	4.2	34.4	8.5	2.8	4.1	54.3	32.1	22.4	65.7	1.4
26	43.7	12.6	4.0	34.5	8.1	2.2	4.5	57.4	29.4	19.6	67.5	1.5
27	36.1	19.3	3.5	34.8	7.7	4.2	3.5	49.0	22.7	19.7	71.9	1.7
28	35.7	11.8	3.3	34.9	9.0	2.2	4.0	58.8	31.1	20.6	66.4	1.5
29	35.3	17.0	3.9	35.1	7.3	3.4	4.3	65.8	41.1	25.5	59.8	1.2
30	34.7	12.3	4.0	35.2	8.3	1.7	4.8	55.3	34.9	22.0	63.9	1.4
31	38.3	17.5	3.8	35.9	8.0	1.8	5.7	55.7	32.5	21.4	65.4	1.4
32	34.8	10.6	3.8	36.7	9.2	1.9	4.3	59.1	36.4	21.9	62.9	1.3
33	36	15.2	3.8	37.2	8.8	2.7	4.5	51.9	26.7	20.6	69.2	1.6
34	32.5	14.6	4.0	38.0	7.1	2.0	3.7	58.3	30.9	23.3	66.5	1.5
35	36.4	14.9	3.8	38.1	8.4	2.4	4.6	57.0	35.3	20.4	63.6	1.3
36	34.6	14.2	3.9	39.5	7.9	2.1	3.9	60.2	37.7	21.2	62.0	1.3
Mean	35.6	15.7	3.7	33.7	8.0	2.3	4.2	56.1	31.0	21.8	66.4	1.5
CV (%)	7.89	19.59	5.47	8.01	10.57	26.59	20.93	7.16	15.07	13.44	4.76	9.09

*Means not followed by the same letter differ at 5% probability by Scott-Knott test; DMPL = total dry matter of plant (%); DMH = dry matter (t ha^{-1}); pH = hydrogen potential; DMSM = dry matter of the silage material (%); CP = crude protein (%); EE = ether extract (%); MM = mineral matter (%); NDF = neutral detergent fiber (%); ADF = acid detergent fiber (%); CF = crude fiber (%); TDN = total digestible nutrients (%); NEL = net energy of lactation (kcal kg of DM^{-1}).

The authors asserted that, for the maximization of dry matter production, there should be maximum development of the structural portions of the plant, i.e., the height and diameter of the stalk.

The pH values varied between 3.34 (GNZX 8132) and 4.23 (30B39Y). According to McDonald et al. (1991), silage is considered to be of satisfactory quality if it exhibits a pH lower than 4.2. However, 30B39Y is the only genotype with no silage quality since good fermentation was not achieved. Thus, pH values for most genotypes were within the range considered ideal by current author. The percentage of the dry matter of the silage material ranged between 28.9 and 39.5%. Ramos et al. (2002) evaluated the chemical composition of maize hybrids in two types of soil in the north of Paraná State, Brazil, and observed rates between 23.5 and 40.2% and between 23.9 and 43.23%. The amount of dry forage matter is an important factor in silage process, and the recommended rates lie between 30 and 35% for maize silage (TOMICH et al., 2004).

There were no significant differences ($p > 0.05$) in the silage's CP among the genotypes, despite a variation between 6.3% (BG 9619) and 10.7% (30A86HX). These values are within the expected range since maize silage protein generally varies between 6 and 9% (MELO et al., 1999). Rates are also similar to those obtained by Vilela et al. (2008), who evaluated the nutritional value of maize silage collected at various stages of maturity and obtained a variation between 8.0 and 10.7% for CP levels.

The amounts of NDF and ADF averaged 56.1 and 31.7%, respectively. These rates are above those recommended by Fancelli and Dourado Neto (2000), who state that good quality silage should have less than 50% NDF and less than 30% ADF. Thus, the rates of most evaluated genotypes are above the recommended ones. Rates in current study are similar to those reported by Mello et al. (2004), who found values of 54.0 and 27.8% for NDF and ADF levels, respectively. Similar values were found by Pinto et al. (2010).

TDN levels varied between 57.9 and 71.9%, with greater amplitude than that reported by Pimentel et al. (1998), who observed values ranging from 62.50 to 63.87%. Rosa et al. (2004), evaluating the nutritional value of silage from different corn hybrids, observed values ranging from 68.62 to 69.35%. According to Flaresso et al. (2000), good-quality silage should be between 64 and 70% TDN. The average TDN value (66.4%) of the genotypes evaluated lies within the range cited by the author.

Conclusion

The best maize genotypes for silage production should be selected not on the genetic group or grain type, but rather according to the individual characteristics of each genotype. The vast majority of genotypes evaluated displayed sufficient silage production capacity and quality to be recommended to producers.

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