http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

PARENTAL COMMERCIAL MAIZE SELECTION FOR SILAGE PRODUCTION

LUCIANA GONÇALVES CHAVES[1], GLAUCO VIEIRA MIRANDA[2], LEANDRO VAGNO DE SOUZA[3], ODILON PEREIRA GOMES[4] e JACKSON SILVA E OLIVEIRA[5]

[1]*Zootecnista, Mestre em Genética e Melhoramento, Universidade Federal de Viçosa - UFV. CEP. 36570-000 Viçosa, MG, Brazil. E-mail: lucianagchaves@yahoo.com.br*
[2]*Prof. Associado, Departamento de Fitotecnia, Universidade Federal de Viçosa, bolsista CNPq. CEP. 36570-000 Viçosa, MG, Brazil. E-mail: glaucovmiranda@ufv.br*
[3]*Empresa de Pesquisa Agropecuária de Minas Gerais, Centro Tecnológico Triângulo e Alto Paranaíba, Caixa Postal 351, CEP 38001-970 Uberaba, MG, Brazil. E-mail: souzalv@hotmail.com*
[4]*Prof. Associado, Departamento de Zootecnia, Universidade Federal de Viçosa, bolsista CNPq. CEP. 36570-000 Viçosa, MG, Brazil. E-mail: odilon@ufv.br*
[5]*Embrapa Gado de Leite. Rua Eugênio do Nascimento, 610, CEP 36038-330 Juiz de Fora, MG. E-mail: jackoliv@cnpgl.embrapa.br*

Revista Brasileira de Milho e Sorgo, v.7, n.2, p. 183-194, 2008

ABSTRACT – The objectives of this study were to select maize genitors and determine the selection strategy for obtaining high quality silage maize hybrids. An experiment was conducted involving 45 hybrids obtained using a diallel scheme among commercial hybrids and four controls, in a triple lattice 7 x 7 design. The general combining ability (GCA) and specific combining ability (SCA) were significant for dry matter yield (DMY) and crude protein (CP), indicating additive and non-additive gene effects in genetic control. Only GCA was significant for plant height (PH), green matter yield (GMY) and hemicelluloses (HEM), which indicates a greater importance of additive than non-additive genetic effects in genetic control. The GCA and SCA of neutral detergent fiber (NDF) and acid detergent fiber (ADF) did not differ significantly between the hybrids, but there was a variance of 33% to 49% for NDF and 15 to 24% for ADF. The cultivars P30F90 and SHS4070 were the most recommended for increasing PH, GMY and DMY, while 2B619 and DKB466 were recommended to increase CP, and BRS3003 and AG1051 to reduce HEM. The hybrid combinations XB8028 x DKB 466, Valent x CD307, Valent x DKB466, SHS4070 x AG1051, BRS3003 x 2B619 and 2B619 x AG1051 are promising for maize silage production, because of their associated productive and qualitative traits.
Key words: plant breeding, genetic variability, diallel, germplasm

SELEÇÃO DE GENITORES COMERCIAIS DE MILHO PARA PRODUÇÃO DE SILAGEM

RESUMO – Objetivou-se, com este trabalho, selecionar genitores de milho e identificar estratégia de seleção para obtenção de híbridos de silagem de alta qualidade nutricional. Foi instalado um experimento com 45 híbridos, obtidos do cruzamento dialélico entre dez híbridos comerciais e quatro testemunhas, com o delineamento látice triplo 7 x 7.

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

As capacidades geral (CGC) e específica (CEC) de combinações foram significativas para produtividade de matéria seca e proteína bruta, o que indicou efeitos gênicos aditivos e não aditivos no controle genético. Somente as CGC foram significativas para altura de planta, produtividade de matéria verde e hemicelulose, indicando maior importância dos efeitos gênicos aditivos no controle genético. As CGC e CEC da fibra em detergente neutro e em detergente ácido não diferiram significativamente entre os híbridos, mas ocorreu a variação de 33% a 49% de FDN e 15 a 24% para FDA. As cultivares P30F90 e SHS4070 foram as mais indicadas para aumentar a média de AP, PMV e PMS, enquanto 2B619 e DKB466, para PB, e BRS3003 e AG1051, para reduzir porcentagem HEM. As combinações híbridas XB8028 x DKB 466, Valent x CD307, Valent x DKB466, SHS4070 x AG1051, BRS3003 x 2B619 e AG1051 x 2B619 são promissoras para produção de silagem, pois associaram características produtivas e qualitativas.

Palavras-chave: melhoramento vegetal, variabilidade genética, dialelo, germoplasma

The need to provide extra fodder for animals, especially in arid and cold periods of the year in Central Brazil, when tropical grasses virtually halt their growth, has increased the use of maize silage, especially among farmers involved in milk production. This increase has caused a great demand for high quality maize silage hybrids so that the herd can express their genetic potential and maintain high productivity.

In Brazil, although maize is a high quality crop, with excellent attributes for use as silage, high dry matter yield per hectare, appropriate content of soluble carbohydrates and low capacity buffer, there are few maize breeding programs that give priority to the development of hybrids for silage maize production.

In many maize breeding programs, hybrids that produce more grain and have excellent green mass yield are also recommended for silage production. However, in practice, this strategy has led to a decrease in the average nutritional value of maize hybrids, as genetic drift is not favorable for the characteristics related to the nutritional value of silage, which have not been investigated in maize breeding programs for grain (Barrière et al., 2004).

The nutritional value of maize silage is associated with the composition of the cell wall and macromolecular interactions between its various components (Barrière et al., 2005). However, there is little published information about the genetic basis of the concentration of fiber and lignin in maize, although genetic variability for these characteristics in maize germplasm has been reported (Krakowsky et al., 2006).

Usually, breeders must consider several traits simultaneously, in order to determine the superiority of a maize genitor. This is true for the decision to select the best combinations of hybrids for silage production, which depends on dry matter yield, as well as the characteristics associated with silage digestibility, such as acid detergent fiber (ADF) and neutral detergent fiber (NDF).

In view of the need to optimize the performance of dairy cattle, the objective of

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

this study was to select maize genitors and to identify the best strategy to select high quality silage maize hybrids.

Material and Methods

The field experiment was conducted at the Experimental Station of the Universidade Federal de Viçosa, Coimbra, Southeast of Minas Gerais, Brazil, located at 20° 51' 'W latitude, 42° 48' S longitude and 720m altitude. This region presents an average annual rainfall of 1300mm to 1400mm concentrated mainly in the period from October to March, an average relative humidity of 80 to 85% and an average annual temperature of 19 °C.

Ten maize hybrids recommended for the Southeast region of Brazil (XB8028, Valent, CD307, P30F90, Pointer, SHS4070, BRS3003, AG1051, 2B619 and DKB466) were crossed in a total diallel scheme, in the absence of reciprocity, whose characteristics are shown in Table 1. The hybrids were planted in pairs, in rows 8m long and 0.9m apart. At flowering, artificial crosses were done.

The 45 treatments (hybrid combinations) obtained by diallel crosses and four controls (BR 201, DKB 333B, AG 2060 and DKB 747) were evaluated in a 7 x 7 lattice design, with three replicates, in 2007/8 agricultural season. Each plot comprised two 8-m-long rows, 0.9m apart, with 6 plants m-1. Cultural practices and sprinkler irrigation were carried out as necessary. The agronomic characteristics associated with silage productivity were plant height (PH, cm) and green matter yield (GMY, t ha-1). Harvest was done at 75% milk-line stage, as in Fancelli and Golden Neto (2000).

In order to determine bromatological characteristics related to silage quality, five plants were sampled in each plot. They were cut by hand near the soil surface, chopped and immediately silaged in PVC (polyvinyl chloride) silos with 10cm diameter and 40cm length, and maintained at room temperature for 40 days. After opening each silo, the silage was mixed, and about 600 grams was collected and dried at 65 °C for 72 hours. Pre-dried samples were ground in a mill (Wiley), using a 1 mm screen, and submitted to bromatological analysis:

TABLE 1 – Description of commercial maize hybrids used in this research

Code	Hybrid	Developer	*Type	Type of grain	Maturity
1	XB8028	Semeali	DC	Semident	Late
2	Valent	Syngenta	TC	Flint	Early
3	CD307	Coodetec	SC	Semident	Early
4	P30F90	Pioneer	SC	Semiflint	Intermediate
5	POINTER	Syngenta	SC	Flint	Early
6	SHS4070	SantaHelena	DC	Dent	Late
7	BRS3003	Biomatrix	TC	Semiflint	Early
8	AG1051	Monsanto	DC	Dent	Late
9	2B619	DowAgroscienc e	SC	Semiflint	Intermediate
10	DKB466	Monsanto	TC	Dent	Early

*SC = single cross hybrid; DC = double-cross hybrid; TC = Three-way crosses hybrid;

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

crude protein (CP, %) by the Kjeldhal method (Horwitz, 1980), neutral detergent fiber (NDF, %) and acid detergent fiber (ADF, %) (Van Soest et al., 1991). Estimates of hemicellulose were obtained from the difference between NDF and ADF content. Dry matter content was determined by oven drying at 105°C (DMY, %) (Horwitz, 1980). The dry matter yield (DMY, t ha^{-1}) of each plot was calculated by multiplying DMY and green matter yield.

The collected data were subjected to analysis of variance and grouping means ($p < 0.05$) by the Scott and Knott test. Method IV, proposed by Griffing (1956), was used for the diallel analysis employing the program GENES (Cruz, 1997). The quadratic components that express the variability of the genitors were estimated to give general combining ability (GCA) and specific combining ability (SCA), as in Cruz and Regazzi (2004). The sums of squares of treatments were broken down into GCA and SCA, using method 4, model 1, as proposed by Griffing (1956).

Results and Discussion

The mean squares for GCA and SCA were significant for dry matter yield and crude protein, which indicates that genitors differ in their average allele frequency and that additive and non-additive genetic effects are involved in controlling these characteristics (Table 2). For PC and DMS, the effects of the quadratic components associated with SCA were higher than those related to the GCA, with a predominance of non-additive genetic effects. The most appropriate strategy for the exploitation of these effects is to obtain hybrid cultivars and evaluate these characteristics in hybrid combinations. The GCA mean squares were significant and SCA mean squares were not significant for plant height (PH), green matter yield (GMY) and hemicellulose (HEM) (Table 2). This indicates that genitors differ in mean allele frequency and their contributions to the increase (PH and GMY) or decrease (HEM) in the characteristics, that additive genetic effects prevailed in the control of these characteristics, and that selection can be made at the genitor stage.

Neutral detergent fiber (NDF) and acid detergent fiber (ADF) of maize hybrids, associated with silage digestibility, showed no significant differences in GCA and SCA, indicating the same allelic frequencies among genitors. Roth et al. (1970), Dhillon et al. (1990) and Silva (2002), working with NDF, ADF and lignin, obtained significant effects for both GCA and SCA. Therefore, to obtain hybrid combinations with lower percentages of NDF and ADF, the introduction of other genotypes with lower mean values to these characteristics may be the best way to explore the effect of hybrid vigor and reduce the percentage of these characteristics in commercial germplasm, as achieved by the cited authors.

There was a significant difference between hybrid combinations in terms of PH, GMY, DMY and CP. For CP, the means ranged from 5.66 to 7.44%, and 31% of the hybrid combinations showed means greater than the best control, DKB333B. Estimates of CP were similar to those obtained by Allen et al. (1990) and Ferret et al. (1997), who found CP values between 5.70 and 8.10%.

DMY ranged from 10.69 to 19.92 tons ha^{-1} and GMY from 29.89 to 49.91 tons ha^{-1}. The hybrid combination 2x3, 8x9, 2x9, 2x7, 2x10, 7x9, 1x10 and 7x10 showed the highest

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

TABLE 2. Mean square analysis of variance, means and estimates of general combining ability (GCA) and specific combining ability (SCA) components (Φ) for plant height (HP), green matter yield (GMY), dry matter yield (DMY), crude protein (CD), neutral detergent fiber (NDF, %), acid detergent fiber (ADF ,%) and hemicellulose (HEM,%). Viçosa-UFV, 2007.

SV	DF	Mean Square						
		HP	GMY	DMY	CP	NDF	ADF	HEM
Treatments	44	400.72*	81.31**	12.57**	0.64**	30.69ns	9.03ns	8.21ns
GCA	9	1338.61**	151.78**	22.38**	0.99**	44.85ns	14.71ns	12.63*
SCA	35	159.54ns	63.18ns	10.05*	0.55**	27.06ns	7.56ns	7.07ns
Error	96	257.94	43.93	6.566	0.309	26.96	9.05	5.79
CV(%)		7.49	16.31	16.52	8.56	12.73	15.58	11.20
Mean		215.79	41.16	15.69	6.52	40.85	19.36	21.48
ΦGCA		45.028	4.494	0.658	0.028	0.745	0.235	0.285
ΦSCA		0	6.419	1.159	0.081	0.033	0	0.430

NS not significant; *significant at $p < 0.05$ by the F test; ** significant at $p < 0.01$ by the F test

DMY and GMY means among the superior hybrid combinations to CP (Table 3). The means for DMY were similar to the results found by Melo et al. (1999a, 1999b), who reported a MS productivity between 9 and 22 ton ha^{-1}. Gomes et al. (2004) evaluated inbred maize lines and obtained a range between 5.84 to 15.68 t ha^{-1}, considered high due to their low vigor. The DMY found in this study was higher than that observed by Mello et al. (2005), who reported means of 22.4 and 28.6 t ha^{-1} for hybrid maize for silage production. Miranda et al. (2004) found a mean value of 14.92 t ha^{-1} in 49 silage maize hybrids. The best performance in this study, in the same region, was 21.52 t ha^{-1}. The average PH in hybrid combinations ranged from 187 to 216cm, close to the found by Bordallo et al. (2005) for maize cultivars. Fonseca et al. (2002) observed varieties of maize silage with PH means between 194 and 297 cm.

The components of the cell wall (NDF, ADF and HEM) showed no significant difference at 5% according to the F test (Table 2). Although there were no statistical differences in ADF, variance ranged from 15.47% (CD307 x P30F90) to 23.96% (P30F90 x DKB466), which represents a reduction of 35%, while NDF values were 33.87% (Valent x CD307) and 49.26% (P30F90 x DKB466), corresponding to a reduction of 31%. HEM ranged between 17.97% (Valent x CD307) and 25.29% (P30F90 x DKB466), corresponding to a 29% reduction (Table 3). Among the hybrid combinations showing highest crude protein average, the combinations Valent x CD307, AG1051 x 2B619, CD307 x P30F90, BRS3003 x 2B619 and CD307 x DKB 466 presented lowest NDF and ADF average values, which is desirable because many studies have shown that high fiber content has a negative impact on the digestibility of maize and other forage species (Casler and Jung, 1999). It is interesting to emphasize that there is wide variation in estimates of the components of the cell wall, the genetic variability of these traits has been reported in tropical and temperate

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

TABLE 3. Means of plant height (HP), green matter yield (GMY), dry matter yield (DMY), crude protein (CD), neutral detergent fiber (NDF, %) and acid detergent fiber (ADF ,%) and hemicellulose (HEM,%) for hybrid combinations obtained by diallel cross and controls in experiments conducted in Viçosa, MG. 2007.

Hybrid combination	HP (cm)	GMY (t ha^{-1})	DMY (t ha^{-1})	CP (%)	NDF (%)	ADF (%)	HEM (%)
2 x 3	216.89a	43.19a	17.34a	7.44a	33.87a	15.91a	17.97a
8 x 9	199.39b	41.54a	15.28b	7.42a	36.96a	16.88a	20.08a
2 x 9	199.28b	45.79a	16.16a	7.39a	44.63a	20.81a	23.81a
1 x 8	200.89b	36.79b	15.24b	7.32a	40.76a	18.13a	22.63a
1 x 9	191.00b	37.52b	14.12b	7.09a	43.01a	19.96a	23.05a
3 x 4	219.17a	38.55b	15.54a	7.07a	34.93a	15.47a	19.45a
2 x 7	202.17b	41.85a	17.10a	7.04a	40.16a	19.17a	20.98a
1 x 3	211.11b	38.39b	13.74b	7.00a	45.11a	21.46a	23.65a
2 x 10	230.45a	45.43a	17.35a	6.98a	41.28a	19.85a	21.42a
7 x 9	215.28a	47.69a	19.92a	6.96a	37.01a	16.80a	20.20a
9 x 10	200.39b	33.35b	13.38b	6.84a	41.06a	19.31a	21.76a
1 x 10	226.22a	47.89a	16.36a	6.82a	41.69a	19.70a	21.99a
3 x 10	226.22a	40.19b	14.79b	6.81a	39.06a	18.88a	20.17a
7 x 10	210.33b	44.43a	15.84a	6.72a	41.14a	19.43a	21.71a
DKB 333B	187.28b	34.12b	13.43b	6.68a	40.68a	18.92a	21.76a
4 x 5	218.44a	45.99a	16.39a	6.66a	40.31a	18.73a	21.57a
8 x 10	213.11b	34.53b	12.88b	6.65a	39.96a	19.17a	20.79a
3 x 9	209.50b	29.89b	10.69b	6.65a	40.74a	18.85a	21.88a
3 x 7	207.17b	40.07b	16.77a	6.64a	37.08a	17.75a	19.33a
2 x 4	229.22a	44.57a	17.09a	6.63a	44.06a	20.71a	23.35a
2 x 5	205.33b	34.05b	12.34b	6.62a	46.41a	22.44a	23.97a
5 x 9	212.67b	40.67b	15.40b	6.57a	38.72a	17.72a	20.99a
5 x 10	226.89a	42.41a	16.47a	6.55a	38.11a	18.86a	19.26a
4 x 10	226.83a	41.96a	14.37b	6.55a	49.26a	23.96a	25.29a
5 x 6	225.83a	46.88a	17.19a	6.49b	43.91a	21.92a	21.99a
3 x 5	216.67a	37.44b	15.83a	6.49b	40.38a	19.25a	21.13a
6 x 10	228.67a	48.59a	18.21a	6.45b	41.87a	21.16a	20.72a
1 x 7	197.33b	35.33b	13.99b	6.43b	40.65a	20.04a	20.61a
BR 201	199.39b	34.37b	12.61b	6.42b	43.29a	19.96a	23.32a
7 x 8	220.78a	43.62a	17.79a	6.41b	36.11a	17.32a	18.79a
5 x 7	206.89b	44.13a	17.54a	6.25b	38.07a	18.45a	19.62a
5 x 8	224.06a	46.37a	18.18a	6.23b	37.07a	18.23a	18.85a
6 x 9	225.61a	45.53a	16.63a	6.19b	45.54a	21.53a	23.99a
4 x 7	221.67a	43.38a	16.46a	6.18b	42.13a	19.01a	23.12a
1 x 5	198.72b	33.12b	12.83b	6.18b	47.23a	22.76a	24.44a
AG 2060	208.44b	34.04b	13.75b	6.16b	37.47a	16.52a	20.94a

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

Table 3 continuation

6 x 8	234.28a	47.21a	16.89a	6.15b	39.77a	18.66a	21.11a
6 x 7	222.39a	49.91a	18.59a	6.09b	42.79a	20.33a	22.45a
4 x 8	233.89a	45.99a	18.47a	6.09b	39.02a	18.41a	20.60a
4 x 6	230.72a	47.71a	18.26a	6.09b	38.69a	19.17a	19.52a
1 x 6	207.67b	37.87b	15.17b	6.08b	41.68a	20.10a	21.58a
DKB 747	198.78b	36.11b	14.49b	6.00b	38.39a	18.89a	19.49a
3 x 6	228.56a	34.77b	13.06b	5.99b	44.58a	21.58a	22.99a
2 x 6	227.17a	37.89b	15.02b	5.99b	39.44a	18.27a	21.17a
1 x 4	216.22a	45.23a	17.03a	5.99b	40.66a	18.58a	22.08a
4 x 9	216.22a	38.49b	14.46b	5.88b	40.35a	18.10a	22.25a
2 x 8	212.89b	39.76b	14.98b	5.84b	39.78a	19.29a	20.49a
1 x 2	196.17b	36.36b	13.46b	5.75b	43.05a	20.16a	22.89a
3 x 8	218.56a	30.01b	11.27b	5.66b	39.93a	19.05a	20.88a

1 = 1: XB8028; 2: Valent; 3:CD307; 4: P30F90; 5: Pointer; 6: SHS4070; 7: BRS3003; 8: AG1051; 9: 2B619; 10: DKB466. Means followed by identical letters belong to the same group according to the Scott e Knott test at 5% probability.

maize germplasm, and the practice of selecting plants has altered levels of these components (Barrière et al., 2003). These characteristics are important for obtaining high-quality silage hybrids because NDF levels above 60% have a negative correlation with the consumption of MS (Van Soest, 1994).

The hybrid combinations Valent x CD307 and AG1051 x 2B619 deserve attention, as both presented high means of GMY, DMY and CP and low NDF, ADF and HEM averages.

With regard to the GCA effects (GI) for CP, it seems that 2B619 is the genitor that promoted the most genetic gain followed by DKB466, CD307, Valent and BRS3003 (Table 4). This trait is important for obtaining silage with high nutritional value and high energy, along with DMY, GMY and digestibility. Among the hybrids with the highest CP averages, BRS 3003 and CD307 had a negative estimate for NDF, ADF and HEM, which indicated that they present higher digestibility and are therefore promising when the goal of the breeding program is the increased digestibility of the cell wall components. Several studies have demonstrated the relationship between silage digestibility and animal performance, indicating that more palatable maize hybrids improve food efficiency and, consequently, the performance of the animals (Barrière et al., 1992).

For GMY, GCA was highest in hybrids DKB 466 and BRS 3003, and for DMY it was highest in BRS3003. These hybrids could therefore have important contributions to increasing productivity.

For PH, hybrids DKB466 and CD307 had positive GCA estimates, indicating an increase in the genetic contribution to plant height in the hybrid combinations. The differences between cultivars can be explained by the effects of the characters of each hybrid on height and days for flowering (Table 1).

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

TABLE 4. Estimates of general combining ability effects (Gi) and standard deviation (SD) of hybrids for plant height (HP), green matter yield (GMY), dry matter yield (DMY), crude protein (CD), neutral detergent fiber (NDF, %) and acid detergent fiber (ADF,%) and hemicellulose (HEM,%) in experiments carried out in Viçosa, MG. 2007.

Hybrids	HP	GMY	DMY	CP	NDF	ADF	HEM
2B619	-9.025	-1.262	-0.640	0.289	0.051	-0.535	0.586
DKB466	5.933	1.041	-0.189	0.213	0.730	0.757	-0.027
CD307	1.599	-4.741	-1.519	0.136	-1.490	-0.760	-0.730
Valent	-2.858	-0.195	-0.043	0.124	0.634	0.293	0.341
BRS3003	-4.774	2.486	1.606	0.006	-1.556	-0.745	-0.810
XB8028	-12.024	-2.742	-1.155	-0.002	2.026	0.827	1.199
Pointer	-0.774	0.069	0.125	-0.076	0.323	0.512	-0.188
AG1051	1.933	-0.577	-0.024	-0.111	-2.278	-1.141	-1.136
P30F90	8.766	2.679	0.859	-0.188	0.225	-0.263	0.489
SHS4070	11.225	3.240	0.980	-0.392	1.333	1.056	0.277
SD (Gi)	3.110	1.283	0.496	0.107	1.005	0.582	0.465
SD (Gi-Gj)	4.636	1.913	0.739	0.160	1.498	0.868	0.694

Among hybrids, BRS3003 was the only one to combine positive estimates of GCA for DMY and CP and negative estimates for ADF, NDF and HEM. This is a very favorable combination, as demonstrated by the good performance of the characteristics associated to silage quality. These characteristics are mainly controlled by additive genetic effects, indicating that dominance effects contribute little to genetic variation.

The SCA effects can be interpreted as the expected deviation based on the general combining ability of the genitor combination. The highest estimates are found in cultivars with the most different gene frequencies, but estimates are also influenced by gene frequency in the diallel (Vencovsky, 1970). With regards to the SCA, only the hybrid combinations XB8028 x DKB466, Valent x CD307, Valent x DKB466, SHS4070 x AG1051, BRS3003 x 2B619 and 2B619 x AG1051 showed favorable signs of deviations of all the characteristics, i.e., positive for PH, GMY, DMY and CP and negative for ADF, NDF and HEM (Table 5). For the characteristics associated with digestibility, the lowest estimate indicates the best cultivar, as these cell wall components limit plant digestibility, which affects the nutritional value. The highest estimates for each trait were different among hybrid combinations. However, the combination of Valent x CD307 and AG1051 x 2B619 produced high estimates of DMY and CP as well as a lower estimate for ADF, NDF and HEM and an adequate average for these characteristics. These hybrids combined productivity and silage quality and may therefore be a promising combination for development of population-based programs for improving maize silage production.

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

TABLE 5. Estimates of specific combining ability effects (Sij) and standard deviation (SD) of hybrids for plant height (HP), green matter yield (GMY), dry matter yield (DMY), crude protein (CD), neutral detergent fiber (NDF,%) and acid detergent fiber (ADF,%) and hemicellulose (HEM,%) in experiments carried out in Viçosa, MG. 2007.

Hybrid combination	HP	GMY	DMY	CD	NDF	ADF	HEM
1 x 8	-5.041	-1.044	0.729	0.909	0.166	-0.918	1.085
8 x 9	-9.375	2.219	0.261	0.719	-1.660	-0.801	-0.859
2 x 3	2.125	6.969	3.211	0.655	-6.111	-2.987	-3.123
3 x 4	-6.833	-0.544	0.508	0.607	-4.647	-2.867	-1.780
2 x 9	-4.583	6.085	1.158	0.456	3.094	1.689	1.404
5 x 6	-0.583	2.409	0.405	0.441	1.412	0.987	0.424
4 x 5	-5.125	2.089	-0.284	0.409	-1.093	-0.874	-0.218
2 x 7	-6.166	-1.606	-0.146	0.387	0.233	0.259	-0.026
1 x 3	5.958	4.715	0.725	0.349	3.727	2.027	1.699
1 x 9	-3.749	0.367	0.231	0.287	0.090	0.304	-0.213
2 x 4	7.625	0.924	0.585	0.170	2.356	1.317	1.038
4 x 6	-5.125	0.627	0.731	0.158	-3.709	-0.985	-2.724
7 x 9	13. 333	5.243	3.270	0.145	-2.328	-1.273	-1.054
6 x 8	5.375	3.389	0.254	0.135	-0.134	-0.622	0.488
2 x 10	11.458	3.424	1.890	0.122	-0.933	-0.563	-0.370
6 x 10	-4.291	3.155	1.728	0.104	-1.031	-0.019	-1.012
1 x 10	16.625	8.427	2.018	0.091	-1.911	-1.248	-0.663
2 x 5	-6.833	-6.988	-3.425	0.049	4.608	2.275	2.333
8 x 10	-10.333	-7.097	-2.586	0.036	0.667	0.194	0.473
4 x 10	-3.833	-2.923	-1.982	0.008	7.458	4.110	3.347
7 x 8	7.708	0.550	0.527	-0.006	-0.891	-0.157	-0.734
7 x 10	-6.625	-0.260	-1.262	-0.019	1.124	0.054	1.070
3 x 7	-5.291	1.164	0.998	-0.026	-0.718	-0.110	-0.608
6 x 7	0.083	3.018	0.322	-0.038	2.163	0.653	1.509
1 x 6	-7.000	-3.790	-0.343	-0.047	-2.524	-1.146	-1.378
3 x 10	3.000	2.731	0.816	-0.056	-1.025	-0.475	-0.550
3 x 5	0.374	0.953	1.537	-0.083	0.700	0.129	0.570
5 x 8	7.041	5.715	2.387	-0.097	-1.814	-0.506	-1.307
1 x 7	-1.333	-5.577	-2.142	-0.097	-0.661	0.597	-1.258
5 x 10	6.041	0.133	0.852	-0.102	-3.785	-1.774	-2.010
4 x 8	7.499	2.724	1.942	-0.122	0.230	0.455	-0.225
4 x 7	1.875	-2.947	-1.689	-0.150	2.618	0.655	1.962
5 x 9	6.999	0.638	0.234	-0.159	-2.496	-1.614	-0.882
9 x 10	-12.041	-7.590	-1.474	-0.184	-0.562	-0.278	-0.284
5 x 7	-3.583	0.414	0.123	-0.194	-1.541	-0.680	-0.861
6 x 9	8.000	2.393	0.600	-0.226	3.305	1.654	1.650

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

Table 5 continuation

2 x 6	3.166	-6.317	-1.609	-0.254	-3.370	-2.440	-0.930
1 x 5	-4.333	-5.367	-1.830	-0.263	4.009	2.058	1.950
3 x 6	0.375	-4.886	-2.090	-0.272	3.889	1.917	1.971
3 x 9	0.958	-5.272	-2.833	-0.291	1.331	0.782	0.548
1 x 4	3.458	4.133	1.636	-0.334	-2.438	-1.349	-1.089
2 x 8	-2.208	-0.626	-0.641	-0.692	0.582	0.774	-0.192
4 x 9	0.458	-4.084	-1.447	-0.746	-0.774	-0.462	-0.311
3 x 8	-0.666	-5.831	-2.874	-0.882	2.854	1.583	1.271
1 x 2	-4.583	-1.864	-1.022	-0.893	-0.459	-0.326	-0.132
SD (Sij)	8.177	3.374	1.304	0.283	2.643	1.531	1.224
SD (Sij – Sik)	12.266	5.0621	1.9571	0.425	3.965	2.297	1.837
SD (Sij – Skl)	11.356	4.6866	1.8119	0.393	3.671	2.127	1.700

1 = 1: XB8028; 2: Valent; 3:CD307; 4: P30F90; 5: Pointer; 6: SHS4070; 7: BRS3003; 8: AG1051; 9: 2B619; 10: DKB466

Conclusion

The strategy of using the combining ability of genitors has proven effective in identifying hybrid combinations with improved productivity and high quality silage.

These hybrids have the genetic potential to increase average productivity associated with high quality silage, achieving greater complementarities of favorable alleles.

The combinations of hybrid cultivars Valent x CD307 and AG1051 x 2B619 showed high estimates of specific combining ability for all the variables studied, and so are promising for breeding programs for maize silage production.

Acknowledgments

We thank to our friends of Programa Milho of Universidade Federal de Viçosa, Laboratório de Biotecnologia e Melhoramento Vegetal (LBMV). We are grateful for financial support and grants of Fundação de Apoio a Pesquisa em Minas Gerais (FAPEMIG), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

References

ALLEN, M. S.; MAIN, D. G.; O'NEIL, K. A.; BECK, J. Variation in fiber fractions and in vitro true and cell wall digestibility of corn silage hybrids. **Journal of Dairy Science**, Champaign, v. 73, p. 129, 1990. Supplement 1.

BARRIÈRE, Y.; TRAINEAU, R.; EMILE, J. C.; HÉBERT, Y.; Variation and covariation of silage maize digestibility estimated from digestion trials with sheep, **Euphytica**, Wageningen, v. 59, p. 61–72, 1992.

BARRIÈRE, Y.; GUILLET, C.; GOFFNER, D.; PICHON, M.; Genetic variation and breeding strategies for improved cell wall digestibility in annual forage crops. A review.

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

Animal Research, Haddington, v. 52, p. 193–228, 2003.

BARRIÈRE, Y.; EMILE, J. C.; TRAINEAU, R.; SURAULT, F.; BRIAND, M.; GALLAIS, A. Genetic variation for organic matter and cell wall digestibility in silage maize. Lessons from a 34-year long experiment with sheep in digestibility crates. **Maydica**, Bergamo, v. 49, p. 115–126, 2004.

BARRIÈRE, Y.; ALBER, D.; DOLSTRA, O.; LAPIERRE, C.; MOTTO, M.; ORDAS, A.; VAN WAES, J.; VLASMINKEL, L.; WELCKER, C.; MONOD, J. P. Past and prospects of forage maize breeding in Europe. I. The grass cell wall as a basis of genetic variation and future improvements in feeding value. **Maydica**, Bergamo, v. 50, p. 259–274, 2005.

BORDALLO, P. N.; PEREIRA, M. G.; AMARAL JÚNIOR, A. T.; GABRIEL, A. P. C. Análise dialélica de genótipos de milho doce e comum para caracteres agronômicos e proteína total. **Horticultura Brasileira**, Brasília, DF, v. 23, n. 1, p.123-127, 2005.

CASLER, M. D.; JUNG, H. J. G. Selection and evaluation of smooth bromegrass clones with divergent lignin or etherified ferulic acid concentration. **Crop Science**, Madison, v. 39, p. 1866–1873, 1999.

CRUZ, C. D. **Programa GENES**–Aplicativo computacional em genética e estatística. Editora UFV: Viçosa, 1997. 394 p.

CRUZ, C. D.; REGAZZI, A. J. **Modelos biométricos aplicados ao melhoramento genético**. 3. ed. Viçosa: UFV, 2004. 390 p.

DHILLON, B. S.; PAUL, C.; ZIMMER, E.; GURRATH, P. A.; KLEIN, D.; POLLMER, W. G. Variation and covariation in stover digestibility traits in diallel crosses of maize. **Crop Science**, Madison, v. 30, p. 931-936, 1990.

FERRET, A.; GASA, J.; PLAIXATS, J.; CASANÃS, F.; BOSH, L.; NUEZ, F. Predition of voluntary intake and digestibility of maize silages given to sheep from morphological and chemical composition, in vitro digestibility or rumen degradation characteristics. **Animal Science**, Haddington, v. 64, p. 493 - 501, 1997.

FONSECA, A. B. **Características químicas e agronômicas associadas a degradabilidade da silagem de milho**. 2000. 93 f. Dissertação (Mestrado) - Universidade Federal de Lavras, Lavras.

GOMES, M. S.; PINHO, R. G. V.; RAMALHO, M. A. P.; FERREIRA, D. V.; BRITO, A. H.; Variabilidade genética em linhagens de milho nas características relacionadas com a produtividade de silagem. **Pesquisa Agropecuária Brasileira**, Brasília, DF, v. 39, n. 9, p 879-885, 2004.

GRIFFING, B. Concept of general and specific combining ability in relation to diallel crossing systems. **Australian Journal of Biological Science**, Melbourne, v. 9, p. 463-493, 1956.

HORWITZ, W. (Ed.). **Official methods of analysis of the Association of Official Analytical Chemists**. 13. ed. Washington: AOAC, 1980. 1018 p.

KRAKOWSKY, M. D.; LEE M.; COORS J. G., Quantitative trait loci for cell wall components

http://dx.doi.org/10.18512/1980-6477/rbms.v7n2p183-194

in recombinant inbred lines of maize (Zea mays L.) II: leaf sheath tissue. **Theoretical Applied Genetics**, New York, v. 112, p. 717–726, 2006.

MELO, W. M. C.; PINHO, R. G. V.; CARVALHO M. L. M.; PINHO, E. V. R. V.; Avaliação de cultivares de milho para produção de silagem na região de Lavras- MG. **Ciência e Agrotécnica**, Lavras, v. 23, n.1, p. 31-39, 1999a.

MELO, W. M. C.; PINHO, R. G.VON; PINHO, E. V. R. VON; CARVALHO, M. L. M.; FONSECA, A. H. Parcelamento da adubação nitrogenada sobre o desempenho de cultivares de milho para produção de silagem. **Ciência Agrotecnológica**, Lavras, v. 23, p. 608 - 616, 1999b.

MELLO, R.; NÖRNBERG, J. L.; ROCHA, M. G. da; DAVID, D. B. de.; Características produtivas e qualitativas de híbridos de milho para produção de silagem. **Revista Brasileira de Milho e Sorgo,** Sete Lagoas, v. 4, n.1, p. 79-94, 2005.

MIRANDA, G. V.; RODRIGUES, T. C.; SOUZA, L. V.; FURTADO, A. L.; CALAIS, M. J. R.; CRUZ, J. R. S.; BARROS, H. B. Desempenho de novos cultivares de milho para a produção de silagem na região de Viçosa, MG. **Revista Ceres**, Viçosa, MG, v. 51, n. 298, p. 707-718, 2004.

ROTH, L. S.; MARTEN, G. C.; COMPTON, W. A.; STUTHMAN, D. D. Genetic variation for quality traits in maize (*Zea mays* L.) forage. **Crop Science**, Madison, v. 10, p. 365-367, 1970.

SILVA, P. C. **Seleção recorrente recíproca e cruzamentos dialélicos em milho (*Zea mays* L.) para a obtenção e avaliação de híbridos forrageiros**. 2002. 92 f. Tese (Doutorado em Genética e Melhoramento de Plantas) – Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Jaboticabal.

VAN SOEST, P. J.; ROBERTSON, J. B.; LEWIS, B. A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. **Journal of Dairy Science**, Champaign, v. 74, p. 3583-3597, 1991.

VAN SOEST, P. J. **Nutritional ecology of the ruminant**, 2 ed. Ithaca: Cornell University Press, 1994. 476 p.

VENCOVSKY, R. **Alguns aspectos teóricos e aplicados relativos a cruzamento dialélicos de variedades**. 1970. 59 f. Tese (Livre-Docente) – Escola Superior “Luiz de Queiroz”. Universidade de São Paulo, Piracicaba.