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ESTIMATES OF MEANS COMPONENTS FOR MAIZE GRAIN-FILLING TRAITS

Abstract – One of the strategies to increase maize yield is to select lines that present a higher matter accumulation rate in the grains. This work was carried out to identify the population with the most significant potential to obtain this line type. For this, nine commercial hybrids' F_1 and F_2 generations were evaluated in four environments, involving two years and two seasons each year. The traits evaluated were the number of days to female flowering (NDF) and physiological maturity (NDPM), dry matter accumulation rate (RATE), and grain yield (YLD). For each trait, the contribution of the loci in homozygosity ($m+a$) and heterozygosis (d) was estimated. NDF, NDPM, and RATE predominated an additive effect with a higher $m+a$ estimate. Regarding YLD, the estimate of d was much higher than $m+a$, indicating the greater importance of dominance. Hybrid 5 is the most promising for obtaining the segregating population because it associates a high $m+a$, and d estimate that, although it was not among the highest, represented 56.03% of the average. For this hybrid, considering the YLD, the mean of the lines in $F\infty$ will be the highest and associated with sufficient variability in the population to enable successful selection.

Keywords: Plant breeding, Quantitative Genetics, Components of mean.

ESTIMATIVAS DE COMPONENTES DE MÉDIAS DOS CARACTERES RELACIONADOS AO ENCHIMENTO DE GRÃOS DE MILHO

Resumo - Uma das estratégias para se aumentar a produtividade da cultura do milho é selecionar linhagens que apresentem maior taxa de acúmulo de matéria seca nos grãos. Para se identificar população com maior potencial na obtenção desse tipo de linhagem foi realizado esse trabalho. Para isso, as gerações F_1 e F_2 de nove híbridos comerciais, foram avaliadas em quatro ambientes, envolvendo dois anos e duas safras, em cada ano. Os caracteres avaliados foram o número de dias para o florescimento feminino (NDF) e maturidade fisiológica (NDPM), taxa de acúmulo de matéria seca (RATE) e produtividade de grãos (YLD). Estimaram-se para cada um deles, a contribuição dos locos em homozigose ($m+a$) e heterozigose (d). Para os caracteres NDF, NDPM e RATE, predominou efeito aditivo (maior estimativa de $m+a$). Com relação a YLD a estimativa de d foi bem superior a $m+a$, indicando a maior importância da dominância. O híbrido 5 é o mais promissor para obtenção de populações segregantes, pois associa alta estimativa de $m+a$ e d, que embora não estivesse entre as maiores. Correspondeu a 56,03% da média. Para esse híbrido, considerando o YLD, a média das linhagens, na $F\infty$, será a maior e associado a suficiente variabilidade, na população, para possibilitar sucesso com a seleção.

Palavras-chave: Melhoramento de plantas, Genética Quantitativa, Componentes de média.

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Maize yield in Brazil has increased significantly over the last 40 years (Ramalho et al., 2017, 2021). This increase is particularly significant because, in the last 30 years, maize has grown at two seasons per year. In the first season, the sowing extends from September to November, depending on the region, and in the second season, sowing occurs primarily from January to March. This second season is grown under unfavorable conditions due to several factors. The rainfall amount and distribution is the predominant factor in southern Minas and other regions of Brazil (Andrea et al., 2019). Additionally, the presence of maize plants in the field throughout the entire year has created substantial problems with pests and pathogens that were previously less significant. Despite these issues, the success of this second season has been substantial and currently accounts for more than 50% of the maize production in Brazil (CONAB, 2017).

A considerable research effort has been made to continue the increase in yield. Breeding programs are notable for many lines acquired and hybrids tested annually, primarily by private companies. Among the traits that affect maize yield those related to the number of days to flowering (NDF), the number of days to physiological maturity (NDPM), and the rate of dry matter accumulation (RATE) in the grains are essential.

Grain filling is divided into three phases. Initially, there is a relatively short period in which the dry matter accumulation is still incipient. This stage is characterized by rapid cell division that aims to increase the number of cells in the grain (Yadegari & Drews, 2004). In the literature, this period is referred to as the lag phase (Gasura et al., 2014). This phase begins with fertilization, but its end is more challenging to determine. When dry matter accumulation begins, the second period is the linear phase. Ultimately, the duration and rate of dry matter accumulation during this phase determine the grains' final dry weight and yield. This period begins 7 to 15 days after fertilization and ends when the black layer is formed. This black layer indicates the termination of dry matter accumulation in the grain and corresponds to the end of the grain-filling stage (Gasura et al., 2014). The final period, called the maturation drying phase, corresponds to the loss of water by the grain until the moment of harvest.

One of the alternatives is to seek more information about genetic control. Then, depending on the type of allelic interaction, the breeder can direct his work towards improving the performance of the lines *per se* or in heterosis. Different methodologies can be applied to study the genetic control of a trait (Bernardo, 2020; Hallauer et al., 2010; Ramalho et al., 2012a). These methodologies include the use of variances or means. In the latter case, the estimates of $m+a$ (the contribution of homozygous loci) and d (the contribution of heterozygous loci) have some advantages. Furthermore, due to its feasibility and less associated error genetic control of traits can be used to identify new lines in populations with a higher mean in $F\infty$ generation and more

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significant variability for selection (Vencovsky, 1987; Ramalho et al., 2012b).

Some studies have estimated *m*+*a* and *d* for grain yield in maize (Souza Sobrinho, 2001; Viana et al., 2009; Ribeiro et al., 2014). Overall, the authors report an expressive dominance effect on the phenotypic expression of this trait. It is crucial to assess whether these estimates behave similarly for traits related to the blooming and grain-filling periods directly associated with yield.

This study aimed to obtain information on genetic control through estimates of the contribution of homozygous loci (*m*+*a*) and heterozygous loci (*d*) of the traits: the number of days for female flowering, the number of days to physiological maturity, the dry matter accumulation rate and grain yield, aiming to identify promising commercial hybrids for extraction of lines, focusing on those traits.

Materials and Methods

The study was conducted in the experimental area of the Center for Scientific and Technological Development at the Federal University of Lavras (UFLA), which is located in the southern region of the state of Minas Gerais (MG), Lavras, Brazil, at 919 m elevation, 21º14'S and 45º'W. The regions' mean temperature and precipitation data were obtained for the experimental period (Figure 1).

Table 1 lists the nine commercial hybrids that were used in this study. The commercial seeds correspond to the F_1 generation. Seeds of the F_2 generation were obtained by self-fertilization of a sample of plants from the F_1 generation of each hybrid. The F_1 and F_2 generations of the different hybrids were evaluated in four sowing seasons: two sowed in October/November and two sowed in January for two years.

The experiments utilized a randomized complete block design with four replicates of a split-block arrangement. The plots containing each treatment's F_1 and F_2 generations were close. The plots consisted of three 4-m-long rows with eight seeds/linear m, leaving four plants/linear m after thinning. The rows were spaced 60 cm apart. The remaining crop management practices were those typically adopted in the region.

The variables to be analyzed were: a) the number of days to female flowering (NDF). The NDF was defined as the number of days from sowing until 50% or more of the plants in the plot exhibited female flowering; b) number of days to physiological maturity (NDMP). NDMP was defined as the number of days from flowering until the black layer appeared in 50% of the grains. The NDMP was evaluated at the time of sampling to determine the dry matter accumulation; c) means of dry matter accumulation rate (RATE).

At ten days after flowering, one ear per plant was collected from the plot's central row at regular intervals of seven days to determine the RATE. From the harvested ear, 100 grains were obtained which were removed from the central part of the ear and then dried in a forced-air oven at approximately 80º C for 96 hours. The equation to evaluate dry matter accumulation

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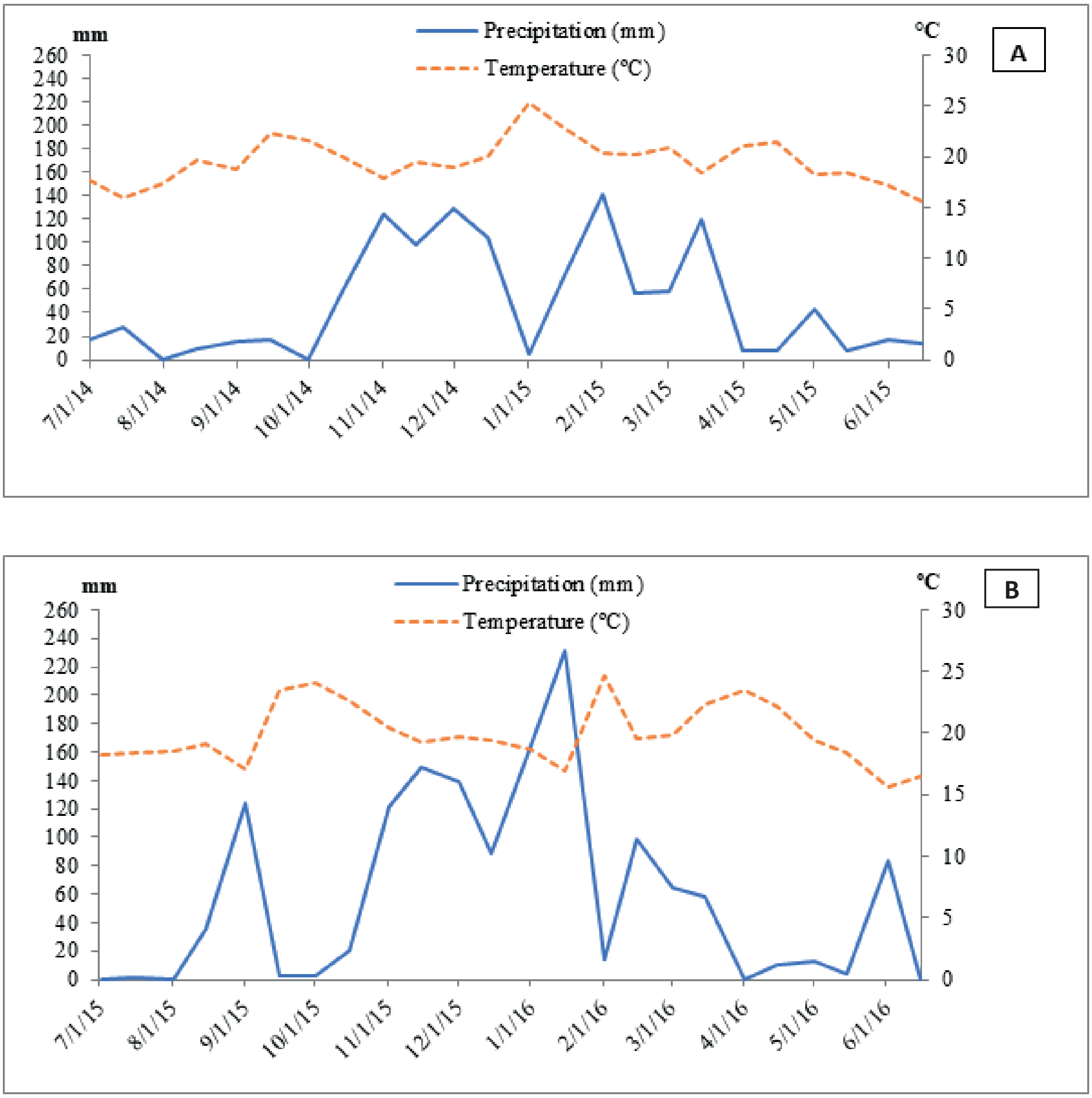

Figure 1. Mean precipitation and temperature during the study. **A**. Experiments conducted during 2014/2015. **B**. Experiments conducted during 2015/2016.

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Table 1. Identification and some characteristics of the commercial hybrids used to estimate the mean genetic components.

Number	Hybrid	Company	Type of grain
1	Formula TL	Syngenta	Semi-dent, Yellow and Orange
2	AS 1551 PRO2	Agroeste	Semi-dent, Yellow
3	AS 1656 PRO2	Agroeste	Semi-dent, Yellow and Orange
4	AS 1660 PRO2	Agroeste	Semi-dent, Yellow and Orange
5	AG 7088 PRO	Agroceres	Semi-dent, Yellow and Orange
6	DAS 2B587 HX	Dow AgroSciences	Orange
7	DAS 2B810 PW	Dow AgroSciences	Semi-dent and Orange
8	DKB 390 PRO	Bayer	Flint, Yellow and Orange
9	P 30F53H	Pioneer	Semi-dent, Orange

in maize grains should represent the biological phenomenon as best as possible, which was challenging. The literature provides alternative approaches (Darroch & Baker, 1990; Borrás et al., 2003; Prado et al., 2013; Gasura et al., 2013, 2014), and the one adopted in this study was the logistic equation used by Darroch and Baker (1990). The daily rate per plot was obtained by dividing the dry matter at physiological maturity by the number of days to physiological maturity; d) grain yield (YLD). The YLD was obtained by weighing the threshed grains (g plant^{-1}) from one of the plot rows corrected to 13% moisture, in which no ear sampling was performed.

The individual variances analysis was realized for each trait, and afterward, the joint variance analysis was carried out (Ramalho et al., 2012a). The contribution of homozygous loci (*m*+*a*) for each plot was estimated using the estimator $2F_2 - F_1$. The contribution of heterozygous loci (*d*) was estimated using the estimator $2(F_1 - F_2)$ where F_1 and F_2 are the data obtained for each hybrid in the F_1 and F_2 generations. An analysis of variance was also realized for *m*+*a* and *d*. Later, a joint analysis was realized for all characters and considering all environments. No restriction was observed regarding the assumptions of the analysis of variance. The level of inbreeding depression (%) was estimated using the equation $\left[\left(\bar{F}_1 - \bar{F}_2\right) \div \bar{F}_1\right] x100$ .All analyses were performed using the R software (R development core team, 2015).

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Results and Discussion

All sources of variation for the evaluated traits were significant (p≤0.01), except for the F_1 vs. F_2 contrast x environment interaction for NDPM (Table 2). However, it is essential to emphasize that although the hybrid x F_1 vs. F_2 contrast and the hybrid x environment interactions were significant, the focus was on the overall mean because there was relatively good agreement in the comparison between the F_1 and F_2 generations for the different hybrids, the primary aiming of this study. Regarding the significant interaction, the objective was not to study the interaction by the environment but to have more replications of the results to have greater security in the inferences. Although, the issue of hybrid x contrast interaction for different traits will be further discussed in some situations.

The NDF was very similar among the four seasons. The range in the NDF was only three days, i.e., 4.5% of the overall mean (66 days). Although the F test was significant for the NDF, the averages in the NDF between the environments were very similar. The significance was due, probably, to the greater precision with which they evaluated this characteristic. The mean number of days from flowering to physiological maturity (the mean of the four-season, nine hybrids, and two generations) was 62 days (Table 3).

About the RATE, it is evident that the daily dry matter accumulation rate for the second season was lower than in the first season (Table 3). On average for the two years, the RATE for the first season was 12.6% higher than the average of the second season.

The effect of the environment on YLD was very similar to the results for RATE. The YLD was consistently higher in the first season. On average, the yield of the first season (sown in October and November) was 35.4% higher than the second season (sown in January/March). Results obtained previously in this region indicate that the delay in sowing maize afterward in October resulted in a reduction of 27 kg ha^{-1} day^{-1}; this was true for sowing until December (Ramalho et al., 2001). Similarly, Ribeiro (1998) documented a reduction of 28.3 kg ha^{-1} day^{-1}. It should be emphasized that in these last two reports, the delay in sowing was evaluated considering only the first season. Similar results were obtained by Pereira et al. (2022) in hybrid evaluation experiments, carried out in several locations in Brazil, involving both seasons.

The environmental stress in the second season is even greater (Andrea et al., 2019). The most significant area sown in Brazil's southern and central regions is usually in the second season. In the southern region of Minas Gerais, the planted area is increasing in the second harvest, and the primary stress observed is the irregularity in the distribution of rainfall (Figure 1). Durães et al. (2004) reported that a water deficit, particularly during flowering and grain filling, is considered limiting in obtaining maximum yield.

Considering the average of the hybrids, NDF formed five groups with the Scott and

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Table 2. Summary of joint analysis of variance for the number of days to female flowering (NDF), the mean number of days to physiological maturity (NDPM), mean of dry matter accumulation rate (RATE: 10^{-3} g grain^{-1} day^{-1}), and grain yield (YLD; g plant^{-1}) of the F_1 and F_2 generations of nine commercial maize hybrids in the four environments (Years/seasons) evaluated in Lavras, MG.

SV	df	MS			
		NDF	NDPM	RATE (10^{-3})	YLD
Environment (E)	3	128.55**	1050.21**	8.19**	67635.20**
Rep/E	12	8.25	7.63	0.13	540.93
Hybrids (H)	8	80.87**	55.90**	3.965**	3709.80**
H x E	24	7.93**	55.60**	0.38**	1930.51**
Error a	96	1.54	3.34	0.02	78.25
Generations (G)	1	783.42**	95.68**	9.54**	189638.13**
G x E	3	32.21**	15.58^{ns}	2.07**	921.85**
Error b	12	1.66	4.59	0.03	24.60
H x G	8	17.04**	55.13**	0.25**	641.31**
H x G x E	24	3.86**	53.68**	0.25**	417.21**
Error c	96	1.17	1.85	0.02	31.69
Mean		**66.00**	**62.19**	**4.09**	**116.71**

**, significant by the F test at the 1% probability; ^{ns}, not significant by the F test.

Knott (1974) test (Table 4). Hybrid 4 flowered the earliest, and hybrids 7, 8, and 9 flowered the latest. Regarding the NDPM, only two groups were formed (Table 4). The ideal hybrid would combine the earliest flowering and most extended period of dry matter accumulation in the grains.

The hybrids were also classified into five groups for RATE (Table 5). Hybrids 6, 8, and 9 showed the highest mean dry matter accumulation rate. For YLD, the variability was even more remarkable, and the hybrids were classified into seven groups. The highest mean yield was exhibited by hybrid 6 (Table 5). Hybrid 6 was also classified in the group with the highest dry matter accumulation rate. Gasura et al. (2014) reported a positive association ($r_{gg'}$ = 0.61) between these two traits, explaining why the same hybrid combines a high dry matter accumulation rate and a high grain yield.

It is important to note that there was a significant difference between the F_1 vs. F_2 contrast, which is essential for achieving the objectives of this study. Among the traits evaluated, the NDF showed a distinct response, i.e., the mean for the F_2 generation, for all hybrids and environments, was higher than the F_1 generation (Table 4). The effect of inbreeding depression was similar among the hybrids for RATE and YLD. However, the overall mean inbreeding depression for YLD (36%) was higher

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Table 3. The mean number of days to female flowering (NDF), the mean number of days to physiological maturity (NDPM), mean of dry matter accumulation rate (RATE: 10^{-3} g grain^{-1} day^{-1}), and grain yield (YLD: g plant^{-1}) of for the F_1 and F_2 generations of nine commercial maize hybrids in the four environments (Years/seasons) evaluated in Lavras, MG.

	NDF			**NDPM**		
	F_1	**F_2**	**Mean**	**F_1**	**F_2**	**Mean**
1st season of 2014/2015	65.36	70.14	67.75	64.03	63.47	63.75
2st season of 2015	64.36	66.56	65.46	64.31	63.39	63.85
1st season of 2015/2016	62.56	66.64	64.60	65.94	63.42	64.68
2st season of 2016	65.11	67.25	66.18	56.81	56.19	56.50
Mean	**64.35**	**67.65**	**66**	**62.77**	**61.62**	**62.19**
		RATE (10^{-3})			**YIELD**	
1st season of 2014/2015	4.46	3.76	4.11	134.20	78.33	106.27
2st season of 2015	3.94	3.76	3.85	126.31	78.47	102.39
1st season of 2015/2016	4.56	4.57	4.57	191.51	132.97	162.24
2st season of 2016	4.15	3.55	3.5	117.47	74.43	95.95
Mean	**4.28**	**3.91**	**4.09**	**142.37**	**91.05**	**116.71**

than for RATE (8.5%) (Tables 5).

The joint analysis results for the estimates of *m*+*a* and *d* are shown in Tables 6 and 7. There was a significant difference in the estimates for all the evaluated traits. For NDF, as previously mentioned, the dominance was in the direction of reducing the trait expression. It is worth noting that although the estimate of *d* was always of small magnitude, it was significant, primarily due to the high accuracy of the evaluation of this trait. In the literature, some report that when dominance occurs, it has a negligible effect on the trait expression (Hallauer et al., 2010). However, the NDF results indicate that the additive effect predominates for this trait, as seen by the enormous magnitude of *m*+*a* compared with *d*.

For the NDPM, the dominance effect was also less relevant than the additive effect. In the literature, there are few reports of this phenomenon. However, using variance components, Wang et al. (1999) and Gasura et al. (2013) showed that the dominance variance was more significant than the additive variance.

As expected, the dominance effect was also less critical than the additive effect for the RATE. In the mean of the nine hybrids, *m*+*a* contributed almost 83% to the mean performance (Table 5). Similar results were obtained by Gasura et al. (2013).

Table 4. Mean of F_1 and F_2 generations and estimates of *m+a* and *d* for the number of days to female flowering (NDF) and physiological maturity (NDPM). Means were calculated for the four environments (Years/season) of nine hybrids evaluated in Lavras, MG.

NDF							
Hybrids	F_1	F_2	**Mean**	*m+a*	**(%)[2]**	**d**	**(%)[2]**
1	62.19	66.37	64.28d[1]	70.56c	113.47	-8.38b	-13.47
2	63.44	67.06	65.25c	70.69c	111.43	-7.25b	-11.43
3	63.87	68.69	66.28b	73.50b	115.07	-9.62c	-15.07
4	62.37	64.00	63.19e	65.62d	105.21	-3.25a	-5.21
5	64.81	68.81	66.81b	72.81b	112.34	-8.00b	-12.34
6	63.75	67.00	65.37c	70.25c	110.20	-6.50b	-10.20
7	65.00	70.25	67.62a	75.50a	116.15	-10.50c	-16.15
8	67.06	68.37	67.72a	69.69c	103.91	-2.63a	-3.91
9	66.62	68.25	67.44a	69.87c	104.91	-3.25a	-4.88
Mean	**64.35**	**67.65**	**66.00**	**70.94**	**110.30**	**-6.56**	**-10.30**
NDPM							
1	60.69	60.65	60.62b[1]	60.44b	99.6	0.25c	0.41
2	62.75	59.50	61.12b	56.25c	89.6	6.50b	10.36
3	65.19	62.25	63.72a	59.31b	91.0	5.88b	9.01
4	61.19	62.19	61.69b	63.19a	103.3	-2.00c	-3.27
5	60.19	61.44	60.81b	62.69a	104.2	-2.50c	-4.15
6	64.12	61.69	62.91a	59.25b	92.4	4.88b	7.60
7	67.37	61.31	64.34a	55.25c	82.0	12.12a	18.00
8	62.50	62.50	62.87a	64.00a	102.4	-1.50c	-2.40
9	60.94	62.37	61.66b	63.81a	104.7	-2.88c	-4.72
Mean	**62.77**	**61.62**	**62.19**	**60.46**	**95.57**	**2.31**	**3.43**

[1]Means followed by the same letter in the same column belong to the same group based on the Scott and Knott (1974) test at the 5% probability level.

[2]Percent contribution of *m+a* and *d* to trait manifestation as calculated from the expression $\left[(m+a)\div\overline{F_1}\right]\times 100$ or $\left[(d)\div\overline{F_1}\right]\times 100$. Values greater than 100% occur when *d* is negative. *m+a* was the estimate greater than 100 because the dominance was in the direction of reducing the phenotypic expression of the trait. However, a magnitude of *d*, as can be recorded, was minimal.

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Table 5. Mean of F_1 and F_2 generations and estimates of *m+a, d*, and inbreeding depression for the dry matter accumulation rate (RATE; 10^{-3} g $grain^{-1}$ day^{-1}) and grain yield (YLD; g $plant^{-1}$). Means were calculated for the four environments (Years/season) of nine hybrids evaluated in Lavras, MG.

RATE								
Hybrids	**F_1**	**F_2**	**Mean**	**Inbreeding depression**	***m+a***	**(%)[2]**	***d***	**(%)[2]**
1	3.84	3.35	3.59e[1]	12.92	2.85d	74.15	0.99b	25.85
2	4.21	3.75	3.98c	10.90	3.29c	78.20	0.92b	21.80
3	4.33	4.15	4.24b	4.21	3.97a	91.58	0.36c	8.42
4	4.36	4.13	4.25b	5.39	3.89a	89.23	0.47c	10.77
5	4.04	3.40	3.72d	15.8	2.76d	68.41	1.28a	31.59
6	4.52	4.31	4.41a	4.60	4.10a	90.79	0.42c	9.21
7	3.80	3.62	3.71d	4.69	3.45c	90.62	0.36c	9.38
8	4.58	4.27	4.42a	6.77	3.96a	86.47	0.62c	13.53
9	4.81	4.24	4.53a	11.84	3.67b	76.33	1.14a	23.67
Mean	**4.28**	**3.91**	**4.09**	**8.51**	**3.55**	**82.86**	**0.73**	**17.14**
YLD								
1	124.91	77.07	100.99f[1]	38.30	29.23d	23.40	95.69b	76.60
2	132.40	86.50	109.45e	34.67	40.60c	30.67	91.80b	69.33
3	144.29	95.87	120.08d	33.56	47.44b	32.88	96.85b	67.12
4	118.61	79.72	99.16g	32.79	40.83c	34.43	77.77c	65.57
5	144.05	103.60	123.83c	28.08	63.16a	43.84	80.89c	56.26
6	156.71	98.07	127.39a	37.42	39.42c	25.15	117.29a	74.85
7	150.40	89.60	120.00d	40.43	28.79d	19.14	121.61a	80.86
8	152.64	94.11	123.38c	38.35	35.58c	23.31	117.06a	76.69
9	157.32	94.92	126.12b	39.67	32.51d	20.66	124.82a	79.34
Mean	**142.37**	**91.05**	**116.71**	**36.05**	**39.73**	**28.17**	**102.64**	**71.83**

[1]Means followed by the same letter in the same column belong to the same group based on the Scott and Knott (1974) test at the 5% probability level.

[2]Percent contribution of *m+a* and *d* to trait manifestation as calculated from the expression $\left[(m+a)\div\overline{F_1}\right]\times 100$ or $\left[(d)\div\overline{F_1}\right]\times 100$.

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Table 6. Joint analysis of variance of the estimate of *m+a* for the number of days to female flowering (NDF), the number of days to physiological maturity (NDPM), the dry matter accumulation rate (RATE; 10^{-3} g grain^{-1} day^{-1}) and grain yield (YLD; g plant^{-1}) for the four environments (Years/season) of nine commercial maize hybrids in Lavras, MG.

SV	DF	MS			
		NDF	NDPM	RATE (10^{-3})	YLD
Environment (E)	3	276.76**	408.60**	20.00**	19843.30**
Rep/E	12	43.91	104.53	0.58	678.82
Hybrids (H)	8	124.98**	167.64**	3.94**	1819.31**
ExH	24	27.49**	268.32**	1.13**	2829.04**
Residual	96	6.87	11.81	0.09	152.21

**significant by the F test at the 1% level.

Table 7. Joint analysis of variance of the estimate of *d* for the number of days to female flowering (NDF), the number of days to physiological maturity (NDPM), the dry matter accumulation rate (RATE; 10^{-3} g grain^{-1} day^{-1}), and grain yield (YLD; g plant^{-1}) for the four environments (Years/season) of nine commercial maize hybrids in Lavras, MG.

SV	DF	MS			
		NDF	NDPM	RATE (10^{-3})	YLD
Environment (E)	3	257.66**	124.63**	16.53**	7374.92**
Rep/E	12	53.07	147.04	0.88	787.08
Hybrids (H)	8	136.30**	441.07**	2.04**	5130.48**
ExH	24	37.57**	429.42**	2.01**	3337.61**
Residual	96	9.39	14.84	0.14	253.52

**significant by the F test at the 1% level.

The dominance effect was the predominant effect only for yield, where 71.8% of the variation among the means was due to *d* (Table 5). This result coincides with many previous studies of this trait in maize (Lima et al., 2008; Hallauer et al., 2010; Ribeiro et al., 2014). Ramalho et al. (2012a) presented a compilation of results for the estimates of *m+a* and *d* in North American (USA) and Brazilian hybrids. They showed that in the mean of 28 hybrids, the estimate of *d* explained 69.7% of the mean yield of the hybrids. Ribeiro et al. (2014) evaluated ten simple hybrids and five lines through a complete diallel cross. The authors reported 102.6% heterosis for grain yield per plant. The existence of dominance for grain yield in maize using variance estimates was also reported by Hallauer et al. (2010). They compiled 99 estimates and observed that the ratio between V_D/V_A was 0.94.

Because dominance is less critical for the NDF, NDPM, and RATE traits, the overall mean is a good criterion for identifying populations for line selection. Thus, for the mean of the four-season, hybrid 4 showed the earliest flowering. Hybrid 6 was notable for the remaining traits (NDPM and RATE). For YLD, the estimate of *m+a* indicates which hybrid, after successive self-fertilizations, is expected to have a higher mean for the F_∞ lines. The estimate of d can provide helpful information about which hybrid should have a more significant number of heterozygous considering that all the segregating loci have the same contribution to the trait. Thus, the hybrid variation in the segregating population should be expected to be more significant. Ideally, select a hybrid that combines the high estimate of m+a and d. Based on the analyzes presented, hybrid 5 is promising for line selection because this hybrid has an estimate of *m+a* higher than the others and has a relatively high d magnitude for YLD. Emphasizing, the highest estimate of *m+a* for hybrid 5 indicates that if it is used in the breeding program, the mean of the lines derived from it will be higher than that of the others. The major magnitude of d makes it possible to comparatively infer the number of segregating locos. Therefore, the population derived from this hybrid must have sufficient variability for success in selecting the best lines.

Conclusions

The additive effect predominates for the traits NDF, RATE, and NDPM, as indicated by the higher estimate of *m+a.* However, for YLD, the estimate of d was more expressivesignificantly more significant than the estimate of *m+a*, thus indicating the greater importance of the dominance effect and heterosis.

Considering a breeding program, the population derived from hybrid 5 is the most promising because it associates a high average expectation of the lines to be obtained and sufficient variability, among them, for the success of the selection.

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