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NOTE

Genetic parameters of wheat populations in environments with contrasting temperatures

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Abstract - *The objective of this study was to estimate genetic parameters of wheat segregating populations grown in environments with different thermal conditions. Thus, two experiments were carried out at Universidade Federal de Viçosa, Brazil. A 16 by16 square lattice design was used with two replications, where 240 families from eight segregating populations, 30 families from each population, plus 16 parents were evaluated. In the first experiment, sown in February 2007 (summer), $S_{0:2}$ families were evaluated. In the second one, in June 2007 (winter), $S_{0:3}$ families were evaluated. Grain yield and thousand grains weight were recorded. So, the most promising population to be grown under different levels of temperature is the Population II originated from BR24/Aliança//EP93541/CPAC9662. It was verified that the thermal conditions might interfere in the wheat genotypes performance and also in the genetic parameters estimates.*

Key words: Triticum aestivum *L., components of variation, high temperatures.*

INTRODUCTION

The 2011 Brazilian wheat harvest estimated by the Instituto Brasileiro de Geografia e Estatística (IBGE 2011) will be approximately five millions tons, equivalent to only about 50 % of the consumption. This deficit in the Brazilian wheat production is a factor that has been repeated for many years, what makes the country highly dependent on the wheat importation.

Efficient and qualified farmers have been dedicated to the wheat cultivation in Central Brazil with notable technical and economic viability. On the other hand, that region presents an inconvenient high temperatures occurrence during the wheat cycle. Many studies have confirmed the damaging effect of heat on wheat (Yang et al. 2002, Shah and Paulsen 2003, Rane and Nagarajan 2004, Cargnin et al. 2006), as well as the presence of genotype by environment interaction under contrasting temperature conditions (Souza and Ramalho 2001, Cargnin et al. 2006).

The study of the genotype by environment interaction and the estimation of genetic parameters are needed, once it provides information about the nature of genes involved in the inheritance of traits under investigation and help in choosing the most satisfactory breeding method, what helps breeders to make decisions. In addition, the most traits with agronomic importance for self-pollinated plants breeding, such as plant height, cycle length, yield, etc are typical examples

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of quantitative traits, being heavily affected by environment. For those traits is needed to know how much of the phenotypic variability is inheritable.

Thinking on the genotypes by adverse environments interaction and on the selection of better plants, there is something that is a fact, the breeding has been more efficient to generate cultivars for high yield environments than the contrary, and few studies have been conducted in marginal conditions. So, such studies deserve more attention (Ceccarelli 1994, Dawson et al. 2008), especially given the current scenarios of global climate change.

In this context, know the way how different environmental conditions can interfere in phenotypic and genetic estimates is essential for the plant breeding to achieve its goals. This will allow determining more precisely the genotypes evaluation and genotypes selection strategies. Thus, the objective of this study was to estimate genetic parameters of wheat segregating populations grown in environments with different thermal conditions.

MATERIAL AND METHODS

Two trials were carried out in the experimental area of the Universidade Federal de Viçosa (UFV) (lat 20º 45' 14'' S, long 42º 52' 54'' W and 649 m asl), in the State of Minas Gerais, Brazil. The first experiment was sown in February 2007, which corresponds to the summer season (high temperatures). The second one was sown in June 2007, corresponding to the winter season (mild temperatures).

At sowing, 250 kg ha^{-1} of 08-28-16 NPK fertilizer were applied. Later, at the beginning of tillering, 50 kg ha^{-1} nitrogen were applied as ammonium sulfate. The other practices were performed following technical recommendations for an irrigated wheat crop. The experiments used populations from a second cycle of recurrent selection. In both experiments were evaluated eight segregating populations (Table 1), consisted by families of four unrepeated parents, a diallel crossing. In the first experiment, under high temperatures, were evaluated $S_{0:2}$ families. The $S_{0:3}$ seeds obtained from the first experiment were sown in the second one, winter season.

The eight populations contributed to 30 families each one, totaling 240, which were evaluated by a 16 x 16 square lattice design, with two replications. Eight wheat lines (cultivars) plus the eight best families, selected from the previous recurrent selection cycle, were added to complete the lattice.

Table 1. Populations evaluated and the crossings used to assemble them

Populations	Crossings
I	BH1146/BR24//Aliança/EP93541
II	BR24/Aliança//EP93541/CPAC9662
III	Aliança/EP93541//CPAC9662/Pioneiro
IV	EP93541/CPAC9662//Pioneiro/BRS207
V	CPAC9662/Pioneiro//BRS207/Anahuac
VI	Pioneiro/BRS207//Anahuac/BH1146
VII	BRS207/Anahuac//BH1146/BR24
VIII	Anahuac/BH1146//BR24/Aliança

Plot size was three rows, being 3.0 m long by 18.6 cm row spacing, providing an evaluation area of 1.67 m^2. Planting density was 350 viable seeds per m^2. Data were collected concerning the traits grain yield (g/1.67 m^2) and thousand grain weight (g).

The data from the two seasons (summer and winter) were subjected to separate analyze of variance. After analysis of variance of each experiment and confirming the homoscedasticity of residual variances between the seasons, a joint analysis of the experiments was performed, as described by Ramalho et al. (2005).

Later, genetic parameters were estimated in the environments - summer, winter and environments mean (combined analysis). For the F test and genetic parameters estimates, the genotype effect was considered random and the environment effect as fixed, constituting a mix model. The mathematical expectations of the mean squares were determined as Cruz et al. (2004). The mean square of the interaction was split in simple and complex part, as presented in Cruz et al. (2004).

Once were evaluated $S_{0:2}$ families in the summer experiment and $S_{0:3}$ families in the winter one, was estimated the realized heritability (h^2_{rij}) of the populations, by selection of the 20 % best families of each population in summer - those ones with greatest yield and thousand grain weight - by the Fehr (1987) expression: $h^2_{rij} = \frac{GSj/mj}{dsi/mi}$, where GSj is the performance in generation j of the families selected in generation i, minus the overall population mean of the generation j; dsi is the mean of the families selected in generation i minus the overall mean of this generation; mi and mj, are the means of the families selected in generation i and j, respectively.

It was estimated the gain by divergent selection, given by the expression:

$GS (\%) = [(A-B) / B] \times 100$, where: $GS (\%)$ is the percentage gain with divergent selection; A is the mean of the 20 % best families of each population, selected in generation i and evaluated in generation j; B is the overall mean of the families of a population, evaluated in generation j.

RESULTS AND DISCUSSION

Significant differences were detected between the genotypes for the evaluated traits in both seasons (Table 2). It should draw attention for the existence of population's genetic variability, the main aim of this study. The significant differences found ($P \leq 0.01$) between the populations in the environments evidence the possibility of selecting heat resistant families between and inside the populations.

By the joint analysis results can be noted

Table 2. Summary of analyses of variance - summer, winter and joint analysis – from wheat genotypes for the traits yield and thousand grains weight

Sources of variation		df	Mean Squares			
			Yield ($g/1.67m^2$)		Thousand grains weight (g)	
			Summer	Winter	Summer	Winter
Adjusted treatments		255	12445.64**	16477.15**	12.06**	17.91**
Families		239	12698.09**	16234.40**	12.23**	17.94**
Populations		7	168123.70**	129626.80**	42.95**	75.25**
Checks		15	9158.06*	21413.56**	8.59**	14.83**
Families vs Checks		1	1423.98	449.47	23.65**	54.72**
Effective error		225	4629.87	7221.83	2.67	5.77
Mean			268.60	458.68	34.50	40.66
CV (%)			25.33	18.53	4.73	5.91
Lattice efficiency (%)			106.15	117.59	105.36	101.81
Joint analysis						
Environments (E)		1	9249820.47**		9691.74**	
Genotypes		255	19184.56**		23.24**	
Families		239	19276.52**		23.28**	
Populations		7	272914.32**		101.31**	
Checks		15	18989.28**		19.08**	
Fam. by Checks		1	136.70		75.17**	
Genotypes x E		255	9738.23**		6.73**	
Families x E		239	9655.97**		6.89**	
Populations x E		7	24836.130**		16.890**	
Checks x E		15	11582.34*		4.35	
Families vs Checks x E		1	1736.66		3.18	
Mean effective error		450	5925.85		4.22	
Mean			363.64		37.58	
CV (%)			21.17		5.46	
Interaction	Simple		141.18		0.29	
	Complex		9597.41		6.44	

** and *: significant at 1 % and 5 % probability, respectively, by F test.

significant difference between the environments and the environments-by-populations interaction ($P \leq 0.01$). It also can be realized that the most part of the genotypes-by-environments interaction had a complex nature, what means that there was no correlation between the genotypes on the different temperature conditions. The complex genotype-by-environment interaction indicates that there were genotypes with good performance in an environment, but there were not in another one, what makes the plant breeding harder (Cruz et al. 2004).

In order to know more about the performance of the eight populations under the temperature conditions, was estimated some genetic parameters in summer, winter and combined environments (Table 3). About the grain yield, the population with the highest genetic variance estimates for all the environments was the population II. The population IV also presented high estimates for that parameter. As to thousand grain weight, the populations with high $\hat{\sigma}^2_g$ in both seasons were III, IV, V and VI. The only population that presented similar performance for both traits was the population IV. The phenotypic variance ($\hat{\sigma}^2_f$) is directly related to the genetic one. So, in a general way, same performance was detected for this parameter between the populations.

Table 3. Genetic parameters estimates from eight wheat segregating populations for the traits yield (YLD) in g/1,67m^2 and thousand grains weight (TGW) in g, in summer, winter and environment means (combined)

Populations	Environments	Genetic parameters*									
		$\hat{\sigma}^2_g$		$\hat{\sigma}^2_f$		$\hat{\sigma}^2_{ga}$		h^2_a		h^2_{rij}	
		YLD	TGW	YLD	TGW	YLD	TGW	YLD	TGW	YLD	TGW
	Summer	2834.6	1.7	5199.5	3.0	-----	-----	0.55	0.56		
I	Winter	177.0	4.7	3787.9	7.6	-----	-----	0.05	0.62	0.12	0.77
	Combined	527.2	2.9	2008.7	4.0	978.6	0.2	0.26	0.74		
	Summer	3970.8	3.0	6285.7	4.4	-----	-----	0.63	0.69		
II	Winter	6627.5	1.8	10238.4	4.7	-----	-----	0.65	0.39	0.26	0.35
	Combined	3427.6	2.0	4909.1	3.1	1871.5	0.4	0.70	0.66		
	Summer	-69.8	4.6	2245.1	5.9	-----	-----	-0.03	0.77		
III	Winter	1957.0	6.6	5567.9	9.5	-----	-----	0.35	0.70	0.09	0.60
	Combined	680.2	4.5	2161.7	5.5	263.4	1.1	0.31	0.81		
	Summer	2312.1	4.7	4626.9	6.0	-----	-----	0.50	0.78		
IV	Winter	4210.1	6.3	7820.9	9.2	-----	-----	0.54	0.69	0.51	0.84
	Combined	3359.9	5.2	4841.4	6.3	-98.9	0.3	0.69	0.83		
	Summer	706.6	5.8	3021.5	7.1	-----	-----	0.23	0.81		
V	Winter	4240.7	7.4	7851.7	10.3	-----	-----	0.54	0.72	-0.05	0.20
	Combined	825.3	5.0	2306.8	6.1	1648.4	1.6	0.36	0.83		
	Summer	1491.3	7.9	3806.3	9.2	-----	-----	0.39	0.86		
VI	Winter	745.0	9.5	4355.9	12.4	-----	-----	0.17	0.77	0.03	0.79
	Combined	719.3	7.6	2200.8	8.6	398.9	1.1	0.33	0.88		
	Summer	121.3	2.7	2436.2	4.1	-----	-----	0.05	0.67		
VII	Winter	2241.5	2.5	5852.5	5.3	-----	-----	0.38	0.46	0.06	0.60
	Combined	919.8	2.4	2401.2	3.4	261.7	0.2	0.38	0.69		
	Summer	2147.8	4.1	4462.7	5.5	-----	-----	0.48	0.76		
VIII	Winter	2166.1	2.9	5777.2	5.9	-----	-----	0.37	0.51	-0.04	0.73
	Combined	936.3	3.8	2417.8	4.9	1220.6	0.3	0.39	0.78		

*$\hat{\sigma}^2_g$: genetic variance [(g/1,67m^2)^2]; $\hat{\sigma}^2_f$: phenotypic variance; $\hat{\sigma}^2_{ga}$: genotype by environment variance; h^2_a : broad-sense heritability; h^2_{rij} : realized heritability.

Genetic variance estimates were greater in non-heat environment than heat environment for the most populations, independently on the trait. Similar performance was also verified for $\hat{\sigma}^2_f$. Regarding the joint analysis, the $\hat{\sigma}^2_g$ and $\hat{\sigma}^2_f$ estimates stayed between values from summer and winter season or lower than these. It was expected due the way how it is calculated.

Some studies verified, when comparing favorable conditions with unfavorable conditions, that genetic variance decreases, while the error variance can increase (Ud-Din et al. 2004, Brancourt-Hulmel et al. 2005). In situations like that would be harder to detect significant differences between the genotypes (Banziger et al. 1999). In the present study, in a general way, the genetic variance was lower under high temperatures. However was not detected increase of the error variance in summer season compared with winter season.

According to Dawson et al. (2008), the decrease of genetic variance under less favorable environments makes the breeders prefer to do the selection in environments with better conditions, believing that the genetic gain will also occur to non-optimal environments. Ceccarelli (1994) stated that the selection in high yield environments (optimal conditions) for performing in marginal conditions is a type of indirect selection, justified only if the heritability of the trait under selection is significantly superior in conditions of high yield.

Given the importance of knowing the heritability under such conditions, were estimated the broad-sense heritability and the realized heritability (Table 3). For grain yield, highlight for populations II and IV, with high heritability estimates in all conditions. For thousand grain weight, all the populations presented high values of heritability, except the populations II and VII in the winter.

Five of the eight populations obtained greater heritability for yield in the winter season than summer, although low values in some cases. The opposite happened to thousand grain weight, where seven populations obtained greater heritability values in summer. The heritability calculated in the joint analysis presented intermediate values and, most times, greater than individual analysis. Azevedo Filho et al. (1998), studying soybean populations on aluminum saturated soils, verified high range of heritability for a same trait, but from different crossings and, the environmental effect on the heritability was dependent on the trait.

The realized heritability, what represents in fact how much was transmitted from a generation to another one, showed relevant results for some populations. For grain yield highlight for populations I, II and IV with 12, 26 and 51 %, respectively. For thousand grains weight, practically all populations showed satisfactory values of realized heritability, varying from 20 to 84 %. It should be noted that the realized heritability values are overestimated by the environmental effect, once the populations were evaluated in more appropriated temperature conditions (mild temperatures) in generation $S_{0:3}$. However it brings information about the genetic variability of the populations.

The heritability is a parameter extremely important for plant breeding programs. This is the proportion of phenotypic variation in a population that is due to genetic variation between individuals. Thus, it can be perpetuated via selection and has been object of study by many authors (Londero et al. 2006, Dawson et al. 2008).

A controversial issue related to the heritability is about its greater or lower magnitude in marginal environments. It has been shown in some studies that the heritability increases as the environmental conditions get better (Singh and Chaudary 2006), a fact that occurred in the present study. However, an extensive revision done by Ceccarelli (1994) shows that it is not a rule and must be considered the coefficient of genetic correlation. It should be noted that the heritability is not a constant value of a trait, but it is a characteristic of it. So, it depends on the populations and on the environmental conditions where the plants are evaluated (Falconer and Mackay 1996), therefore it can change.

It was performed the selection of 20 % of the most productive families in the three conditions of study. Further issues related to the selection, it brings information about the genetic variability of the populations. The percentage of families selected in each population and the mean of yield of each population are presented in Table 4.

Emphasis for populations I and II in summer, because they had the most families selected with heat resistance. In the winter emphasis should be given to populations II and IV, once they had most families selected when the environment got better. Regarding the joint analysis, the populations I and II were again well qualified.

It should be noted the superiority of the populations I and II and their genetic variability in both temperature conditions. This is a relevant aspect, because the ideal genotype would be that one with high productive potential under mild temperature, and additionally, a good performance under high temperatures, in case it was grown in such conditions or occasionally it was submitted to heat stress.

Still regarding the selection of families, it was estimated the divergent selection of the 20 % best families of each population in summer and evaluated in winter (Table 5). For most families, the selection in $S_{0:2}$ (summer) enabled gains in $S_{0:3}$ (winter), what indicates these populations as families with potential for both environments. Populations II and IV showed the greatest gains by divergent selection for yield, being 7.83 and 18.12 %, respectively. As to thousand grains weight it ranged from 2.77 to 9.78 % of gain.

In a general way, it was perceived that high temperatures can interfere on wheat genotypes performance and on the genetic parameter estimates. As to the best environment to do the selection, there is no unanimity. However, it is already known that the argument to select in non-stress condition, assuming that the heritability is greater, is not consistent. Moreover, Ceccareli (1994) argues that in cases where heritability was greater in favorable conditions, the genotypes had been previously selected in high yield environments and then tested in low yield environments.

Table 4. Percentage of selected families and yield mean from eight wheat segregating populations, considering 20 % of selection intensity in the environments summer, winter and environment means (combined)

Populations	Percentage of selected families			Yield (g/1.67m^2)		
	Summer	Winter	Combined	Summer	Winter	Combined
I	31.3	12.5	27.1	343.1	486.3	414.7
II	33.3	29.2	37.5	335.2	523.0	429.1
III	6.3	6.3	6.3	276.8	459.0	367.9
IV	8.3	20.8	12.5	260.2	470.9	365.6
V	2.1	4.2	0	208.3	372.2	290.3
VI	2.1	2.1	2.1	192.2	417.4	304.8
VII	4.2	10.4	4.2	266.0	454.4	360.2
VIII	12.5	14.6	10.4	263.6	488.2	375.9

Table 5. Means of 20 % best families ($\overline{Xs}$) from eight wheat segregating populations and gain by divergent selection (GS %) for the traits yield and thousand grain weight

Populations	Yield (g/1.67m^2)		Thousand grains weight (g)	
	$\overline{Xs}$	GS (%)	$\overline{Xs}$	GS (%)
I	502.72	3.37	41.94	4.94
II	563.89	7.83	43.46	2.77
III	468.44	2.05	41.89	6.09
IV	556.28	18.12	44.30	8.33
V	366.01	-1.67	40.53	2.16
VI	423.94	1.58	45.26	9.78
VII	460.74	1.41	42.29	5.45
VIII	480.79	-1.53	44.76	5.85

$\overline{Xs}$: means of 20 % best families selected in generation $S_{0:2}$ (summer) and evaluated in generation $S_{0:3}$ (winter)

Parâmetros genéticos de populações de trigo em ambientes com temperaturas contrastantes

Resumo – *Este trabalho objetivou estimar parâmetros genéticos de populações segregantes de trigo cultivadas em ambientes contrastantes de temperatura. Para isso, foram conduzidos dois experimentos na Universidade Federal de Viçosa, Brasil. Utilizou-se o delineamento látice quadrado 16x16 com duas repetições, composto por 240 famílias oriundas de oito populações segregantes, com 30 famílias cada, mais 16 genitores. No primeiro experimento, semeado em fevereiro de 2007 (verão), foram avaliadas famílias $S_{0:2}$ e no segundo, em junho de 2007 (inverno), avaliaram-se famílias $S_{0:3}$. Foram avaliados produção de grãos e massa de mil grãos. De uma forma geral, a população com maior potencial para ser explorada em condições de temperaturas amenas e elevada é a População II, oriunda do cruzamento BR24/Aliança//EP93541/CPAC9662. Foi constatado que as condições térmicas podem interferir no desempenho de genótipos de trigo e também nas estimativas de parâmetros genéticos.*

Palavras-chave: Triticum aestivum *L., componentes de variação, temperaturas altas.*

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