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RELATIONSHIP BETWEEN GRAIN YIELD AND BLOSSOMING IN UPLAND RICE LINES

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ABSTRACT - For upland rice, it is desired, among many objectives, to obtain highly productive and early genotypes, consequently reducing the risk of establishing a crop regarding climatic adversities. Therefore, this study aimed to verify the correlation between the agronomic traits days to flowering and grain yield of 14 upland rice lines. The experiment was conducted in seven environments, in the 2013/14, 2014/15 and 2015/16 crop years, in a randomized complete block design with three replications. Both the genotypic and phenotypic correlation were significant and positive, whereas the genotype correlation was superior to the phenotype. However, it was noted a low magnitude of the correlation values. It was concluded that a favorable and simultaneous selection is possible for high grain yield and plants with early blossoming cycle in upland rice.
Keywords: association, breeding, agronomic traits.

CORRELAÇÃO ENTRE PRODUTIVIDADE E FLORESCIMENTO DE LINHAGENS DE ARROZ DE TERRAS ALTAS

RESUMO - Para o arroz de terras altas, deseja-se entre muitos objetivos, a obtenção de genótipos altamente produtivos e precoces, diminuindo assim, o risco adoção da cultura em relação às adversidades climáticas. Objetivou-se com o presente estudo, verificar a correlação existente entre os caracteres agronômicos dias de florescimento e produtividade de grãos de 14 linhagens de arroz de terras altas. O experimento foi conduzido em sete ambientes, nas safras 2013/14, 2014/15 e 2015/16, em delineamento experimental de blocos ao acaso, com três repetições, onde foram avaliados os dias para florescimento e produtividade. Tanto as correlações genotípicas e fenotípicas foram significativas e positivas, sendo que a correlação genotípica foi superior à fenotípica. Contudo, observou-se baixa magnitude dos valores das correlações. Conclui-se que é possível uma seleção favorável e simultânea para alta produtividade de grãos e plantas com florescimento precoce em arroz de terras altas.
Palavras-chave: associação, melhoramento, variáveis agronômicas.

INTRODUCTION

Rice is considered one of the cereals with the biggest production and consumption in the world, characterized as the main food for more than half of the world population. Estimates indicate that by 2025, rice production worldwide will be 70% higher than what was produced in the year of 1995. To keep up with these data, the search is constant for answers from plant breeding programs, which has a significant role supplying for food demand. Silva et al. (2017) suggest that plant breeding has been the basis of modern agriculture. The performance of plant breeding in the development of new dryland rice cultivars is important to maintain a self-sufficiency production of rice in Brazil and it allows the opening of new agricultural frontiers.

The use of early cycle cultivars is one of the propositions of breeding programs. These are important to save water, present greater flexibility of sowing period and harvesting scalation, besides the possibility to anticipate the commercialization of the production when better prices are available, with a faster return of the invested capital. For upland rice, in particular, precocity has a major importance especially in regions with higher risks of dry spells drought stresses (COLOMBARI FILHO; RANGEL, 2015).

The correlation between variables is a parameter of great value for plant breeding programs, which allows simultaneous selection between characteristics. Therefore, one of the measures applied is the selection of plants based

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on characteristics that are correlated with the main variable (CRUZ et al., 2012).

The correlation can be positive, that is, the characters vary in the same direction, or negative, in which the characters vary jointly but in opposite directions. The correlation between two characters can be of a phenotypic, genotypic or environmental nature, with the genotypic correlations the one with most interest for breeding, once they include an association of heritable matter (OLIVEIRA et al., 2011).

It is known, therefore, that most of the agronomic characteristics are correlated and often, this correlation occurs in directions. In this manner, it is possible to establish an indirect selection of a character that presents complex heritage, low heritability or manifestation in advanced generations through the selection in another character, with a simpler heritage or higher heritability (CRUZ et al., 2012).

The rice breeding program of the Federal University of Lavras (UFLA) in partnership with the Brazilian Agricultural Research Corporation (EMBRAPA Arroz e Feijão) and the Minas Gerais Agricultural Research Corporation (EPAMIG), currently has 20 genotypes in the phase of VCU, with a potential to be launched soon as new cultivars. Therefore, this study aimed to correlate the characters of yield and days to flowering in order to check the relationship between these phenotypic characters as well as to select genotypes of upland rice from the VCU tests with higher grain yield associated with an early productive cycle.

MATERIALS AND METHODS

The experiments were conducted in seven environments, two of them were held on 2013/2014 crop year, two on 2014/2015 crop year and tree on 2015/2016 crop year, all of them on the state of Minas Gerais. For the first crop year, the locations chosen to establish the experiments were the cities of Lavras (MG) and Patos de Minas (MG). For the second crop year, the cities used for the experiment were Lavras/MG and Lambari/MG. Finally, for the third crop year, the experiment were located in the cities of Lavras, Lambari and Patos de Minas, Minas Gerais, with geographical coordinates, altitudes and climate type, according to the Köppen-Geiger classification, described on Table 1.

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TABLE 1 - Geographic coordinates and altitudes of the cities where the experiments were evaluated.

Locals	Latitude	Longitude	Altitude	Climate
Lavras (MG)	21°14’ S	44°59’ W	919 m	*Cwa*
Lambari (MG)	21°58’ S	45°21’ W	887 m	*Cwa*
Patos de Minas (MG)	18^{o}29’ S	46°26’ W	1074 m	*Cwa*
Fazenda Muquém (MG)	21°12’ S	45°00’ W	954 m	*Cwa*

Fourteen genotypes were evaluated (CMG 1896, CMG 2085, CMG 1509, CMG 1511, CMG 2170, CMG 2093, CMG 2089, CMG 2097, CMG 1977, BRS ESMERALDA, CMG 1987, BRSMG RELAMPAGO, BRSMG CAÇULA, BRSMG CARAVERA) belonging to the Value for Cultivation and Use test (VCU).

The experiments were conducted in a randomized block design with three replications and plots of four lines with five meters, considering the three central lines as the useful plot. The seedling rate was 80 seeds per linear meter with a 35 cm spacing between rows and a useful plot of 4.8 m^2.

The trials were sowed following the conventional system, using plowing and harrowing techniques. Then, planting fertilization was carried out, in the amount of 450 kg ha^{-1} of the formulated N-P_2O_5-K_2O (08-28-16). A top-dressing fertilization with 250 kg ha^{-1} of KNO_3 was also applied. The other crop traits were the same recommended for growing upland rice, according to Utumi (2008), except the application of fungicide, once breeding program also evaluates genotypes that are resistant to diseases.

The evaluated characters were: number of days to blossoming (number of days after planting when 50% of the plants in the plot emitted panicles) and grain yield (measured in grams per plot adjusted to kg ha^{-1}, concerning the useful area of the plot).

The data were submitted to individual variance analysis, for environment, and joint for both characters. The coefficient of variation (CV%) and accuracy were also calculated. The interaction for both genotypes x environments was split and the averages were compared using the Scott-Knott test considering a 5% probability of error. From the mean squares results were estimated the genetic, phenotypic and environmental variances, and subsequently the respective correlations (genotypic, phenotypic and environmental) and their significance analyzed using the Student’s t-test. All analyzes were performed using the software Genes (CRUZ, 2011).

RESULTS AND DISCUSSION

In order to estimate the reliability and quality of the experiments, values of accuracy ($r_{\hat{g}g}$) and coefficient of variation (CV%) were calculated. According to Resende and Duarte (2007), accuracy is the most recommended to measure experimental precision when evaluating progenies and/or cultivars. It is associated to the correlation between predicted genetic values and true genetic values of individuals, meaning, the higher accuracy estimate, the greater is the reliability in the evaluation and in the predicted genetic value (PIMENTEL et al., 2014). Regarding the coefficient of variation, Silva (2011) implies that more accurate and reliable results are obtained from the reduction of the effect of the experimental error.

Therefore, in this study, the values obtained for accuracy were higher than 90% (Table 2). According to Resende and Duarte (2007), considering precision and control of quality in trials of value for cultivation and use, these estimates are considered highly accurate, a fact that supports the detection of significant differences concerning the characters evaluated in this study. In accordance with Pimentel-Gomes (2009), in field trials, the coefficient of variation can be classified as low, if it is lower than 10%, medium, if it oscillates between 10-20%, high, if it is between 20- 30% and very high, when it is over than 30%. However, the coefficients of variation, considering all environments, showed estimates below 20% for all characters, demonstrating good precision in the experiments conducting.

According to the results from the joint variance analysis, covering all environments, it was identified a significant difference for the sources of variation genotypes, environments and genotype x environment interaction (Table 2), by the F-test. The variability between the genetic materials evaluated was already expected due to the fact that the genotypes tested differs in terms of their genetic background (GESTEIRA et al., 2015).

TABLE 2 - Summary of the joint variance analysis for the characters grain yield (YIELD) (kg ha^{-1}) and number of days to flowering (NDF) (days).

SOV	DF	MS	
		YIELD	NDF
Genotypes (G)	13	4260761,36**	275,42**
Environment (E)	7	69955885,62**	2140,43**
G x E	91	2284445,41**	29,46**
Blocks	16	2223455,15**	12,15*
Residual	208	418997,17	6,18
Means		4827,63	85,84
CV(%)		13,41	2,9
Accuracy		0,95	0,99

SOV = Sources of variation, DF= degrees of freedom, MS = mean square, * and ** indicate statistical significance at the 5% and 1% levels, by Student's t-test, respectively.

The genotype-by-environment interaction was significant for all studied traits, indicating that the phenotypic component of the lineages did not match with the seven environments evaluated, in that way, there was a difference in the sensitivity of the genotypes regarding the changes in the environmental conditions in which they were exposed. This fact is well elucidated through the averages of the environments, for both characters. This fact makes it hard to recommend cultivars for different environments (RAMALHO et al., 2012), because it is not possible, under these circumstances, to make a uniform recommendation for all locations without losing considerable yield.

According to Faria et al. (2009) the diversity of the environmental conditions to which the crop is exposed contributes to the interaction genotypes-by-environment, in other words, there is a change in the relative performance of cultivars in virtue to differences between environments. Therefore, early materials, besides high grain yield, they must have a predictable behavior and respond to stimulus caused by the environment. In accordance with Cordeiro (2010), most of the studies that confirm the occurrence of genotype x environment interaction in rice were done with an emphasis on the identification of more stable materials based on competition of lineages and cultivars trials.

The adjusted averages of the 14 genotypes, for all characters, after the joint analysis, are presented in the Table 3. For the grain yield character, the averages collected varied from 4102.2 kg ha^{-1} to 5387.7 kg ha^{-1}, between the lineages BRS MG CARAVERA and CMG 1896, respectively, with an overall average of 4825.4 kg ha^{-1}.

Thereby, it is notable the existence of yield variability among them, with emphasis on the genotypes CMG1896, CMG1509, CMG2085, CMG1511 which were the most productive by the Scott-Knott test ($p < 0.05$). It is worth highlighting that this estimate was higher than the national yield average for upland rice in the last harvest (2017/2018), which was nearly 2410 kg ha^{-1} (CONAB, 2018), indicating, initially, the success of the breeding program aiming the selection of genotypes for the character grain yield and blossoming cycle. The number of days to flowering varied from 78 to 90 days, for the BRS MG Caçula and BRS MG ESMERALDA lineages, respectively, with an overall average of 85.7 days to flowering.

TABLE 3 - Joint average of lineages for the characters: grain yield (YIELD) and number of days to flowering (NDF).

Genotypes	YIELD (kg ha^{-1})	NDF
CMG1896	5387,75 a*	89 a
CMG2085	5276,45 a	86 b
CMG1509	5238,34 a	87 b
CMG1511	5201,67 a	85 c
CMG2170	5095,37 b	89 a
CMG2093	4993,04 b	84 c
CMG2089	4986,72 b	86 b
CMG2097	4945,26 b	89 a
CMG1977	4742,79 b	86 b
BRS ESMERALDA	4521,10 c	90 a
CMG1987	4500,06 c	87 b
BRSMG RELAMPAGO	4387,83 c	81 d
BRSMG CAÇULA	4177,97 d	78 e
BRSMG CARAVERA	4102,27 d	84 c
Means	4825,40	85,7

*Means followed by the same letter belong to the same cluster by the Scott-Knott test (p<0.05).

Figure 1 shows the graph of the performance of genotypes regarding grain yield and number of days to blossoming. Note that genotypes that bloomed between 77 and 84 days were less productive. It is observed that the most productive lineage bloomed after 89 days, being an intermediate value regarding days to flowering among the lineages. Also, note that the earliest and the latest lineages showed similar results regarding grain yield.

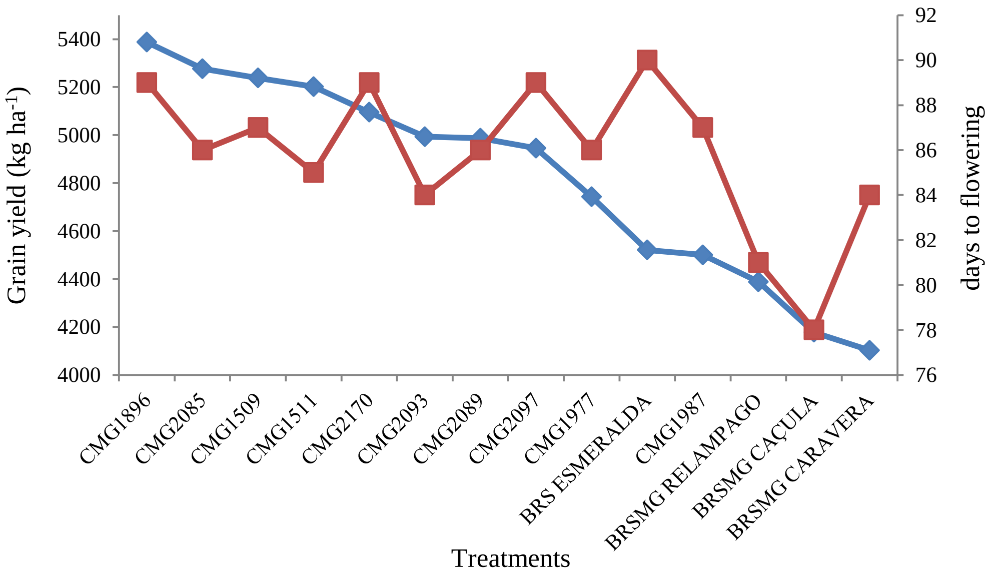

FIGURE 1 - Performance of genotypes regarding the characters grain yield (kg ha^{-1}) and number of days to flowering.

Observing the values of grain yield found, it is proposed that an average grain yield of this magnitude is favorable, considering that for the state of Minas Gerais, the average grain yield of upland rice is about 2,638 kg ha^{-1} (CONAB, 2018), therefore, all the evaluated genotypes were higher than the state average. However, there is a non-correspondence among the most productive genotypes and those who had an early blossoming, which requires a better investigation upon the correlations between grain yield and days to flowering.

The phenotypic, genetic and environmental correlations between variables were calculated, which are displayed in Table 4. Note that there was no significance for the environmental correlation among the characters, suggesting that the environment does not have the same effect for both characteristics. On the other hand, the other two correlations were significant and the genotypic correlation (0.58) were superior than the phenotypic correlation (0.55), both being positives.

TABLE 4 - Coefficient of phenotypic, genotypic and environmental correlation between the characters number of days to flowering (days) and grain yield.

	Flowering (days)		
	Phenotypic	Genotypic	Environmental
Grain Yield (kg ha^{-1})	0,5481**	0,5841**	-0,0055

Cargnin et al. (2010) in his study on genetic diversity of rice cultivars, evaluating two groups of cultivars, obtained as result between blossoming and grain yield, a positive correlation and high magnitude for the early group, so-called, and for the delayed group, a negative correlation and a high magnitude. According to the authors, from the divergence among the signs of the correlation between the groups, it is possible to infer that due to the differences in the environmental conditions existing in different regions, the cultivars express greater potential of production when their blossoming stage is around 90 days.

Cultivars considered as delayed cycle tend to deliver higher yields than those with early cycle, once they have a longer period of time to accumulate assimilates and to recover from stresses that may occur during the vegetative phase (COLOMBARI FILHO; RANGEL 2015).

Into upland rice breeding programs, the objective is the obtainment of lineages with earlier blossoming, in order to escape of the drought stress, associated with a high productive performance. That is because the plant of rice is very sensitive to water deficit, which is frequent during the months of January and February, being one of the main causes of low productivity and instability when growing upland rice, a situation that reinforces upland rice to be considered a high-risk crop.

Awareness of the association among characters is utmost important for breeding studies (CRUZ et al., 2012). When working with several characters in breeding programs, it is advisable to quantify the existence of an association between them. According to Ramalho et al. (2012), correlation is a measure of linear intensity association of two variables; it might be positive or negative. Coefficients of correlation are dimensionless, ranging positively or negatively from 0 to 1, in which a null correlation shows no absence and lack of linear relationship between characteristics, while coefficients of correlation rated between -0.5 to -1 and 0.5 to 1 are appreciated due to the magnitude of their values on the interpretation adopted of correlations (NOGUEIRA et al., 2012).

Therefore, the correlations allow quantifying the indirect potential gains through selection in correlated characters, in other words, it measures the intensity of association between two variables. The knowledge of the association between characters becomes particularly important when the selection in one of the characters shows difficulty, as it is for low heritability or even in hard/late evaluation or identification (SCHNEIDER et al., 2016).

One of the main causes of genetic correlations between two characters concerns the association among genes, in other words, the gene (s) that control blooming, are probably linked to the genes that affect yield (RAMALHO et al., 2012). Rangel et al. (2000) found a positive correlation of 0.3 between these same characters, emphasizing yet the possibility of increase in yield productivity within breeding programs while maintaining blossoming averages, although the positive correlation and low magnitude. Consequently, the correlation between grain yield and days to flowering makes it viable and favorable the selection of both characters simultaneously.

CONCLUSION

In conclusion, it is possible to achieve a favorable and simultaneous selection for high grain yield and plants with an early blossoming cycle in upland rice.

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