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Genetic and Phenotypic Parameters in the Selection of Upland Rice Genotypes

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Abstract

To assist in upland rice breeding programs, estimated genetic and phenotypic parameters are extremely important in the selection of superior lines. Thus, the objective of this study was estimate the genetic and phenotypic parameters of upland rice lines of the breeding program of UFLA in partnership with Embrapa Arroz e Feijão and Epamig. The experiment was installed in an experimental area of the Department of Agriculture at UFLA. It was evaluated 36 upland rice lines of the preliminary trial of the 2014/15 season, in randomized blocks, with three replications and plots consisted of five rows and each row has four meters. For this, it was evaluated the characters: plant height (cm), yield (kg·ha^{-1}), 100-grain weight, days until flowering, percentage of filled grains and rice blast severity. The variance analysis and genetic parameters were estimated using the software SAS. To evaluate the experimental precision was estimated the accuracy, which varied between 63% and 98%, showing experimental precision, moderate to high. The lines differed significantly for all characters, meaning there is genetic variability among genotypes evaluated. With intensity of selection of 10% of lines, it was obtained a genetic gain of 325.29 kg·ha^{-1} in the character productivity, a plant height (cm) reduction in 5.50 cm, and days until flowering, with a reduction of 9.23 days, with selection of earlier plants. The estimated values for heritability ranged from 38% - 96%. Estimates confirm the possible success with the selection of the upland rice lines for these characters.

Keywords

Lines, Plants Breeding, Preliminary Trial, *Oryza sativa*

1. Introduction

The rice (*Oryza sativa*) is one of the most produced and consumed cereals in the world. It is considered as a main source of food for more than 50% of the world population [1], being the main carbohydrate source for humanity [2].

The increases of food production are related with the manipulation of genetic traits in different plant species [3]. The development of new cultivars through plant breeding has been the basis for modern agriculture [3].

The performance of plant breeding in development of new cultivars of upland rice is important, because it keeps self-sufficiency of rice production in Brazil, and also enables new agricultural frontiers to be opened in Brazil. Therefore, it is crucial to point out that the new cultivars and their technologies had allowed increments in yield, which is interesting for all rice productive chain and Brazilian society. Thus, as the quality of upland rice cultivars improves, it performs an important role as a rice price regulator, and an alternative rent to other farmers. Furthermore, that is relevant that upland cultivation have a production cost per hectare about 32% lower than the cultivation irrigated by flooding in Brazil [4].

In order to obtain the cultivars, the knowledge of genetic gains has crucial relevance in breeding programs to make possible to evaluate its success, to search new methods to amplify effectiveness, helping define future research actions and re-evaluate the strategies employed [5] [6]. Usually, estimate of the genetic progress in a breeding program means to review the effective participation of plant breeding in the elevation of averages in the selected genotypes in a year and test it in the following year [7].

Associated with the estimation of genetic gains, the information acquisition of the genetic parameters of a population allows to know about the nature of the action of the genes involved in the characters inheritance and establish the basis to choose the most suitable breeding methods [3]. These estimates greatly help breeders to make decisions at the time toward the selection of better genotypes. Moreover, the estimation of genetic and phenotypic parameters performs an important predictive role for targeting breeding programs in relation to the selection process of the most promising genotypes [8].

Thus, this work aims to select lines of upland rice of the preliminary trial in the breeding program of UFLA, based on estimates of genetic and phenotypic parameters to obtain superior genotypes.

2. Material and Methods

The experiment was installed in an experimental area of the Department of Agriculture at Federal University of Lavras (UFLA), during the 2014/15 season. The climate of Lavras shows distinct seasons, one is dry from April to September and the other is rainy from October to March, it is classified Cwb, according to Köeppen climate classification. The annual temperature stays around 19.3˚C, having on the hottest month and on the coldest month temperatures around 22.1˚C e 15.8˚C, respectively. The annual normal precipitation is 1530 mm, the total annual evaporation is 1034.3 mm and the annual relative humidity is 76% [9].

It was evaluated 36 upland rice lines of the preliminary trial of the breeding program of the Federal University of Lavras in partnership with Embrapa Arroz e Feijão and Epamig. The experiment was installed in randomized complete blocks design, with three replications and plots consisted of five rows, and each row had four meters.

The following characters were evaluated:

- **100-grain weight (g):** after the harvest were collected 8 random samples of 100 grains per plots and subsequently a weigh check with a precision scale;
- **Percentage of filled grains:** they were collected 10 panicles of each plot and estimated the average percentage of filled grains in each plot;
- **Days for flowering:** number of days from sowing to flowering, when the plot presents approximately 50% of plants with panicles;
- **Plants height**: the average height of five plants of each plot, measured from the soil to the tip of the highest panicle, in centimeters;
- **Diseases severity**: Blast severity (*Magnaporthe oryzae*) was evaluated, according to the methodology [10]. The evaluation was visual, assigning grades according to the following scale:

➢ Note 1: less than 5% of infected leaves and/or panicles;
➢ Note 3: 5% to 10% of infected leaves and/or panicles;
➢ Note 5: 11% to 25% of infected leaves and/or panicles;
➢ Note 7: from 26% to 50% of infected leaves and/or panicles;
➢ Note 9: more than 50% of infected leaves and/or panicles;

- **Yield (kg/ha):** total grains weight of each plot after harvesting and drying to 13%.

Applying fertilizer in the planting and in the surface were realized on the basis of recommendations for the crop, take into account the soil analysis made in the place of planting. Thus, were applied at the rate 24 kg, 84 kg and 48 kg of N, P_2O_5, K_2O respectively in plantation furrows and added a top-dressing with 40 kg of nitrogen, 25 days after sowing. In case of disease control, were not used fungicides as the disease tolerance of these plants were part of the experiment assessments. Standard agronomic practices were followed [11] and plant protection measures were taken as required. For each characteristic evaluated was made the individual variance analysis using the statistical program SAS [12]. Were estimate the components of the phenotypic (σ_f^2) and the genotypic variance (σ_g^2), heritability (h_a^2) in the broadest sense for selection the average of the lines and the selection gain (SG), considering a 10% selection intensity of the best lines for the characters in question. The correlation estimates among the characteristics evaluated were realized according to the methodology by [3]. The averages were compared by Scott-Knott's test with $P = 0.05$.

3. Results and Discussions

The summary of the variance analysis and the estimates of phenotypic and genetic parameters for 100-grain weight (g), percentage of filled grains (%), yield (kg·ha^{-1}), plant height (cm), days until flowering (days) and rice blast severity obtained at the comparative preliminary trial in the 2014/2015 season, are presented in **Table 1**. The accuracy is a measure of precision that reflects the quality of the information of the estimated genotypic values, and the correlation between the actual and estimated genetic values. Thus, the accuracy is an important tool to inform about the correct ordering of the cultivars for selection purposes and high values of this estimate should be desired within the experiments of breeding programs [13]. It was observed values of accuracy between 63% (rice blast severity) and 98% (days until flowering), showing experimental moderate to high precision, according to [14] [15]. Values already expected, because the accuracy is related to the heritability of the characters, it will be greater when it is heritability, so characters of high heritability as 100-grain weight (g) and days until flowering (days) were those that presented the highest accuracy values.

Heritability indicates the genotypic proportion present in the phenotypic behavior of the lines, this estimate varies from 0% to 100%, and characters with values close to 100% have high heritability and are usually controlled by one or a few genes [16]. Values higher than 50% represent a high heritability coefficient, values between 20% and 50% indicate medium heritability coefficient, and lower than 20% refer to low heritability coefficients [17]. Moreover, from this estimate it is possible to estimate the success with the selection.

The values found for heritability were 86.00%, 53.00%, 45.00%, 73.00%, 96.00% and 38.00% for 100-grain weight (g), percentage of filled grains, yield (kg·ha^{-1}), plant height (cm), days until flowering (days) and rice blast severity (Blast), respectively. The values that were found proving a potential success with the selection of the characters evaluated, except for productivity (0.45) and rice blast severity (0.38), they present lower heritability which is expected due to be characters controlled for a lot of genes.

Table 1. Analysis of variance summary and estimates of genetic parameters of upland rice, to days until flowering (DF), plant height (PH), percentage of filled grains (PFG), 100 grain weight (GW), and productivity of grains (Prod), rice blast severity (Blast), Preliminary trial, Lavras/MG, 2014/2015 season obtained of the comparative preliminary trial Lavras, 2014/15.

		GW	PFG	Prod	PH	DF	Blast
Lines	35	4.63**	118.16**	804,355.23**	87.10**	140.35**	0.24**
Replication	2	1.94	36.07	989,003.57	430.68**	72.03**	0.26**
Error	70	0.65	56.06	443,165.55	23.56	5.01	0.15
Accuracy		0.93	0.72	0.67	0.85	0.98	0.63
σ_g^2		1.987	31.05	180,593.5	31.75	67.67	0.03
σ_f^2		2.313	59.08	402,177	43.55	70.175	0.08
h_a^2		0.858	0.53	0.45	0.73	0.96	0.38
SG		1.49	4.61	325.29	−5.50	−9.23	−0.15

**significantly in 5% de probability by the F's test and not significantly. (σ_f^2) phenotypic variance (σ_g^2) genotypic variance (h_a^2) heritability (SG) selection gain.

This was also the case for the characters 100-grain weight and percentage of filled grains, observed in another study [18], which reported that 43 upland rice accessions were estimated the heritability for the character of 100-grain weight and percentage of filled grains were the measured results showed a genetic advance.

Similar findings were reported by [19], with numbers 87.40%, 96.50%, 84.30%, 97.40%, for 100-grain weight (g), percentage of filled grains (%), plant height (cm) and days until flowering (days) respectively which implies that heritability could be used as a selection criterion for breeding programs.

The lines differed significantly for all characters, it means that there is significant genetic variance and that had not coincidental behavior among the lines (**Table 1**). Those estimates prove that there is existence of superior lines of upland rice.

[20] estimated the characters grain yield, plant height and days until flowering using 603 trials conducted in different Brazilian states, was observed in third phase for yield gain 315.0 kg·ha^{-1} per year, there was a reduction 3 cm for plant height and 0.25 day for days until flowering, presented flowering time between 75 and 85 days. In agreement from this study, the genetic gain for grain yield, plant height and days until flowering computed were satisfactory.

For all characters evaluated, the selection gain observed has shown efficiency in the selection of the best lines. Where stands out with intensity of selection of 10% of lines, the character yield, which is expected a genetic gain of 325.29 kg·ha^{-1}, plant height (cm) with an average reduction in 5.50 cm, and days until flowering, with a reduction of 9.23 days, with selection of earlier plants. In upland rice breeding, it is extremely important to obtain early-cycle lines, because late plants remain longer time in the field and are therefore more susceptible to biotic and abiotic stresses that may compromise grain yield (**Table 1**).

In **Table 2**, the Scott-Knott's test is presented. It is possible to observe the different performance of the lines for the characters evaluated. For the character days until flowering, it is possible to observe the earlier plants in the lines CMG 215-2 and 6 MG 215-3, which flourish in average with 84 days (**Table 2**). For the character plant height, the lines evaluated had a slightly higher average than the ideal mentioned in the literature, which is 100 cm [21]. The character 100-grain weight changes with the genotype and grain size, the values found in the assay were consistent with the average found in the literature, which ranging from 19 to 24 g [22], and the line CMG 2071 presented superior average, 26.28 g (**Table 2**).

The rice blast (*Magnaporthe oryzae*) is considered to be the most significant and potentially damaging rice disease [23]. Blast fungus can affect all parts above the ground on rice plant: collar, node, leaf, neck and panicles. At the later stages of the blast fungus, the infection can generate a severe disease in a rice plant, reducing leaf area and to reach neck and nodel what is seems more injures at farmers field, because it causes drastic loss in yield grains [24]. Thus, there is the

Table 2. Days until flowering (DF), plant height (PH), percentage of filled grains (PFG), 100 grain weight (GW), and yield grains (Prod), rice blast severity (Blast), Preliminary trial, Lavras/MG, 2014/2015 season.

	Lines	DF	PH	PFG	GW	Prod	Blast
30	CMG 2119	92.30 d	110.00 b	79.50 a	22.33 c	4823.01 a	1.00 c
36	CMG 2071	94.70 d	106.70 b	89.21 a	26.28 a	4689.68 a	1.00 c
25	CMG 601-7	101.00 c	109.00 b	83.51 a	22.15 c	4659.52 a	1.00 c
34	CMG 2143	98.00 c	109.30 b	86.39 a	23.09 b	4500.79 a	1.00 c
35	CMG 2171	97.00 d	106.70 b	72.77 b	20.94 c	4384.92 a	1.67 b
24	CMG 601-6	102.70 b	103.30 b	75.74 b	22.49 c	4289.68 a	1.00 c
23	CMG 601-5	102.70 b	107.30 b	82.69 a	21.94 c	4249.20 a	1.00 c
28	CMG 801-6	108.00 a	119.60 a	79.74 a	23.97 b	4237.30 a	1.67 b
31	CMG 2121	93.70 d	104.30 b	70.32 b	22.76 b	4002.38 a	1.00 c
32	CMG 2136	98.00 c	109.70 b	67.85 b	22.78 b	3979.36 a	1.00 c
2	BRS Esmeralda	99.70 c	105.70 b	70.59 b	22.56 c	3963.49 a	1.00 c
5	CMG 215-2	84.30 e	119.00 a	79.02 a	21.90 c	3962.69 a	1.00 c
6	CMG 215-3	84.30 e	121.30 a	78.81 a	22.02 c	3945.23 a	1.00 c
4	CMG 215-1	87.00 e	118.30 a	78.92 a	21.97 c	3939.68 a	1.67 b
13	CMG 310-8	104.70 a	100.30 b	74.02 b	21.10 c	3939.68 a	1.00 c
16	CMG 418-5	105.70 a	106.00 b	71.06 b	23.39 b	3882.54 a	1.00 c
21	CMG 601-3	103.00 b	107.00 b	83.26 a	21.97 c	3873.01 a	1.00 c
11	CMG 221-8	88.30 e	108.70 b	83.98 a	23.56 b	3872.22 a	1.00 c
27	CMG 601-9	102.30 b	108.00 b	72.51 b	20.91 c	3859.52 a	1.00 c
9	CMG 221-5	87.00 e	104.30 b	80.77 a	22.92 b	3857.14 a	1.00 c
26	CMG 601-8	103.70 b	105.70 b	74.79 b	21.45 c	3747.61 a	1.00 c
18	CMG 419-3	92.30 d	112.70 a	78.94 a	21.21 c	3684.92 a	1.00 c
22	CMG 601-4	103.00 b	105.00 b	82.63 a	21.32 c	3624.60 a	1.00 c
10	CMG 221-6	90.70 d	105.30 b	80.75 a	23.17 b	3612.69 a	1.00 c
14	CMG 318-2	106.30 a	106.30 b	78.22 a	25.81 a	3607.93 a	1.00 c
20	CMG 601-2	101.70 b	101.30 b	74.29 b	21.04 c	3596.03 a	1.00 c
29	CMG 2110	98.00 c	105.70 b	71.16 b	23.28 b	3540.47 a	1.00 c
17	CMG 419-2	97.00 c	115.30 a	80.46 a	21.41 c	3526.19 a	1.00 c
15	CMG 418-4	93.30 d	110.70 b	69.07 b	22.21 c	3423.80 a	1.00 c
12	CMG 301-1	91.70 d	110.30 b	71.66 b	22.85 b	3419.84 a	1.00 c
33	CMG 2140	95.00 d	110.30 b	78.73 a	21.66 c	3411.90 a	1.00 c
19	CMG 422-8	93.00 d	116.30 a	74.81 b	23.68 b	3323.01 a	1.00 c
8	CMG 221-1	86.30 e	105.00 b	82.28 a	23.24 b	3305.55 a	1.00 c
7	CMG 215-4	84.00 e	118.70 a	88.89 a	21.27 c	3202.38 a	1.00 c
1	BRSMG Caravera	92.30 d	103.70 b	67.03 b	22.07 c	2514.28 a	2.33 a
3	CMG 207-6	94.00 d	107.30 b	62.56 b	20.90 c	2418.25 a	1.00 c

Averages followed by the same letter in the columns did not differ according to Scott-Knott's test.

need to implementing breeding programmes for blast resistance in rice because they are economically and environmentally sustainable [23].

In the present study, it has been found the character rice blast severity the potential tolerance of the lines for the evaluated disease, being all scores lower than 2, with exception the line BRSMG Caravera (**Table 2**). According to the score scale used for assessment [10], the lines presented lower percentage of disease severity, essential fact for the recommendation of these genotypes.

For the character yield the averages were not grouped into different groups. Nevertheless, 34 lines presented productivity above average of the Minas Gerais state, which is around 2973.5 ton·ha^{-1} [25]. Remarkable that the lines 36 and 34 presented higher productivity, greater 100-grain weight and potential tolerance to rice blast, however, it is important to note that the genotypes were evaluated in the irrigated production system, a fact that favors the phenotypic expression.

The test of phenotypic, genotypic and environmental correlation among the characters is presented in **Table 3**. Interpretations of correlations shows three aspects must be considered: magnitude, direction and significance. Positive correlation coefficients indicate the tendency of one variable to increase when the other increases. Negative correlations indicate a tendency for one variable to increase while the other one decreases [26], in other words, they express themselves in opposite directions. Knowing the correlations allows making indirect selection of characters.

Table 3. Phenotypic, genotypic and environment correlation of days until flowering (DF), plant height (PH), percentage of filled grains (PFG), 100 grain weight (GW), and yield (Prod), rice blast severity (Blast), Preliminary trial, Lavras/MG, 2014/2015.

	DF	PH	PROD	BLAST	PFG	GW
DF F	-	−0.4306**	0.2419ns	−0.0342ns	−0.146ns	0.0545ns
G	-	−0.4969**	0.4611ns	−0.0009ns	−0.1497ns	0.0808ns
E	-	−0.141ns	−0.4388ns	−0.2291ns	−0.3034ns	−0.2679ns
PH F		-	0.0298ns	0.0869ns	0.2302ns	−0.0225ns
G		-	−0.0715ns	0.1481ns	0.4865**	−0.025ns
E		-	0.1832ns	0.0179ns	−0.1981ns	−0.115ns
PROD F			-	−0.1845ns	0.44**	0.2401ns
G			-	−0.4942**	0.9498**	0.213ns
E			-	0.0416ns	−0.0419ns	0.3868ns
BLAST F				-	−0.254ns	−0.0618ns
G				-	−0.9532**	−0.1462ns
E				-	0.3383ns	0.0804ns
GW F					-	0.2605ns
G					-	0.3984ns
E					-	−0.0277ns

ns = not significantly; ** = significantly, in 5% de probability by the F's test.

The genotypic and phenotypic correlations for most of the characters are similar in relation to magnitude and sign, however, genotypic correlations are generally, in absolute values, superior to phenotypic coefficients, showing a greater contribution of the genetic factors and a smaller contribution of the factors environmental impacts. This fact is extremely favorable to the success of breeding programs, which focus on selection, to reduce the environmental effect on phenotypic expression [27].

The highest positive and significant phenotypic and genotypic correlations were observed between productivity and percentage of filled grains (0.95). Indicating that the higher the percentage of filled grains, higher the productivity. The plant height showed a positive and significant genotypic correlation of 49% among the percentage of full grains, showing that taller plants produce a larger number of grains.

The causes for high correlations may be due to pleiotropic or due to linked genes. Linked genes that are inherited together with the other genes as they are located on the same chromosome. In the case of pleiotropy, the same gene influences the expression of more than one character. This information is useful in plant breeding, it favors the simultaneous selection of two or more characters by selection in only one of these.

The highest phenotypic correlations, negative genotypic and significance were observed between the characters percentage of filled grains and blast severity (−0.95). The lower the incidence of blast severity is, percentage of grains filled is higher and consequently the higher the yield. This result is expected, whereas the blast is one of the main diseases of rice, the losses are variable, being higher in upland rice and can compromise production up to 100% in the years of epidemic attacks.

4. Conclusion

There is great genetic variability among the upland rice lines, carrying in a positive result with the selection of upland rice superior lines for the characters studied. Selecting 10% of the lines obtained a genetic gain of 325.29 $kg \cdot ha^{-1}$ for the yield. The lines CMG 2071 and CMG 2143 presented higher productivity, greater 100-grain weight and potential tolerance to rice blast and can be classified as precocious.

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