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Physical, chemical and industrial quality in upland rice genotype

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Abstract: For the recomendation of the new rice cultivars, it is necessary that these have the physical, chemical and industrial standard of quality required by the market. The lines must have long thin classification, intermediate amylose content and gelatinization temperature, and high percentage of whole grains. This study aimed to evaluate the quality of grains in the elite lines of the UFLA Rice Breeding Program. The experiments were carried out in the experimental area of the Department of Agriculture, UFLA/MG in the 2013/14 and 2014/15 seasons, and in the Epamig experimental farm, Sertãozinho experimental field, in Patos de Minas/MG, in the 2013/15 season. After harvest evaluated the traits: yield (kg.ha^{-1}), percentage of whole grains, length/thickness ratio (mm), chalky grains percentage, amylose content (%) and gelatinization temperature (notes) were processed and determined. For most traits evaluated, the genotypes x environments interaction was significant, indicating differences in the behavior of lines in different environments. The lines showed thin long grain classification, intermediate amylose content and medium to low gelatinization temperature. CMG 2097 genotype is outstanding, which has a high percentage of whole grains, high yield potential and ideal phenotypic traits for high quality of grain.

Keywords: *Oryza sativa* L, Grain quality, Baking quality.

Qualidade física, química e industrial em genótipos de arroz de terras altas

Resumo: Para lançamento de novas cultivares de arroz é necessário que essas atendam o padrão de qualidade física, química e industrial exigido pelo mercado. As linhagens devem apresentar classificação longo fino, teor de amilose intermediário e alta porcentagem de grãos inteiros. O trabalho objetivou avaliar a qualidade dos grãos em linhagens elites do Programa de Melhoramento de Arroz da UFLA. Os experimentos foram conduzidos na área experimental do Departamento de Agricultura, da UFLA/MG nas safras 2013/14 e 2014/15, e na fazenda experimental da Epamig, campo experimental de Sertãozinho, em Patos de Minas/MG, na safra de 2013/14. Após a colheita, os grãos foram beneficiados e foram determinados os caracteres, porcentagem de grãos inteiros, relação comprimento/espessura, porcentagem de gessamento, teor de amilose e temperatura de gelatinização. Para a maioria dos caracteres avaliados a interação genótipos x ambientes foi significativa, indicando diferença no comportamento das linhagens nos diferentes ambientes. As linhagens apresentaram classificação de grãos longo fino, teor de amilose intermediário e média a baixa temperatura de gelatinização. Pode-se destacar a linhagem CMG 2097, que apresentou alta porcentagem de grãos inteiros e características fenotípicas ideais para alta qualidade.

Palavras chave: *Oryza sativa* L, Qualidade de grãos, Qualidade de cozimento.

Introduction

Rice (*Oryza sativa* L.) is growing in every continent, covering about 120 countries. This grain is consumed by more than 40% of the population and hardly suffers replacement. The evolutionary process of rice cultivation led to the adaptation of plants to many environmental conditions including stress conditions (Shehab et al., 2010).

More broadly, in Brazil two major ecosystems are considered for culture: the lowland (flooded) and the upland (dryland). In the country, the area used for rice production has been reduced in about % in the last 40 years, second National Supply Company [CONAB] One of the factors that led to the planted area reduction in the system called upland was the absence of cultivars with long thin grains. However, breeding programs began to change the grain type of cultivars intended for that farming system since 1990 (Breseghello et al., 2011).

The “quality of grain” term used in rice production has different meanings, where it is designed differently depending on the consumer type and purpose of consumption to which it will be submitted. Since most of the rice consumption occurs as whole grains, husked, polished and boiled (physical and chemical of the grain, such as rice texture after baking, influence the final consumption of product. related to final quality of the rice grains are influenced by genotype, conditions and cultivation ways, post-harvest processes (storage and processing) and method of grain preparation (Paiva et al., 2015).

In Brazil, there was an old belief that there was difference in quality between the rice grown in upland and that grown in lowland, the latter which was considered better (Soares et al., 2004). However, national breeding programs of rice cultivation, to meet the requirements of consumption and demand for new areas, launched cultivars in uplands with high grain quality.

Due to the need to meet the demands of the consumer market, the cultivars to be recommended must have intermediate amylose content (20.1 to 25%) whole grains, when cooked, have dried and loosed, with intermediate gelatinization temperature (63 to 73 °C), which provides a quick cooking, and long thin classification (ratio length thickness ≥ 2.75 mm), preferentially in grain form and high percentage of whole grains. These factors are directly related to the financial return to the producer and better consumer acceptance (Brasil, 2012 & Bergman, 2019).

Thus, this work aims to identify and select phenotypically superior lines with the intention of the futher market lauching.

Material and methods

The experiment was carried out at two sites: Lavras/MG, at an altitude of 954 m, 21º12’11’’ south latitude and 44º58’47’’west longitude, in the 2013/14 and 2014/15 seasons; and Patos de Minas/ MG, at an altitude of 832 m, 46º31’05’’ south latitude and 18º34’44’’ west longitude, Epamig, experimental field of Sertãozinho in the 2013/14 season. The design used was a randomized block with three replications, consisting of five rows of four meters with spacing of 35 cm between rows, where the three central rows were considered as a useful area.

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. Standard agronomic practices were followed by Utumi (2008) and plant protection measures were taken as required.

It was evaluated seven upland rice lines of the VCU test of the breeding program of Federal University of Lavras [UFLA] in partnership with Embrapa arroz e feijão and Epamig (CMG 2170, CMG 2097, CMG 2089, CMG 2085, CMG 1977, CMG 1896, CMG 1511) four controls (BRSMG *relâmpago*, BRSMG *caravera*, BRSMG *caçula*, BRS *esmeralda*) This plot area was harvested with moisture rate of the grain nearby 18%. After harvesting, the grains were dried to about 13% moisture rate and weighed to obtain the estimate of productivity per plot, which was extrapolated to kilograms per hectare.

The grain processing of the genotypes used was carried out after harvesting and drying. From the total each harvested plot, a sample of 100 grams of grains was taken, which were subject to processing by peeling and burnishing, using test engine Suzuki, MT 86® model. In order to remove the shell seed and embryo, the sample was peeled three times. After that, the grain pellicle removal occurred by means of burnishing process for one minute.

Thereafter, the burnish grains were placed in "trieur" number 1 and the separation of both broken and whole grains was processed for one minute. Thus, the grains which remained in the "trieur" were weighed, obtaining the percentage of whole grains, and the rest were considered as broken grains (Brasil, 1988).

The miling yield: was determined by adding yield grains and yield broken grains, resulting in the percentage of rice benefited from rice sample with shell of each experimental unit.

The grain: yield was determined by weighing the peeling and burnishing grains with a greater than three-quarters of its lengths.

The amylose content was estimated by the colorimetric method described by Martinez et al. (1989). The processed grains of each plot were ground into micro mill, and a sample of 100 mg was transferred to test tube where 1 mL of ethyl alcohol 96% GL and 9 mL of NaOH 1 N solution was added. This solution was subject to water bath at 100 °C for 10 min, and cooled for 30 min. After cooling, the volume was completed to 100 mL with aid beakers and samples were transferred to Erlenmeyer. An aliquot of 5 mL was removed from each sample and transferred to another Erlenmeyer, to which 1 mL of acetic acid 1 N and 2 mL of iodine solution 2% (p/v) prepared three hours before the analysis were added. Finally, the volume was completed with distilled water to 100 mL with aid beakers. To build the standard curve, 40 mg of pure amylose subjected to the same procedure used in rice flour samples was used. Aliquots of 1, 2, 3, 4, and 5 ml were taken from the Erlenmeyer and 0.2; 0.4; 0.6; 0.8 and 1 mL of acetic acid and 0.4; 0.8; 1.2; 1.6 and 2 mL of iodine, respectively, were added, completing the volume to 100 mL with distilled water. The absorbance reading was performed 30 min after iodine solution addition at 610 nm of absorbance (A). The result was obtained by means of a standard curve built in each analysis.

The gelatinization temperature was estimated indirectly according to the method proposed by Little et al. (1958). Six rice grains burnished from each plot were placed in Petri dishes containing 10 ml of KOH solution to 2.08%. The plates were covered and kept for 24 hours at 30 °C. The grains expansion degree was evaluated on a numerical scale from 1 to 7 (1 = unaffected grain; 2 = swollen grains; 3 = swollen grains with incomplete collar or narrow; 4 = swollen grains with complete collar and wide; 5 = slit grains with complete collar and wide; 6 = scattered grains, united by the collar; 7 = completely dispersed grains and mixed with each other).

Rice grains samples ranging from 1 to 2 of the Alkaline digestion were considered high gelatinization temperature; range 3 high/intermediate gelatinization; between 4 and 5 medium, and 6 and 7 low temperature.

After processing grain which remained in "trieur" number 1, a subsample of 100 grains was taken from each plot. Rice grain images capture was performed with the aid of GroundEye® equipment. The grains were placed in the tray of the equipment without any defined position.

The images were captured by high-resolution camera and then the GroundEye® configuration was made. For calibration of background color, brightness values, dimensions "a" and "b", and the minimum grain size were adjusted according *O. sativa* L. After processing grains which remained in "trieur" number 1, another subsample of 100 grains was taken from each plot.

From the samples taken, 100 random grains were separated by the presence or absence of chalky in endosperm, determining the percentage of chalky grains in each.

For statistical analyses were used the statistical program R (R Core Team, 2019) and the averages grouped by Scott-Knott test with $p > 0.05$.

The contrasts between cultivars control and evaluated lineages were estimated to characterize differences between the averages of the evaluated. For this analysis the confidence interval test between two averages was used with the statistical program SISVAR (Ferreira, 2019).

Results and discussions

In general, the values of coefficient of variation (CV%) obtained in the experiment reflect the experimental precision. According to CV% values below 20 are considered of excellent to good precision. All traits evaluated, except for chalky (22.77), showed CV% values less than 20% (Table 1), confirming the accuracy in conducting experiments. The high CV (%) found for chalky can be explained by the fact that it is a trait evaluated indirectly and subjectively by different evaluators.

Table 1 - Probability values of the F test of the joint variance analysis, means of the genotypes and coefficient of variation for the amylose content (AC), gelatinization temperature (GT), length/thickness ratio (LT), whole grains (WG), chalky grains (CG) and yield (Y) rice grains test of value for cultivation and use of the breeding program of upland rice in Lavras, 2013/14 and 2014/15 seasons and Patos de Minas 2014/15 season, MG.

SV	DF	Pr>Fc					
		AC (%)	GT (notes)	LT (mm)	WG (%)	CG (%)	Y (kg.ha^{-1})
Genotypes	10	0.028	0.419	0.002	0.000	0.0003	0.000
Environments	02	0.000	0.156	0.017	0.038	0.0000	0.000
Genotypes x Environment	20	0.531	0.038	0.022	0.020	0.0051	0.000
Repetitions/Environment	06	0.018	0.339	0.868	0.382	0.4299	0.004
Error	60						
CV (%)		7.87	18.67	5.52	11.37	22.77	13.69
Average Lines		23.24	4.98	3.35	52.81	17.27	5833.18
Average control		23.18	4.67	3.34	45.13	15.07	4960.89
Contrasts Lines vs Controls		0.06*	0.31*	0.01*	7.68	2.20*	872.29

The variance analysis showed significant differences (p≤0.05) for all characteristics evaluated, except for gelatinization temperature, considering the sources of variation genotypes and environment (Table 1). The significance indicates the presence of genetic variability among genotypes of VCU test of the UFLA breeding program.

The significance of interaction genotype x environment for all traits, except for amylose content, shows that behavior of each line, in relation to the traits studied in different environments, was not coincident. This interaction is not favorable for breeding programs aiming at the grain quality, since it can affect the indication of cultivars for different regions (Ramalho et al., 2012). Also, according to Ramalho et al. (2012), the most widely used alternative to attenuate the effect of genotype x environment interaction is the identification of lineages with enhanced phenotypic stability. This study should be done to the genotypes and traits evaluated.

The average of genotypes, considering all the characteristics, are shown in Table 2. For the amylose content (AC), lines obtained averages between 21 and 25%. According to, AC values between 20.1 to 25% are considered intermediate to high, which characterizes dry and loose grains after cooking, highly desirable characteristic for the consumer.

Gelatinization Temperature (GT) is another trait, which influences in cooking grains. In general, it assesses the resistance to cooking, i.e, the cooking time. According to Little et al., (1958), lines that present GT notes between 4 and 5 are considered medium to low GT, which provides a quick grain cooking. All tested lines showed average notes from 4.33 to 5.44 (Table 2), and may be classified as ideal, meeting the market demands.

In the Brazilian market, the preferred grain type is the long thin that is characterized by presenting a length/thickness ratio ≥ 2.75 mm (. Despite showing significant difference in the average test, no genotype obtained estimates of length/thickness ratio less than 2.75 mm (Table 2). All are, therefore, classified within long thin standard.

The genotypes showed percentage of whole grains higher than the national average ranging from 51 to 55% (Table 2). Although the genotypes present averages above those national, this percentage is still low when compared to the averages found in the literature that exceed 60% (Garcia et al., 2015). According to Grigg and Siebenmorgen (2015), the percentage of whole grains at the end of the beneficiation process is related to the physical properties of the grains.

Table 2 - Average phenotypic joint analysis of amylose content, gelatinization temperature, length/thickness ratio, whole grains, chalky and yield rice grains test of value for cultivation and use of the breeding program of upland rice in Lavras, 2013/14 and 2014/15 harvests and Patos de Minas 2014/15 harvests, MG.

Genotypes	Amylose content (%)	Gelatinization temperature (notes)	Length/ Thickness (mm)	Whole grains (%)	Chalky (%)	Yield (kg.ha^{-1})
CMG 2170	22.72 a	4.78 a	3.25 b	54.13 a	16.14 a	5437.05 a
CMG 2097	23.48 a	5.00 a	3.25 b	55.15 a	11.83 b	5884.92 a
CMG 2089	24.37 a	5.11 a	3.50 a	51.58 a	23.32 a	5828.92 a
CMG 2085	23.44 a	4.67 a	3.46 a	51.04 a	20.57 a	6142.43 a
CMG 1977	22.77 a	4.89 a	3.32 b	51.98 a	16.04 a	5394.79 a
CMG 1896	22.95 a	5.00 a	3.21 b	51.40 a	22.11 a	6246.28 a
CMG 1511	22.96 a	5.44 a	3.47 a	54.40 a	10.89 b	5897.92 a
BRSMG *Relâmpago*	24.70 a	4.67 a	3.25 b	48.34 a	18.79 a	5538.49 a
BRSMG *Caravera*	23.46 a	4.56 a	3.31 b	42.06 b	18.44 a	4312.80 b
BRSMG *Caçula*	23.34 a	5.11 a	3.31 b	51.96 a	14.94 b	5197.85 b
BRS *Esmeralda*	21.23 a	4.33 a	3.49 a	38.15 b	08.11 b	4794.42 b

Averages followed by the same letter in the column belong to the same group by Scott-Knott test at 5% probability.

The lines evaluated showed yield of whole grains higher than those of the control, as noted in the contrast, where, although not significant, it shows that the average of the lineages present 7.68% more of whole grains (Table 1).

The translucency rice grains may be replaced by opaque regions in the endosperm known as chalk (Brasil, 2012). According to, chalk occurs because of a disorder in arrangement of starch and protein molecules, so that there is space filled with air between the molecules. Even the grain with small chalk areas depreciates the commercial value of the product. The genotypes presented chalky grains percentages ranging from to 23% (Table 2). Control presented average of chalky grains lower than the genotypes of VCU. The lines of VCU presented 2.20% more chalky grains (Table 1). The percentages obtained can be further reduced, since there are reports in the literature of only 3% of chalky grains (Pierobon et al., 2016)

For the trait yield (kg.ha$^{-1)}$, VCU's lines presented a high yield potential, with average 5394.79 to 6246.28 kg.ha^{-1}, higher than those of control where the average ranged from 4312.80 to 5538.49 kg.ha^{-1}. According to the contrast, VCU's lines presented higher averages than those of control. Although not significant, this difference is 872.29 kg.ha^{-1} (Table 1). The averages obtained in the experiments exceed the national average for upland rice, which is about 2421 kg.ha^{-1} (CONAB, 2020).

Given the above, VCU's lines evaluated generally presented high physical, chemical and industrial quality of rice grains, and high yield potential, produced under the upland system. The quality standards achieved by VCU's lines meet the main demands of the consumer market, which is highly selective to the grain type.

The high quality obtained disagree with the statements made by Soares et al. (2004), who stated that the quality of grain produced in the flooded system is better than the quality of the grain produced in the upland system. However, the results corroborate those found by Pagnan et al. (2015), who say there is no difference between the quality of the grain produced in both systems. Moreover, the high grain quality and high yield confirm the selection efficiency of the breeding program of UFLA in partnership with Embrapa arroz e feijão and Epamig.

Conclusions

The lines test of value for cultivation and use of the breeding program of UFLA upland rice in partnership with Embrapa arroz e feijão and Epamig have high yield potential and high physical, chemical and industrial quality of rice grains.

The line CMG 2097 stands out for presenting the highest percentage of whole grains and high yield potential, along with other phenotypically ideal characteristics of an upland rice genotype.

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