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RESEARCH ARTICLE

OCCURRENCE OF GRAIN CHALKINESS IN UPLAND RICE GENOTYPES GROWN WITH AND WITHOUT IRRIGATION

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ABSTRACT

Among physiological disorders, chalkiness is one of the main problems in rice breeding since it directly affects grain quality and rice price in the market. Chalkiness can occur due both genotypic and environmental effects, including malformed grains, moisture content, pest attack, and water stress. Therefore, the study of mechanisms influencing the expression of chalkiness can greatly help breeders to deal with this problem. The objective of this study was to access the influence of water supply on the occurrence of chalkiness in rice grains of twenty elite inbred lines from the Upland Rice Breeding Program from the Brazilian public research institutions UFLA, EMBRAPA and EPAMIG. Lines were evaluated for grain chalkiness in two irrigated environments and in a non-irrigated one. The experiments were carried out in the 2013/2014 growing season following a randomized block design with three replications. The proportion of chalkiness was accounted of the number of chalky grains of a random sample of 100 grains taken from 10 random panicles of each plot. Genotype x environment interaction was significant in the combined analysis of variance of all environments, so progenies performance varied across environments. Lines showed variability for chalkiness on the non-irrigated environment and on the mean of all environments, but they did not differed on the irrigated environments separately, indicating that the expression of chalkiness in this study occurred mostly due to the environment rather than to genotypes. Lines evaluated in the non-irrigated environment showed a significant large proportion of chalky grains compared to the proportion found in the irrigated environments, suggesting that water supply influenced the expression of grain chalkiness. Lines CMG 1987 and CMG 1698 showed significant tolerance of chalkiness in the non-irrigated condition.

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INTRODUCTION

Riceis the most widely consumed staple food for a large part of the population, and Brazil is the only non-Asian country among the ten biggest producers of rice in the world. About twenty species of *Oryza* are known, but the main proportion of cultivated rice is from *Oryza sativa* L. (Limberger *et al*., 2008). This specie characteristically has a high starch concentration, besides proteins, vitamins, minerals, and low content of lipids. However, the grain content can vary due to environmental conditions, directly impacting on nutritional composition of grains (Breseghello, 2006). Starch accounts approximately 90% of polished rice dry matter. The amylose content is crucial to grain clumping, and thus is considered the major factor to determine grain quality (Vieira and Rabelo, 2006). Marker quality is mainly determined by physical properties such as translucence, which relates to the degree of crystallinity of the starch, a function of the structure and packaging of the amylopectin molecules, and to the ability of the light to be refracted without interfering with protein bodies (Ishimaru *et al*., 2009). Chalkiness is the opposite of translucence, one of the main problems in rice breeding since it directly affects grain quality and rice price in the market (Kim *et al*., 2000). Chalky is the opaque area in the rice grain that occurs due to malformed starch granules with air spaces between them. The air spaces diffract the light, making the grain look opaque (Ishimaru *et al*., 2009). Despite disappearing on cooking and having no effect on rice taste or aroma,

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chalkiness detracts from the appearance and thus downgrades milled rice (IRRI, 2006). The chalky appearance can occur due to genetic and environmental causes. Studies showed that chalkiness is a quantitative trait, which may be controlled by triploid endosperm genetic effects, cytoplasm genetic effect, diploid maternal effect, or simultaneous effects of all of these (Shi *et al*., 2002). Regarding environmental effects, the main causes seems to be malformed grains, presence of many immature grains, humidity and pest attack before harvesting (Vieira *et al*., 2006). However, the major cause of chalkiness is considered to be exposure to high temperatures during the ripening period (Tashiro and Wardlaw, 1991). Chalky grains are frequently found when temperature during the 20 day period after heading is above 26°C (Wakamatsu *et al*., 2007), which is a very commonly condition in many Brazilians agricultural areas. It seems that the resistance of plants to high temperatures is directly affected by water supply during crop season. It is possible that water stress in rice may increase the temperature of the soil-plant system, leading to physiological disorders that can cause chalkiness in rice grains. If so, selecting genotypes that do not present chalkiness in environments with water stress can be an efficient strategy in Brazilian areas that have potential to crop upland rice but where is not possible to irrigate due to the landscape or to the economical condition of some small farmers. Therefore, the aim of this study was to access the influence of water supply on the occurrence of chalkiness in grains of rice lines from the Brazilian Upland Rice Breeding Program, and to select upland rice lines tolerant to grain chalkiness in conditions under no irrigation.

MATERIALS AND METHODS

Twenty elite inbred lines from the Upland Rice Breeding Program from the Brazilian public research institutions UFLA, EMBRAPA and EPAMIG were evaluated for grain chalkiness under two conditions: with and without irrigation. The non-irrigated experiment (named NI) was carried out in the Experimental Station of "Muquem", located near the city of Lavras-MG, Brazil (21°14'43''S, 44°59'59''W). The irrigated experiment was carried out in two locations: in the experimental area at the Agriculture Department of UFLA in Lavras-MG, Brazil (named I1), and in the Experimental Station of "EPAMIG" (named I2) in Patos de Minas-MG, Brazil (18°34'44''S, 46°31'05''W). All experiments were grown in the 2013/2014 season following a randomized block design with three replications and plots consisting of five rows, of which the two side rows were used as borders. Plot rows were 4m long, spaced 25cm, with 80 seeds per meter. All cultivation practices necessary for the development of the crop were performed according to the technical recommendation for each environment. The proportion of chalky grains was accounted of 10 random panicles taken from the three centerlines of the plot of each line. The grains of all panicles were first processed in order to remove its skin and embryo. The proportion of chalkiness was accounted of the number of chalky grains of100 random grains sampled from the 10 panicles taken from each plot. Analyses of variance were computed for each environment and across environments using the statistical software Sisvar (Ferreira, 2011), and the means compared according to the Scott-Knott approach (Scott and Knott, 1974) with 5% of probability.

RESULTS AND DISCUSSION

Highly significant differences ($p < 0.05$) between lines were detected in the analyses of variance in all environments and across environments (not shown), indicating the existence of genetic variability, essential condition to achieve success with selection. Lines means varied between 29.67%and93% of chalky grains in the non-irrigated environment (NI), and from 4.33% to 22.67% in the irrigated environment I1 and from 3.00% to 21.67%in I2. In all cases, high accuracy estimates (over 0.80) were observed indicating that all experiments were carried out with high precision (Resende and Duarte, 2007). Genotype x environment interaction was significant in the combined analysis of variance of all environments, indicating that the progenies performance varied across environments. Lines evaluated in the non-irrigated environment (NI) showed a significant large mean of chalky grains (60.82%[a]) showed by the Scott-Knott test compared with the means found in the irrigated environmentsI1 (12.13%[b]) and I2 (11.19%[b]). This result suggests that water supply influenced the expression of grain chalkiness in the upland rice lines. According to Praba *et al*. (2009), besides yield reduction, water stress during the reproductive stage, combined with the plant genotype, can cause qualitative loses in rice grains. Yoshioka *et al*. (2007) discuss that the occurrence of chalky grains is directly related to a high temperature during the grain filling stage. This condition reduces the enzymatic activity related to grain filling, leading to a reduction of the grain weight, amount of amylase, consumption of photo assimilates, and interfering the water balance (Li *et al*., 2011).

Table 1. Phenotypic means of the proportion of chalky grains in the twenty elite upland rice lines across environments (AE), in the non-irrigated environment (NI), and in the irrigated environments I1 and I2

Lines	Chalkiness (%)[1]			
	NI	I1	I2	AE
BRS Esmeralda	29.67 d	9.33 a	11.33 a	16.78 d
CMG 1987	35.67 d	7.67 a	4.67 a	16.00 d
CMG 1698	42.33 d	8.67 a	3.33 a	21.89 d
CMG 2074	46.33 c	12.33 a	10.00 a	22.89 c
CMG 1511	48.67 c	4.33 a	13.67 a	22.22 c
BRSMG Caçula	49.00 c	15.33 a	7.00 a	23.78 c
BRSMG Relâmpago	54.33 c	15.00 a	12.67 a	27.33 c
CMG 1567	56.33 c	10.00 a	6.67 a	24.33 c
CMG 2173	57.67 c	5.00 a	3.00 a	21.89 c
CMG 1097-7	58.33 c	14.00 a	11.33 a	27.89 c
CMG 1509	63.00 b	9.33 a	12.33 a	28.22 c
CMG 2017	63.33 b	13.00 a	12.67 a	29.67 b
CMG 2097	64.00 b	11.67 a	7.00 a	28.56 c
CMG 1896	69.00 b	16.00 a	13.67 a	32.89 b
CMG 1977	69.00 b	17.67 a	12.00 a	32.89 b
CMG 2170	70.33 b	16.33 a	14.67 a	33.78 b
BRS Curinga	77.67 a	14.00 a	6.33 a	32.67 b
BRSMG Caravera	79.33 a	22.67 a	16.33 a	39.44 a
CMG 2089	89.33 a	11.00 a	20.33 a	40.22 a
CMG 2085	93.00 a	9.33 a	21.67 a	41.33 a

[1]Means followed by the same letter in the column do not differ with a probability of 5% by the Scott-Knott approach

The upland rice lines evaluated showed variability for chalkiness on the non-irrigated environment and on the mean

of all environments, but they did not differed on the irrigated environments separately (Table 1). The proportion of chalky grains ranged from 16.78% to 41.33% on the mean of all environments. This result suggests that the expression of chalkiness in this study occurred mostly due to the environment rather than to genotypes. However, lines CMG 2089, CMG 2085, BRS Curinga and BRSMG Caravera showed asignificant proportion of chalky grains in the non-irrigated environment compared to the other lines, suggesting that their genotypes also contributed to the occurrence of chalkiness. According to Vieira *et al*. (2006), the main environmental causes for chalkiness are malformed grains, presence of many immature grains, humidity and pest attack before harvesting. Among physiological disorders, chalkiness is one of the main problems in rice because it directly affects rice price in the market (Zhou *et al*., 2009). Chalky grains are frequently found when temperature during maturing is above 26°C (Ishimaru *et al*., 2009). It is possible that water stress increases the temperature of the soil-plant system, leading to physiological disorders that can cause chalkiness in rice grains. Irrigated environments, on the other hand, provide a more balanced condition to the plant development, favoring the production of grains with higher quality. The harvesting period is also a key factor for the expression of chalkiness (Smiderle and Dias, 2008). The association of early harvesting and high humidity increase the proportion of malformed and chalky grains. According to Castro *et al*. (1999), an average of 26% of moisture content already causes chalkiness. In general, the optimal period to harvest is from 30 to 40 days after flowering, when most grains show moisture content around 18-25% (Binotti *et al*., 2007). In this case, the selection of lines resistant to water stress turns to be an important strategy to obtain lines with grains with higher quality in what regards to chalkiness, specially in Brazilian areas that have potential to crop upland rice but where is not possible to irrigate due to the landscape or to the economical condition of some small farmers.

Conclusion

The non-irrigated environment favored the expression of chalkiness in grains of upland rice lines. Lines CMG 1987 and CMG 1698 showed significant tolerance of chalkiness in a non-irrigated condition.

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