Effects of Growing Temperature and Nitrogen Supply on Grain Chalkiness in Rice

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Abstract: ABSTRACT - Grain chalkiness or white patches in rice kernel is a major problem in almost all types of rice, as it lowers the mill-out yield and consumer acceptance. Adverse environmental conditions, particularly higher temperatures during grain filling have been reported to enhance chalkiness. In this study, the effects of two different nitrogen (N) levels and temperature regimes, on the extent of chalk (%) were tested. Interestingly, chalkiness was higher in the high N grown plants, which was further exacerbated by higher temperatures. Thus, in plants grown with higher N with more seed set, the supply and/or synthesis of carbohydrates is the limiting factor that is further impaired at higher temperatures and results in increased proportion of chalky grains. Results from the SEM analysis of starch packaging in endosperm of these grain samples, in relation to chalkiness, are discussed.
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ABSTRACT - Grain chalkiness or white patches in rice kernel is a major problem in almost all types of rice, as it lowers the mill-out yield and consumer acceptance. Adverse environmental conditions, particularly higher temperatures during grain filling have been reported to enhance chalkiness. In this study, the effects of two different nitrogen (N) levels and temperature regimes, on the extent of chalk (%) were tested. Interestingly, chalkiness was higher in the high N grown plants, which was further exacerbated by higher temperatures. Thus, in plants grown with higher N with more seed set, the supply and/or synthesis of carbohydrates is the limiting factor that is further impaired at higher temperatures and results in increased proportion of chalky grains. Results from the SEM analysis of starch packaging in endosperm of these grain samples, in relation to chalkiness, are discussed.

KEY WORDS – Rice chalkiness; temperature regime; nitrogen supply; starch packaging.

INTRODUCTION

Grain chalkiness or white patches in rice kernel is an undesirable attribute in all types of rice except the Arborio-rice used for making risotto and the sake rice used for wine making. Chalky grains are prone to breakage thus give poor head rice yield [1] - [2]. Additionally, chalkiness tends to affect the physicochemical and cooking properties of rice [3] - [4]. In general chalkiness is attributed to the grain position on panicle and limitation of photosynthates, especially when leaf to grain ratio is low [5] - [7]. Adverse environmental conditions, particularly higher temperatures during grain filling have been reported to enhance grain chalkiness in rice [4], [8] - [9]. In addition, there are genetic differences among rice lines for their susceptibility to chalk [10] - [11]. It has been reported that top-dressing of nitrogen fertilizers at booting stage can reduce the proportion of chalky grains [12].

The objectives of this study were to investigate the effects of two temperature regimes on mature grain appearance and to see if supplementary nitrogen can ameliorate the extent of chalkiness in rice.

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Material and Methods

Plant material and growth conditions

Two japonica rice lines, one prone to chalkiness and the other moderately-tolerant, were grown in the sand pots under the day/night temperature of 30/20°C. The two nitrogen (N) rates used were 60 or 240kg/ha, with half the amount supplied at sowing and the second half at the panicle initiation (PI) stage. At flowering, one set of pots (ten) were transferred to a growth-room at 27/17°C and the other at 35/25°C. Mature grains were harvested and cured at 25°C for 14 days before de-hulling and milling. Grain yield in each treatment and chalkiness (% of grains showing white patches) in different samples were recorded.

Scanning Electron Microscopic (SEM) analysis

A portion of white grain samples (with and without chalk) was freeze-fractured, mounted on stubs and carbon coated for SEM analysis on a Phillips XL-30 microscope.

III. RESULTS AND DISCUSSION

In plants grown at high N, the number of tillers/plant and florets/panicle were higher, thus resulting in 2-3 times higher grain yield than in plants grown at lower N. The tolerant rice line, grown at 27/17°C, showed minimal chalk (~0.9%) irrespective of the N nutrition. Chalkiness increased to ~1.52% but only in plants grown at higher N and elevated temperature, however the grain yield in these plants was also increased by 2 folds. The chalk prone line showed ~2.3% chalkiness in plants grown at 60Kg N and low temperature. In both the lines, grains matured ~10 days earlier in plants subjected to higher temperature than those grown at lower temperature. Interestingly, chalkiness was greater in the high N grown plants (4.0%), which was further exacerbated by higher temperatures (8.8%). These results imply that in plants grown with higher N, with more seed set, the leaf to grain ratio was relatively lower, thus causing limitation in the supply of carbohydrates from source to sink. Similar observations have been reported in other studies, particularly in rice lines with dense panicles and high seed set [6] – [7]. In addition, higher proportion of chalky grains observed in plants grown at elevated temperature regime, where the rate of grain maturity was enhanced, further substantiates the impaired supply of photosynthates. It has been reported that at elevated temperatures, expression levels/activity of a number of starch biosynthetic enzymes in developing rice grains is reduced thus affecting starch synthesis and its packaging [13] – [14].

Results from the SEM analysis of starch packaging in the endosperm tissues of the chalky and normal grains (Fig. 1) showed that the
starch granules were very compact and polygonal shape in the normal grains while in the chalky grains the granules were a bit larger, spherical and loosely packed (Fig. 1). These results on poor packaging of starch granules in chalky endosperms are consistent with the past observations [1] and [4]. Grain samples from plants grown at higher nitrogen and low temperature regime also showed a higher proportion of protein bodies as compared to those grown at low nitrogen (data not shown).

Fig. 1. Normal (left) and chalky (right) grains from the chalk-prone rice line and the SEM analysis of their starch granule structure and packaging.

Conclusion

This study indicates that the source to sink ratio plays an important role in dictating the extent of grain chalkiness, which is exacerbated by elevated temperatures during grain development. The interactions between nitrogen supply, grain chalkiness and higher temperature appears to be complex and needs further investigations with a range of indica and japonica rice lines, to draw clear inferences.

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REFERENCES