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Grain quality changes and responses to nitrogen fertilizer of *japonica* rice cultivars released in the Yangtze River Basin from the 1950s to 2000s

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ABSTRACT

While the yield potential of rice has increased but little is known about the impact of breeding on grain quality, especially under different levels of N availability. In order to investigate the integrated effects of breeding and N levels on rice quality 12 *japonica* rice cultivars bred in the past 60 years in the Yangtze River Basin were used with three levels of N: 0 kg N ha^{-1}, 240 kg N ha^{-1}, and 360 kg N ha^{-1}. During the period, milling quality (brown rice percentage, milled rice percentage, and head rice percentage), appearance quality (chalky kernels percentage, chalky size, and chalkiness), and eating and cooking quality (amylose content, gel consistency, peak viscosity, breakdown, and setback) were significantly improved, but the nutritive value of the grain has declined due to a reduction in protein content. Micronutrients, such as Cu, Mg, and S contents, were decreased, and Fe, Mn, Zn, Na, Ca, K, P, B contents were increased. These changes in grain quality imply that simultaneous improvements in grain yield and grain quality are possible through selection. Overall, application of N fertilizer decreased grain quality, especially in terms of eating and cooking quality. Under higher N levels, higher protein content was the main reason for deterioration of grain quality, although lower amylose content might contribute to improving starch pasting properties. These results suggest that further improvement in grain quality will depend on both breeding and cultivation practices, especially in regard to nitrogen and water management.

1. Introduction

Rice (*Oryza sativa* L.) is the most important staple food in the world, providing more than 21% of the calorific needs of the world population, but up to 76% of the calorific intake of the population in South East Asia [1]. In China, next to yield, improvement in grain qualities is becoming a priority, along with improvements in economic and living standards. Development of both high yield and high quality in rice varieties is essential [2].

Grain quality traits dictate market value and have a pivotal role in the adoption of new varieties. Rice quality traits encompass milling recovery, physical appearance, cooking and eating qualities, and nutritional value [3, 4]. The evaluation

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Table 1 – Growth duration, plant height, grain weight and the largest application area of the selected *japonica* rice cultivars.

Decade	Cultivar	Growth duration (days)	Plant height (cm)	Grain weight (mg grain^{-1})	Largest area of cultivation (×10^4 ha)
1950s	Huangkezao	138	121.2	21.6	>22
	Guihuaqiu	152	125.4	27.1	>25
1960s	Jinnanfeng	152	93.5	24.5	>120
	Guihuahuang	154	94.8	24.6	>150
1970s	Xudao 2	141	98.6	23.8	>45
	Liming	130	97.8	24.2	>20
1980s	Sidao 8	145	102.5	24.3	>42
	Yanjing 2	148	101.6	23.7	>75
1990s	Zhendao 88	144	110.4	25.9	>60
	Huaidao 5	151	108.9	26.7	>80
Since 2000	Huaidao 9	151	108.5	28.9	>20
	Lianjing 7	147	110.3	27.9	>120

criteria for milling quality mainly include brown rice percentage, milled rice percentage, and head rice percentage, which reflect the proportion of whole kernels (head rice or head milled rice) and broken kernels produced during milling of rough rice. Appearance quality is mainly determined by grain size, translucency, chalky grain percentage, chalky area and degree of chalkiness. Starch granules in chalky areas of the grain are smaller and less densely packed than the larger tightly packed granules in translucent areas of the grain [5]. Cooking and eating qualities are mostly specified by amylose content, gelatinization temperature, and gel consistency of the grain starch [6–8]. Nutritional value is essential because rice is a main source of dietary protein and micronutrients for most of rice growing countries. In order to improve quality traits along with yield it is necessary to understand the important quality traits, to select for them in a breeding program, and to control them through appropriate nitrogen and water management.

Historically, many breeding programs took yield potential as the priority target, particularly in China. Rice yields have increased from 2.0 t ha^{-1} in the 1950s to 6.6 t ha^{-1} in the 2000s [9, 10]. In 2006, the average rice grain yield in China was more than 50% higher than the world average [11]. The Yangtze River Basin is the main rice planting area in China, and represents 51.2% of the total rice growing area and 51.3% of the total rice production in the country [12, 13]. During the period, the yield potential has significantly improved [2, 12]. Farmers often use excessive N fertilizer to maximize grain yield. For example, China's national average N application for rice in 2006 was 193 kg ha^{-1}, more than 90% above the world average [11]. In Jiangsu province the average N application is more than 300 kg ha^{-1} in some high yielding counties [12]. Over-use of N fertilizer also contributes to poor eating and cooking quality of the grain [2, 12]. However, little is known about the impact of breeding selection on grain quality of rice, especially under different N levels. Understanding the changes in grain quality of the rice cultivars bred in different decades and their levels of response to of N fertilizer should be beneficial for improving rice quality in both rice breeding and cultivation.

In this experiment we selected twelve representative *japonica* rice cultivars bred in the area during the last 60 years. Milling characteristics, appearance, cooking and eating quality, and nutritional value of these cultivars were studied. Such a study should provide useful information for achieving a high-quality and high-yield rice production system with inputs from both agronomy and breeding.

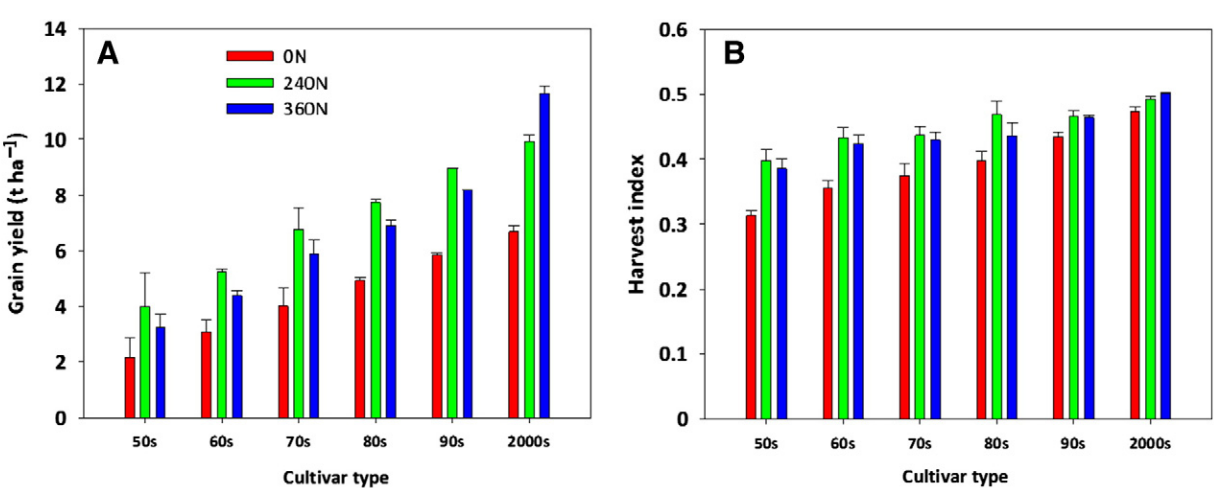

Fig. 1 – Grain yield (A) and harvest index (B) of rice cultivars released in the 1950s, 1960s, 1970s, 1980s, 1990s, and 2000s under 0 kg N ha^{-1} (0 N), 240 kg N ha^{-1} (240 N), and 360 kg N ha^{-1} (360 N) application levels. Data are averages of two years ±1 S.E. (vertical bars).