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RESEARCH ARTICLE

Charactering protein fraction concentrations as influenced by nitrogen application in low-glutelin rice cultivars

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Abstract

To optimize both grain yield and quality of low-glutelin rice cultivars under N-fertilizer strategies, two-year field experiments involving three low-glutelin rice cultivars (W1240, W1721, W025) and an ordinary rice cultivar (H9405) with five N treatments were carried out to determine the effects of N application rate and genotype on protein fractions contents and Glutelin/Prolamin ratio (Glu/Pro). The difference of protein fraction concentrations affected by N application rate existed in genotypes. Ordinary rice cultivar had a larger increase in glutlein concentration affected by N application rate than low-glutelin rice cultivars did. Glutelin in H9405 had a increase of 30.6 and 41.0% under the N4 treatment (360 kg N ha^{-1}) when compared with N0 treatment (no fertilizer N) in 2010 and 2011 respectively, while all the low-glutelin rice cultivars showed relatively smaller increases for two years. Variance analysis showed no significant effect of N application rate on glutelin in W1240 and W025 while the effects on albumin, globulin and prolamin were significant in low-glutelin rice. What's more, N treatment had no significant influence on Glu/Pro ratios in low-glutelin rice cultivars while a significant increase in Glu/Pro ratio was observed in ordinary rice cultivar. So low-gultelin rice cultivars showed a different pattern from ordinary rice cultivars when influenced by N application rate.

Keywords: low-glutelin rice, nitrogen, protein fractions, Glu/Pro

1. Introduction

Rice grain proteins were empirically classified into albumin, globumin, prolamin and glutelin based on their solubility. These proteins accumulate in two types of morphologically distinct organelles called protein bodies (PB). It has been shown that the type I protein body (PB-I) stores prolamin, whereas the type II protein body (PB-II) mainly contains digestible protein glutein (Becthel and Juliano 1980; Tanaka *et al*. 1980). Rice proteins are of better nutritional quality because the major of them are glutelins, which are nutritionally more important than prolamins due to their greater digestibility by humans and higher lysine concentration (Cagampang *et al*. 1966; Islam *et al*. 1996; Zhang *et al*. 2008).

Kidney disease has already been a common disease in the worldwide general population (Levey *et al*. 2007). It has boosted people's needs of the rice with low ratios of digestible proteins that kidney diseases patient had been on a very low protein diet to delay the progression of kidney

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diseases and the need for renal replacement therapy (Ohta *et al*. 2012). Low-glutelin rice with low ratios of digestible proteins had generally been developed in recent years (Iida *et al*. 2004; Nishimura *et al*. 2005; Su *et al*. 2008). Such rice cultivars are anticipated for production of dietary foods for patients with kidney disease and passed clinical test and verify. Moreover, they have been examined for brewing Japanese sake, because glutelin acidic subunits derive bitter-tasting sake peptide (Hashizume *et al*. 2007). Thus, the composition of rice protein is considered to affect not only the function of low-glutelin rice but also sake quality.

Low-glutelin rice faces the problems of lower yield and higher market price. Increasing N fertilizer applications has been a major measurement which contributes significantly to the rice yield improvement (Guo *et al*. 2010; Peng *et al*. 2010). In order to obtain higher economic benefits, more N fertilizer has been applied. Many studies showed that rice grain protein content increase markedly when more N fertilizer was applied (Ning *et al*. 2010; Kim *et al*. 2013). Therefore, N fertilization had a greater effect than genotype on the prolamin and glutelin fraction of the rice protein (Leesawatwong *et al*. 2005; Ning *et al*. 2010).

Contrary to ordinary rice, it is extraordinarily necessary to control the glutelin contents of rice grain in low-glutelin rice cultivars, because higher contents of glutelin fraction decrease the quality of dietary foods for kidney disease patients and Japanese sake production. There is a contradiction in low-glutelin rice: More N fertilizer applied to obtain higher grain yield will lead to a drop in quality of its function.

Ohdaira *et al*. (2010) reported that the effect of temperature on the rate of glutelin content was larger in low-glutelin rice than in ordinary rice cultivar. In low-glutelin rice cultivar, a decrease in prolamin and an increase in glutelin were recognized under high temperature during ripening (Ashida *et al*. 2013). Nevertheless, there have been no reports on the effect of N fertilizer application rate on the protein fractions in low-glutelin rice cultivars. Whether N fertilizer will lead to a damage of function in low-glutelin rice cultivars remains unclear.

In the present study, three low-glutelin rice cultivars and one ordinary rice cultivar were used and five N application rates were applied. Albumin, globulin, prolamin, and glutelin percent contents in polished rice grain were assayed and variation characteristic of four protein fractions were analyzed. Our aims were to: (1) identify genotypic differences between contents of four protein fractions in low-glutelin rice and ordinary rice in response to N application rates; (2) analyze the difference characteristics among four protein fractions in low-glutelin rice cultivars under different N application rates.

2. Results

2.1. Grain protein fractions in low-glutelin rice and ordinary rice

Significant genotypic variations of grain protein content among the cultivars existed (Table 1). Average total protein content of low-glutelin rice under the five N treatments was significantly lower than that of the ordinary rice H9405 in both two years (Tables 2 and 3). Average albumin fraction content did not reach a significant level between low-glutelin and ordinary rice cultivars in both years. However, average globulin fraction content was lower in ordinary rice except for the cultivar W025 in 2011. By contrast, prolamin fraction content of the ordinary rice H9405 was higher than any of the three low-glutelin rice. Almost the same as prolamin fraction, glutelin fraction content of ordinary rice was nearly 4% higher than that of low-glutelin rice in 2010 and 2011 (Tables 2 and 3).

2.2. Effect of N application on grain protein fraction among different genotypes

Total protein content Generally, with N level increasing, grain protein concentrations increased in both years, being the lowest for N0 (no fertilizer N) and the highest for N4 (360 kg N ha^{-1}). On average, the total grain protein concentration of the four cultivars in N4 increased by 21.7% relative to the N0 treatment in 2010, and increased by 23.2%

Table 1 Analysis of variance of genotype (G) and N effect on grain yield and contents of the four protein fractions in milled rice

Source of variation	*df*	Albumin	Globulin	Prolamin	Glutelin	Total	Glu/Pro
Year (Y)	1	73.613**	3.355	1.738	23.479**	25.870**	18.497**
Genotype (G)	3	19.710**	209.541**	466.225**	879.910**	924.780**	177.139**
N effect (N)	4	31.242**	17.193**	27.031**	25.761**	38.038**	0.871
Y×G	3	2.494	34.780**	36.346**	1.621	3.160*	10.664**
Y×N	4	0.577	0.112	1.022	0.392	0.364	0.499
G×N	12	0.729	0.878	0.869	5.484**	5.286**	1.699
Y×G×N	12	0.701	0.954	0.427	0.701	0.705	0.389

Data presented are mean squares. * and **, significant at 0.05 and 0.01 probability levels, respectively.