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Effect of Amount of Nitrogen Application on Physicochemical Properties, Taste value and Yield of Chinese *japonica–type* Rice Varieties

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The effects of the amount of nitrogen application on physicochemical properties, palatability (taste value) and yield were investigated by using, Chinese *japonica–type* (Jinchuan 1 and Yanfeng 47). With the increase in the amount of nitrogen application, the protein content increased but the amylose content, the maximum viscosity and the breakdown value decreased. These factors were a decrease of a 1000–grain weight by increase of the amount of nitrogen (N) application. The taste value was the highest at 7.5 N m^{-2} in Jinchuan 1, but it decreased with the increase in the amount of nitrogen application in Yanfeng 47. In both varieties, yield increased with the increase in the amount of nitrogen application. The protein content is linearly correlated with the amount of nitrogen application. The protein content was positively correlated with the amount of applied nitrogen per grain, and negatively with 1000–grain weight. From the relative ratio to maxim value of taste value and yield, the amount of nitrogen application suitable for high palatability and yield was assumed to be about 15 kg m^{-2} in both Jinchuan 1 and Yanfeng 47.

Key words: Amount of nitrogen application, Chinese *japonica–type* rice varieties, Palatability, Physicochemical properties, Yield.

INTRODUCTION

It's generally recognized that the amount of nitrogen fertilizer has a big influence on the yield, the physicochemical properties and the palatability.

The protein content is the very important of the physicochemical properties related to the palatability of rice. In the investigation of Cui *et al*. (2016b), among 260 rice varieties collected from various districts of China, only 49 varieties (18.8%) had the same superior physicochemical properties as in palatable Japanese varieties. This is because Chinese rice varieties have high protein content (Cui *et al*., 2000; Bian *et al*., 2006) and a large amount of nitrogen fertilizer is applied in China (Cui *et al*., 1999).

An increase in the amount of nitrogen fertilizer surely increases the protein content of rice (Inatsu, 1988; Matsue, 1993, 2012). However, nitrogen fertilizer used in China is 2–3 times that used in Japan (Cui *et al*., 2000, 2001). Therefore, it is important to examine the relationship between the amount of nitrogen application and protein content of the Chinese rice varieties. However, there are almost no reports on the relationship between physicochemical properties and yield of the Chinese rice varieties examined from this point of view.

In this study, the physicochemical properties, taste value and yield of rice cultivated with five levels of nitrogen application were examined, and from the point of view of the yield and the palatability, the optimum amount of nitrogen fertilizer was discussed.

MATERIALS AND METHODES

Used varieties and cultivation method

In this experiment, Jinchuan 1 and Yanfeng 47 which were leading varieties in Tianjin Municipality were used. Both varieties were cultivated at the Tianjin Stock Seed Farm in 2008. Seedlings of each cultivar were transplanted in the paddy field on June 15, with a density of 22.2 hills m^{-2} (30 cm row spacing and 15 cm hill spacing), one plant per hill. The amount of nitrogen application per m^{-2} was 0 g (treatment plot I), 3.75 g (Ⅱ), 7.5 g (Ⅲ), 15 g (Ⅳ) and 30 g (Ⅴ). The experimental plot was made 3 repetitions. Forty percent of nitrogen fertilizer was applied as basal dressing, 30% as topdressing at the tillering stage, and 30% as topdressing at the panicle formation stage. In all plots, 7.5 g phosphate was applied as basal dressing.

Methods of measuring physicochemical properties, taste value and yield

Brown rice was polished to 91~92%, and it was used to investigate physicochemical properties at the China–Japan Joint Research Center on Palatability and Quality of Rice in Tianjin Agricultural University. Amylose and protein contents of the polished rice were measured with an auto–analyzer AA–3 (BRAN + LUEBBE Co.). The protein content was shown on a dry matter basis. Amylogram properties of polished rice flour, maximum and minimum viscosities were measured by using a Rapid Visco Analyzer RVA–4 (NEWPORAT SCIENTIFIC

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Co.), and breakdown value was obtained from the difference between them. The taste value of rice was measured with Satake Rice Taste Analyzer (SATAKE Co.). Yield components and yield were examined according to the method of Tianjin Stock Seed Farm.

RESULTS

Physicochemical properties, taste value and yield

Table 1 shows physicochemical properties and taste values. In Jinchuan 1 and Yanfeng 47, the amylose content decreased with the increase in the amount of nitrogen application, but no significant difference was observed between treatment plots. On the other hand, the amylose content showed a significant positive correlation with 1000–grain weight in both varieties (Fig. 1). Other physicochemical properties varied significantly with the plot. The protein content increased with the increase in the amount of nitrogen application. The maximum viscosity in Jinchuan 1 was low in plot I, high in plots Ⅱ and Ⅲ, and decreased from plot Ⅳ to plot V. In Yanfeng 47, it decreased from plot I to V. The breakdown value tended to change in the same manner as in maximum viscosity. The taste value in Jinchuan 1 increased in the order of plot Ⅲ, Ⅱ, I, Ⅳ and V, but that in Yanfeng 47 was highest in plots I and Ⅱ, and decreased in the order of plots V, Ⅳ and Ⅲ.

The coefficient of variation was smaller in amylose content in both varieties. In Junchuan 1, the coefficient of variation was large in maximum viscosity and breakdown value, but in Yanfeng 47, it was the largest in protein content. The range (maximum – minimum) of taste value was 17.3 in Junchuan 1 and 8.4 in Yanfeng 47. The coefficient of variation of taste value between plots was 10.5% in Junchuan 1 and 6.2% in Yanfeng 47. Thus, the variation in taste value depending on the amount of nitrogen was larger in Junchuan 1 than in Yanfeng 47.

In all plots, the amylose content was higher in

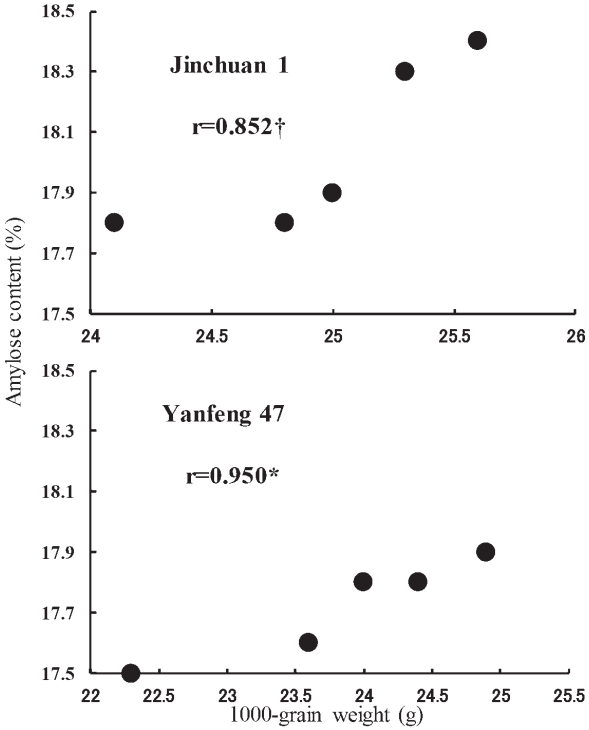

Fig. 1. Relationships between the amylose content and 1000–grain weight.
†, * : Significant at 10% and 5% level, respectively.

Table 1. Physicochemical properties and taste value

Variety	Treatment	Amylose content (%)	Protein content (%)	Maximum viscosity (RVU)	Breakdown value (RVU)	Taste value
Jinchuan1	I	18.4a	6.2c	205b	86b	65.3b
	Ⅱ	18.3a	6.5c	240a	104a	67.0ab
	Ⅲ	17.9a	6.8bc	241a	103a	69.8a
	Ⅳ	17.8a	7.2ab	192c	86b	62.3c
	V	17.8a	7.8a	182c	81b	52.5d
	Mean value	18.0	6.9	212	92	63.4
	C.V.	1.6	9.1	12.9	11.6	10.5
Yanfeng47	I	17.9a	6.7c	227a	113a	58.2a
	Ⅱ	17.8a	6.8c	217ab	111ab	58.2a
	Ⅲ	17.8a	7.3bc	211b	108ab	55.8a
	Ⅳ	17.6a	8.2ab	201bc	106b	54.7ab
	V	17.5a	8.7a	192c	104b	49.8b
	Mean value	17.7	7.5	210	108	55.3
	C.V.	0.9	11.7	6.5	3.4	6.2

Treatment I, Ⅱ, Ⅲ, Ⅳ and V : 0, 3.75, 7.5, 15, and 30 g N m^{-2}, respectively.
C.V. : Coefficient of variation. The different small alphabets are significantly different at 5% level.
The different small alphabets are significantly different at 5% level.

Junchuan 1 than in Yanfeng 47, but the protein content and the breakdown value were higher in Yanfeng 47. The difference in maximum viscosity was not clear. The taste value was higher in Junchuan 1 than in Yanfeng 47 in all plots.

Table 2 shows yield and yield components. Yield increased with the increase in the amount of nitrogen application and a significant difference was observed among the plots. The coefficient of variation in yield was not so large in both varieties, but the range of yield was 291 gm^{-2} in Junchuan 1 and 233 gm^{-2} in Yanfeng 47.

Panicle number also increased with the increase in the amount of nitrogen application. On the other hand, spikelet number per panicle decreased with the increase in the amount of nitrogen application, but the difference between the plots was small. Thousand–grain weight decreased with the increase in the amount of nitrogen application. The coefficient of variation was the largest in panicle number among yield components.

Yield was higher in Jinchuan 1 than in Yanfeng 47 in all plots, but panicle number was larger in Yanfeng 47. Spikelet number per panicle and 1000–grain weight

Table 2. Yield and yield component.

Variety	Treatment	Yield ($g\ m^{-2}$)	Panicle number (m^{-2})	Spikelet number ($Panicle^{-1}$)	1000–grain weight (g)
Jinchuan1	I	438e	128e	140b	25.6a
	II	553d	131de	157a	25.3ab
	III	598c	141cd	156a	25.0bc
	IV	672b	171b	148ab	24.8c
	V	729a	224a	139b	24.1cd
	Mean value	598	159	148	25
	C.V.	18.7	25.2	5.8	2.3
Yanfeng47	I	385d	167e	106a	24.9a
	II	470c	171de	110a	24.4b
	III	483c	178cd	108a	24.0bc
	IV	573b	231b	108a	23.6c
	V	618a	280a	94b	22.3d
	Mean value	506	205	105	23.8
	C.V.	18.1	23.9	6.1	4.1

Treatment I, II, III, IV and V : 0, 3.75, 7.5, 15, and 30 g N m^{-2}, respectively.
C.V.: Coefficient of variation. The different small alphabets are significantly different at 5% level.
Treatment , II, III, IV and V: 0, 3.75, 7.5, 15, and 30 g N m^{-2}, respectively.
The different small alphabets are significantly different at 5% level.

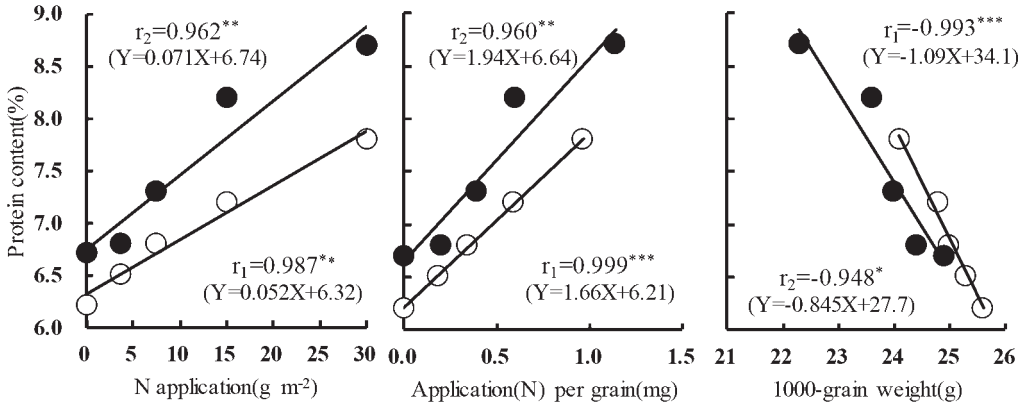

Fig. 2. Correlation of protein content with the amount of nitrogen (N) application, the amount of applied(N) per grain and 1000–grain weight.
– ○ –: Jinchuan 1, – ● –: Yanfeng 4.
r_1 : Correlation coefficient in Jinchuan 1 (Regression equation).
r_2 : Correlation coefficient in Jinyan 47 (Regression equation).
*, **, *** : Significant at 5%, 1%, and 0.1% level, respectively.

were larger in Jinchuan 1.

Factors controlling the protein content

Fig. 2 shows the correlation of protein content with the amount of nitrogen application per m^2, the amount of applied nitrogen per grain and 1000–grain weight. The protein content was significantly correlated with those factors. In both varieties, the protein content increased linearly with the increase in the amount of nitrogen application, and the slope of the regression line was 0.052 in Jinchuan 1 and 0.071 in Yanfeng 47.

The protein content increased linearly with the increase in the amount of applied nitrogen per grain and with the decrease in 1000–grain weight. The rate of increase in protein content to applied nitrogen per grain was larger in Yanfeng 47. On the other hand, the rate of increase in protein content to 1000–grain weight was larger in Jinchaun 1.

Response of taste value and yield to the amount of nitrogen application

Fig. 3 shows the relative ratio expressed by the percentage of each plot to the maximum plot of taste value and yield. The relative ratio of taste value in Jinchuan 1 was larger in plot Ⅲ than in plot Ⅰ and Ⅱ, and rapidly decreased from plot Ⅳ to Ⅴ. The relative ratio of taste value of Yanfeng 47 was the highest in plot Ⅰ and Ⅱ, and successively decreased from plot Ⅲ. The relative ratio of yield increased with the increase the amount of nitrogen application in both varieties.

The curves of relative ratio of taste value and yield plotted against the amount of nitrogen application crossed at around plot Ⅳ.

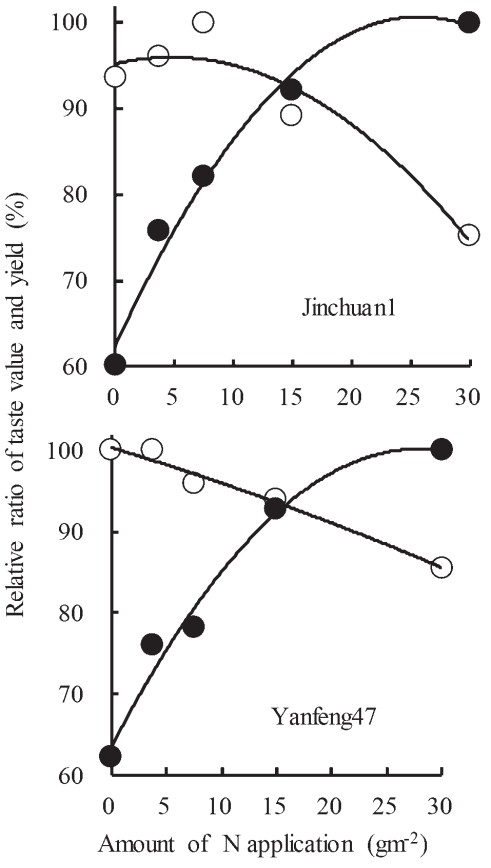

Fig. 3. Relationships between relative ratio of taste value, yield and amount of nitrogen (N) application.
– ○ –: Taste value, – ● –: Yield.
Relative ratio is the percentage to the maximum value.

DISCUSSION

The effect of the amount of nitrogen application on physicochemical properties related to palatability and yield were examined. Among physicochemical properties, the coefficient of variation due to the difference in the amount of nitrogen application was the smallest in amylose content. This suggests that amylose content is hardly changed by nitrogen application. As mentioned above, amylose content showed a positive correlation with 1000–grain weight. From these results one may say that among the varieties have the same heading time, amylose content is affected by grain weight rather than by the amount of nitrogen application.

The coefficients of variation of protein content and amylogram properties were larger than that of amylose content. Especially the coefficient of variation of amylogram properties in Jinchuan 1 and that of protein content in Yangung 47 were large. Among yield components, panicle number had the largest coefficient of variation, so that panicle number was assumed to be most strongly affected by nitrogen application. Thousand–grain weight was decreased with the increase in the amount of nitrogen application, and grain size was decreased by increasing nitrogen application.

These results indicate that palatability tended to decrease and yield to increase with the increase in the amount of nitrogen fertilizer. The decrease of palatability was caused by increase in protein content, and the increase of yield was caused by increase in panicle number (Table1, 2).These responses to nitrogen application varied with variety, and the effects of nitrogen on palatability and yield were greater in Jinchuan 1 than in Yanfung 47.

The varietal difference in the response of protein content to nitrogen application was examined by drawing the regression line of the correlation between them (Fig. 2). The slope of the regression line was 0.052 in Jinchuan 1, and 0.071 in Yanfeng 47. This means that the increase in nitrogen application of 1 gm^{-2} increased the protein content by 0.052% in Jinchuan 1 and by 0.071% in Yanfeng 47. Thus, the response of protein content to nitrogen application is 1.35–fold larger in Yanfeng 47 than in Jinchuan 1.

The protein content is determined by absorbed nitrogen per grain and grain weight (Cui *et al.*, 2000; Matsue, 2012). In the present experiment, we did not measure absorbed nitrogen per grain, but it may be replaced by the amount of applied nitrogen per grain. Then we examined the correlation of protein content with applied nitrogen per grain and 1000–grain weight. The protein

content increased linearly with the increase in applied nitrogen per grain, and it decreased linearly with the increase in 1000– grain weight (Fig. 2). The slopes of these regression lines varied with variety. The slope against applied nitrogen per grain was steeper in Yanfeng 47 and that against 1000–grain weight was steeper in Jinchuan 1. It was considered that the response of protein content to nitrogen application was greatly influenced by grain weight (size of grain) in Jinchuan 1, and by the amount of absorbed nitrogen per grain in Yangfeng 47.

As mentioned above, the larger the amount of nitrogen application, the higher the yield and the lower the palatability. Therefore, to obtain both high yield and superior palatability, appropriate amount of nitrogen must be applied. Then, the relative ratios of yield and taste value in each plot to their maximum values are calculated. The curves of two relative ratios plotted against the amount of nitrogen application crossed at near 15 gm^{-2} (Fig. 3). This shows that in the field with about 15 gm^{-2} nitrogen fertilizer, both yield and taste value were 90–95% of the maximum. In China, nitrogen application of 15 gm^{-2} may be the appropriate value for both taste and yield.

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