THE CROP JOURNAL 3 (2015) 67–73

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Effects of rice or wheat residue retention on the quality of milled *japonica* rice in a rice–wheat rotation system in China

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A R T I C L E   I N F O

Article history:
Received 18 March 2014
Received in revised form 4 August 2014
Accepted 5 August 2014
Available online 6 October 2014

Keywords:
Japonica rice
Crop straw
Grain quality
Paddy–upland rotation

A B S T R A C T

In rice–wheat rotation systems, crop straw is usually retained in the field at land preparation in every, or every other, season. We conducted a 3-year-6-season experiment in the middle–lower Yangtze River Valley to compare the grain qualities of rice under straw retained after single or double seasons per year. Four treatments were designed as: both wheat and rice straw retained (WR), only rice straw retained (R), only wheat straw retained (W), and no straw retained (CK). The varieties were Yangmai 16 wheat and Wuyunjing 23 *japonica* rice. The results showed contrasting effects of W and R on rice quality. Amylopectin content, peak viscosity, cool viscosity, and breakdown viscosity of rice grain were significantly increased in W compared to the CK, whereas gelatinization temperature, setback viscosity, and protein content significantly decreased. In addition, the effect of WR on rice grain quality was similar to that of W, although soil fertility was enhanced in WR due to straw being retained in two cycles. The differences in protein and starch contents among the treatments might result from soil nitrogen supply. These results indicate that wheat straw retained in the field is more important for high rice quality than rice straw return, and straw from both seasons is recommended for positive effects on soil fertility.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important crops in the world, and provides much of the energy, protein, and other nutrients for half of the world population [1]. Rice quality is determined by genetic factors, environmental factors, and cultivation measures [2]. Studies conducted in recent years indicate that increased temperature, soil moisture, and

Abbreviations: SOM, soil organic matter; TN, total nitrogen; TP, total phosphorus; TK, total potassium; AP, available phosphorus; AK, available potassium

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Peer review under responsibility of Crop Science Society of China and Institute of Crop Science, CAAS.

http://dx.doi.org/10.1016/j.cj.2014.08.003
2214-5141/

fertilizer affect rice quality. However, research on the relative effects of rice versus wheat residue retention on subsequent rice grain quality in rice–wheat rotation systems is rare [3–12].

Rice–wheat rotation is the dominant practice in the middle-lower Yangtze River area of China [13]. The return of crop residue to fields is an important way to conserve and sustain soil productivity [14,15]. Xu et al. [11] reported the effect of wheat residues on the quality of direct-seeded rice, and Liu et al. [8] described the effects of no tillage and wheat straw retention on rice quality in a regional experiment. Normally, most of the residue decomposes before rice transplanting when rice straw is returned to the field in the wheat-growing season [16]. Additionally, the possible impacts of rice straw on rice quality may be minor and short term. There are no reports regarding the effects on rice quality of returning rice straw in a rice–wheat rotation system. Indeed, the effects of rice and wheat straw in rice–wheat rotations on rice quality are unclear. Moreover, the full mechanical incorporation of the straw in each season or every other season may be the main method for residue management in rice–wheat rotation systems in the future. Thus, it is necessary to understand the effects of wheat straw, rice straw, and their interactions on rice quality. The present research comprised a 3-year, regional experiment in a wheat–rice rotation system which was conducted to support high quality and efficient rice cultivation by evaluating the effects of retention of rice straw, wheat straw, and a combination of both straw types on subsequent rice grain quality.

2. Materials and methods

2.1. Experimental site

The field experiment was performed at Danyang Experimental Station of Nanjing Agricultural University, Jiangsu province (31°54′31″N, 119°28′21″E), an area where the primary cropping regime is an annual paddy rice–winter wheat rotation. The soil type is a periodically waterlogged paddy soil. The characteristics of the soil before the experiment were: SOM, 17.15 g kg^{-1}; TN, 0.973 g kg^{-1}; TP, 0.5 g kg^{-1}; TK, 10.99 g kg^{-1}; AP, 13.6 mg kg^{-1}; and AK, 93.5 mg kg^{-1}. In addition, the soil fertility for different treatments in 2012 is described in Table 1.

2.2. Experimental treatment and design

The field experiment started with the wheat–growing season in October 2009 and ended after rice harvest in October 2012, encompassing three cycles and six crop seasons. The analyses for the present study were conducted after the rice season in the third year of the rotation. A randomized split-plot design with three replications was used. Four straw-retention treatments were applied: continuous retention of wheat and rice residues in every season (WR), rice residues only retained in every wheat season (R), (3) wheat residues only retained (W), and a control with no residue retention (CK). Each plot, 7.0 m × 4.5 m in size, was separated by a ridge. Combined harvesters left all residues as short pieces of rice or wheat straw on the soil surface of each experimental plot, and the pieces were incorporated within 0.15 m of the top soil before seeding (wheat) or transplanting (rice); in other plots residues were removed from the plots as required. The nutrient contents of nitrogen, phosphorus and potassium were respectively 1.29%, 0.30%, and 3.23% in rice straw; and 0.58%, 0.04%, and 2.77% in wheat straw. The wheat variety Yangmai 16 was seeded on 30 October 2009, 9 November 2010, and 16 November 2011 and harvested on 5 June 2010, 7 June 2011, and 31 May 2012, respectively. The rice variety Wuyunjing 23 was sown in seedbeds, transplanted, and harvested on 25 May, 26 June, and 2 November 2010; 27 May, 24 June, and 3 November 2011; and 28 May, 27 June, and 31 October 2012, respectively. The wheat seeding rate was 225 kg ha^{-1}, and the density of rice transplants was 30.0 cm × 13.3 cm. Fertilizer was applied in the manner used locally for high production (225–105–105 kg ha^{-1} N–P_2O_5–K_2O in the wheat season, and 300–150–240 kg ha^{-1} N–P_2O_5–K_2O in the rice season). Water management was set as wet–dry–wet–dry, as described in Hou et al. [17].

2.3. Sample collection and measurements

At maturity, approximately 100 panicles of similar maturity were harvested from each replication. The samples were dried naturally and then dehulled. Brown rice was milled for 90 s with a JNMJ3 rice polisher (Taizhou Grain Industry Instrument Corp, Zhejiang, China), and ~10% of the outer layers were removed. The milled rice was ground in a stainless steel grinder for 3 min, and the resulting powders were used for chemical analysis. The traits measured included appearance quality (grain length, grain width, ratio of kernel length to width (L/W), and grain thickness), milling quality (brown rice recovery, milled rice recovery, and head-milled rice recovery), physicochemical properties (amylose content, amylopectin content, starch content, and RVA profiles), and protein components.

Quality traits, including grain length, width, and thickness, and brown rice, milled rice, and head-milled rice recovery rates, amylose content, and starch content were measured according to China National Standards (GB/T 17891-1999).

Table 1 – Soil fertilities (0–20 cm) in different straw retention treatments in 2012.

Treatment	pH	SOM (g kg^{-1})	TN (g kg^{-1})	TP (g kg^{-1})	TK (g kg^{-1})	AP (mg kg^{-1})	AK (mg kg^{-1})
WR	6.28 a	17.80 a	1.11 a	0.40 a	13.98 a	14.93 a	111.77 a
R	6.17 ab	17.62 a	1.08 a	0.50 a	13.78 a	19.07 a	108.58 a
W	6.05 b	17.71 a	1.07 a	0.47 a	13.41 a	14.38 a	101.73 a
CK	6.25 ab	17.19 b	0.97 b	0.48 a	13.96 a	14.87 a	82.42 b

Soil fertilities were measured in the 2012 crop seasons. Means followed by different letters are significantly different according to least significant difference (LSD) at P = 0.05.