Field Crops Research 141 (2013) 63–68

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Short communication

On-farm assessment of effect of low temperature at seedling stage on early-season rice quality

Min Huang[a], Ligeng Jiang[a], Yingbin Zou[b,c,*], Weixing Zhang[d]

[a] Key Laboratory of Crop Cultivation and Farming System, Guangxi University, Nanning 530004, China
[b] College of Agronomy, Hunan Agricultural University, Changsha 410128, China
[c] State Key Laboratory of Hybrid Rice, Changsha 410125, China
[d] China National Rice Research Institute, Hangzhou 310006, China

ARTICLE INFO

Article history:
Received 23 August 2012
Received in revised form 31 October 2012
Accepted 31 October 2012

Keywords:
Low temperature
Growth period
Rice quality
Rice structure
Source capacity

ABSTRACT

Low temperature often occurs at seedling stage in early rice-growing season in southern provinces of China. However, it is not clear whether the low temperature at seedling stage has an impact on early-season rice quality. This on-farm study was conducted to compare quality and growth traits of an early-season rice cultivar between two contrasting years with respect to temperature at seedling stage, 2009 (normal temperature) and 2010 (low temperature). The results showed that brown rice percentage, milled rice percentage, gelatinization temperature and gel consistency were significantly lower in 2010 than 2009, whereas 2010 had significantly higher percentage of chalky rice grains, degree of chalkiness and protein content than 2009. The yearly difference in rice quality was attributed to variation in rice structure. In 2010, a marked decrease of grain weight was observed, which was not accompanied by a decrease in rice length or width. Source capacity (aboveground biomass accumulation) did not explain the difference in grain weight between 2009 and 2010, because grain-filling rate was comparable in the two years. Shortened grain-filling duration, indirectly caused by the low temperature at seedling stage, was responsible for the decreased grain weight in 2010. These results suggest that low temperature at seeding stage can affect early-season rice quality through its indirect effect on grain-filling duration.

1. Introduction

Rice quality is one of the most important characteristics, as it exerts a large effect on the market value and consumer acceptance (Lapitan et al., 2007). Development of cultivars with good quality is an important objective in rice improvement programs (Pingali et al., 1997). However, besides the effect controlled by genetic factors, rice quality is also greatly affected by environmental conditions (Senanayake and Wijeratne, 1990; Shi et al., 1997). Rice quality can vary inexplicably from year to year and often from field to field (Cooper et al., 2006).

Variations in growth temperature could be a cause of quality variation in rice (Matsue, 1995). Studies investigating the effect of temperature on grain development have indicated that higher temperatures during grain-filling stage result in decreased milled rice percentage (MRP), increased percentage of chalky rice grains (PCRG) and gelatinization temperature (GT), and loosely packed starch granules (Yoshida and Hara, 1977; Resurreccion et al., 1977; Lisle et al., 2000; Zhong et al., 2005). Lower growth temperatures result in an increase of amylose content (AC) in rice cultivars with low AC, and in a decrease of AC in rice cultivars with high and intermediate AC, sometimes changing the cultivar's amylose class, depending on the temperature treatment (Resurreccion et al., 1977). However, these researches were usually performed using controlled temperature chambers. This approach is limited in that it does not necessarily reproduce field conditions (Cooper et al., 2006).

China is one of the major rice-producing countries in the world, and double rice-cropping system is occupying large portion of rice land in southern provinces of the country (Zhu et al., 2010; Zou, 2011). In these areas, early-season rice is generally grown from April to July and late-season rice from July to October (Wu et al., 2012). Due to early-season rice experiences much higher temperature than late-season rice during grain-filling stage, the quality of early-season rice is remarkably poorer than that of late-season rice (Zhu et al., 1993). But on the other hand, a cold-current often outbreaks in April in southern China, which makes early-season rice seedlings rot, causing decreased panicle number and delayed growth period. However, it is not clear whether the effect of low temperature at seeding stage on growth of early-season rice will result in a subsequent effect on its quality.

* Corresponding author at: College of Agronomy, Hunan Agricultural University, Changsha 410128, China. Tel.: +86 731 84618758; fax: +86 731 84673648.
E-mail address: ybzou123@126.com (Y. Zou).

0378-4290/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fcr.2012.10.019

In the present study, quality and growth traits of an early-season rice cultivar were compared between two contrasting years with respect to temperature at seedling stage by using data from on-farm research. Our objectives were to (1) determine whether early-season rice quality is affected by the low temperature at seedling stage and (2) identify the key factors that contribute to the effect low temperature at seedling stage on early-season rice quality.

2. Materials and methods

An on-farm study was conducted in Changde (29°03′N, 111°53′E), Hunan province, China in early rice-growing seasons of 2009 and 2010. Seasonal mean temperature in 2009 was 23.9 °C, which was close to the average seasonal mean temperature (23.8 °C) during 2000–2010 (Fig. 1a). In 2010, seasonal mean temperature was 22.0 °C, which was the lowest during 2000–2010. The low seasonal mean temperature in 2010 was mainly attributed to a cold-current at seedling stage (Fig. 1b). Average daily mean temperature during grain-filling stage was 29.3 °C and 28.7 °C in 2009 and 2010, respectively (Fig. 1c). Ten nearby farmer's fields were selected in this study. The area of each field was about 667 m^2. Xiangzaoxian 45, an *indica* rice cultivar, was grown in each year. The soil of the fields was alluvial sandy loam with the following properties: pH = 6.2–6.4, organic matter = 32.6–45.1 g kg^{-1}, alkali-hydrolysable N = 130–169 mg kg^{-1}, available P = 3.40–4.03 mg kg^{-1} and available K = 49.4–95.0 mg kg^{-1}. Field management was carried out according to local practices and was the same between the two years. Compound fertilizer (N:P_2O_5:K_2O = 22%:8%:10%) was applied at a rate of 375 kg ha^{-1} as basal. At mid-tillering, urea (46% N) and potassium chloride (60% K_2O) were applied at rates of 225 and 112 kg ha^{-1}, respectively. Water management adopted a strategy of flooding–midseason drainage–reflooding–moist intermittent irrigation. Weeds, insects and diseases were controlled with herbicides and pesticides as needed. There was no lodging in either year.

Three sampling sites were randomly selected in each field at harvesting time. Grains were sampled from a 2-m^2 area in each sampling site for rice quality analysis. The sampled grains from different sampling sites were combined and sun-dried. One hundred thirty grams of the dried grains were de-hulled with a roller sheller and polished in a polishing machine according to the National Standard NT 147-88 of China. Brown rice percentage (BRP) and milled rice percentage (MRP) were calculated based on the rough rice weight. Rice length and width were measured on 10 intact milled grains using a photoenlarger magnified at 10×. Percentage of chalky rice grains (PCRG) was defined as the proportion of grains having an opaque, chalky appearance compared with all of the milled rice grains. Chalkiness covered a region of the grain. Degree of chalkiness (DC) was the result obtained by multiplying the percentage of chalky rice grains by the chalkiness areas. Gelatinization temperature (GT) was measured based on the alkali spread value. Six intact milled grains were put into a boat with 10 mL of 1.7% KOH, and then incubated at 30 °C for 23 h to allow the grains to spread. Grains that were unaffected were given an alkali spread value score of 1, while grains that disappeared completely were given an alkali spread value score of 7. A low score indicates a high GT and a high score corresponds to a low GT. The milled rice grains were ground into flour with a miller and passed through a 100-mesh sieve for determining gel consistency (GC), amylose content (AC) and protein content (PC). GC was measured by the following procedure: 0.1 g of the flour was dispersed in 0.2 mL of 95% ethanol containing 0.025% thymol blue in a 10 mm × 110 mm culture tube, and then 2.0 mL of 0.2 M KOH was added. The tubes were covered with glass marbles and boiled in a water bath for 8 min. After being placed on ice for 20 min, they were laid down horizontally onto a table

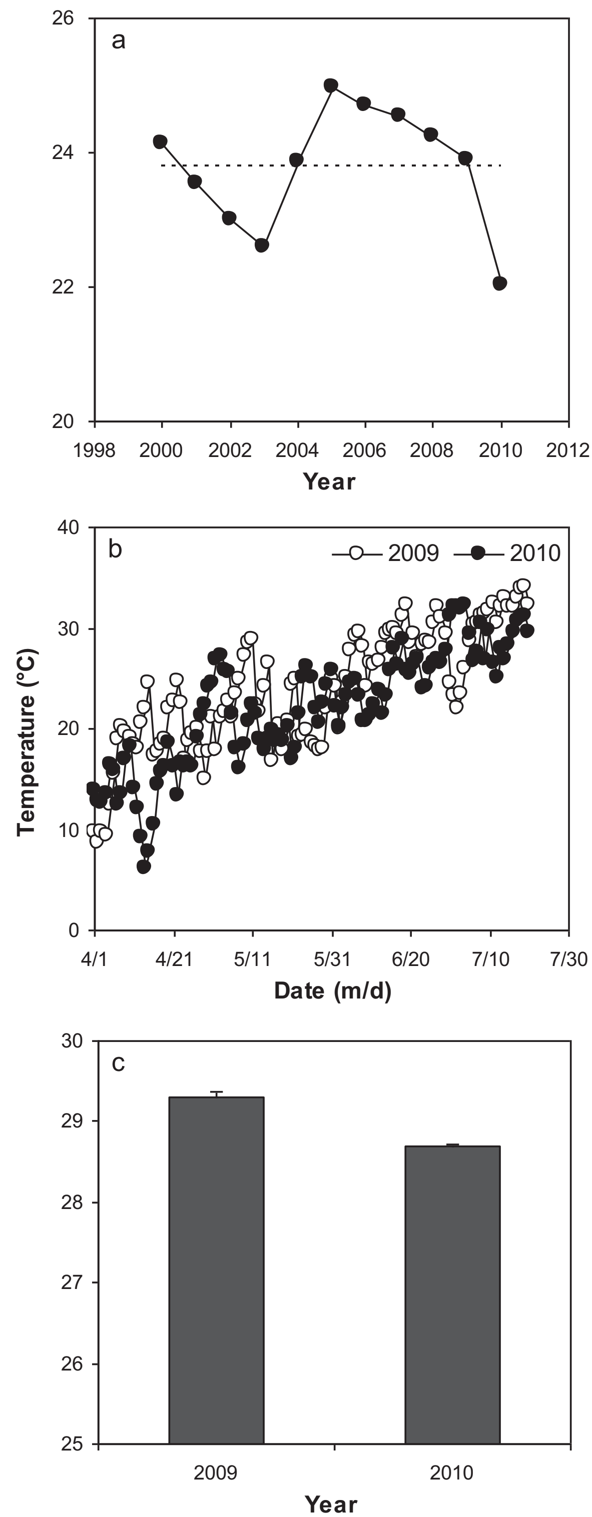

Fig. 1. Seasonal mean temperature (a), daily mean temperature (b) and average daily mean temperature during grain-filling stage (c) of early rice-growing season in Changde, Hunan province, China. Dotted line is the average seasonal mean temperature during 2000–2010. Vertical bars represent the SE (n = 10).

surface. After 1 h, the gel length from the bottom of the tube to the front of the gel was measured. A longer length indicates a softer GC. AC was determined according to the following procedure: exactly 10 mg of the flour was gelatinized overnight in 3.0 mL of 2% NaOH in a water bath at 30 °C. The solution was boiled in the water bath for 10 min, and was diluted to a volume of 100 mL. Three milliliters