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RESEARCH ARTICLE

Suitable growing zone and yield potential for late-maturity type of Yongyou *japonica/indica* hybrid rice in the lower reaches of Yangtze River, China

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Abstract

Late-maturity type of Yongyou *japonica*/*indica* hybrids series (LMYS) have shown great yield potential, and are being widely planted in the lower reaches of Yangtze River, China. Knowledge about suitable growing zone and evaluation of yield advantage is of practical importance for LMYS in this region. Fifteen LMYS, two high-yielding inbred *japonica* check varieties (CK-J) and two high-yielding hybrid *indica* check varieties (CK-I) were grown at Xinghua (119.57°E, 33.05°N) of Lixiahe region, Yangzhou (119.25°E, 32.30°N) of Yanjiang region, Changshu (120.46°E, 31.41°N) of Taihu Lake region, and Ningbo (121.31°E, 29.45°N) of Ningshao Plain in 2013 and 2014. The results showed that maturity dates of the 15 were later than the secure maturity date at Xinghua and 6, 14 and 15 LMYS were mature before the secure maturity date at Yangzhou, Changshu and Ningbo, respectively. One variety was identified as high-yielding variety among LMYS (HYYS) at Yangzhou, 8 HYYS in 2013 and 9 HYYS in 2014 at Changshu, 9 HYYS at Ningbo. HYYS here referred to the variety among LMYS that was mature before the secure maturity date and had at least 8% higher grain yield than both CK-J and CK-I at each experimental site. Grain yield of HYYS at each experimental site was about 12.0 t ha^{-1} or higher, and was significantly higher than CK varieties. High yield of HYYS was mainly attributed to larger sink size due to more spikelets per panicle. Plant height of HYYS was about 140 cm, and was significantly higher than check varieties. Significant positive correlations were recorded between duration from heading to maturity stage and grain yield, and also between whole growth periods and grain yield. HYYS had obvious advantage over check varieties in biomass accumulation and leaf area duration from heading to maturity stage. Comprehensive consideration about safe maturity and yield performance of LMYS at each experimental site, Taihu Lake region (representative site Changshu) and Ningshao Plain (representative site Ningbo) were thought suitable growing zones for LMYS in the lower reaches of Yangtze River. The main factors underlying high yield of

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HYYS were larger sink size, higher plant height, longer duration from heading to maturity stage and whole growth periods, and higher biomass accumulation and leaf area duration during grain filling stage.

Keywords: *japonica/indica* hybrid rice, Yongyou series, late-maturity type, suitable growing zone, yield potential

1. Introduction

Rice (*Oryza sativa* L.), one of the most important cereal crops, provides 35–60% of the dietary calories for the majority people in the world (Fageria 2003). Faced with great challenge driven by increasing demands for food in the following decades (Normile 2008), breeding high-yielding rice varieties and developing high-yielding cultivation techniques were thought of as two key methods to meet this challenge (Peng *et al.* 2008; Long *et al.* 2010).

Hybrid *indica* rice, which was reported to have more than 15% yield increase over inbred rice (Bueno *et al.* 2010; Xangsayasane *et al.* 2010), has brought about another leap in yield potential of rice after the Green Revolution (Virmani *et al.* 1982; Yuan 1994). Meanwhile, the factors, related with great yield advantage of hybrid *indica* rice over inbred rice, have been identified by many studies (Khan *et al.* 1998; Katsura *et al.* 2007; Yang *et al.* 2007; Bueno and Lafarge 2009; Lafarge and Bueno 2009). Such studies suggested that hybrid *indica* rice showed large sink size (Lafarge and Bueno 2009), high harvest index (Yang *et al.* 2007) and great biomass accumulation before heading (Khan *et al.* 1998; Katsura *et al.* 2007). However, yield stagnation of hybrid *indica* rice was observed since the 1990s in China, which was mainly due to its insufficient genetic diversity (Peng *et al.* 2008). Besides, concerns regarding rice quality of hybrid *indica* rice arose with improved living conditions (Ni *et al.* 2011; Zhou *et al.* 2015), and high chalkiness and low ratio of head rice to rough rice were considered as the salient problems for the majority of hybrid *indica* rice in China (Ni *et al.* 2011).

The *japonica*/*indica* hybrid rice has long been considered to own strong heterosis and to have higher yield potential over hybrid *indica* rice (Yuan 1994; Peng *et al.* 1999). However, the application of *japonica*/*indica* hybrids in production has been greatly restricted by some obstacles, such as poor grain filling in F_1 generation (Yang *et al.* 2002). In recent years, important progress was made in breeding *japonica*/*indica* hybrids with high yield potential in China (Wang L Y *et al.* 2014). One of the representative high-yielding *japonica*/*indica* hybrids was late-maturity type of Yongyou *japonica*/*indica* hybrids series (LMYS). For example, Yongyou 12 yielded over 13.5 t ha^{-1} on-farm practice for two executive years in a rice-wheat rotation system in the lower reaches of Yangtze River, China (Wang X Y *et al.* 2014).

Owing to high yield performance, the growing area of late-maturity type of Yongyou *japonica*/*indica* hybrids series (LMYS) has increased rapidly in the lower reaches of Yangtze River in recent years. Up to 2012, the accumulated planting area of LMYS has been 1 million ha (Ma R R 2013, personal communication). To further promote LMYS in the lower reaches of Yangtze River and to stimulate its high yield potential, the knowledge about suitable growing zone and evaluation of yield advantage of LMYS in the lower reaches of Yangtze River is essential. To date, however, this knowledge is still limited.

The objectives of this research were to: (1) define suitable growing zone of LMYS in the lower reaches of Yangtze River, (2) evaluate yield advantage of LMYS over check varieties and select some high-yielding varieties among LMYS, and (3) identify the factors underlying high yield of LMYS by comparing yield components, leaf area index (LAI), leaf area duration (LAD), and dry matter accumulation.

2. Results

2.1. Maturity date

The maturity dates of all the 15 LMYS were later than the secure maturity date at Xinghua. Only six LMYS, including Yongyou 4304, Yongyou 4306, Yongyou 4348, Yongyou 4375, Yongyou 4377, and Yongyou 4395, were mature before the secure maturity date at Yangzhou. At Changshu, 14 LMYS were mature before the secure maturity date and only Yongyou 12 was mature later than the secure maturity date. At Ningbo, all the 15 LMYS were mature before the secure maturity date (Table 1).

2.2. Grain yield, yield components and characteristics of panicle

To elucidate the factors underlying high yield in LMYS, LMYS were separated into two types, high-yielding variety among LMYS (HYYS) and medium-yielding variety among LMYS (MYYS). HYYS here referred to the variety that was mature before the secure maturity date and had at least 8% higher grain yield than inbred *japonica* check varieties (CK-J) and hybrid *indica* check varieties (CK-I) at each experimental site, and MYYS referred to the variety that was mature before the secure maturity date, but had less than 8% higher grain yield than CK-J and CK-I at each experimental site.