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Short communication

Impact of temperature changes on early-rice productivity in a subtropical environment of China

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ABSTRACT

The impact of climate warming on rice production has attracted considerable attention. In this study, we (1) analyzed trends in maximum and minimum temperatures and low temperature events from 1980 to 2010 for early season, (2) evaluated relationships between rice-yield attributes and maximum or minimum temperature by using data from field experiments conducted in early seasons of 1991–2004, and (3) compared grain yield among different rice establishment methods by using data from field experiments done in early seasons of two contrasting years (2009 and 2010) with respect to low temperature events in Changde, Hunan Province, China. The results showed that maximum and minimum temperatures in early season increased by 2.2 °C and 2.1 °C, respectively, during the period 1980–2010 and there was a significant relationship between early-rice grain yield and maximum temperature. Grain yield increased by 7% for each 1 °C increase in growing-season maximum temperature. The increase in grain yield with maximum temperature was driven from the increased daily yield rather than growth duration. However, stabilizing growth duration was critical to overcome the potential negative impact of future climate warming on early-rice production. On the other hand, the climate warming did not lead to significant decreases in low temperature events. In the year with low temperature events, direct seeding produced less grain yield than transplanting and seedling throwing by 32% and 23%, respectively. Our study suggests that direct seeding is a high risk establishment method for early-rice production and seedling throwing may be a more satisfactory method of establishing early-rice under current climate change scenarios.

1. Introduction

China accounts for about 30% of global rice production (Xiong et al., 2008). Maintaining high rice productivity in China is very important for world food security (Liu et al., 2012). In the next decade, world rice yield must increase by more than 1.2% annually to meet the growing demand for food that will result from population growth and economic development (Normile, 2008). However, during the last 10 years, rice yields have shown declining or stagnant trends in most rice production provinces in China (Fan et al., 2009). To break the yield ceiling, great efforts have been made to breed new rice varieties with higher yield potential (Peng et al., 2008). Nevertheless, the rice yield depends not only on the varietal characters but also on the growth environments (Zou et al., 2003).

Global mean surface air temperature increased by approximately 0.74 °C in the 20th century and is projected to further increase by 1.1–6.4 °C in this century (IPPC, 2007). Peng et al. (2004) observed that rice yield declined by 10% for each 1 °C increase in growing-season minimum temperature in the Philippines. Srivani et al. (2007) evaluated the impact of future climate change on rice productivity in India. Their results showed that rice yield would steadily decrease from 2000 to 2020, 2050 and 2080 due to increase in temperature. In China, a warming trend has been well documented during the last several decades, and there have been reports describing the effect of the temperature rise on rice. Tao et al. (2006) showed that climate warming over the period of 1981–2000 had accelerated rice phonological development and decreased rice yields in Hefei, China. On the contrary, Tao et al. (2008) reported that due to an increase in growing-season temperature, total rice production in China was estimated to have increased by 3.2×10^5 t decade^{-1} during 1951–2002. Recently, Liu et al. (2012) indicated that climate warming would have led to a reduction in the length of rice growing period and a reduction in grain yield in China, if no varietal changes had occurred. However,

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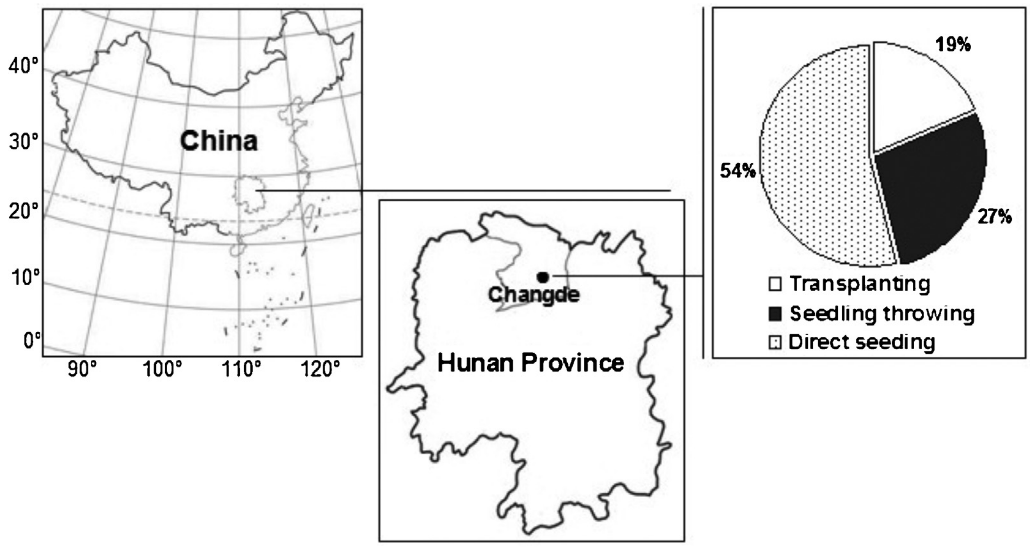

Fig. 1. Study site and rice establishment methods used at the site in early season of 2010. Data were obtained from local agricultural bureau.

the adoption of new rice varieties stabilized growing duration and increased grain yield.

On the other hand, yield loss caused by low temperature is still a worldwide problem in rice production (Peyman and Hashem, 2010). In the double-rice cropping regions in south China, a cold-current outbreak in April often makes early-rice seedlings rot, causing a heavy seed loss and a delayed growth period (Qian et al., 2000). Although such a problem is more serious in direct-seeded rice than in transplanted rice, direct seeding has replaced transplanting in many regions over the last decade mainly due to its labor-saving benefits (Li et al., 2008; Wang et al., 2010; Ao et al., 2011). Ao et al. (2011) pointed out that climate warming was also partly responsible for the rapid spread of direct-seeded rice. However, there is no direct evidence that low temperature events have been decreasing in early season.

In the present study, we (1) analyzed trends in maximum and minimum temperatures and low temperature events from 1980 to 2010 for early season, (2) evaluated relationships between rice-yield attributes and maximum or minimum temperature by using data from field experiments conducted in early seasons of 1991–2004, and (3) compared grain yield among different rice establishment methods by using data from field experiments done in early seasons of two contrasting years (2009 and 2010) with respect to low temperature events in Changde, Hunan Province, China. Our objectives were (i) to determine whether there were significant time trends in changes of maximum and minimum temperatures in early season and whether these trends had an impact on early-rice productivity, and (ii) to examine whether there were significant time trends in changes of low temperature events and discuss which establishment method is more appropriate for early-rice production under current climate change scenarios.

2. Materials and methods

2.1. Site description

The study was carried out in Changde, Hunan Province, China (Fig. 1). Hunan Province (24°39′–30°28′ N, 108°47′–114°45′ E) is located in central south China. The province has a subtropical monsoon climate with an average annual sunshine of 1300–1800 h, an annual average temperature of 16–18 °C, a frost-free period of 260–310 days and a mean annual precipitation of 1200–1700 mm. Among the provinces in China, Hunan ranks first in rice production and contributes about 14% of the national rice-harvested area. There are two rice cropping systems in the province: (1) double-rice cropping with early-rice grown from late-March to late-July and with late-rice grown from mid-June to end-October; (2) single-rice cropping with single-rice grown from April to September in rotation with an upland crop such as oilseed rape, and the former is dominant (accounting for about 70% of the provincial rice-harvested area). Transplanting is the traditional rice establishment method in Hunan, but in the recent decade, this method has been replaced by direct seeding in many northern regions of the province. Changde (28°24′–30°07′ N, 110°29′–112°17′ E) lies in northern Hunan, and is a major double-rice production region of the province. In 2010, more than 50% of early-rice was grown under direct seeding in this region (Fig. 1).

2.2. Data collection

2.2.1. Temperature data

Daily mean, maximum and minimum temperatures in Changde from 1980 to 2010 were collected from a local weather station (29°02′ N, 111°41′ E). Growing-season maximum and minimum temperatures of early-rice were calculated by averaging daily maximum and minimum temperatures during March 30th and July 20th, respectively. As the critical low temperatures (daily mean temperature) in rice are 10 °C for germination, 12–13 °C for seedling establishment and 16 °C for rooting (Yoshida, 1981), here we defined low temperature events as those with daily mean temperature less than 10 °C, 13 °C or 16 °C during April 5th to 25th.

2.2.2. Rice data

Grain yield, daily yield and growth duration of early-rice were collected from field experiments conducted at the farm of Changde Institute of Agricultural Sciences (29°02′ N, 111°37′ E) in 1991–2004 and at the farmer's fields of Dingcheng district, Changde (29°03′ N, 111°53′ E) in 2009 and 2010. The field experiments in 1991–2004 were variety trials. In each year, Xiangzaoxian 13 (the check variety) and other varieties (the other varieties differed from year to year) were grown under irrigated conditions with optimal management, and were arranged in a randomized complete-block design with three replications and plot size of 13.3 m^2. Pre-germinated seeds were sown in seedbeds between March 29th and 31st. About 30-day-old seedlings were transplanted at a hill spacing of 17 cm × 20 cm with four seedlings per hill. Fertilizers used were