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RESEARCH ARTICLE

Influence of water potential and soil type on conventional *japonica* super rice yield and soil enzyme activities

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Abstract

We carried out a pool culture experiment to determine the optimal water treatment depth in loam and clay soils during the late growth stage of super rice. Three controlled water depth treatments of 0–5, 0–10 and 0–15 cm below the soil surface were established using alternate wetting and drying irrigation, and the soil water potential (0 to –25 kPa) was measured at 5, 10 and 15 cm. A 2-cm water layer was used as the control. We measured soil enzyme activities, root antioxidant enzyme activities, chlorophyll fluorescence parameters, and rice yield. The results showed that the 0–5-cm water depth treatment significantly increased root antioxidant enzyme activities in loam soil compared with the control, whereas soil enzyme activities, chlorophyll fluorescence parameters and yield did not differ from those of the control. The 0–10- and 0–15-cm water depth treatments also increased root antioxidant enzyme activities, whereas soil enzyme activities, chlorophyll fluorescence parameters and yield decreased. In clay soil, the soil enzyme activities, root antioxidant enzyme activities, chlorophyll fluorescence parameters, and yield did not change with the 0–5-cm water treatment, whereas the 0–10- and 0–15-cm water treatments improved these parameters. Therefore, the appropriate depths for soil water during the late growth period of rice with a 0 to –25 kPa water potential were 5 cm in loam and 15 cm in clay soil.

Keywords: rice, yield components, soil type, soil enzyme activity, antioxidant enzyme activity, chlorophyll fluorescence parameters, water potential

1. Introduction

Rice is one of the top three food crops worldwide and has the largest planting area and total yield in Asia. The rice planting area in China is broad, and includes the area from Heilongjiang Province to Hainan Province. The soil types differ in these areas and include a variety of paddy soils (Li 1992). In recent years, the majority of the region has promoted water-saving cultivation techniques, such as alternate wetting and drying and ridging, and aerobic irrigation technology, due to a water shortage (Luo 2010). Reasonable intermittent irrigation increases soil water use efficiency and maintains stable yields compared to maintaining the water layer in paddy soil (Borrell *et al.* 1997). Zhang *et al.* (2008) reported that wetting irrigation at the early stage, shallow irrigation at the booting stage and alternate wetting

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and drying irrigation at the heading stage increase flag leaf chlorophyll content, postpone leaf senescence and improve net photosynthetic rate and peroxidase (POD) and superoxide dismutase (SOD) activities, which are conducive to maintaining normal cell metabolism and increasing production. Qian *et al.* (2005) discovered that root biomass, absorbing area, and absorbing capacity are significantly better when using ridge culture than flat planting because roots extend deeper. Light alternate wetting and drying irrigation increases the flag leaf photosynthetic rate at the grain filling stage (Zhang *et al.* 2011), increases 1000-grain weight (Yang *et al.* 2005), improves rice quality (Liu *et al.* 2008), and increases rice yield (Dong *et al.* 2011; Fu *et al.* 2014). Ridge and furrow cultivation, aerobic irrigation and alternate wetting and drying irrigation adjust soil moisture, enhance soil permeability and improve soil redox conditions. However, the appropriate depth range to detect soil moisture at the late rice growth stage remains unclear, particularly because there are no moisture criteria for different soil depths in paddy soil. In this study, a soil potential of –25 kPa was selected as the standard soil water condition in loam and clay paddy soil to reveal the suitable depth to regulate soil moisture during the late rice growth stage. Then, we investigated soil enzyme activities, root antioxidant enzyme activities, chlorophyll fluorescence parameters, and rice yield at different water depths. The results of this study will provide a theoretical basis for cultivating high-yielding rice in different soil types.

2. Materials and methods

2.1. Experimental design

The experiments were carried out in the experimental park at Henan Agricultural University (Zhengzhou, China) in May–November of 2014 and 2015. Conventional *japonica* super rice Xindao 18 was selected as the test material. Soil physical and chemical properties are shown in Table 1. During the rice growing period, 480 kg ha^{-1} urea was supplied as base fertilizer, tiller fertilizer and panicle fertilizer at an application ratio of 3:3:4. The ratio of nitrogen, phosphate and potassium was 1:0.5:1.2. Seeds were sown singly on May 5 using a plastic floppy disk. Seedlings were transplanted manually in early June into a 30 cm×13 cm area.

The pool experiments (concrete walls on three sides and a glass wall on one side; length×width×height=2 m×1.5 m×1 m) included three controlled water depth treatments (0–5, 0–10 and 0–15 cm below the soil surface) established by introducing holes in the glass side at 5, 10 and 15 cm (Fig. 1). One pool was maintained at a 2-cm water layer as the control (CK). Water treatments started at the booting stage by opening the holes at different soil depths. Vacuum water potential sensors (Institute of Soil Science, Chinese Academy of Sciences) were buried at 5, 10 and 15 cm corresponding to the treatments. When the soil water potential decreased to –25 kPa as a result of alternate wetting and drying irrigation (Yang *et al.* 2005; Liu *et al.* 2008), the pools were irrigated to the 2-cm water layer. Each treatment was repeated three times.

2.2. Measurement and methods

Yield and its components Four representative plants were collected from each pool at maturation, and effective panicle number, grain number, seed setting rate, 1000-grain weight, and yield per plant were measured.

Determining soil enzyme activities Soil samples were

Table 1 Soil physical and chemical properties

Soil type	Sand (0.05–2 mm) (%)	Silt (0.002–0.05 mm) (%)	Clay (<0.002 mm) (%)	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})	Soil bulk density (g cm^{-3})	pH
Loam	66.61	16.59	16.80	23.27	18.63	70.64	1.46	6.55
Clay	27.77	45.09	27.14	16.21	20.15	105.23	1.75	6.91

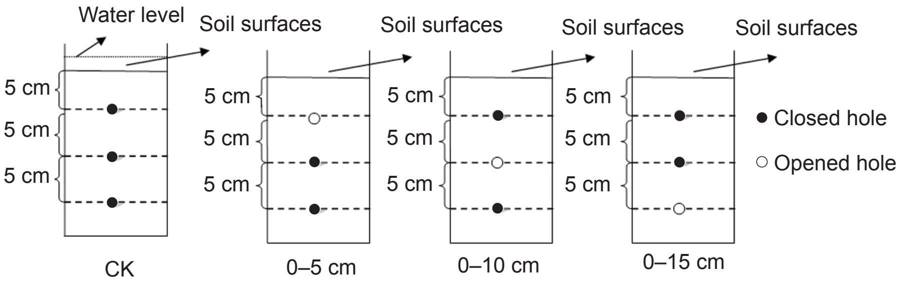

Fig. 1 Schematic diagram of the cement pool culture experiment.

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