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Long-Term No-Tillage Direct Seeding Mode for Water-Saving and Drought-Resistance Rice Production in Rice-Rapeseed Rotation System

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Abstract: To study the effects of long-term no-tillage direct seeding mode on rice yield and the soil physiochemical property in a rice-rapeseed rotation system, a comparative experiment with a water-saving and drought-resistance rice (WDR) variety and a double low rapeseed variety as materials was conducted under no-tillage direct seeding (NTDS) mode and conventional tillage direct seeding (CTDS) mode for four years, using the CTDS mode as the control. Compared with the CTDS mode, the actual rice yield of WDR decreased by 8.10% at the first year, whereas the plant height, spikelet number per panicle, spikelet fertility, 1000-grain weight, grain yield, actual yield, and harvest index increased with no-tillage years, which led to the actual yield increase by 6.49% at the fourth year. Correlation analysis showed that the panicle length was significantly related to the actual yield of WDR. Compared with the CTDS mode in terms of the soil properties, the pH value of the NTDS mode decreased every year, whereas the contents of soil organic matter and total N of the NTDS mode increased. In the 0–5 cm layer of the NTDS mode, the soil bulk decreased, whereas the contents of soil organic matter, total N, and available N increased. In the 5–20 cm layer of the NTDS mode, the available N and K decreased, whereas the soil bulk, contents of soil organic matter, and total N increased. In summary, the NTDS mode increased the rice yield, and could improve the paddy soil fertility of the top layer.
Key words: no-tillage direct seeding; rice yield; soil physiochemical property; water-saving and drought-resistance rice; rotation system

No-tillage is currently one of the major farming patterns in the world, but it has a relatively slow development in China (Tang and Zhang, 1996; Bhushan et al, 2007; Chen et al, 2013). The rice no-tilling culture is more common in Asia, wherein the main method is no-tillage direct seeding (NTDS) (Pandey and Velasco, 1999; Yang et al, 2013). In China, the Yangtze River Basin is the major area for rice and rapeseed production, where the rice-rapeseed rotation system is mainly adopted. In recent years, farming initiative has declined because of the factors of market, technology, and labor transfer. Farmland abandonment and the decline in farmer initiatives have led to rapeseed acreage reduction (Xia, 2006; Wu et al, 2009).

Studies on single cropping rice and paddy field rapeseed under the NTDS mode have been reported (Feng et al, 2006; Wang et al, 2011). However, studies on rice-rapeseed via long-term no-tillage cultivation are rare. The NTDS mode of rice in one season is conducive to nutrient fortification in the soil surface layer, and does not lead to soil acidification with higher rice yield than conventional tillage direct seeding (CTDS). In the present study, water-saving and drought-resistance rice (WDR) (Luo, 2010) and double low rapeseed variety, both of which are suitable for the NTDS mode, were chosen, and rice-rapeseed rotation was conducted for a number of successive years under the NTDS mode to determine the yield formation characteristics of rice and physiochemical properties of soil, which will provide a basis for the formation of a no-tillage cultivation technology system.

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MATERIALS AND METHODS

Tested materials

Hybrid rice variety Hanyou 3 was used in this study, which is characterized by water- and fertilizer-saving, good lodging resistance, high and stable yield, high quality, wide adaptability, and simple cultivation (Yu et al, 2005). Also, a middle maturity double low rapeseed variety Huyou 17 was chosen, which is characterized by strong stalk, fertilizer tolerance, good lodging resistance, high yield, good performance against viral diseases, strong sclerotinia resistance at the maturation stage, thick shell, good antinatural burst of silique when ripe, strong threshing resistance, and mechanical harvesting applicability (Sun et al, 2005).

Field trial design

A field experiment was conducted for a period of four successive years (2007–2010) in Zhuanghang Integrated Experiment Station of Shanghai Academy of Agricultural Science, China. The experimental field was an abandoned agricultural land during new rural construction, and rice-rapeseed tillage cultivation began in 2004. The physiochemical properties of soil in 2007 are shown in Table 1. The experiment was conducted using a rice-rapeseed rotation system with two types of treatment, the NTDS mode and CTDS mode (CK), with three replications. The area of each plot was 0.2 hm^2.

The seeds of rice variety Hanyou 3 were sown annually on 30 May, with the seeding rate of 45 kg/hm^2. After seed drying for 1–2 d, the seeds were soaked for 48 h in a solution consisting of 30 g of 17% fenitrothion-ethylicin, 10 g of 10% imidacloprid, and 9 kg of water to accelerate germination and shell breaking. After chemical control and weeding of the field, the seeds were directly sown into the moist soil. The seeds of rapeseed variety Huyou 7 were sown annually on 10 October. Before sowing, a herbicide was sprayed. The seeds were direct seeded using a no-tillage drill seeder with a seeding rate of 4.5 kg/hm^2.

The fertilization management standard of WDR was total nitrogen (N) of 240 kg/hm^2, which was applied as base fertilizer (35%), seedling fertilizer (15%), tillering fertilizer (35%), and panicle fertilizer (15%), respectively on 26 May, 4 July, 16 July, and at the jointing-booting stage. Phosphorus (P) and potassium (K) fertilizers were applied once as base fertilizer at 100 (count by P_2O_5) and 90 kg/hm^2 (count by K_2O), respectively. Water-saving irrigation was used. After seedling transplantation, the surface soil was kept moist, and basin irrigation was used only during fertilization. The pest, disease, and weeds were controlled based on the occurrence rule of WDR in Shanghai, China.

The fertilization management standard of rapeseed was total N of 240 kg/hm^2 (count by pure N), which was applied as base fertilizer (50%), seedling fertilizer (20%), and bud stage fertilizer (30%). P and K fertilizers were applied once as base fertilizer at 120 (count by P_2O_5) and 120 kg/hm^2 (count by K_2O), respectively. The pest, disease, weeds, and water were controlled as needed.

Analysis of rice yield and soil physiochemical properties

Upon maturity of the rice variety, five positions were chosen along the diagonal, and five single plants from each position were investigated to test the yield traits measured with the average. A rice combine harvester (Kubota PRQ-488) was used for harvesting in accordance with plot distinction. Rice grains were dried with impurities being removed and weighed. The standard yield was calculated according to the moisture content, which was determined by a rapid moisture meter and usually defined the average as 13.5%.

After rice was harvested and before rapeseed was sown in 2009 and 2010, the soil samples from the surface layer (0–5 cm) and subsurface layer (5–20 cm) of the arable layer were taken to the Institute of Ecology, Shanghai Academy of Agricultural Sciences, China to test their physiochemical properties. Soil pH was determined using a potentiometry (immersion method) with a water-soil ratio of 5:1. The organic matter content was measured using K dichromate oxidation, which is an external heating method. The total N content was measured by the semi-micro Kjeldahl method, and available N was detected by alkaline hydrolysis diffusion. Available P was measured

Table 1. Physiochemical properties of the tested soil.

Soil layer	pH	Organic matter (%)	Total N (%)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Soil bulk (g/cm^3)
0–5 cm	6.82	1.78	0.13	36.22	24.91	130.00	1.42
5–20 cm	6.87	1.63	0.11	32.88	23.00	101.38	1.47