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Influence of rice straw mulching on seed yield and nitrogen use efficiency of winter oilseed rape (*Brassica napus* L.) in intensive rice–oilseed rape cropping system

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ABSTRACT

In intensive rice–winter oilseed rape (*Brassica napus* L.) cropping system in China, winter oilseed rape is often planted beyond the optimum period due to late harvest of rice. Under such condition, growth of rape seedlings is adversely affected due to low temperature and seasonal drought in winter, which causes a low rapeseed yield. Considering the enormous amounts of rice straw produced in this intensive cropping system, rice straw mulching in winter oilseed rape season may be a potential practice to adjust soil micro-climate, thereby improve productivity of winter oilseed rape. A two-year field study (2010–2011 and 2011–2012) was conducted to evaluate the effect of rice straw mulching and nitrogen (N) fertilization on (i) soil water, soil temperature and yield of winter oilseed rape and, (ii) N uptake, ammonia volatilization and soil inorganic N status in rice–winter oilseed rape cropping system. In general, straw mulching improved the dry matter accumulation and N uptake of winter oilseed rape over the growing period regardless of N fertilizer application or not, which might be attributed to the higher soil water content and the lower soil temperature oscillation under straw mulching compared to no mulching. Nevertheless, the relative magnitude of the increase in dry matter accumulation and N uptake of winter oilseed rape between the mulched and un-mulched treatments reduced with progressive increase in crop growth after seedling stage. Straw mulching resulted in more N loss through ammonia volatilization from top dressed fertilizer N and a significantly lower soil inorganic N content after seedling stage, which might be an important factor that was responsible for decreased positive effects of straw mulching on oilseed rape growth and N uptake after seedling stage under the condition of N fertilization. The positive effects of straw mulching on oilseed rape yield were influenced by the amount and distribution pattern of seasonal rainfall, with a significant increase in 2010–2011 only. In summary, these results suggest that rice straw mulching has the potential to enhance the productivity of winter oilseed rape, even though some changes in method of topdressing fertilizer N may be needed to avoid negative effects of straw mulching.

1. Introduction

Oilseed rape (*Brassica* species) is one of the most widely cultivated oil crops in the world. The world production of rapeseed was about 62.4 million tons in 2011 and, as edible vegetable oil, only soybean and palm oil production exceeded that of oilseed rape (FAOSTAT, 2011). China, as one of the most important country in rapeseed production, provided 21.5% of the total rapeseed production of the world, with over 13 million tons of the total yield of oilseed rape (*Brassica napus* L.) in 2011 (FAOSTAT, 2011). Within a period of five decades from 1960s to 2010s, rapeseed yield in China was rapidly increased with the substitution of Swede rape (*Brassica napus* L.) for Turnip rape (*Brassica rapa* L.), with the introduction of high yield potential cultivars and the adoption of improved agronomic practices (Wang, 2010). Nevertheless, a further increase of rapeseed yield will still be required to match the rising demand for edible oil due to population growth and economic development in the future (Wang, 2010).

In China, oilseed rape is mainly cultivated in an area of 5.5 million hectare in the Yangtze River basin (National Bureau of Statistics of China, 2012), where intensive crop production systems are commonly practiced by farmers in order to gain more crop yield and income on limited arable land. In this region, oilseed rape is usually planted as a winter crop following rice under the single rice–oilseed rape system or the double rice–oilseed rape system.

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The region, which has a subtropical monsoon climate, is characterized by uneven rainfall and temperature. Seasonal drought and low temperature is prevailing in winter. In order to accommodate this climate condition, the planting time from late September to middle October is usually recommended so that seedlings of oilseed rape can achieve adequate growth to protect against low temperature and seasonal drought in winter and realize high rapeseed yield (Liu, 1987). However, in fact, the plant time of oilseed rape in this region is often beyond the optimum period due to late harvest of rice, especially in the double rice–winter oilseed rape system. Because late-season rice is usually harvested in late October, the planting time of winter oilseed rape is often delayed to early November in the double rice–winter oilseed rape cropping system. Under such conditions, the rape seedlings are adversely affected due to low temperature and seasonal drought in winter, which often causes a low rapeseed yield (Liao and Guan, 2001; Ma et al., 2010; Tang et al., 2008; Yang et al., 2009). In order to boost the productivity of winter oilseed rape, management practices that could weaken the negative effects resulting from the late planting should be researched and adopted.

The practice of straw mulching has been widely used as a management tool in agriculture in many parts of the world. One of the major advantages associated with straw mulching is retaining greater availability of soil water by controlling evaporation loss from the soil surface and improving water infiltration (Chen et al., 2007; Qin et al., 2006; Sharma et al., 2011). Straw mulching also keeps the soil warmer in winter and cooler in summer as well as reduces soil temperature oscillation (Blanco-Canqui and Lal, 2009a; Chen et al., 2007; Lal, 1974). Long-term use of straw mulching may increase soil organic carbon content, replenish soil nutrients, enhance soil aggregation and promote biological activity (Blanco-Canqui and Lal, 2007a; Blanco-Canqui and Lal, 2007b; Blanco-Canqui and Lal, 2009b; Salinas-Garcia et al., 2001). Straw mulching may represent an important option for enhancing soil quality as well as crop productivity and sustainability (Cadavid et al., 1998; Fuentes et al., 2009; Malhi and Lemke, 2007).

The annual production of crop straw is about 760 million tons in China, and the traditional disposal method for crop straw is burning as fuel or feeding livestock (Gao et al., 2009). Recently, with the increase of living standard, farmers have greatly changed their energy structures: commercial energy sources like coal, liquefied petroleum gas and natural gas have been consumed by more and more farm families. The biomass energy is being substituted by commercial energy, which has led to overplus of the crop straw (Wang and Feng, 2004; Zeng et al., 2007). In addition, with the change of agricultural structure, farmers have been no longer engaged in breeding big animals. This seriously separates the crop planting and livestock raising, which again has led to overplus of the crop straw (Liu et al., 2008). Farmers are opting for a large scale burning to dispose off the surplus straw, which causes the waste of resources and environmental pollution. According to statistics, about 20.5% of the total crop straw is discarded directly through burning in the open fields per year in China (Liu et al., 2008). Utilization of crop straw is therefore an important issue for sustainable agriculture. In the Yangtze River basin, intensive rice production contributes to the most serious straw overplus and straw burning compared with other crops (Bi, 2010). Alternatives to burning are consequently needed more urgently for rice than other crop straw in this region. Therefore, using rice straw as a soil mulch material in winter oilseed rape season may provide an opportunity not only to improve crop productivity considering its beneficial effects on soil micro-climate, but also to utilize surplus straw.

Nitrogen nutrition has played an important role in increasing oilseed rape yield in actual farming (Wang et al., 2010; Zou et al., 2011). However, the responses of oilseed rape to N fertilization depend on many environmental factors, such as water availability, ambient temperature and soil properties including soil texture, content of organic matter, particle size, soil pH and cation exchange capacity and so on (Rathke et al., 2006). Straw mulching may affect N-transport and N mineralization in soil and plant N uptake through its effect on soil temperature and moisture (Knoepp and Swank, 2002; Quemada and Cabrera, 1997; Rathke et al., 2006). All of these factors may alter the responses of winter oilseed rape to N fertilization, and thus affecting the seed yield.

The objectives of the present study are to examine the effects of rice straw mulching and N fertilization on (i) soil temperature, soil moisture content, crop growth and seed yield of winter oilseed rape, and (ii) ammonia volatilization, soil inorganic status, crop N uptake and N use efficiency of winter oilseed rape in rice–winter oilseed rape cropping system. Results from this study may provide some information that can be used to (i) determine whether rice straw mulching has the potential of improving the productivity of winter oilseed rape; (ii) preliminarily judge whether winter oilseed rape requires different N management practices under straw mulching.

Table 1
Selected soil properties (0–30 cm soil layer) at experimental site at the beginning of experiments in 2010–2011 and 2011–2012.

Selected soil properties	Growing season	
	2010–2011	2011–2012
pH	5.95	5.73
Organic matter (g kg^{-1})	12.13	19.84
Total nitrogen (g kg^{-1})	0.83	1.27
Nitrate nitrogen (mg kg^{-1})	10.03	8.84
Ammonium nitrogen (mg kg^{-1})	2.12	4.41
Olsen-P (mg kg^{-1})	9.95	14.32
Exchangeable K (mg kg^{-1})	106.08	151.65

2. Materials and methods

2.1. Experimental site

A replicated field experiment was conducted for two seasons (2010–2011 and 2011–2012) at the Experimental Farm of Huazhong Agricultural University (30°28′12″N, 114°21′05″E, 27 m ASL), Wuhan, China. With a subtropical monsoon climate, the experimental site's mean annual temperature is 16.7 °C and its winter mean temperature is 3.8 °C. The mean annual rainfall is 1257 mm, around 70% of it is concentrated during the months of March–August. The experimental site's soil is a yellowish brown clay loam. Within the site, different field was used for experiment in different seasons. The initial soil status of the field in each season is given in Table 1. The experimental field used in 2011–2012 had relatively higher organic C, total N, available P and available K compared with the field used in 2010–2011. The soil inorganic N content (Nitrate N + Ammonium N) was comparable between the two fields.

Rainfall and temperature during the two seasons are shown in Fig. 1. In both seasons, temperatures during the winter oilseed rape growing period were similar and close to the long-term mean, except for significantly lower temperature in January 2011. Total rainfall during the growing period was 210 mm in 2010–2011 and 564 mm in 2011–2012, respectively. The mean rainfall during the growing period over the last 30 years was 592 mm at the study area. The period from the 2010–2011 is therefore considered to be seriously dry. In the 2011–2012, rainfall from November 2011 to February 2012 (108 mm) was only 54% of the long-term mean (201 mm), whereas the amount from March 2012 to May 2012 (456 mm) was 17% more than long-term mean (391 mm), which indicated that there was an obviously maladjusted precipitation in this season.