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Crop rotation-dependent yield responses to fertilization in winter oilseed rape (*Brassica napus* L.)

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ABSTRACT

Differences in soil physical, chemical and biological properties between paddy–upland and continuous upland rotations will influence nutrient relations and crop growth. With the aim of estimating rapeseed yield performance in response to fertilization in rice–rapeseed (RR) and cotton–rapeseed (CR) rotations, on-farm experiments were conducted at 70 sites across Hubei province, central China. The economically optimal fertilizer rates of winter oilseed rape in different rotations were determined. Field experiments showed that previous crops significantly influenced seed yields. Without N fertilization, seed yields were significantly lower for the RR rotation than for the CR rotation. The average yield increase ratio and agronomic efficiency associated with nitrogen (N) fertilization in the RR rotation were 96.6% and 6.56 kg kg^{-1}, significantly higher than those in the CR rotation. No seed yield differences were detected between the two rotations under phosphorus (P) and potassium (K) fertilization. In contrast to the CR rotation, N fertilizer played a more vital role in maintaining high seed yields in the RR rotation owing to the lower indigenous soil N supply. Compared with local N fertilizer recommendation rates for the RR rotation, on average an additional 18 kg N ha^{-1} was recommended according to the economically optimal N fertilizer rate (EONFR). In contrast, the EONFR was 14 kg N ha^{-1} lower than the locally recommended N fertilizer rate for the CR rotation. There were no differences between the two rotations for the average economically optimal P and K fertilization rates. Consequently, the average EONFR of winter oilseed rape could be reduced if cotton rather than rice preceded the winter oilseed rape.

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1. Introduction

Oilseed rape (*Brassica napus* L.) is used to produce important edible oil for human consumption and is also a promising biodiesel crop. Increasing demand for edible oil and fuel with limited arable land and expanding population will require greater oilseed rape production worldwide [1]. Reliance on the use of mineral fertilizer has resulted in high oilseed rape production [2–5], even under unpredictable environmental conditions [6]. However, imperfect fertilizer management has always resulted in the inconsistent and inappropriate application of fertilizer in agricultural production, with consequent environment risks [7]. Managing agricultural nutrients to provide a safe and secure food supply and protect the environment remains one of the great challenges of the 21st century [8].

Crop nutrient uptake and crop yield are the primary factors determining optimal fertilization practices [9]. However, seed yields are highly variable in winter oilseed rape production, depending on the crop rotations [3,10]. Rapeseed yields following cereal crops are considerably lower than those following peas, possibly owing to higher residual soil nitrogen (N) content and greater net soil N mineralization under cultivation in rotation with a legume [4,11]. A lower rapeseed yield response to mineral N fertilizer was observed in a pea than in a barley–winter oilseed rape rotation [12]. Optimal N fertilizer rate could be reduced if peas or fallow rather than winter wheat preceded the rape crop [3].

Differently from oilseed rape rotations in Europe, paddy-oilseed rape is the predominant oilseed rape rotation in Asia. Repeated transitions from flooding to drying affect soil physical, chemical, and biological properties [13,14]. Paddy–upland rotations showed a larger potential for carbon (C) sequestration, owing to the perennially flooded conditions [15,16]. Moreover, a rice-based crop rotation could enhance native arbuscular mycorrhizal (AM) activity and improve the phosphorus (P) nutrition of subsequent crops [17]. Thus, changes in soil physical, chemical, and biological features in paddy–upland rotation will influence nutrient relations and crop growth. Besides paddy-oilseed rape rotation, upland–oilseed rape rotations such as cotton–, peanut–, and spring maize–oilseed rape rotations are important oilseed rape rotations in Asia. So the question arises whether rapeseed yields and yield responses to mineral fertilization for paddy–upland rotations and continuous upland rotations are different. If there are differences between these two rotations, the recommended fertilizer rates of winter oilseed rape should be adapted to the respective previous crop, a critical measure for improving fertilizer use efficiency.

Winter oilseed rape followed by rice or cotton is the dominant oilseed rape rotation in the Yangtze River basin, where 91% of the total oilseed rape in China is produced [18]. From September 2009 to May 2010, on-farm experiments were conducted at 70 sites across Hubei province, central China to study the influences of different mineral fertilizer application rates on winter oilseed rape yield with the aim of providing guidance for reasonable winter oilseed rape fertilization. At 35 sites the previous crops were cotton, whereas the other 35 on-farm winter oilseed rape crops followed rice. The results from these experiments allowed the estimation of (1) the winter oilseed rape yield response differences to mineral fertilization between the RR and CR, and (2) the economically optimal rate of fertilization for winter oilseed rape in these two different rotations. These estimates will be helpful for improving fertilizer advisories for different rotations and for achieving sustainable oilseed rape production.

2. Materials and methods

2.1. Site characteristics

Hubei province (29°25′ N–33°20′ N, 108°21′ E–116°07′ E) is located in the middle of the Yangtze River basin in central China. The climate in this region is subtropical, with an average annual temperature of 15–17 °C, 750–1600 mm of precipitation, and a mean frost-free period of 230–300 days. Rice–rapeseed (RR) and cotton–rapeseed (CR) are the dominant winter oilseed rape rotations in the province. Rice is typically transplanted at the end of May and harvested at the end of September. Winter oilseed rape plants are usually transplanted after the rice harvest to improve land use efficiency, to lessen erratic winter weather-related adverse impacts on seedlings, and to achieve high yields. Farmers sow the seeds in nursery beds in the middle of September and then manually transplant 30- to 40-day-old oilseed rape seedlings with 4–5 leaves at a density of 105,000 plants ha^{-1}. The cotton growing period is longer than that of rice, with cotton being usually transplanted at the end of May and harvested in early November. Approximately one week after the cotton harvest, 30- to 40-day-old winter oilseed rape seedlings are transplanted to the field. The double-low rapeseed cultivars, including Huashuang (HS), Huayouza (HYZ), Zhongshuang (ZS), and Zhongyouza (ZYZ), are widely grown and have average seed yields of 1.75 t ha^{-1}, varying from 0.96 to 2.44 t ha^{-1} [18].

On-farm experiments at 70 sites across Hubei were conducted from September 2009 to May 2010. In 2009–2010

Table 1 – General soil properties of 70 winter oilseed rape fields from different rotations in Hubei province, central China.

Soil property	CR (n = 35)				RR (n = 35)			
	Mean	Min.	Max.	CV (%)	Mean	Min.	Max.	CV (%)
SOM (g kg^{-1})	22.7	11.0	38.8	29.0	25.6	11.3	44.0	33.3
Available N (mg kg^{-1})	123	49.0	204.0	34.4	118.0	33.0	248	39.4
Olsen-P (mg kg^{-1})	15.8	2.5	48.2	65.7	12.1	3.1	27.4	46.1
NH_4OAc–K (mg kg^{-1})	110.0	25.0	250.0	46.7	96.0	44.0	246.0	40.6
pH	7.1	4.0	8.4	14.8	6.1	4.7	8.1	12.8

1) CR: cotton–oilseed rape rotation; RR: rice–oilseed rape rotation.
2) Available N is alkaline hydrolyzable N.
3) CV: coefficient of variation.