Journal of Integrative Agriculture 2015, 14(4): 670–680

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RESEARCH ARTICLE

Nutrient deficiency limits population development, yield formation, and nutrient uptake of direct sown winter oilseed rape

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Abstract

Direct-sowing establishment method has great significance in improving winter oilseed rape (*Brassica napus* L.) production and guaranteeing edible oil security in China. However, nutrient responses on direct sown winter oilseed rape (DOR) performance and population development dynamic are still not well understood. Therefore, five on-farm experiments were conducted in the reaches of the Yangtze River (RYR) to determine the effects of nitrogen (N), phosphorus (P), and potassium (K) deficiencies on population density, dry matter production, nutrient uptake, seed yield, and yield components of DOR plants. Four fertilization treatments included the balanced NPK application treatment (NPK, 180 kg N, 39.3 kg P, 100 kg K, and 1.8 kg borax ha^{-1}) and three nutrient deficiency treatments based on the NPK treatment, i.e., –N, –P, and –K. The results indicated that DOR population density declined gradually throughout the growing season, especially at over-wintering and pod-development stages. Nutrient deficiency decreased nutrient concentration in DOR plants, limited dry matter production and nutrient uptake, and thereby exacerbated density reduction during plants growth. The poor individual growth and reduced population density together decreased seed yield in the nutrient deficiency treatment. Averaged across all the experiments, seed yield reduced 61% by N deficiency, 38.3% by P deficiency, and 14.4% by K deficiency. The negative effects of nutrient deficiency on DOR performances followed the order of –N>–P>–K, and the effects were various among different nutrient deficiencies. Although N deficiency improved DOR emergence, but it seriously limited dry matter production and nutrient uptake, which in turn led to substantial plants death and therefore resulted in a very low harvested density. The P deficiency significantly reduced initial density, limited plants growth, and exacerbated density reduction. The K deficiency mainly decreased individual growth and yield, but did not affect density dynamic. Our results highlighted the importance of balanced NPK application in DOR production, suggesting that management strategy of these nutrients should be comprehensively considered with an aim to build an appropriate population structure with balanced plant density and individual growth.

Keywords: oilseed rape (*Brassica napus* L.), direct-sowing, nutrient deficiency, population density, seed yield, yield components, nutrient uptake

1. Introduction

The reaches of the Yangtze River (RYR) is the largest winter oilseed rape cultivation belt both in the world and China (Yin *et al*. 2010). In this region, transplanting method was formerly practised by farmers to establish winter oilseed rape.

Received 13 March, 2014 Accepted 6 May, 2014

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doi: 10.1016/S2095-3119(14)60798-X

However, transplanted oilseed rape (TOR) has been limited due to the increasing scarcity of agricultural labour and rising cost, with the economic development and rural-urban migration (Ma *et al*. 2012; Zhong *et al*. 2013). This limitation of TOR has reduced oilseed rape planting areas and thereby caused a stagnant rapeseed production. Direct-sowing culture is considered as a method of "low input cultivation" with faster and easier operation, decreased labor demand, and greater benefit as compared with transplantation (Wang *et al*. 2011). It has become a dominated alternative to transplanting crops in many countries, such as rice (*Oryza sativa* L.) in China, South and Southeast Asian countries (Farooq *et al*. 2011; Liu *et al*. 2014) and maize (*Zea mays* L.) in South Africa and Bangladesh (Biswas *et al*. 2009; Fanadzo *et al*. 2009). In the RYR, direct sown winter oilseed rape (DOR) has showed rapid development and spread during the past decade. A recent survey showed that the cultivated area of DOR in the RYR was roughly equal to the size of TOR (Xu 2012). Under the current situation, direct-sowing establishment method will be more important in improving winter oilseed rape production and increasing edible oil supply in China.

Presently, most studies of winter oilseed rape in China have focused on TOR plants, while little work has been conducted on DOR plants. The lagging techniques on cultivation and fertilization have limited DOR yield and the further development (Wang *et al*. 2013). Previous studies found that DOR had contrasting population structure and individual morphology with TOR at maturity, mainly due to the altered plant density and growth duration (Fu *et al*. 2009; Wang *et al*. 2011). Compared with TOR, individual DOR plant was relatively poor as reflected by fewer branches and pods. Consequently, a higher DOR sowing rate was recommended to exert population dominance and increase seed yield (Ma *et al*. 2009; Zhang *et al*. 2012). However, plants numbers in DOR population trended to decrease during the growing season under a high planting density (Leach *et al*. 1999). Similarly, density reduction during plants growth was also observed in winter wheat (Liu *et al*. 2006). Thus, it is important to ensure a sufficient plant density at maturity for building appropriate population structure in DOR plants, and this requires to understand the development process of DOR population during the growing season. Nevertheless, there appears to be no available relevant information on DOR in the RYR.

The applications of N, P, and K fertilizers played important roles in oilseed rape growth and yield formation (Cheema *et al*. 2001; Lu 2010; Wang *et al*. 2013). Compared with TOR, DOR showed higher nutrient demands at the vegetative growth stage, especially for N. The N uptake in DOR plants at the seedling stage accounted for over 80% of the total N uptake throughout the growing season (Liu *et al*. 2011), while the corresponding proportion was less than 48% for TOR plants (Zou *et al*. 2008). In addition, Wang *et al*. (2013) reported that DOR plants had larger yield reductions than TOR plants under the nutrient omission conditions. This suggested that DOR plants might have different nutrient characteristics and management practices with TOR plants. However, the studies on the nutrient response of DOR performance are limited, and none have examined the effects of nutrient deficiency on DOR population development.

The objectives of this study were (i) to estimate the N, P, and K responses on DOR performances at maturity, including seed yield, yield components, dry matter, and nutrient accumulation, and (ii) to investigate the effects of nutrient deficiency on development dynamics of DOR population during the growing season, in terms of plant density, dry matter production, nutrient concentration, and nutrient uptake. Our results could help increase the understanding on population development dynamics and nutrient responses of DOR plants, and provide some suggestions to improve the nutrient management.

2. Results

2.1. Seed yield

Seed yield was significantly affected by fertilization treatments, locations, and their interaction (Table 1). Of the five locations, seed yields were relatively higher at Jingmen and were lower at Huangmei. In each experiment, the highest seed yield was observed in the balanced NPK application treatment (180 kg N, 39.3 kg P, 100 kg K, and 1.8 kg borax ha^{-1} were applied during oilseed rape growing season). Averaged across all the locations, the NPK treatment was followed by K deficiency (–K), P deficiency (–P), and N deficiency (–N) treatments. Compared with the NPK treatment, seed yield decreased significantly in all the nutrient deficiency treatments. At various locations, yield reduction rates ranged from 38.3 to 96.9% in –N treatment (averaged 61.0%, 1 471 kg ha^{-1}), from 8.0 to 78.1% in –P treatment (averaged 38.3%, 880 kg ha^{-1}), and from 3.7 to 33.8% in –K treatment (averaged 14.4%, 315 kg ha^{-1}). The negative influence of nutrient deficiency on DOR yield followed the order of N>P>K.

2.2. Yield components

All the yield components including harvested density, pods $plant^{-1}$, seeds pod^{-1}, and 1 000-seed weight varied among fertilization treatments and locations (Table 1). The fertilization×location interactions were significant for all the parameters except 1 000-seed weight. At each location, the highest harvested density was observed in the NPK