Europ. J. Agronomy 62 (2015) 38–45

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Effect of depth of fertilizer banded-placement on growth, nutrient uptake and yield of oilseed rape (*Brassica napus* L.)

Wei Su[a,b], Bo Liu[a,b], Xiaowei Liu[c], Xiaokun Li[a,b], Tao Ren[a,b], Rihuan Cong[a,b], Jianwei Lu[a,b,*]

[a] Department of Plant Nutrition, College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China
[b] Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River), Ministry of Agriculture, Wuhan 430070, China
[c] Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China

ARTICLE INFO

Article history:
Received 25 February 2014
Received in revised form 25 August 2014
Accepted 9 September 2014
Available online 28 September 2014

Keywords:
Fertilizer banded-placement depth
Oilseed rape
Shoot growth
Root growth
Nutrient uptake
Seed yield

ABSTRACT

A better understanding of crop growth and nutrient uptake responses to the depth of fertilizer banded-placement in the soil is needed if growth and nutrient uptake responses are to be maximized. A two-year field study covering two rape seasons (2010–2011 and 2011–2012) was conducted to examine the effect of banded-placement of N–P–K fertilizer at various depths on growth, nutrient uptake and yield of oilseed rape (*Brassica napus* L.). The results showed that fertilization at 10 cm and 15 cm soil depth produced greater taproot length and dry weight than fertilization at 0 cm and 5 cm. 0 cm and 5 cm deep fertilization significantly increased the lateral root distribution at 0–5 cm soil depth, while 10 cm and 15 cm deep fertilization induced more lateral root proliferation at 5–15 cm soil depth. At 36 days after sowing (DAS), 5 cm deep fertilization produced better aboveground growth and nutrient uptake than 10 cm and 15 cm deep fertilization. However, reversed results were observed after 36 DAS. 10 cm and 15 cm deep fertilization produced more rapeseed than 0 cm and 5 cm deep fertilization, moreover, the yield difference was more significant in drought season (2010–2011) than in relatively normal season (2011–2012). In summary, these results preliminarily suggest that both 10 cm and 15 cm are relatively proper fertilizer placement depth when the practice of banding fertilizer is used in oilseed rape production. But from the viewpoint of diminishing the production cost, 10 cm deep fertilization should be recommended in actual farming. Because 15 cm deep fertilization may require higher mechanical power input, and thus resulting in higher cost of production.

1. Introduction

Optimizing the fertilization method to simultaneously achieve high nutrient use efficiency and high crop productivity is necessary in modern agriculture, because modern agricultural production not only needs to meet the increasing demand for global food production, but also needs to minimize depletion of natural resources and deterioration of environmental conditions (Cassman, 1999; Cassman et al., 2003; Tilman et al., 2002).

Extensive studies have been performed to contrast the effects of different fertilizer application methods on nutrient use efficiency, crop productivity and nutrient loss. In general, banding fertilizer in soil could result in increased fertilizer use efficiency and crop yield compared with other application methods. Nash et al. (2013) found that strip-till and deep banding placement of nitrogen (N) fertilizer produced significantly greater corn yield than no-till system with broadcast N fertilizer in poorly drained claypan soils. Borges and Mallarino (2001) studied the improvement of potassium (K) application method for corn in 15 experimental sites, the results showed that the deep-band K placement increased the K uptake of corn over the broadcast K in 14 sites. Ma et al. (2013) reported that side-banded application of ammonium and phosphorus (P) could significantly improve maize growth, nutrient uptake and grain yield on a calcareous soil, which was associated with localized nutrient-induced root proliferation. In a three-year field experiment, Trapeznikov et al. (2003) observed that higher wheat yield occurred in the treatments with banded placement of granulated NPK fertilizer at 8–10 cm depth compared with homogeneous application fertilizer in the 0–18 cm soil layer; moreover, the

* Corresponding author at: Department of Plant Nutrition, College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China. Tel.: +86 27 87288589; fax: +86 27 87288589.
E-mail addresses: suweiwm@webmail.hzau.edu.cn (W. Su), lunm@mail.hzau.edu.cn (J. Lu).

http://dx.doi.org/10.1016/j.eja.2014.09.002
1161-0301/

difference was more significant in the drought season. All of these results indicated that banding fertilizer had some advantages in improving crops growth and nutrient uptake compared with broadcasting or mixing fertilizer. The emergence of comparative advantages is mainly attributed to two factors. (1) Banding fertilizer saturates the soil solution with nutrients especially slowly-mobile nutrients such as P and K in a relatively small area within the root zone, which can reduce fixation and adsorption of nutrients by soil particles, and thus increasing nutrients availability (Farmaha et al., 2013; Fernández and White, 2012; McLaughlin et al., 2011). Additionally, when fertilizer is applied in soil with deep bands, relatively greater water availability in the subsurface of soil will enhance nutrient-solution and nutrient-transport, which is also in favor of a higher nutrient availability (Li, 2008; McLaughlin et al., 2011). (2) Localized nutrient concentrations especially localized N and P concentrations resulted from banding fertilizer can stimulate root development and establishment of a virtually ideal root architecture, and thus increasing crops nutrient uptake and yield (Shen et al., 2013).

Besides improving nutrient use efficiency and crop yield, banding fertilizer also could reduce the nutrient loss. Rochette et al. (2009) reported that banding urea significantly decreased the ammonia volatilization by 52% compared to urea broadcast in a no-till soil. Cheng et al. (2002) found that N_2O + NO emissions from urea fertilizer were lower from band than broadcast application applied to Chinese cabbage. Kimmell et al. (2001) observed significant P placement effects on P runoff losses. As reported by them, P runoff losses were significantly lower with knife placement P compared with broadcast P.

Although banding fertilizer in the root zone represents an effective fertilization practice to simultaneously achieve high nutrient use efficiency and high crop productivity, it still has the room for further improvement. As pointed in reports by Mcconnell et al. (1986) and Murphy and Zaurov (1994), the effect of banding fertilizer on crop growth, nutrient uptake and yield significantly varied with the change of fertilizer placement depth, suggesting determining the proper placement depth is an effective approach for further improving the effect of banding fertilizer.

Oilseed rape is the most important oil crop in China with about 7.3 million hectares of the total sown areas and 14.0 million tons of the total rapeseed yields in 2012 (FAOSTAT, 2014). For a long time, the alternative fertilization technique for oilseed rape in China was only broadcast or broadcast and incorporation into the soil surface (0–3 cm depth) due to the shortage of both labor force and farm machines. Partially related to these imprudent fertilization methods, the nutrient use efficiency of oilseed rape was always maintained on a low level. In recent years, banding fertilizer has become an emerging fertilization technique in oilseed rape production in China with rapid development of agricultural mechanization (Ma et al., 2010; Wu et al., 2005, 2007; Zhou et al., 2011), which offered an opportunity to improve the productivity and nutrient use efficiency of oilseed rape. But as the technique which is in the early stages of adoption, the underlying strategy of banding fertilizer such as proper depth of fertilizer placement remains largely to be determined. Therefore, we conducted a two-year field experiment in main oilseed rape producing area of China. The overall goal of this study was to preliminarily determine proper fertilizer placement depth, thereby helping farmers perfect the practice of banding fertilizer. In order to achieve this goal, we examined the effect of depths of N–P–K fertilizer banded-placement on shoot growth, nutrient uptake and seed yield of oilseed rape. Besides, given that different depths of fertilizer placement could result in changes in root morphology (Murphy and Zaurov, 1994; Weligama et al., 2008), and thus determining shoot growth and nutrient uptake (Hammer et al., 2009; Singh et al., 2005; Wang et al., 2004), we also assessed root response of oilseed rape to different depths of N–P–K fertilizer banded-placement including taproot growth parameters and lateral root distribution.

2. Materials and methods

2.1. Experimental site

Oilseed rape were grown for two seasons (2010–2011 and 2011–2012) in rotation with rice 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 field's soil was a yellowish brown clay loam with bulk density 1.41 g cm^{-1}, pH 5.72 (1: 5 soil: water suspension), organic matter 18.25 g kg^{-1}, total N 1.10 g kg^{-1}, Olsen-P 18.23 mg kg^{-1}, exchangeable K 80.26 mg kg^{-1} in the topsoil layer (0–30 cm).

Climate condition during the two seasons is shown in Fig. 1. In both the seasons, temperatures during the 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 was 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.

2.2. Experimental design and crop management

The experiment consisted of five treatments, each with three replicates in a completely randomized block design: (1) no fertilization (ck); (2) N–P–K fertilizer banded placement at soil depth of 0 cm (D_0); (3) N–P–K fertilizer banded placement at soil depth of 5 cm (D_5); (4) N–P–K fertilizer banded placement at soil depth of 10 cm (D_{10}) and (5) N–P–K fertilizer banded placement at soil depth of 15 cm (D_{15}). The plot size was 4 m × 5 m.

All fertilization treatments received N 180 kg ha^{-1} as urea (N 46%), P 40 kg ha^{-1} as calcium superphosphate (P 5.2%) and K 100 kg ha^{-1} as potassium chloride (K 52.3%). The full rates of fertilizers were applied just before seeding. A mixture of N, P and K fertilizers was banded in terms of designed depth. Each plot consisted of 15 fertilizer bands 5 m in length and 0.20 m apart.

Winter type oilseed rape (cv. Huashuang 5, supplied by the Wuhan Research Branch of the National Rapeseed Genetic Improvement Center) was seeded on 9 October 2010 and 17 October 2011, harvested on 13 May 2011 and 18 May 2012 for the season of 2010–2011 and 2011–2012, respectively. The method of hill-seeding was used in present study. Forty hills were arranged on each fertilizer band. Intrarow spacing of hills was 0.11 m with three seeds per hill. After emergence of oilseed rape completed, only one plant was left in each hill. Plant population of 0.3 million per hectare was maintained. No irrigation was adopted in the whole life of oilseed rape in both seasons.

2.3. Sampling and measurement

Plant height and number of leaves of oilseed rape were determined at 36 and 76 days after sowing (DAS) during seedling stage in 2010–2011 and 2011–2012. Heights of eight randomly selected