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RESEARCH PAPER

Growth and Yield Formation of Direct-Seeding Rapeseed Under No-Tillage Cultivation in Double Rice Cropping Area in Hubei Province

WANG Cui-Cui, CHEN Ai-Wu, WANG Ji-Jun, ZHANG Dong-Xiao, TANG Song, ZHOU Guang-Sheng*, HU Li-Yong, WU Jiang-Sheng, and FU Ting-Dong

College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, China

Abstract: In the Yangtze River basin, winter fallow is popular for the double cropping rice (*Oryza sativa* L.). In this study, the possibility of adding a rapeseed cropping season after late rice harvest in this area was studied with the purpose of extending direct-seeding rapeseed under no-tillage cultivation pattern. In a 2-year field experiment from 2008 to 2010, the rapeseed cultivar Huashuang 5 (*Brassica napus* L. cv. Huashuang 5) were planted in 3 locations in Hubei Province of China after harvesting late rice. At both individual and population levels, the effects of plant density and nitrogen (N) application rate on rapeseed growth and yield formation were measured at seedling, budding, flowering, podding, and maturity stages. The cultivation pattern of no-tillage and direct-seeding after late rice harvest shortened the growth duration of rapeseed, especially at seedling stage, but prolonged the late budding stage in spring. The biomass accumulation from emergence to early budding was deficient severely, resulting in quick growth from budding to flowering of rapeseed. Application of N fertilizer had significant effects on enhancing the growth and yield formation of rapeseed through improving the individual and population qualities. Under the N rate of 270 kg ha^{-1} condition, the highest yield of rapeseed was approximately 2250 kg ha^{-1} at the density of 4.5×10^5 plants or 6.0×10^5 plants per hectare. The yield level was higher than that of average local rapeseed production. In the practice of no-tillage and direct seeding cultivation technique in the double rice cropping rice area, both nitrogen application rate and planting density should be considered simultaneously to obtain high quality of plant population and high yield of rapeseed.

Keywords: rapeseed; double rice cropping area; no-tillage and direct seeding pattern; yield

In the Yangtze River basin, winter fallow is popular for the double cropping rice (*Oryza sativa* L.) due to the short interval between rice seasons and tillage difficulties in clay soil. At present, approximately 6 million hectares in this area were fallowed after harvesting late rice [1–4]. Although some of the fallow fields have been reported to plant potato, forage grass, vegetables, and flax during winter [5–7], the acreages are very limited in production. Rapeseed is another crop with theoretical feasibility to be planted in the winter fallow fields in the Yangtze River basin. This extra rapeseed season can not only improve the usage of farmland and increase outputs but also has no conflicts to food crop production and labor resources. It is estimated that the current rapeseed growing area will be increased by 70% if half of these winter fallow areas (3 million hectares) can be used in rapeseed production, and the shortage of edible vegetable oil supply is able to be improved consequently [1–4].

In the Yangtze River basin, seedling transplanting is a cultivation mode used in rapeseed production to shorten the growth duration of current crop and ensure enough accumulated temperature for the successive crop. However, the labor resource is limited in this area due to the flow of rural population into cities, resulting in less use of seedling transplanting technique. In single rice cropping rice area, rapeseed under no-tillage and direct-seeding cultivation is favorable to local farmers due to no conflict to the rotation

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* Corresponding author. E-mail: zhougs@mail.hzau.edu.cn

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system and exempt land tillage [8–10]. In double rice cropping area, this mode for rapeseed cultivation has been rarely studied. The fallowed land during winter can theoretically be used in rapeseed production in the double rice cropping area in Yangtze River basin. In this study, we discussed the applicability of no-tillage and direct-seeding cultivation in rapeseed production in the double rice cropping area based on growth status of rapeseed and yield components. If such cultivation mode can be extended, the extra cropping season of rapeseed not only makes high-efficient use of farmland but also increases the total rapeseed yield of rapeseed and supply of edible oil at the national level. After 2-year and 3-site experiments, we suggest that direct-seeding rapeseed can be cultivated in the winter fallow field under no-tillage pattern in double rice cropping area in Hubei Province, China.

1 Materials and methods

1.1 Materials and experimental design

The experiments were conducted in 3 rice fields with similar soil fertilities in Wuhan, Wuxue, and Shayang, Hubei Province, China across 2 cultivation cycles from 2008 to 2010 (Table 1). Under the spilt plot design, nitrogen (N) was the primary factor with 3 levels as 90 (N6), 180 (N12), and 270 kg ha^{-1} (N18); plant density was the secondary factor with 4 levels as 150,000 (D1), 300,000 (D2), 450,000 (D3), and 600,000 (D4) plants per hectare. The traditional tillage (0.2 m in depth) with N 180 kg ha^{-1} and plant density of 300,000 plants per hectare was used as the control. Half N fertilizer was applied before seeding, and the remaining N fertilizer was applied at budding stage (early February). The phosphorus (P), potassium (K), and boron (B) fertilizers were all applied before seeding, together with half N fertilizer, at the rates of P_2O_5 150 kg ha^{-1}, K_2O 225 kg ha^{-1}, and borax 15 kg ha^{-1} in all plots, respectively. The area of plot was 15 m^2 (2.0 m × 7.5 m). Each plot contained 37 rows with 0.2 m interval between lines. Only one rapeseed cultivar, Huashuang 5, was employed in all experiments, which was sown on 30 October in all no-tillage direct-seeding treatments and on 30 September in the controls. Field management follows the local conventional practices including disease and insect pest control. Rapeseed was harvested from 28 April to 12 May after fully maturating.

1.2 Growth status of rapeseed individual and population

Six successive plants from the second row were sampled at seedling, budding, flowering, and maturity stages for measuring agronomic traits of individuals. The plant population was based on plot, and the trait values of population were obtained by multiplying individual values and the plant density. For leaf area index (LAI), a green leaf was defined as the green area exceeding half of leaf area; and LAI was measured using LI-3000C (LI-COR, Lincoln, NE, USA). Plant roots were dug out gently after wetting the soil to keep the integrity of root system. Root samples were then cleaned with water and the length of main root and the total dry weight were measured. The dry weight of plant shoots was also determined to calculate the rate of root-to-shoot. Crown thick was represented with the diameter between the first pair of lateral roots and the cotyledon knot. Growth period was recorded according to the description by Hu et al. [11]. Pod area was determined using the Clark formula [12] as follows: Pod area (cm^2) = $\pi dh_1 + 1/3\pi dh_2$, where d is the width of pod, h_1 is the product of 0.8 and length of pod, h_2 is the product of 0.2 and length of pod. At maturity stage, 20 successive plants of the sixth row were sampled for measuring number of primary branches, number of secondary branches, pod number of main inflorescence, thickness of rhizome, branch position, length of main inflorescence, pod density, dry weight of shoot, economic coefficient, and yield component traits (pod number per plant, seed number per pod, and 1000-seed weight). The actual plot yield was determined at maturity stage.

1.3 Data analysis

Data were arranged in Microsoft Excel and statistically analyzed using SAS 8.1 software. Means of treatments were compared at the significant level of P = 0.05 according to the least significant difference (LSD) test. We found that the results from the 3 trial sites were consistent. In this article, only data from the Wuhan site were listed in most cases.

2 Results

2.1 Yield of direct-seeding rapeseed under no-tillage cultivation

The rapeseed yields varied with the trial locations. Under the control condition, Wuhan site had the highest average yield across the 2 years (3042 kg ha^{-1}), and Wuxue site had the lowest average yield (2730 kg ha^{-1}). However, in other treatments, the highest yields were observed in Wuxue site except for treatments N18D3 and N18D4; and the yields in Shayang site were relatively low (Table 2).

Analysis of variance (ANOVA) showed that effects of N

Table 1 Basic nutrient status in 0–20 cm soil lays of field plots in this study

Trial site	pH	Organic matter (g kg^{-1})	Available N (mg kg^{-1})	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Wuhan	6.3	36.4	94.5	11.3	107.7
Wuxue	6.0	31.6	180.2	8.2	101.4
Shayang	6.7	22.6	104.6	18.8	94.8