Industrial Crops and Products 40 (2012) 27–32

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

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

Influences of plant density on the seed yield and oil content of winter oilseed rape (*Brassica napus* L.)

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ARTICLE INFO

Article history:
Received 24 August 2011
Received in revised form 10 February 2012
Accepted 13 February 2012

Keywords:
Field experiment
Oil production
Plant density
Yield component

ABSTRACT

A field experiment was conducted to investigate the influences of plant densities on the seed yield and oil content of the winter oilseed rape (*Brassica napus* L.), which included two varieties, Zhongshuang No. 11 (ZS) and Ganyouza No. 1 (GY), and three densities (2.4×10^4, 3.6×10^4 and 4.8×10^4 plant hm^{-2}) treatments in two consecutive growing seasons (2009–2010 and 2010–2011). Results showed that, compared with 2.4×10^4 plant hm^{-2}, the seed yield per plot of 3.6×10^4 and 4.8×10^4 plant hm^{-2} treatments were significantly increased in both growing seasons, which might be due to the raceme and pod numbers per unit area were significantly increased with the increase in plant densities. And the seed oil content was significantly increased with the increase in plant densities, which might be due to the proportion of seed yield of main raceme significantly increased. Meanwhile, the seed oil content and 1000 seed weight of main raceme were significant higher than branch raceme about 1.0% and 10.0%, respectively. And the influences of plant densities on the seed yield of winter oilseed rape are mainly on the branch raceme and less on the main raceme. These results indicated that increasing the main raceme numbers per unit area and the production capacity of main raceme might be an effective means to increase the seed yield and oil production of winter oilseed rape.

1. Introduction

World population is increasing at an alarming rate and is expected to reach about nine billion by the end of year 2050, which induces the food and edible oil requirement continuous increasing (Mahajan and Tuteja, 2005). Oilseed rape (*Brassica napus* L. and *Brassica rapa* L.) is one of the world's major oilseed crops and produces at least double the oil per hectare compared with soybean (Durrett et al., 2008). Besides its role as the most important source of edible oil in the human diet, the increasing demand for rapeseed oil is also fuelled by its growing use as a renewable energy source in recent decades (Adamsen and Coffelt, 2005; Durrett et al., 2008; Zanetti et al., 2009; Zhang et al., 2010). Rapeseed oil is primarily composed of various triacylglycerols, molecules that consist of three fatty acid chains esterified to glycerol, and its subsequent combustion in place of conventional diesel reduces greenhouse gas emissions by 40% (Durrett et al., 2008). Erucic acid, another component of rapeseed, also has been interesting industrial uses, such as the production of behenic acid, behenic alcohol and their derived compound used as pour point depressants and to produce caprenin (Zanetti et al., 2009). It is well known that the oil production of oilseed rape is determined primarily by the attainable seed yield and less by the seed oil content (Sidlauskas and Bernotas, 2003; Rathke et al., 2006). It is important to increase the seed yield and oil content of oilseed rape for rapeseed oil production. But the processes of yield formation are highly variable and depend on cultivation varieties, environmental conditions and agronomic factors as well as the interactions between them.

Plant density is an important management factor that influences the seed yield of food crops (López-Bellido et al., 2005; Dong et al., 2010; Ciampitti and Vyn, 2011). Crop seed yield per unit area responds to plant density in a curvilinear fashion, with maximum yield occurring at the optimum plant density which depends upon crop species, environmental conditions and agronomic factors (Hiltbrunner et al., 2007; Dong et al., 2010; Ciampitti and Vyn, 2011). As plant densities decline, reduction in the number of plants per unit area is partially compensated by an accompanying increase in the productivity of each plant. At low densities, oilseed rapes compensate by producing larger leaf area, more branches and a greater pod numbers per plant. While, at high densities, oilseed rapes are often more susceptible to lodging and increased disease incidence without the benefit of any yield increase (Leach et al., 1999).

Some reports in the literature have been considered the influences of plant densities on the seed yield of oilseed rape, but the results were markedly different at which the highest seed yield was

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doi:10.1016/j.indcrop.2012.02.016

Table 1
Soil properties at the beginning of the 2009–2010 and 2010–2011 growing seasons.

Parameter	Unit	2009–2010	2010–2011
pH		6.71	6.59
Dissolved organic carbon	mg kg^{-1}	104.1	95.3
Total N	g kg^{-1}	1.28	1.42
NO_3-N	mg kg^{-1}	4.4	4.7
NH_4-N	mg kg^{-1}	5.4	5.4
Available phosphorus	mg kg^{-1}	36.2	44.7
Available potassium	mg kg^{-1}	63.9	61.9

obtained. And the influences of plant densities on the seed oil contents of oilseed rape were still unclear. For example, Leach et al. (1999) found that, in a series of multi-factorial experiments, the seed yield of winter oilseed rape (*B. napus* L.) increased with plant densities up to 50–60 plants m^{-2}. Momoh and Zhou (2001) through a field experiment found that the highest seed yield of transplanting winter oilseed rape (*B. napus* L. cv. HO605) were observed for plant densities of 9.75×10^4 and 12.75×10^4 plant hm^{-2}. Sidlauskas and Bernotas (2003) reported that the seed yield of spring oilseed rape (*B. napus* L.) was increased with the increase of plant densities up to 120 plant m^{-2}, after which point the effect of plant density on seed yield was less obvious. However, the actual plant density of winter oilseed rape is significant lower in many agricultural systems, especially in China. Therefore, we can hypothesize that there is an increase potential of rapeseed yield through increasing the plant density in a certain range. The aim of the present study was to investigate the influences of plant densities on the yield components, seed yields and oil contents of winter oilseed rape (*B. napus* L.) through a field experiment in two consecutive growing seasons.

2. Materials and methods

2.1. Experimental site and climatic conditions

Field experiments were carried out in two consecutive growing seasons (2009–2010 and 2010–2011) at the Yangluo Research Station, Oil Crops Research Institute of the Chinese Academy of Agricultural Sciences, Wuhan, China (114°54′E, 30°37′N). The climatic characteristics of the field experimental location were: 1289 mm total annual rainfall, 243 frostless days, 1980 h of annual sunshine, 16.7 °C of annual average air temperature, 3.1 °C (lowest −18.1 °C) of average air temperature in January and 28.8 °C (highest 41.3 °C) in July. The soil type was yellow–brown and soil samples (0–30 cm) were collected in October 2009 and 2010 before sowing. Soil samples were air dried, ground, and analyzed for pH (H_2O), dissolved organic carbon (DOC), total nitrogen, NO_3-N, NH_4-N, available phosphorus and available potassium (Table 1). The previous crop for the experimental plots planted from May to September at both growing seasons was soybean (*Glycine max* L.).

The field experiments were conducted between October and following May in both growing seasons. The monthly mean air temperature followed similar trends in both growing seasons except in February, when it was 3 °C cooler in 2010 than in 2011 (Fig. 1). Although the monthly mean air temperature during October and following May varied between 3.9 °C and 22.8 °C in 2009–2010 growing season and between 4.0 °C and 20.7 °C in 2010–2011 growing season, the lowest air temperature was −6.7 °C in 2009–2010 growing season and −4.0 °C in 2010–2011 growing season, respectively. The main climatic difference between the experimental growing seasons was rainfall (Fig. 1). The amounts of rainfall in November, January, March and April were considerably higher in 2009–2010 growing season, and the amounts of rainfall in October,

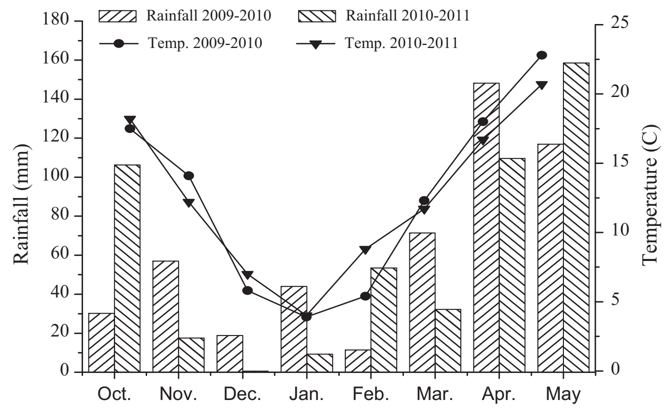

Fig. 1. Monthly rainfall and mean air temperature in 2009–2010 and 2010–2011 growing seasons.

February and May were considerably higher in 2010–2011 growing season, respectively.

2.2. Experimental design

Two varieties of winter oilseed rape (*B. napus* L.) were used, a conventional variety obtained from Oil Crops Research Institute of the Chinese Academy of Agricultural Sciences, cv. Zhongshuang No. 11 (ZS), and a hybrid variety obtained from Northwest Agriculture and Forest University, cv. Ganyouza No. 1 (GY), in the present study. Selected seed were disinfested in 1% sodium hypochlorite solution for 10 min to eliminate possible seed-borne microorganisms, rinsed for 5 min with distilled water and dried for 30 min at room temperature (20–22 °C) before sown. Then, all seed were sown on 1 October 2009 and 2010, in 2 m × 20 m sized plots, in rows about 30-35 cm apart (three rows per meter). Each plot was fertilized with urea (105 kg N hm^{-2}), superphosphate (23 kg P hm^{-2}), potassium chloride (44 kg K hm^{-2}) and borax (15 kg B hm^{-2}) at the beginning of the experiment. Three plant densities, 2.4×10^4, 3.6×10^4 and 4.8×10^4 plants hm^{-2} treatments were thinned by hand when the seedlings had fully developed 4 true leaves. The normal plant density of winter oilseed rape is between 1.8×10^4 and 2.4×10^4 plant hm^{-2} in China. The experimental design took the form of randomized complete blocks with 3 replicates. In the following spring, 40 kg N hm^{-2} and 35 kg N hm^{-2} urea were split applied to each plot at the beginning of spring re-growth and at the stem elongation of plants, respectively.

2.3. Sampling and harvest

At harvest, plants from an area of 1 m^2 (1 m × 1 m) of each plot were sampled to determine the yield components and seed yield per plant. And on each plant, the following measurements and observations were made: the plant height (cm); the primary branch numbers per plant; the main raceme pod numbers (with at least one seed) per plant; the branch raceme pod numbers (with at least one seed) per plant; the total pod numbers (with at least one seed) per plant; the pod length (cm) of main and branch raceme; the seed numbers per pod of main and branch raceme; 1000 seed weight (g) of main and branch raceme; seed yield (g) of main and branch raceme per plant. Then, the residual plants of each plot were carefully harvested to measure the seed yield per plot (kg hm^{-2}). The seed oil content was determined referring to the Chinese National Standard of Method for determination of oil content in oilseed (GB/T 14488.1-93), and the oil production was calculated by seed yield × oil content.