Journal of Integrative Agriculture 2017, 16(11): 2470–2481

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Effects of paclobutrazol on biomass production in relation to resistance to lodging and pod shattering in *Brassica napus* L.

KUAI Jie, LI Xiao-yong, YANG Yang, ZHOU Guang-sheng

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

Abstract

Paclobutrazol was sprayed at 0, 150, and 300 mg L^{-1} during the closed canopy stage and the early bud stage with two high-yielding cultivars of rapeseed, Yangguang 2009 and Fengyou 520. The impact of paclobutrazol on the accumulation and distribution of biomass and its relationship with yield, resistance to lodging and pod shattering were determined. All the treatments increased the resistance as well as yield. The maximum yield was obtained when paclobutrazol was applied during the closed canopy stage at 150 mg L^{-1}. The plant's resistance to both lodging and pod shattering was the maximum when paclobutrazol was applied during the early bud stage at 300 mg L^{-1}. Paclobutrazol also delayed senescence, with the higher concentration or later spraying leading to more obvious effects; improved the net assimilation rate before the early bud stage; and promoted the relative growth rate of the main growth organ at each stage of growth and maximized the rate and quantities of biomass accumulation. However, at the higher concentration and later spraying, the increments were smaller. The spraying also increased the rates of biomass allocation to roots, leaves, and pods, but the rate of allocation to stems decreased as the plants grew shorter. The higher allocation to roots and the lower allocation to stems favoured resistance to both lodging and pod shattering whereas higher allocation to leaves and pods favoured yield. The higher concentration or late spraying led to excessive biomass being allocated to roots, which decreased leaf biomass during the bud stage, leading to greater resistance but lower yields.

Keywords: rapeseed, paclobutrazol, biomass, yield, resistance to lodging and shattering

1. Introduction

Rapeseed (*Brassica napus* L.) is an important oil crop worldwide (Karp and Richter 2011). In China, cultivated on 7.4 million hectares on average with total average output up to 14 million tons, rapeseed accounts for 45% of the country's total edible vegetable oil production according to the NBSC (2013). Small-scale growers often use excessive amounts of nitrogen and high planting densities for higher yields; however, both the practices aggravate lodging and pod shattering, leading to lower yields (Berry and Spink 2012) besides making mechanized harvesting more difficult. Accumulation of biomass and the rate at which it is allocated to different organs reflect the growth and development of crops and therefore are important qualitative physiological indicators. In most crops, yield is influenced by the redistribution of biomass stored in leaves and stems and of photosynthates after heading and blossoming: The

Received 18 November, 2016 Accepted 20 March, 2017
KUAI Jie, E-mail: kuaijie@mail.hzau.edu.cn; Correspondence ZHOU Guang-sheng, Tel/Fax: +86-27-87281822, E-mail: zhougs@mail.hzau.edu.cn

doi: 10.1016/S2095-3119(17)61674-5

accumulation of biomass beyond a given amount usually promises high yields. In cereals, grain yield is closely correlated with biomass allocation to grains (Muchow *et al*. 1993; Dordas 2009). In rapeseed, increased plant growth promotes biomass accumulation in seeds, and the number of pods depends on the accumulation and distribution of biomass and its translocation from vegetative organs (Barłóg and Grzebisz 2004); among the yield components, the most influential is the number of productive pods per plant. Therefore, for higher yield, biomass accumulation during the vegetative state should be increased first, followed by greater allocation of biomass to seeds (Diepenbrock 2000).

As a growth retardant, paclobutrazol acts mainly by changing the balance of endogenous hormones and reorienting the distribution of nutrients within a plant to adjust the 'source- sink' balance (Vu and Yelenosky 1992; Huang *et al*. 1995). At high nitrogen levels, photosynthates, which are produced in leaves, tend to accumulate in leaf blades, petioles, and stems instead of effectively being transferred to roots. This accumulation leads to excessive growth of above-ground parts and makes the plant susceptible to lodging. Paclobutrazol, applied as a spray, significantly reduces the accumulation of carbohydrates in leaves and promotes rapid and effective transfer of the products of photosynthesis to roots, making the roots and stems thicker and stronger, thereby checking not only excessive growth of above-ground parts but also the plant's tendency to lodge (Burrows *et al*. 1992). Many studies have confirmed that paclobutrazol mainly inhibits the growth of above-ground parts, reduces nutrient accumulation in stems (Gill and Singh 1993) and promotes the transport and distribution of nutrients to roots and the growth of roots (Rieger and Scalabrelli 1990). Paclobutrazol also promotes the transfer of biomass accumulated during vegetative growth to seeds in significant amounts (Addoquaye *et al*. 1985). Paclobutrazol sprays are known to reduce lodging in rapeseed (Rajala *et al*. 2002; Tripathi *et al*. 2003) and to boost production (Kuai *et al*. 2015); however, the mechanism by which paclobutrazol does so and its effect on accumulation and allocation of biomass in rapeseed have seldom been studied — A lacuna, the present study seeks to fill. So the objectives of the research were to (i) quantitatively analyze the change trend of biomass accumulation and partitioning as affected paclobutrazol; and (ii) evaluate the relations between biomass, yield and resistance to pod shattering and lodging in rapeseed.

2. Materials and methods

2.1. Experimental site

A replicated field experiment was conducted during two growing seasons (2012/2013 and 2013/2014) at the experimental farm of Huazhong Agricultural University (30°28´12´´N, 114°21´05´´E), Wuhan, China, after harvesting the previous crop. The nutrient status of soil (0–20 cm) at that time, in terms of available nitrogen (N), phosphorus (P), and potassium (K) concentrations, were as follows: in 2012, 119 mg kg^{-1} N, 14 mg kg^{-1} P, and 138 mg kg^{-1} K; in 2013, 126 mg kg^{-1} N, 15 mg kg^{-1} P, and 147 mg kg^{-1} K.

2.2. Experimental design

The experiment was laid out in a split-split-plot design with two cultivars (Yangguang 2009 and Fengyou 520) as the main plots, two application times (T1, the closed canopy stage; T2, the early bud stage) as the split plots and three concentrations (P1, 0 mg L^{-1}; P2, 150 mg L^{-1}; P3, 300 mg L^{-1}) as the split-split-plots. Paclobutrazol, in powder form, was thoroughly dissolved in distilled water and applied with an electronic sprayer. In each plot, the foliage was sprayed with 1.5 L of paclobutrazol either during the closed canopy stage or during the early bud stage. The agronomic traits of the two cultivars were reported by Kuai *et al*. (2015). Yangguang 2009 had higher culm lodging resistance and pod shattering resistance whereas lower yield when compared to Fengyou 520.

Rapeseed was directly sown at a density of 4.5×10^5 plants per ha on 22 September of 2012 and 2013, respectively. Plant density was evaluated immediately after seedling emergence and, at the five-leaf stage, adjusted precisely to attain the desired density. Each treatment had three replicate plots, each with an area of 20 m^2 (10 m long and 2 m wide). Fertilizers were applied as follows (the doses are per ha): 750 kg of calcium superphosphate and 135 kg of potassium chloride were applied manually as a basal dose before sowing, followed by 135 kg of potassium chloride during the bolting stage; 360 kg N was given as urea, 50% before sowing, 20% at the seedling stage, and 30% at the bolting stage. Pest and disease control measures were undertaken according to local management practices. The field was not irrigated during the growing season. The crop was harvested on 20 May in 2013 and on 6 May in 2014.

2.3. Sampling and measurement

Determination of yield, lodging, and pod shattering The plots were harvested when roughly two-thirds of the pod had turned brown. Ten plants picked at random from each plot were sampled to determine the yield components and seed yield per plant. The following measurements and observations were made for each plant in the sample: pods per plant, seeds per pod, weight of 1 000 seeds (g), and total seed yield (g).

The degree of lodging was measured for 20 plants from