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Canola cultivars differ in nitrogen utilization efficiency at vegetative stage

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Abstract

Previous research indicated genotype-specific responses in nitrogen utilization efficiency (NUE) for oilseed rape (*Brassica napus* L.), but mechanisms behind those differences are unknown. Our objective was to determine whether cultivar variations in NUE (dry matter production per unit of N absorbed) could be related to the differences in N and nitrate uptake and partitioning. Four Australian spring canola cultivars (Eyre, Charlton, Pinnacle and Rainbow) were grown in glasshouse under conditions of low- and high-N supply. All cultivars were at the same growth stage when harvested 60 days after sowing (rosette stage with five leaves at low-N supply and nine leaves at high-N supply). Cultivars significantly differed in total N uptake in roots and shoots, but not when the whole plants were considered. Although all cultivars had similar total N uptake per plant, significant differences in NUE existed because of differences in plant biomass. N-efficient cultivars Charlton and Rainbow produced larger plant biomass and had lower N concentration in various aboveground plant parts (including dead leaves) than N-inefficient cultivars Pinnacle and Eyre. Nitrogen concentration in roots did not differ significantly among cultivars. Regardless of N supply, N concentrations in various plant parts were in the order: young blades > old blades > roots > young petioles > stems > old petioles > dead leaves. No significant variation in nitrate-N concentration in roots or various aboveground plant parts was found among tested cultivars. The absence of cultivar × N treatment interaction for plant dry weight, N concentration, N uptake, and consequently NUE, clearly indicated that cultivars that performed best at high-N supply also showed similar responses under N-deficient conditions. Despite similar total N uptake per plant, significant differences in NUE existed because more N-efficient cultivars produced larger plant biomass and tended to have lower N concentrations in all plant parts (except roots) compared with less N-efficient cultivars.

Keywords: Genotypic differences; N uptake; N concentration; N partitioning; Nitrate-N partitioning

1. Introduction

Genetic variation in nutrient efficiency has been documented in many arable crops, including oilseed rape. According to Sattelmacher et al. (1994), genetic variation in nutrient efficiency may be attributed to the two principal components: (i) genotypes may differ in their effectiveness in absorbing nutrients from the soil (uptake efficiency) and/or (ii) they may differ in the efficiency with which the absorbed nutrients are utilized for dry matter production (utilization efficiency).

Oilseed rape has a relatively high demand for nitrogen (N) because content of this nutrient in seeds and plant tissues is greater than in most grain crops. Research on N efficiency in oilseed rape was initiated by Grami and La Croix (1977) in Canada. In their field experiment, consistent differences in the N concentration in various plant parts were found between two spring cultivars, which suggested that N uptake and distribution in oilseed rape plants is an inherited characteristic. Those differences were greater in the upper plant parts than in roots, thus indicating more upward translocation of N in one cultivar compared with the other. Among 40 spring rape genotypes tested in Australia, Yau and Thurling (1987) reported significant differences in N-utilization index (change in dry weight per unit change in N

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content) at the lowest N fertilization level (30 kg ha^{-1}) and for total N uptake in the aboveground parts at the intermediate level (60 kg N ha^{-1}). However, the authors could not explain the mechanisms responsible for observed cultivar differences in the N-utilization index. In addition, those differences did not exist under the high-N treatment (120 kg N ha^{-1}), suggesting that genetic variation in nutrient uptake and efficiency is of greater importance under suboptimal nutrient supply. Similar results were reported by O'Sullivan et al. (1974) on tomato (*Lycopersycum esculentum* Mill.) genotypes grown in nutrient solutions.

Nitrate-N accumulates in plant only when internal demand for N has been fully satisfied. Consequently, nitrate-N concentration has been proposed as an indicator of N status in various crops, including oilseed rape (Scaife and Barnes, 1977; Hocking et al., 1997b). However, no information exists on the potential differences in nitrate concentration in various canola cultivars grown under identical conditions.

Our objective was to determine whether cultivar variations in nitrogen utilization efficiency (NUE) under conditions of low and high nutrient level could be related to: (i) differences in the total N uptake, (ii) nitrate and N concentration or (iii) N partitioning within plant.

2. Materials and methods

Four cultivars of spring canola (Eyre, Charlton, Pinnacle and Rainbow) were grown in a glasshouse at the University of Western Australia (UWA), Perth, Australia. Cultivars were selected from the preliminary glasshouse experiment that tested 84 canola genotypes for potential differences in NUE. In that study, Charlton and Rainbow showed higher NUE than Eyre and Pinnacle based on the results for aboveground plant biomass harvested 6 weeks after sowing.

The soil used was collected from virgin bushland approximately 15 km south-east of Lancelin, WA (31°56′S, 115°20′E). It is brown sand (Uc4.22; Northcote, 1971) with pH (H_2O) 5.9, 2.0% clay and 8 g organic carbon/kg. This sandy soil has been extensively used for glasshouse experiments at UWA since the 1970s because it is low in essential nutrients and plant roots are rarely compromised by soil pathogens in non-sterilized conditions. Soil was sieved through a 4-mm screen, mixed and transferred into undrained plastic pots (25 cm diameter, 25 cm height, lined with polyethylene bags). Each pot contained 9500 g of air-dried soil.

Chosen cultivars were grown under high-N (1176 mg N pot^{-1}) and low-N (294 mg N pot^{-1}) treatments. Nitrogen was applied as ammonium nitrate. One week before sowing, desirable levels of N along with all other nutrients in sufficient amounts were thoroughly mixed with the soil by shaking in the large plastic bags. Deionized water was added to 80% of field capacity 1 day before sowing. Twenty seeds were hand sown in each pot on 23 May 2004. Seedlings were thinned to eight plants per pot a few days after germination. Two weeks later, plants were thinned again to six plants per pot to provide more uniformity within pots. The pots were regularly weighed during the experiment to estimate water loss, and deionized water was added to maintain soil moisture near 80% field capacity.

All six plants per pot were harvested 60 days after sowing when plants were in rosette stage. Each plant was first dissected into stem, old and young leaves. The fully developed leaves from each plant were divided into old and young ones according to their position on the plant, each sample consisting of the same or similar number of leaves. If the plant had uneven leaf number, a sample representing older leaves had one leaf more than a sample consisting of young leaves. Furthermore, leaves were divided into laminas and petioles (including leaf midrib) for both young and older leaf samples. If present, young unfolded leaves were added to the young lamina samples. Immediately after plant dissection, samples were weighed, dried at 70 °C for 72 h and weighed again. Dead leaves were also collected from each pot after being dropped from the plant. One day following aboveground harvest, roots were separated from the soil by washing with tap water. Roots were divided from the stem just above the first lateral root emerging from the taproot. Roots and dead leaves were also dried at 70 °C for 72 h and weighed. The results presented per plant basis were obtained as an average of six harvested plants in each pot.

Nitrate-N concentration was measured by extracting 30 mg of grounded plant material in 30 mL of deionized water at 90 °C for 2 h, and filtering the extract through filter paper (Whatman no. 42). Nitrate concentration in the extracts was determined by ion chromatography (Dionex 2000i/sp) using an AS9SC separation column fitted with an AS9G guard column (Dionex, Sunnyvale, CA). The eluent solution consisted of 1.8 mM Na_2CO_3, 1.7 mM $NaHCO_3$ and the regenerant of 0.025N H_2SO_4. Total N concentration was determined by the Dumas combustion method using an automated CN analyzer (LECO CHN-1000, LECO Company, St. Joseph, MI, USA).

The data collected were used to calculate dry weight, N and nitrate-N concentration, total N uptake (dry weight × N concentration), NUE (dry weight per unit of N taken up) for each of seven plant sections (roots, stems, old petioles, old laminas, young petioles, young laminas and dead leaves) and also per plant (all plant sections combined including dead leaves) and per shoot (aboveground plant parts excluding dead leaves). The NUE is expressed as milligram of dry weight produced for each milligram of N absorbed.

Pots were arranged in a randomized complete block design with three replicates in the glasshouse. Analysis of variance was computed with cultivar and nutrient supply considered fixed (SAS Institute, 1997). Mean separation was calculated using the L.S.D. values if the F-test was significant at $P = 0.05$.