

## COMPETITIVE ABILITY, YIELD AND YIELD COMPONENTS OF CANOLA (*BRASSICA NAPUS* L.) CULTIVARS AS AFFECTED BY NITROGEN RATE AND WEED COMPETITION

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### Abstract

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A field experiment was conducted at Rice Research Institute in Rasht, northern Iran, to determine the effect of nitrogen (N) rate on competitive ability, seed yield and yield components of canola cultivars. The layout of experiment was a factorial design with three randomized complete blocks. Factors were N rates (0, 100, 200 kg ha<sup>-1</sup>), canola cultivars (Hayola 420, Hayola 308, RGS003 and PF), and weed management regimes (weed-free and weedy conditions, weeded and not weeded throughout the growing season, respectively). The analysis of variance indicated that effects of nitrogen rate, cultivar, weed management regime, and the interaction between nitrogen rate and cultivar were significant ( $P < 0.01$ ) for seed yield, but the other two- and three-way interactions were not significant. Averaged across cultivars and weed management regimes, seed yield was significantly increased from 667 kg ha<sup>-1</sup> to 3106 kg ha<sup>-1</sup> as N application rate increased from 0 to 200 kg N ha<sup>-1</sup>. Regardless of N rate and cultivar, canola seed yield was significantly reduced by weed interference. In unfertilized plots and averaged across weed management regimes, the highest and lowest seed yields were recorded for Hayola 420 and PF ( $832.3 \pm 72$  and  $510.3 \pm 61$  kg ha<sup>-1</sup>, respectively). At 100 kg N ha<sup>-1</sup> and averaged across weed management regimes, seed yield of Hayola 420 ( $2322.3 \pm 214$  kg ha<sup>-1</sup>) was significantly higher than that of other cultivars and 1.8 times greater than that of in RGS003, which had the lowest seed yield among the cultivars. At 200 kg N ha<sup>-1</sup> and averaged across weed management regimes, the seed yield for RGS003 ( $3616 \pm 317$ ) was higher than that of other canola cultivars. Moreover, Main effects of N rate and cultivar were significant ( $P < 0.01$ ) for competitive ability of canola cultivars, but the interaction between them was not significant. Averaged across cultivars, competitive ability was significantly increased ( $P < 0.01$ ) as N application rate increased. Regardless of N rate, the highest competitive ability was recorded for Hayola 420 (6.5), which statistically similar to RGS003 (5.7) and PF (5.6). The lowest competitive ability (3.8) was recorded for Hayola 308. This experiment indicated that cultivars had different competitive ability against weeds and high levels of N favor the crop over the weeds.

**Key words:** canola, competitiveness, nitrogen fertilizer

**Abbreviations:** N0, 0 Kg N ha<sup>-1</sup>; N100, 100 Kg N ha<sup>-1</sup>; N200, 200 Kg N ha<sup>-1</sup>; SB, number of side branches; SNMS, silique number per main stem; SNSB, silique number per side branch; SNSMS, seed number per silique of main silique; SNSSB, seed number per silique of side branch; ThSW, 1000-seed weight; Y, canola seed yield.

### Introduction

Canola is the third most important oil-bearing crop in the world only exceeded by palm and soybean (Fu, 2004).

It is grown widely in northern Iran in rotation with rice. In this area, canola is grown from early November through late May. Canola is distinguished from traditional rapeseed by the greatly reduced levels of fatty acids, erucic acid (less than

two percent) and glucosinolates (less than 30 micromoles). Canola oil is the preferred oil for use because of its low level of saturated fat.

Weeds can be the most limiting factor in canola production. Canola cultivars are very susceptible to competition from weeds at early stage growth and weeds will win the competition for nutrients and soil moisture. Merkel et al. (2004) have shown that canola must be kept weed-free before canopy closure to avoid yield loss. In today's conservation production systems that rely mostly on herbicides for weed control, using Integrated Weed Management (IWM) could be a primary tool for preventing and/or managing resistance. This means to utilize a combination of all available control methods (mechanical, cultural, biological and chemical) in an economic and sustainable manner. It is clear that crop rotation, proper tillage, weed-competitive cultivars, fertilizer management and rational herbicide use are the main components of IWM. The competitiveness of a plant is its relative ability to obtain a specific resource when in competition with another plant. It has been reported that crop cultivars and hybrids can vary substantially in response to weed competition (Garrity et al., 1992; Fischer et al., 1997; Cousens and Mokhtari, 1998; Johnson et al., 1998; Fofana and Rauber, 2000; Ni et al., 2000; Fischer et al., 2001; McDonald, 2003; Paolini et al., 2006; Watson et al., 2006 and Hoad et al., 2008). Some cultivars are better able to tolerate competition and suppress weeds than others. A competitive crop utilizes resources before they are available to the weeds. Factors that increase competitive ability include: early emergence, seedling vigor, rapid canopy development, plant height, a growth habit that allows coverage of the soil and greater light capture, early root growth, and an extensive root system (Garrity et al., 1992; Fofana and Rauber, 2000; Ni et al., 2000; Caton et al., 2003; Grevesen, 2003; Zhao et al., 2006 and Williams et al., 2008). Crop competition, may or may not provide sufficient weed management alone. However, the choice of more competitive cultivars could prevent or reduce the dosage of herbicides, improve weed control in the current year and weed problems will be diminished over the long-term (Williams et al., 2008).

Nitrogen (N) is considered the most important determinant for canola and is required in large quantities for optimal crop production. N is a part of many critical plant components such as amino acids, proteins, enzymes, nucleotides, nucleic acids and others. Canola has a high demand for crop nutrients, including N and N deficiency commonly limit canola yield (Grant and Bailey, 1993). Taylor et al. (1991) reported that increasing nitrogen rates increased seed and oil yield and protein content but decreased oil content in canola cultivars. At the same time, nutrient levels are generally recommended on the assumption that herbicides will be used,

and that weeds are not an important consideration. It has been recognized that soil nitrogen levels can affect crop and weed competition. Results from experiments investigating nitrogen effects on weed competition have been contradictory. A number of studies have been conducted which show that high nitrogen application can favor weeds over the crop (Mishra and Kurchania, 2001; Evans et al., 2003; Blackshaw et al., 2003; Cathcart and Swanton, 2004 and Abouzienna et al., 2007). In contrast, Tollenaar et al. (1994) reported that increased N fertilization enhanced the competitiveness of corn over weeds. Moreover, some researches reported that soil N level had little effect on competition between crop and weed (Satorre and Snaydon, 1992 and Gonzalez ponce, 1998). In general, it is supposed that weeds can absorb bigger amounts of nutrients than crop plants and thus can profit more from fertilization. Therefore, managing N fertilizer application can be an element of IWM.

The objectives of this research were to (1) determine the effect of N rate on seed yield and yield components of canola cultivars (2) determine the influence of N rate on competitive ability of canola cultivars.

## Materials and Methods

### Experimental site and design

The field experiment was conducted during 2010-2011 growing season at Rice Research Institute in Rasht (36° 54' N, 40° 50' E; 20 m above sea level), northern Iran, from early November through late May. Monthly precipitation and temperature through canola growing period were presented in Table 1. Soil properties of the experimental field were 2.1% organic matter content, 34% clay, 45% silt, 21% sand and 7.1 PH. The layout of experiment was a factorial design with three randomized complete blocks. Factors were nitrogen rates (0, 100, 200 kg ha<sup>-1</sup>), canola cultivars (Hayola 420, Hayola 308, RGS003 and PF), and weed management regimes (weed-free and weedy conditions, weeded and not weeded throughout the growing season, respectively). Plot size was 3 m × 5 m and plant spacing was 30 Cm × 5 Cm. All canola cultivars were sown in November 2010. Before planting, 33 and 66 kg N ha<sup>-1</sup> was applied as urea in N100 and N200, respectively. The remaining N was provided in two split doses at stem elongation and flowering stages. Moreover, each plot received 50 kg P ha<sup>-1</sup> as triple super phosphate and 75 kg K ha<sup>-1</sup> as potassium sulfate before planting.

### Data collection and analysis

At maturity, ten plants from each plot were selected for the measurement of yield components: silique number per main stem, seed number per silique of main stem, silique number

**Table 1**  
**Monthly precipitation, maximum, minimum and average temperature during canola growth season in northern Iran**

| Month    | Year | Precipitation, mm | Temperature, °C |         |         |
|----------|------|-------------------|-----------------|---------|---------|
|          |      |                   | Maximum         | Minimum | Average |
| November | 2010 | 137               | 19.7            | 8.8     | 14.2    |
| December | 2010 | 0.2               | 18.7            | 8.0     | 13.3    |
| January  | 2011 | 210.4             | 12.1            | 4.9     | 8.5     |
| February | 2011 | 218.2             | 10.0            | 3.3     | 6.7     |
| March    | 2011 | 164.7             | 13.3            | 5.0     | 9.2     |
| April    | 2011 | 94.91             | 15.4            | 11.0    | 13.3    |
| May      | 2011 | 16.31             | 22.3            | 16.5    | 19.4    |

per side branches, seed number per silique of side branches, number of side branches, and 1000-seed weight. To determine yield per unit area, seeds were collected from 6 m<sup>2</sup> in each plot and subsequently was adjusted to 9% moisture content. Relative yield loss (RYL) in weedy plots was calculated as the following equation:

$$\text{Relative yield loss (\%)} = 100[(\text{weed-free yield} - \text{weedy yield}) / \text{weed-free yield}] \quad (1)$$

Aboveground weed biomass was collected from four randomly placed frames of 0.5 m<sup>2</sup> and dried at 70°C for 3-days to a constant weight to obtain weed dry-matter values.

The following equation was used for evaluating the competitive ability of canola cultivars (Challaiah et al., 1986):

$$CI = \left( \frac{Y_{wp}}{Y_{mean}} \right) / \left( \frac{W_i}{W_{mean}} \right), \quad (2)$$

where  $Y_{wp}$  is each cultivar yield from the weedy plot,  $Y_{mean}$  is the average yield of all canola cultivars from the weedy plot,  $W_i$  is weed biomass in each canola cultivar and  $W_{mean}$  is average weed biomass from weedy plots.

In addition, ability to withstand competition for each canola cultivar was calculated by following equation (Watson et al., 2006):

$$AWC = 100 \times (Y_{wp} / Y_{wfp}), \quad (3)$$

where  $Y_{wp}$  is the seed yield from the weedy plot and  $Y_{wfp}$  is the seed yield from the weed-free plot.

The SAS statistical package version 9.1.3 (SAS Institute INC, Cary, NC) was used for all data analyses (SAS, 2004). Where the F-ratios were found to be significant, treatment means were separated using Fisher's protected LSD at  $P < 5\%$ .

## Results and Discussion

### Seed yield

The ANOVA indicated that main effects of N rate, cultivar, and weed management regime were significant for canola seed yield at 0.01% probability level (Table 3). Seed yield

significantly increased from 667 kg ha<sup>-1</sup> to 3106 kg ha<sup>-1</sup> as N application rate increased from 0 to 200 kg N ha<sup>-1</sup> (Table 3). Proper rate of N fertilizer application enables the crop to produce greater leaf area, leaf area duration, light absorption, and crop assimilation, thus contributing to increased seed yield. It has been reported that N deficiency limit canola seed yield (Grant and Bailey, 1993). Some researchers reported that canola seed yield increased with increasing N application (Svecnjak and Rengel, 2006; Kumar et al., 2001 and Jackson, 2000). Regardless of N rate and cultivar, canola seed yield was significantly reduced by weed interference (Table 4). The reduction in seed yield in the presence of weeds may be attributed to competition between canola and weeds for light, water and nutrient elements such as N. Averaged across N rates and weed management regimes, seed yield was statistically different among cultivars; the highest values were recorded for Hayola 420 (1998.9 kg ha<sup>-1</sup>) and RGS003 (1853.6 kg ha<sup>-1</sup>) and the lowest values were recorded for PF (1699.6 kg ha<sup>-1</sup>) and Hayola 308 (1644.4 kg ha<sup>-1</sup>) (Table 3). Additionally, the ANOVA showed that the interaction effect of N×C on seed yield were statistically significant at  $P < 0.01$ , but the other two-way interactions (C×W and N×W) plus three-way interaction (N×C×W) were not significant (Table 2). In unfertilized plots, the highest (832.3 ± 72 kg ha<sup>-1</sup>) and lowest (510.3 ± 61 kg ha<sup>-1</sup>) seed yield was recorded for Hayola 420 and PF, respectively (Table 4). At the 100 kg N ha<sup>-1</sup> application rate and averaged across weed management regimes, seed yield of Hayola 420 (2322.3 ± 214 kg ha<sup>-1</sup>) was significantly higher than that of other cultivars and 1.8 times greater than that of in RGS003, which had the lowest seed yield among the cultivars. At the 200 kg N ha<sup>-1</sup> application rate and averaged across weed management regimes, the seed yield for RGS003 (3616 ± 317 kg ha<sup>-1</sup>) was higher than that of other cultivars (Table 4).

### Yield Components

#### *Silique number per main stem (SNMS)*

Main effects of N rate, cultivar, and weed management regime were significant ( $P < 0.01$ ) for SNMS. Moreover, interac-

tion between cultivar and N rate was not significant ( $P < 0.01$ ), but other 2- way interactions and 3- way interaction were not significant. SNMS was significantly increased as N rate increased from 0 to 200 kg ha<sup>-1</sup> when averaged across cultivars and weed management regimes. Arthamwar et al. (1996) and Nielson (1997) reported similar result. It has been reported that external N-supply during juvenile growth increases leaf area index (LAI), crop growth rate (CGR), and period of photosynthetic activity which resulting in higher number of pods per plant (Rathke et al., 2006). Moreover, N deficiency causes poor growth and a reduced canopy due to less branching. The onset

of flowering is ill timed, the flowering period is shortened and consequently, the number of pods decreases drastically (Rathke et al., 2006). Regardless of cultivar and N rate, SNMS was significantly reduced by weed competition. Hayola 420 and PF produced greater SNMS than Hayola 308 and RGS003 when averaged across N rates and weed management regimes. When N was not applied and averaged across weed management regimes (Table 4), Hayola 420 had the highest SNMS ( $41.5 \pm 2.28$ ), followed by Hayola 308 ( $23.9 \pm 3.03$ ), RGS003 ( $20.4 \pm 1.1$ ) and PF ( $17.8 \pm 1.59$ ). At 100 kg N ha<sup>-1</sup> and averaged across weed management regimes (Table 4), Hayola 420 and PF had

**Table 2**

**Mean squares of ANOVA for seed yield (Y), silique number per main stem (SNMS), silique number per side branch (SNSB), seed number per silique of main silique (SNSMS), seed number per silique of side branch (SNSSB), number of side branches (SB), and 1000-seed weight (ThSW) as affected by cultivar, weed management regime, and N rate**

| Source                     | df | Y                      | SNMS               | SNSB                | SNSMS               | SNSSB                | SB                  | ThSW               |
|----------------------------|----|------------------------|--------------------|---------------------|---------------------|----------------------|---------------------|--------------------|
| R                          | 2  | 191311 <sup>ns</sup>   | 95 <sup>ns</sup>   | 360 <sup>**</sup>   | 27.2 <sup>**</sup>  | 1.3 <sup>ns</sup>    | 0.4                 | 0.55 <sup>**</sup> |
| Nitrogen rate (N)          | 2  | 36228409 <sup>**</sup> | 4435 <sup>**</sup> | 28482 <sup>**</sup> | 122.5 <sup>**</sup> | 2730.2 <sup>**</sup> | 117.8 <sup>**</sup> | 1.78 <sup>**</sup> |
| Cultivar (C)               | 3  | 460317 <sup>**</sup>   | 124 <sup>**</sup>  | 306 <sup>**</sup>   | 55.5 <sup>**</sup>  | 6.3 <sup>*</sup>     | 7.7 <sup>**</sup>   | 1.02 <sup>**</sup> |
| Weed management regime (W) | 1  | 2772227 <sup>**</sup>  | 772 <sup>**</sup>  | 3380 <sup>**</sup>  | 59.6 <sup>*</sup>   | 36.5 <sup>**</sup>   | 3.1 <sup>**</sup>   | 1.17 <sup>**</sup> |
| N×C                        | 6  | 886630 <sup>**</sup>   | 70 <sup>**</sup>   | 295 <sup>**</sup>   | 10.2 <sup>*</sup>   | 13.1 <sup>**</sup>   | 3.7 <sup>**</sup>   | 0.15 <sup>*</sup>  |
| N×W                        | 2  | 140317 <sup>ns</sup>   | 16 <sup>ns</sup>   | 875 <sup>**</sup>   | 1.3 <sup>ns</sup>   | 2.6 <sup>ns</sup>    | 0.6 <sup>ns</sup>   | 0.01 <sup>ns</sup> |
| C×W                        | 3  | 204688 <sup>ns</sup>   | 9 <sup>ns</sup>    | 45 <sup>ns</sup>    | 0.8 <sup>ns</sup>   | 1.8 <sup>ns</sup>    | 0.1 <sup>ns</sup>   | 0.01 <sup>ns</sup> |
| N×C×W                      | 6  | 125703 <sup>ns</sup>   | 36 <sup>ns</sup>   | 61 <sup>ns</sup>    | 1.2 <sup>ns</sup>   | 0.4 <sup>ns</sup>    | 0.1 <sup>ns</sup>   | 0.03 <sup>ns</sup> |
| Error                      | 46 | 108540                 | 32                 | 83                  | 4.3                 | 1.7                  | 0.3                 | 0.06               |

\*, \*\* represent significance at 0.05 and 0.01 probability level, respectively. ns represents no significant difference.

**Table 3**

**Seed yield (Y), silique number per main stem (SNMS), silique number per side branch (SNSB), seed number per silique of main silique (SNSMS), seed number per silique of side branch (SNSSB), number of side branches (SB), and 1000-seed weight (ThSW) response to N rate, cultivar, and weed management regime**

| Factors                                   | Traits     | Y, kg ha <sup>-1</sup> | SNMS | SNSB | SNSMS | SNSSB | SB    | ThSW, g |
|---|------------|------------------------|------|------|-------|-------|-------|---------|
| <u>Nitrogen rates, kg ha<sup>-1</sup></u> |            |                        |      |      |       |       |       |         |
|   | 0          | 667                    | 20.9 | 1.9  | 16.6  | 0.7   | 0.4   | 3.1     |
|   | 100        | 1625                   | 38.5 | 33.2 | 18.3  | 17.8  | 2.1 b | 3.1     |
|   | 200        | 3106                   | 47.6 | 70.8 | 21.1  | 20.3  | 4.8   | 3.6     |
|   | LSD (0.05) | 191                    | 3.3  | 5.3  | 1.2   | 0.7   | 0.3   | 0.2     |
| <u>Weed management regimes</u>            |            |                        |      |      |       |       |       |         |
|   | Weed-free  | 1995                   | 38.9 | 42.2 | 19.5  | 13.6  | 2.66  | 3.42    |
|   | Weedy      | 1603                   | 32.4 | 28.5 | 17.7  | 12.2  | 2.25  | 3.16    |
|   | LSD (0.05) | 156                    | 2.6  | 4.3  | 0.9   | 0.6   | 0.25  | 0.11    |
| <u>Cultivars</u>                          |            |                        |      |      |       |       |       |         |
|   | RGS003     | 1853.6                 | 33.1 | 31.4 | 17.8  | 13.3  | 2.23  | 3.59    |
|   | PF         | 1699.6                 | 36.3 | 32.1 | 17.8  | 12.1  | 1.8   | 3.07    |
|   | Hayola 308 | 1644.4                 | 34.3 | 38.2 | 17.7  | 13.1  | 2.44  | 3.13    |
|   | Hayola 420 | 1998.9                 | 39.1 | 39.5 | 21.3  | 13.4  | 3.35  | 3.38    |
|   | LSD (0.05) | 221.1                  | 3.7  | 6.1  | 1.4   | 0.9   | 0.36  | 0.16    |



the highest SNMS ( $42.8 \pm 1.75$  and  $41.4 \pm 2.1$ , respectively), followed by RGS003 ( $35.3 \pm 4.9$ ) with a value statistically similar to Hayola 308 ( $34.5 \pm 2.12$ ). At 200 Kg N ha<sup>-1</sup> and averaged across weed management regimes (Table 4), Hayola 420 had the highest silique per main stem ( $50.2 \pm 2.08$ ), followed by PF ( $49.6 \pm 4.19$ ), Hayola 308 ( $46.7 \pm 3.78$ ) and RGS003 ( $43.4 \pm 2.83$ ).

#### Silique number per side branch (SNSB)

SNSB was significantly ( $P < 0.01$ ) influenced by N rate, cultivar, and weed management regime. The interaction effects of N rate by cultivar and N rate by weed management regime were also significant at 0.01 probability level, but other 2-way interaction (cultivar by weed management regime) and 3-way interaction (N rate, cultivar by weed management regime) were not significant. In unfertilized plots and averaged across weed management regimes, Hayola 308 had the highest ( $4.5 \pm 1.98$ ) SNSB, followed by RGS003, Hayola 420, and PF (Table 4). At 100 kg N ha<sup>-1</sup> and averaged across weed management regimes, Hayola 420 and PF had the highest SNSB ( $42.8 \pm 1.75$  and  $41.4 \pm 2.1$ , respectively), followed by RGS003 and Hayola 308 (Table 4). At 200 kg N ha<sup>-1</sup> and averaged across weed management regimes, Hayola 308 and Hayola 420 showed the highest SNSB

( $80.1 \pm 9.31$  and  $75.8 \pm 5.37$ ), followed by RGS003 ( $68.1 \pm 6.97$ ) and PF ( $59.2 \pm 7.20$ ) (Table 4). In no added N plots, SNSB did not significantly reduced by weed competition, while in plots fertilized with 100 and 200 kg N ha<sup>-1</sup>, SNSB was significantly reduced by weed interference (Table 5).

#### Seed number per silique of main stem (SNSMS)

N rate, cultivar, and weed management regime had significant effect on SNSMS. Regardless of weed management regime and cultivar, SNSMS was significantly increased with increasing N rate (Table 3). The minimum (16.5) and maximum (21.1) SNSMS were recorded at the N rate 0 and 200 Kg ha<sup>-1</sup>, respectively. These results are consistent with those reported by Chauhan et al. (1995) and Arthamwar et al. (1996). In contrast, Hocking et al. (1997) reported that N fertilizer had little effect on seed number per pod. Averaged across N rates and cultivars, SNSMS was significantly reduced under weedy condition (Table 3). Regardless of N rate and weed management regime, Hayola 420 had a significantly higher SNSMS than the other cultivars (Table 3). Among 2-way and 3-way interactions, only N rate by cultivar had significant effect on SNSMS (Table 2). In unfertilized condition and aver-

**Table 4**  
Effect of nitrogen rates (0, 100 and 200 kg ha<sup>-1</sup>) on seed yield (Y), silique number per main stem (SNMS), silique number per side branch (SNSB), seed number per silique of main silique (SNSMS), seed number per silique of side branch (SNSSB), number of side branches (SB), and 1000-seed weight (ThSW) (averaged across weed management regimes)

| N rates | Cultivars  | Seed yield, kg ha <sup>-1</sup> | SNMS        | SNSB        | SNSMS        | SNSSB        | SB          | ThSW, g     |
|---------|------------|---------------------------------|-------------|-------------|--------------|--------------|-------------|-------------|
| 0       | RGS003     | 688.5 ± 85                      | 20.4 ± 1.1  | 2.4 ± 0.6   | 17.00 ± 1.26 | 1.23 ± 0.31  | 0.6 ± 0.05  | 3.60 ± 0.05 |
|         | PF         | 510.0 ± 61                      | 17.8 ± 1.59 | 0.3 ± 0.15  | 16.00 ± 0.30 | 0.34 ± 0.38  | 0.40 ± 0.05 | 3.05 ± 0.22 |
|         | Hayola 308 | 636.7 ± 55                      | 23.9 ± 3.03 | 4.5 ± 1.98  | 15.91 ± 0.77 | 0.70 ± 0.67  | 0.41 ± 0.05 | 2.82 ± 0.08 |
|         | Hayola 420 | 832.3 ± 72                      | 41.5 ± 2.28 | 0.8 ± 0.28  | 17.61 ± 0.77 | 0.70 ± 0.59  | 0.33 ± 0.02 | 3.18 ± 0.11 |
| 100     | RGS003     | 1255.5 ± 83                     | 35.3 ± 4.9  | 24.0 ± 2.80 | 18.01 ± 0.37 | 19.05 ± 0.91 | 2.05 ± 0.22 | 3.22 ± 0.17 |
|         | PF         | 1566.7 ± 149                    | 41.4 ± 2.1  | 36.9 ± 4.58 | 16.58 ± 0.37 | 16.36 ± 0.26 | 1.45 ± 0.16 | 2.90 ± 0.09 |
|         | Hayola 308 | 1355.5 ± 186                    | 34.5 ± 2.12 | 30.1 ± 3.78 | 16.81 ± 0.65 | 16.10 ± 1.28 | 2.10 ± 0.21 | 3.02 ± 1.14 |
|         | Hayola 420 | 2322.3 ± 214                    | 42.8 ± 1.75 | 41.9 ± 8.71 | 21.76 ± 2.39 | 19.08 ± 0.58 | 2.82 ± 0.34 | 3.30 ± 0.12 |
| 200     | RGS003     | 3616.7 ± 317                    | 43.4 ± 2.83 | 68.1 ± 6.97 | 18.6 ± 0.72  | 19.67 ± 0.4  | 4.05 ± 0.32 | 3.95 ± 0.13 |
|         | PF         | 3022.2 ± 138                    | 49.6 ± 4.19 | 59.2 ± 7.20 | 20.91 ± 0.28 | 19.66 ± 0.34 | 3.55 ± 0.21 | 3.27 ± 0.06 |
|         | Hayola 308 | 2941.2 ± 246                    | 46.7 ± 3.78 | 80.1 ± 9.31 | 20.35 ± 0.44 | 22.24 ± 0.18 | 4.81 ± 0.31 | 3.55 ± 0.13 |
|         | Hayola 420 | 2842.2 ± 134                    | 50.2 ± 2.08 | 75.8 ± 5.37 | 24.55 ± 0.79 | 20.50 ± 0.45 | 6.90 ± 0.40 | 3.66 ± 0.06 |

N0, N100, and N200 indicate 0, 100, and 200 kg N ha<sup>-1</sup>, respectively

**Table 5**  
Interaction between N rate and weed management regime on silique number per side branch (averaged across cultivars)

| N 0         |             | N100         |              | N200         |              |
|-------------|-------------|--------------|--------------|--------------|--------------|
| Weed free   | Weedy       | Weed free    | Weedy        | Weed free    | Weedy        |
| 2.36 ± 1.06 | 1.62 ± 0.59 | 41.13 ± 4.38 | 25.41 ± 2.21 | 83.11 ± 3.41 | 58.48 ± 4.61 |

N0, N100, and N200 indicate 0, 100, and 200 kg N ha<sup>-1</sup>, respectively

aged across weed management regimes, Hayola 420 had a significantly higher SNSMS than PF and Hayola 308 (Table 4). At the 100 kg ha<sup>-1</sup> N rate and averaged across weed management regimes, SNSMS was in the order: Hayola 420 > RGS003 > Hayola 308 = PF. At the 200 kg ha<sup>-1</sup> N rate and averaged across weed management regimes, Hayola 420 had the highest SNSMS (24.55 ± 0.79), followed by PF (20.91 ± 0.28) with a value statistically similar to Hayola 308 (20.35 ± 0.44), and lastly by RGS003 (18.6 ± 0.72) (Table 4).

#### Seed number per silique of side branch (SNSSB)

The ANOVA indicated statistically significant effects due to N rate, cultivar, and weed management regime on SNSSB. Averaged across cultivars and weed management regimes, SNSSB was significantly increased as N rate increased from 0 to 200 kg ha<sup>-1</sup> (Table 3). The reduction in SNSSB due to weed competition was 11% when averaged across N rates and cultivars. Regardless of N rate and weed management regime, PF had significantly lower SNSSB than the other cultivars (Table 3). Additionally, statistically significant interactions were apparent for N rate by cultivar but not for N rate by weed management regime, cultivar by weed management regime, and N rate by cultivar by weed management regime (Table 2). Averaged across weed management regimes, the highest and lowest SNSSB was recorded for RGS003 (1.23 ± 0.31) and PF (0.34 ± 0.38) in no added N plots. At 100 kg N ha<sup>-1</sup> and averaged across weed management regimes, Hayola 420 and RGS003 produced higher SNSSB than PF and Hayola 308. At the 200 kg ha<sup>-1</sup> N rate and averaged across weed management regimes, Hayola 308 had the highest SNSSB (22.24 ± 0.18), followed by Hayola 420 (20.50 ± 0.45), RGS003 (19.67 ± 0.4) with a value statistically similar to PF (19.66 ± 0.34) (Table 4).

#### Side branches per plant (SB)

N rate, cultivar, weed management regime, and N rate × cultivar effects were significant ( $P < 0.01$ ) for SB (Table 2). However, N rate × weed management regime, cultivar × weed management regime, and N rate × cultivar × weed management regime interactions were not significant. Averaged across cultivars and weed management regimes, canola plant tended to produce more SB as N rate increase from 0 to 200 kg ha<sup>-1</sup> (Table 3). N deficiency causes poor growth which in turn resulted in low branching in canola plants (Rathke et al., 2006). Regardless of N rate and cultivar, SB was significantly lower in weedy condition (2.66 SB per plant) than weed-free condition (2.25 SB per plant). Averaged across N rates and weed management regimes, Hayola 420 and PF produced the highest and lowest side branches, with mean values of 3.35 and 1.8 SB per plant, respectively (Table 4). Regardless of weed management regime, RGS003 and Hayola 420 produced the highest and the lowest SB per plant in no added N plots, while

Hayola 420 and PF produced the highest and the lowest SB per plant at the moderate N rate (with values of 2.82 ± 0.34 and 1.45 ± 0.16, respectively) and at the high N rate (with values of 6.90 ± 0.40 and 3.55 ± 0.21, respectively) (Table 4).

#### 1000- Seed weight

1000-seed weight was significantly ( $P < 0.01$ ) affected by N rate, cultivar, and weed management regime. The interaction between N rate and cultivar was also significant for 1000-seed weight, but other 2- and 3-way interactions were not significant. Regardless cultivar and weed management regime, plants fertilized with 100 and 200 kg N ha<sup>-1</sup> produced heavier seed than plants without added N fertilizer. It has been illustrated that growth between the end of flowering and maturity determines the seed weight of canola. High N-supply improves leaf area index, leaf area duration and photosynthetic activity which in turn resulted in an increasing the supply of assimilates to the young siliques (Rathke et al., 2006). This result is agreement with findings of Al-Mobarak (2006), who reported that 1000-seed weight was significantly increased as nitrogen level increased. In contrast, Hocking et al. (1997) reported that N fertilizer had little effect on 1000-seed weight. Weed competition reduced significantly 1000-seed weight by 7.6% when averaged across N rates and cultivars. Regardless of N rate and weed management regime, RGS003 had the highest 1000-seed weight, followed by Hayola 420, Hayola and PF with mean values of 3.59, 3.38, 3.13, and 3.07, respectively. In no added N plots, RGS003 produced heavier seed than the other cultivar when averaged across weed management regimes. Regardless weed management regime, Hayola 420 and RGS003 had greater 1000-seed weight than Hayola 308 and PF in plots fertilized with 100 kg N ha<sup>-1</sup>. On the other hand, RGS003 had the highest 1000-seed weight (3.95 ± 0.13), followed by Hayola 420 (3.66 ± 0.6) with a value statistically similar to Hayola 308 (3.55 ± 0.13), and PF (3.27 ± 0.6) when averaged across weed management regimes.

#### Competitive ability and ability to withstand competition

Main effects of N rate and cultivar were significant ( $P < 0.01$ ) for both competitive ability and ability to withstand competition (Table 6). Averaged across cultivars, competitive ability was significantly ( $P < 0.01$ ) increased as N rate increased from 0 to 200 kg ha<sup>-1</sup> (Figure 1), suggesting that high levels of N favor the crop over the weeds. It has been reported that low N-supply delayed canopy closure and thus, reduced the potential of canola to suppress weeds (Rathke et al., 2006). canola, compared to other crops, has a high potential to suppress weeds after canopy closure especially under conditions of high N-regimes (Rathke et al., 2006). This result agreed with finding reported by Van Delden et al. (2002), but in contrary to the finding of Abouziena et al. (2007), Cathcart and Swanton (2004) and Blackshaw

et al. (2003). Regardless of N rate, the highest competitive ability was recorded for Hayola 420 (6.5), which statistically similar to RGS003 (5.7) and PF (5.6). The lowest competitive ability (3.8) was recorded for Hayola 308 (Figure 2). These results confirmed that canola cultivars had different competitive ability against weeds. Similar results were reported for barley (Watson et al., 2006), chick pea (Paolini, 2006), soybean (Janink et al., 2000), wheat (Blackshaw 1994; Lemerle et al. 1996 and Lemerle et al., 2001) and rice (Fischer et al., 1997; Toung et al., 2000; Gealy et al., 2003 and Zhao et al., 2006) cultivars. The interaction between cultivar and N rate was only significant ( $P < 0.01$ ) for ability to withstand competition (Table 6), indicating that canola cultivars showed different response to added N Fertilizer only for ability to withstand competition. In no added N plots, Hayola 308 and Hayola 420 had the high-

est ability to withstand competition ( $74.16 \pm 3.63$  and  $70.69 \pm 3.94$ , respectively), followed by PF ( $69.31 \pm 2.72$ ), and lastly by RGS003 ( $66.29 \pm 2.38$ ), which had the lowest ability to withstand competition (Table 7). At the moderate and high N application rates, Hayola 420 and PF had the highest ability to withstand competition, respectively. On the other hand, Hayola 308 had the lowest ability to withstand competition both at the moderate and high N application rates (Table 7). Similarly, to this result, Watson et al. (2006) also reported that barley cultivar was differed in ability to withstand competition.

## Conclusions

This experiment indicated that canola seed yield and yield components were significantly increased with increasing N

**Table 6**  
Mean squares of ANOVA for competitive index and ability withstand competition as affected by cultivar and N rate

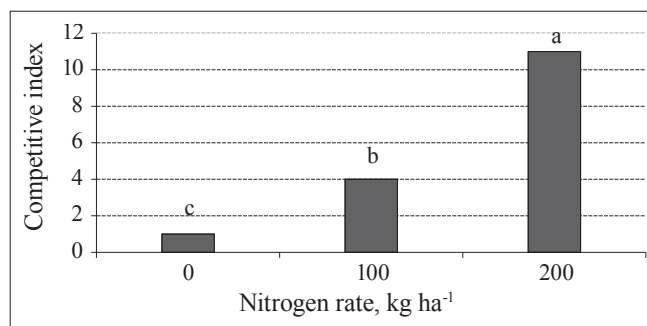
| Source       | df | Competitive ability | Ability to withstand competition |
|--------------|----|---------------------|----------------------------------|
| R            | 2  | 7.6 <sup>ns</sup>   | 57.4 <sup>ns</sup>               |
| Nitrogen (N) | 2  | 327.6 <sup>**</sup> | 646.6 <sup>**</sup>              |
| Cultivar (C) | 3  | 12.1 <sup>**</sup>  | 479.2 <sup>**</sup>              |
| N×C          | 6  | 7.8 <sup>ns</sup>   | 326.6 <sup>**</sup>              |
| Error        | 22 | 3.5                 | 53.7                             |

\*, \*\* represent significance at 0.05 and 0.01 probability level, respectively. ns represents no significant difference.

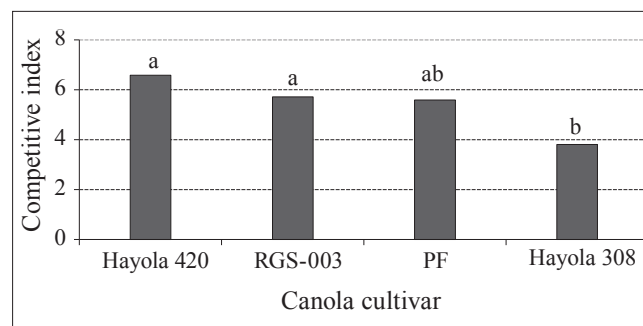
**Table 7**  
Ability to withstand competition for canola cultivars at different nitrogen rates (0, 100 and 200 kg ha<sup>-1</sup>)

| Cultivars  | Ability to withstand competition |              |              |
|------------|----------------------------------|--------------|--------------|
|            | N0                               | N100         | N200         |
| RGS003     | 66.29 ± 6.38                     | 82.17 ± 4.15 | 77.88 ± 1.33 |
| PF         | 69.31 ± 2.72                     | 80.27 ± 2.12 | 93.21 ± 6.29 |
| Hayola 308 | 74.16 ± 3.63                     | 56.89 ± 3.39 | 71.8 ± 3.24  |
| Hayola 420 | 70.69 ± 3.94                     | 88.70 ± 5.77 | 86.79 ± 4.56 |

N0, N100, and N200 indicate 0, 100, and 200 kg N ha<sup>-1</sup>, respectively.



**Fig. 1.** Effect of nitrogen rate on competitive ability (averaged across canola cultivars)



**Fig. 2.** Competitive ability of canola cultivars (averaged across nitrogen rates)

rate. Moreover, seed yield and yield components were significantly reduced by weed competition. At the same time, competitive ability of canola cultivars was significantly increased ( $P < 0.01$ ) as N rate increased from 0 to 200 kg ha<sup>-1</sup>. This experiment suggested that canola seed yield was affected less by weed interference at high N rate.

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