Competitive Ability of Hybrid and Open-Pollinated Canola (*Brassica napus*) with Wild Oat

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Abstract

The competitiveness of three hybrid and three open-pollinated canola cultivars against two wild oat populations was determined under controlled environment conditions at two plant densities and five canola:wild oat ratios. Analysis of replacement series and relative crowding coefficients (RCC), based on shoot dry weight or leaf area, indicated that hybrid canola cultivars were twice as competitive than open-pollinated cultivars when weed interference was relatively high (i.e., high plant density and vigorous wild oat growth). Little difference in competitiveness among cultivar types was apparent when weed interference was lower. The results of this study suggest that hybrid canola cultivars may be best suited for use in an integrated weed management program, particularly for farmers of organic or low input cropping systems.

Introduction

The introduction of hybrid canola (*Brassica napus* L.) in 1989 signified the advent of cultivars with higher yield potential than previous inbred lines, and potentially greater weed competitiveness due to heterosis. Hybrid vigor manifested in greater aboveground biomass or seed yield has been well documented. For example, Van Deynze et al. (1992) reported that hybrids produced 50% more dry matter at maturity and 24% higher seed yield than open-pollinated cultivars. Eight glufosinate-resistant hybrid lines approved for registration in western Canada in 2001 yielded 128% of check varieties that were open-pollinated. In northern Idaho, the most adapted hybrids had a yield advantage compared with the most productive inbred cultivars (Starmer et al. 1998). However, average yield of hybrids was not significantly different from inbred cultivars. Thus, productivity comparisons among hybrid and open-pollinated varieties may be influenced by choice of cultivars and the environment in which they are grown.

Limited information is available on heterotic advantage for weed competitiveness. In a field experiment conducted at three locations in Alberta between 1998 and 2000, a glufosinate-resistant hybrid cultivar had greater aboveground biomass and seed yield and was more competitive with weeds than a glufosinate-resistant open-pollinated cultivar (Harker et al. 2001). Dockage was 50% higher in seeds of the open-pollinated cultivar compared with the hybrid cultivar. In a study conducted in Manitoba, a glufosinate-resistant hybrid cultivar had greater biomass, faster canopy closure, higher seed yield (under both weedy and weed-free conditions), and was more competitive with volunteer barley (*Hordeum vulgare* L.) than a glufosinate-resistant open-pollinated cultivar (Linde et al. 2001).

In canola cropping systems, herbicide application timing and efficacy usually influences the outcome of canola-weed competition much more than the inherent competitiveness of the cultivar. Harker et al. (2000) found no consistent yield advantage for any canola-herbicide combination (three herbicide-resistant open-pollinated varieties with their respective herbicides, glyphosate, glufosinate, and imidazolinones). In a different study, failure to control weeds beyond the four-leaf stage of canola reduced seed yield of the glufosinate-resistant open-pollinated cultivar more than the glufosinate-resistant hybrid cultivar (Harker et al. 2001).
In this study, the objective was to determine the relative competitive ability of three hybrid and three open-pollinated canola cultivars against two wild oat populations.

Materials and Methods

The cultivars used in the investigation are listed in Table 1. The cultivars were randomly chosen from among those grown on a significant acreage in western Canada. Seeds of the cultivars had been produced in 1999 and were not coated with a pesticide. The two wild oat populations used in the experiment were UM5 and AC1, which originated from Manitoba and Saskatchewan, respectively. Both populations were known to be susceptible to wild oat herbicides.

A greenhouse experiment was conducted from May to October of 2000 at Saskatoon, SK and was repeated once. The factorial experiment was arranged in a randomized complete block design with four replications. The factors were canola cultivar (n=six), wild oat population (n=two), density (n=two), and species ratio (n=five). The two densities were 12 and 20 plants per 15-cm diameter pot, equivalent to 680 and 1,130 plants m^{-2}. The five species ratios were monocultures of each canola cultivar or wild oat population and three mixtures at relative proportions of 75:25, 50:50, and 25:75. Thus at the low density, plant numbers (canola:wild oat) for each ratio were 12:0, 9:3, 6:6, 3:9, and 0:12; at the high density, plant numbers were 20:0, 15:5, 10:10, 5:15, and 0:20, respectively. Although these wild oat densities (in monoculture) are higher than maximum densities documented in field surveys, they are comparable to weed densities used in previous replacement series studies (Fleming et al. 1988; Roush et al. 1989; O'Donovan et al. 1999) to ensure that the range of constant final yield is attained to detect competition (Harper 1977). Moreover, comparison of total plant densities used in a pot experiment in the greenhouse versus equivalent densities in the field may not be valid.

Table 1. The Three Hybrid and Three Open-Pollinated Canola (*Brassica napus* L.) Cultivars Used in the Experiment.

	Hybrid	Open-pollinated	Year registered	Herbicide resistance trait
InVigor 2273	✔		1998	glufosinate
Hyola 401	✔		1991	none
AC-H102	✔		1994	none
LG3220		✔	1997	none
LG3295		✔	1998	glyphosate
45A71		✔	1995	imidazolinone

To avoid uneven germination in pots, wild oat and canola seeds were germinated on moist filter paper in petri dishes for 48 and 24 h, respectively, in the dark at 25 ºC. Seedlings with relatively uniform radicle length (3-5 mm) were selected and planted 1 cm deep in pots containing a mixture of soil, peat, vermiculite, and sand (3:2:2:2 by volume) plus a slow-release fertilizer (150 g of 26-13-0 per 75 L potting mixture). Experiments were conducted under a 20/16 ºC day/night temperature regime with a 16-h photoperiod supplemented with 230 ìmol m^{-2} s^{-1} illumination. Pots were watered daily to field capacity.

When plants were still vegetative (45 d after planting), shoots were cut at soil level. Leaf area was measured with a portable area meter. Harvested canola or wild oat aboveground biomass from each pot was placed in separate paper bags, dried at 80 ºC for 48 h, and weighed.

The relative competitiveness of canola cultivars against wild oat was determined using two statistical procedures. The first method was analysis of replacement series experiments (Harper 1977; Roush et al. 1989; Dunan and Zimdahl 1991; Anderson et al. 1996). Data were subjected to ANOVA (SAS 1991). Replacement series diagrams were constructed for the response of plant dry weight or leaf area to species proportion. The relative yield total (RYT) of each mixture was calculated (de Wit and van den Bergh 1965; Harper 1977). The RYT of a mixture is the sum of the relative yields (plant shoot dry weight per pot) of the two species, i.e., relative yield of canola (yield in mixture divided by yield in monoculture) plus relative yield of wild oat. The RYT describes how the species pair utilizes resources. Values of approximately one indicate that the two species are competing for the same limiting resources; values greater than one suggest that species are making different demands on resources, avoiding competition, or maintaining a symbiotic relationship. Values less than one imply mutual antagonism. When the RYT of a species pair is approximately one, the combined yield of species in a mixture is predictable from species monocultures. Deviation of RYT from one for a species mixture was determined using Student’s t-test (Fleming et al. 1988).

Data were also analyzed using the relative crowding coefficient (RCC) (Novak et al. 1993; O’Donovan et al. 1999). The RCC is a measure of competitiveness between two species. Values of approximately one indicate that the two species, canola and wild oat, are equal competitors. Values greater than one indicate that canola is more competitive than wild oat; conversely, values less than one indicate that wild oat is more competitive than canola. The RCC for each canola:wild oat combination was calculated using the equation:

$$RCC = (((Wc^{75:25}/Ww^{75:25}) + (Wc^{50:50}/Ww^{50:50}) + (Wc^{25:75}/Ww^{25:75}))/3) / (Wc^{100:0}/Ww^{100:0})$$

where $Wc^{n:n}$ is dry weight or leaf area of canola at a ratio of n:n, and $Ww^{n:n}$ is dry weight or leaf area of wild oat at a ratio of n:n. The RCC value provides a simple biological expression of competition. Specifically, averaged across ratios, the RCC indicates the factor by which one competitor exceeds another (Harper 1977). RCCs were calculated for each replicate, and the data were subjected to ANOVA. Means were separated using Fisher’s LSD test ($P \leq 0.05$). An orthogonal contrast, ‘hybrid vs. open-pollinated’, was also performed on the RCC data using the same level of significance (SAS 1991).

Results and Discussion

Data were combined across experiments upon confirmation of homogeneity of variance.

Analysis of variance of shoot dry matter and leaf area data indicated significant ($P \leq 0.05$) interactions among canola cultivar, wild oat population, density, and species ratio. Therefore, data were analyzed for each canola cultivar and wild oat population combination at each density.

The replacement series diagrams illustrate the competition between canola cultivars and wild oat populations (some diagrams shown in Fig. 1). The responses of shoot dry weight and leaf area across species ratios generally were similar. Absence of interspecific competition would result in an intersection point of the two curves at the 50:50 ratio. The two curves usually do not intersect at the 50:50 ratio, indicating the frequent occurrence of interspecific competition based on response of shoot dry weight or leaf area. Equal competition between species would be represented by lines with constant slopes across all ratios. For both dry weight and leaf area, the curve representing canola cultivar generally is convex and the curve for wild oat population frequently is concave. This pattern suggests that canola is more competitive than wild oat and gains resources at the expense of the weed. The results of the 24 pair-wise replacement series combinations indicate a general trend of greater shoot biomass production of canola compared with wild oat.

The open-pollinated cultivars appeared to be most adversely affected by UM5 wild oat competition at the high plant density, as indicated by the shape of the curves, i.e., the curves for the open-pollinated canola cultivars are concave and those for UM5 are convex. In herbicide

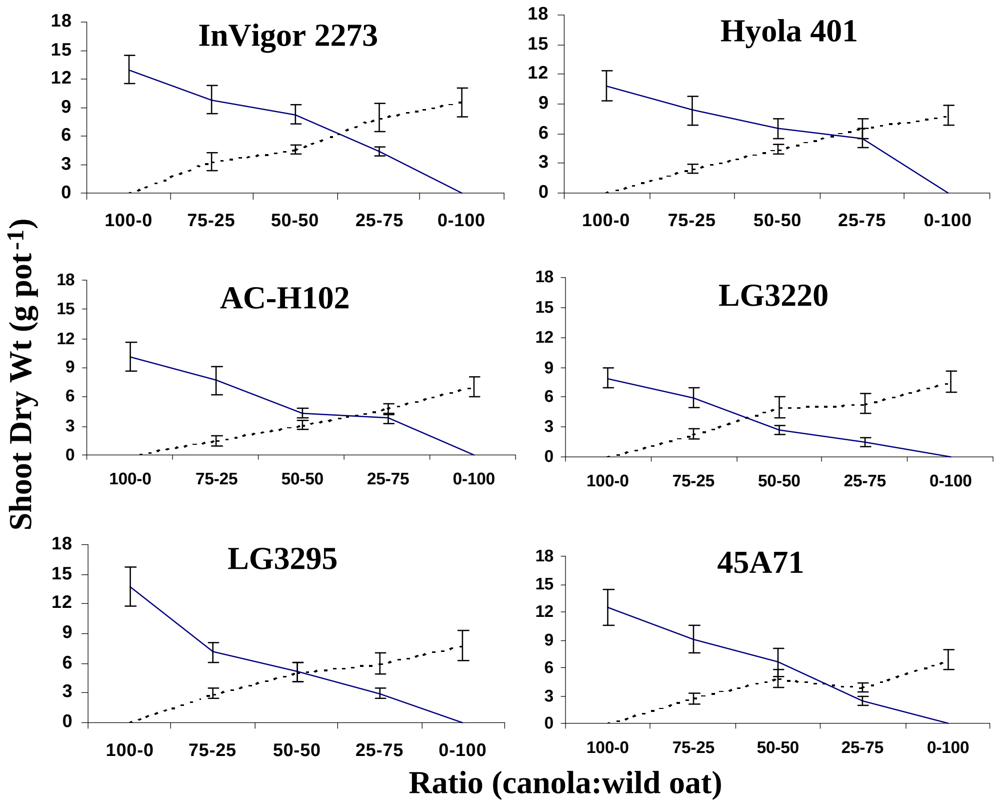

Figure 1. Replacement series diagrams for shoot dry weight (bars = SE) of six canola cultivars (solid line) and wild oat population ‘UM5’ (dashed line) at the high density (the remaining diagrams are not shown).

resistance screening studies (unpublished data), we have observed that UM5 exhibits greater seedling vigor than AC1. Because of the large population genetic variation in wild oat (Sharma and Vanden Born 1978), it should not be surprising that different populations of this species can exhibit a range of phenotypic responses to environmental or experimental conditions. These qualitative results suggest that productivity of these open-pollinated varieties may be more adversely affected than hybrid cultivars in field situations of relatively high wild oat interference.

Values of relative yield total (RYT) for the 72 mixtures based on shoot dry weight generally did not vary significantly from one (data not shown). There were only four instances where RYT exceeded one: 1) 50:50 mixture of AC-H102:AC1 at the low density; 2) 50:50 mixture of InVigor 2273:AC1 at the high density; 3) 25:75 mixture of InVigor 2273:UM5 at the low density; 4) 25:75 mixture of Hyola 401:UM5 at the high density. For all mixtures, RYT values were never less than one. Thus, these two species usually were competing for the same resources (Harper 1977). When the RYT of a species pair is approximately one, the RCC is an appropriate measure of competitive ability (Fleming et al. 1988).

Analysis of variance of RCCs based on shoot dry matter and leaf area indicated a significant interaction among canola cultivar, wild oat population, and plant density. RCCs based on dry matter were similar to values based on leaf area (Table 2), confirming the similarity in responses between the variables observed in the replacement series diagrams. Apparently, shoot biomass and leaf area of canola and of wild oat were highly correlated. Similarity in response between these two variables, however, may be related to the conditions of the study, such as vegetative growth stage of plants, restricted soil volume (i.e., pot), optimum soil moisture, lighting

Table 2. Relative Crowding Coefficients (RCC) for Aboveground Dry Matter and Leaf Area of Canola Cultivar and Wild Oat Population Combinations at the High Density[z]

Canola cultivar:wild oat population	Dry matter	Leaf area
InVigor 2273:AC1	1.42 cd	1.74 b-e
InVigor 2273:UM5	1.28 cd	1.55 c-e
Hyola 401:AC1	1.74 b-d	1.80 b-e
Hyola 401:UM5	1.59 b-d	1.76 b-e
AC-H102:AC1	3.10 a	2.59 a-d
AC-H102:UM5	1.70 b-d	1.44 de
LG3220:AC1	1.34 cd	1.19 e
LG3220:UM5	0.73 e	0.75 f
LG3295:AC1	1.42 cd	1.29 e
LG3295:UM5	0.76 e	0.70 f
45A71:AC1	1.30 cd	1.16 e
45A71:UM5	0.86 e	0.82 f
Contrast[y]		
Hybrid vs. open-pollinated:	*	*

[z]Means within a column followed by the same letter are not significantly different according to Fisher's LSD test (P<0.05).
[y]Orthogonal contrast test (*: significant at P<0.05).

intensity, etc. Other replacement series experiments that measured shoot dry weight and leaf area found that competitive indices based on these variables were the same (Fleming et al. 1988) or different (Dunan and Zimdahl 1991).

The orthogonal contrast test indicated that hybrid cultivars were more competitive with wild oat than open-pollinated cultivars, but only at the high plant density (Table 2). The RCCs for dry matter and leaf area confirmed that open-pollinated cultivars were less competitive with UM5 wild oat than hybrid cultivars at the high plant density. Mean RCCs of hybrid cultivars based on dry weight and leaf area were 1.52 and 1.58, respectively; corresponding values of open-pollinated cultivars were 0.78 and 0.76. No differences among RCC values within cultivar type (i.e., hybrid and open-pollinated) were detected. Therefore, these hybrid cultivars were twice as competitive with UM5 wild oat than the open-pollinated cultivars. Lack of differences between cultivar types against UM5 at the low density may indicate greater resource availability (e.g., nutrients) to plants grown at the low density than at the high density. These results support the recommendation that more than one plant density should be used in replacement series experiments (Hume 1993). The three open-pollinated cultivars were less competitive than UM5 (RCC less than one) at the high density. For other cultivar and wild oat population combinations at both densities, canola was more competitive than wild oat (RCC greater than one). Except for AC-H102 at the high density (dry matter only), no differences among RCCs of hybrid and open-pollinated cultivars against AC1 at the low or high density were detected.

Overall, these results suggest that in fields with high wild oat densities, a hybrid canola cultivar may be able to withstand weed interference better than an open-pollinated cultivar. High population densities occur most frequently in low input or organic production systems (Thomas et al. 2001). Mean wild oat densities in organic fields in Alberta in 2001 were almost twice those in conventional fields; maximum densities in organic fields were six-fold greater than those in conventional fields (A. G. Thomas, unpublished data). Moreover, resource availability, such as nutrient supply, may be more limiting in low input or organic production systems, further accentuating the intensity of crop:weed competition.

Information on the agronomic performance of the six canola cultivars used in this study was obtained from regional variety trials (Anonymous 1998-2001). The three hybrids used in this study each yielded about 10% more than the three open-pollinated cultivars. AC-H102 matures approximately 5-7 d later than the other cultivars used in this study. Cultivar 45A71 is rated as ‘fair’ for lodging and resistance to blackleg, whereas the other cultivars are rated as ‘good’. These co-operative trials were conducted under relatively weed-free conditions. Comparison of these yield results with the findings of Harker et al. (2001) and Linde et al. (2001) would suggest, however, that the relative yield performance of hybrid and open-pollinated cultivars under weedy conditions would be similar to that under weed-free conditions.

The results of this study suggest that greater competitiveness of hybrid canola with wild oat than open-pollinated canola may only be apparent under conditions of relatively high weed interference (high intensity and long duration of competition). Harker et al. (2001) found that a glufosinate-resistant hybrid cultivar was more competitive with weeds than an open-pollinated cultivar, especially when weeds were not removed early. The findings of this study generally agree with the results of the field competition studies.

Nevertheless, future research on the relative weed competitiveness of numerous hybrid and open-pollinated canola cultivars should be conducted under field conditions. This research is planned to commence in 2002. Further information on their relative competitiveness against different communities of weed species in different soils and climates is needed for recommendations of cultivars in different regions that are most appropriate for inclusion in an integrated weed management program based on their weed competitive index ranking. This research would be most beneficial if competitive indices of hybrid cultivars were determined to be frequently greater than open-pollinated varieties, because of the relatively short average lifespan of cultivars in western Canada. Based on results of this study, differences in competitive ability against wild oat within cultivar types were much less than differences between cultivar types. In addition to factors such as harvestability and profitability, relative competitive ability can be another decision aid for farmers when selecting canola cultivars.

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