Effect of neonicotinoid seed treatments on flea beetle damage and performance of Polish canola (*Brassica rapa*) in 2003-2005

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ABSTRACT

Field experiments were conducted at AAFC Saskatoon in 2003-2005 to investigate the effect of neonicotinoid seed treatments on flea beetle damage and the agronomic performance of Polish canola, *Brassica rapa*. Tests were done annually on certified seed lots of a conventional open-pollinated cultivar and synthetic cultivar. Treatments included untreated seed, Foundation Lite® (fungicides only), Assail 50 SF® (400 g acetamiprid/100 kg seed), Gaucho CS FL® (400 g imidacloprid/100 kg seed), Prosper®(200 g and 400 g clothianidin/100 kg seed), Helix® (200 g thiamethoxam/100 kg seed) and Helix XTra® (400 g thiamethoxam/100 kg seed). Flea beetle damage and performance varied yearly. Damage to seedlings grown from untreated seed after 21 days was higher in 2003 (27-30% damage) than in 2004 (19-20% damage) and 2005 (10-15% damage). Seedling emergence, stand establishment, shoot growth, biomass accumulation and seed yield were substantially higher in 2005 than in 2003 and 2004. The effects of seed treatments on flea beetle damage and performance varied yearly but were consistent in the two cultivars from year to year.

Seed treatments had a significant effect on flea beetle damage to the two cultivars 14, 18 and 21 days after seedling (DAS). In each test, damage was highest in seedlings grown from untreated seed and seeds treated with Foundation Lite® or Assail®. Gaucho® provided an intermediate level of protection. Compared to untreated seed, Gaucho® reduced damage over 3 years by 4-5% after 14-18 days and by 3% after 21 days. In ascending order, Prosper® (200 g rate), Helix®, Prosper® (400 g rate) and Helix XTra® provided the best flea beetle protection. Compared to untreated seed, treatments reduced damage over 3 years by 7-12% after 14-18 days and by 6-8% after 21 days. In the Prosper® and Helix® treatments, the 400 g rate provided better protection than the 200 g rate after 14-18 days but not after 21 days. Low or high rates of Prosper® and Helix® reduced flea beetle damage after 21 days to 10-15% in 2003, 15-19% in 2004 and 10-13% in 2005.

Seedling emergence in the two cultivars after 14 days varied depending on the year and seed treatment. Emergence of untreated seed after 14 days averaged 58-63% in 2003 (dry conditions, 20-26% damage), 69-70% in 2004 (moist conditions, 4-5% damage) and 84% in 2005 (very moist conditions, 4-6% damage). Foundation Lite® had little or no effect on emergence of the two cultivars. Compared to untreated seed, Assail® improved emergence by 5-9% in 2003 but had no effect on emergence in 2004 and 2005. Gaucho®, Prosper® (200 g rate) and Helix® improved emergence by 9-17% in 2003, by 0-10% in 2004 and by 0-1% in 2005. Prosper® (400 g rate) and Helix XTra® improved emergence by 15-18% in 2003, by 0-7% in 2004 and by 0-4% in 2005. Neonicotinoid seed treatments improved emergence in 2003 when flea beetle damage averaged 20-26%. However, contrary to patent claims, treatments did not promote faster emergence in 2004 and 2005 when flea beetle damage averaged 6% or less in check plots.

The effect of seed treatments on establishment of Polish canola varied yearly. Establishment of untreated seed after 28 days averaged 55-61% in 2003, 66-68% in 2004 and 81% in 2005. Foundation Lite® had no effect on stand establishment. Compared to untreated seed, Assail® improved establishment of the two cultivars by 4-5% in 2003 and by 4% or less in 2004 and 2005. Stand establishment was higher with other neonicotinoid seed treatments. Gaucho®, Prosper®200 and Helix® improved establishment by 7-13% in 2003, by 4-10% in 2004 and by 1% or less in 2005. Prosper®400 and Helix XTra® improved establishment by 13-16% in 2003, by 2-7% in 2004 and by 3% or less in 2005. Results indicated that Gaucho®, Prosper®200, Prosper®400, Helix® and Helix XTra® improved stand establishment when flea beetle damage exceeded 25% damage in 2003. However, treatments did not promote higher plant stands when damage averaged 20% or less in 2004 and 2005.

Seed treatments had a significant effect on shoot growth of open-pollinated and synthetic Polish canola after 21, 28 and 35 days. In most tests, untreated seed and seeds treated with Foundation Lite®, Assail® or Gaucho® had the lowest shoot dry weight after 21, 28 and 35 days. Seeds treated with Prosper®200, Prosper®400, Helix® or Helix XTra® had the highest shoot weights on most sampling dates. Compared to untreated seed, Prosper®200 and Prosper®400 improved shoot weights over 3 years by 1.2-1.3 times after 21 days, by 1.3-1.6 times after 28 days and by 1.1-1.3 times after 35 days. Improvements in shoot growth with Prosper®200 and Prosper®400 after 21 and 28 days were greater with high flea beetle damage in 2003 (1.5-2.4 X improvement) than with low flea beetle damage in 2004 (1.2-1.4 X improvement) or 2005 (1.0-1.5 X improvement). In each test, shoot weights after 21, 28 and 35 days were not significantly different in the Prosper®200 and Prosper®400 treatments. Compared to untreated seed, Helix® and Helix XTra® improved shoot weights over 3 years by 1.4-1.5 times after 21 days, by 1.3-1.6 times after 28 days and by 1.3-1.4 times after 35 days. Improvements in shoot growth with Helix® or Helix XTra® after 21 and 28 days were greater in 2003 (1.7-2.7 X improvement) than in 2004 (1.3-1.6 X improvement) or 2005 (1.2-1.4 X improvement). In most tests, shoot weights after 14, 21 and 28 days were not significantly different in the Helix® and Helix XTra® treatments. Improvements in shoot weight in 2004 and 2005 support patent claims that low or high rates of Prosper® and Helix® promote seedling vigour and early canopy development when flea beetle damage is less than 25%, the economic threshold. Of the treatments tested, Helix XTra® had the greatest positive effect on shoot growth of Polish canola when flea beetle damage was above or below the economic threshold.

Seed treatments had a significant effect on the shoot biomass of open-pollinated and synthetic Polish canola after 21, 28 and 35 days. In most instances, untreated seed and seeds treated with Foundation Lite® or Assail® had the lowest shoot biomass. Compared to untreated seed, Gaucho® improved shoot biomass over 3 years by 1.0-1.2 times after 21 days and by 1.1-1.3 times after 28 days. Seeds treated with low or high rates of Prosper® and Helix® had the highest shoot biomass on most sampling dates. Compared to untreated seed, 200 g and 400 g rates of Prosper® improved biomass over 3 years by 1.1-1.3 times after 21 days, by 1.4-1.7 times after 28 days and by 1.2-1.3 times after 35 days. Improvements in biomass with low or high rates of Prosper after 21-28 days were greater with high flea beetle damage in 2003 (1.9-3.1 X improvement) than with low flea beetle damage in 2004 (1.1-1.5 X improvement) or 2005 (1.0-1.5 X improvement). In each year, shoot biomass after 14, 21, 28 or 35 days was not significantly different with 200 g and 400 g rates of Prosper®. Compared to untreated seed, Helix® and Helix XTra® improved shoot biomass over 3 years by 1.3-1.6 times after 21 days, by 1.3-1.7 times after 28 days and by 1.2-1.5 times after 35 days. Improvements in biomass with Helix® and Helix XTra® after 21-28 days were also greater in 2003 (2.1-3.5 X improvement) than in 2004 (1.3-1.9 X improvement) or 2004 (1.1-1.4 X improvement). In most tests, shoot biomass after 14, 21 and 28 days was not significantly different with Helix® and Helix XTra® . Improvements in shoot biomass in 2004 and 2005 indicate that Prosper®200, Prosper®400, Helix® and Helix® XTra enhance biomass accumulation when flea beetle damage is below the economic threshold. Of the treatments tested, Helix XTra® had the greatest positive effect on biomass accumulation in Polish canola when flea beetle damage was above or below the economic threshold.

Seed treatments had a significant effect on the yield of open-pollinated and synthetic Polish canola in 2003, 2004 and 2005. In each year of testing, yield of untreated seed was not significantly different from that of seeds treated with Foundation Lite®, Assail® or Gaucho®. Compared with untreated seed, low or high rates of Prosper® improved yields of the two cultivars by 4-26% in 2003, by 11-22% in 2005 and by 0-6% in 2005. Over 3 years, yields of the two Polish cultivars improved by 7% with the 200 g rate of Prosper® and by 12% with the 400 g rate of Prosper®. Compared to untreated seed, economic returns increased by $13.30/acre ($32.85/ha) with the 200 g rate of Prosper® and by $21.70/acre ($53.60/ha) with the 400 g rate of Prosper®. Helix® and Helix XTra® improved yields of the two cultivars by 16-39% in 2003, by 13-20% in 2004 and by 5-7% in 2005. Yields over 3 years improved by 11% with Helix® and by 17% with Helix XTra®. Economic returns increased by $20.30/acre ($50.14/ha) with Helix® and by $28.00/acre ($69.16/ha) Helix XTra®. Prosper® 400, Helix® and Helix XTra® were the only neonicotinoid seed treatments that improved yield significantly when flea beetle damage was above or below the economic threshold.

INTRODUCTION

The crucifer flea beetle, *Phyllotreta cruciferae* (Goeze), is a serious pest of summer turnip rape, *Brassica rapa* L., in western Canada (Anonymous 1997). After overwintering in canola stubble and non-crop areas, adult beetles migrate into canola fields and feed on emerging seedlings (Burgess 1977). Feeding injury to the cotyledons, true leaves and stems results in seedling mortality, reduced seedling growth, delayed maturity, reduced grade and lower seed yield (Putnam 1977, Lamb 1984, 1988). Natural enemies provide limited regulation of flea beetles, so canola producers are reliant on seed treatments and foliar-applied insecticides (Lamb and Turnock 1982, Weiss *et al*. 1991, Anonymous 1997). The latter treatment is recommended when the economic or action threshold for flea beetle damage (≥25% leaf surface) is exceeded (Anonymous 1997).

In 2001-2002, five neonicotinoid seed treatments were registered in Canada for control of flea beetles in canola. Seed treatments containing imidacloprid (Gaucho CS FL®), acetamiprid (Assail 50 SF®), clothianidin (Prosper FL®) or thiamethoxam (Helix®, Helix XTra®) were registered at rates ranging from 150 to 600 g AI/100 kg seed. However, limited information was available on the efficacy of the treatments against flea beetles and the effect of application rate on efficacy and agronomic performance. Neonicotinoid insecticides have translaminar and/or systemic activity in plants and inhibit nervous conduction in insects by blocking the nicotinic acetycholine receptor (Tomizawa and Casida 2003). In laboratory bioassays, synthetic neonicotinoids are more potent and have a greater margin of safety than nicotine (Tomizawa and Casida 2003). Recent findings also suggest that neonicotinoids have a direct effect on seedling growth in several field crops (Asrar *et al*. 2004). According to a patent issued in the U.S.A., neonicotinoid insecticides including acetamiprid, imidacloprid, clothianidin, thiamethoxam improve seedling vigour and seed yield when insect pest populations are below the economic threshold (Asrar *et al*. 2004). A technical bulletin, released in November 2006, states that thiamethoxam, the active ingredient in Helix® and Cruiser®, promotes faster emergence, greater plant stands, early canopy development, increased root mass and higher seed yield (Syngenta Crop Protection 2006).

The objectives of the present study were to determine the effect of neonicotinoid seed treatments on flea beetle damage and the performance of summer turnip rape. Cultivars of open-pollinated and synthetic *B. rapa* mature within 86-92 days (Falk 1997) and are typically seeded in late May or early June when flea beetle populations tend to decline (Milbrath *et al*. 1995). Experiments focused on the effect of seed treatments on flea beetle damage to the cotyledons, seedling emergence, stand establishment, shoot growth, biomass accumulation and seed yield.

EXPERIMENTAL METHODS

Field experiments

Field experiments were conducted in 2003, 2004 and 2005 at the Agriculture and Agri-Food Canada Research Farm at Saskatoon. Fertility requirements were based on yearly soil test recommendations for canola production. A fertilizer blend (N/P/K/S) was banded at 5-10 cm depth in the fall. A granular formulation of trifluralin (Treflan QR5) was applied at 27.9 kg/ha in October (2004 test) or at 17.0 kg/ha in early May (2003 and 2005 tests). The herbicide was incorporated with a cultivator and harrows.

Seed treatments

Tests were conducted annually on certified seed lots of a conventional open-pollinated cultivar and synthetic cultivar. Tests were done on ‘AC Parkland’ and ‘Hysyn 110' in 2003 and ‘AC Sunshine’ and ‘ACS-C7' in 2004 and 2005. Treatments included untreated seed, Foundation Lite® (fungicides only), Assail 50 SF® (400 g acetamiprid/100 kg seed), Gaucho CS FL® (400 g imidacloprid/100 kg seed), Prosper FL® (200g and 400 g clothianidin/100 kg seed), Helix® (200 g thiamethoxam/100 kg seed) and Helix XTra® (400 g thiamethoxam/100 kg seed). Each field experiment had four replicates arranged in a randomized split-plot design with cultivars as main plots and seed treatments as subplots. Untreated seeds and treated seeds were planted in six-row subplots at 200 seeds per 6.1 m row, 0.30 m row-spacing and 1.5-2.0 cm depth. Tests were planted on May 30 (2003 and 2005 tests) and June 4 (2004 test) with a four-cone, double-disc drill, equipped with on-row packers.

Sampling procedures

Flea beetle damage to 20 cotyledons from each subplot was assessed 14, 17-18 and 21 days after seeding (DAS) using a 10-point rating scale that corresponded to the percentage of cotyledon surface eaten by flea beetles (Palaniswamy *et al*. 1992). The crucifer flea beetle, *P. cruciferae*, was the predominant species present. Numbers of seedlings along a centre row of each subplot were counted 14, 21 and 28 DAS. Shoot growth was assessed by harvesting 10 plants randomly from the outer rows of each subplot 14, 21, 28 and 35 DAS. Samples were placed in plastic bags, labeled and transported to the laboratory in coolers. Shoots were cleaned and weighed to determine shoot fresh weight on a per plant basis. Samples were dried at 60°C for 4-7 days to assess shoot dry weight. Shoot biomass, expressed in g/m-row, was calculated from numbers of seedlings/m-row and shoot fresh weights 14, 21, 28 and 35 DAS. The four centre rows of each subplot were harvested at maturity with a small-plot combine. Samples were cleaned, dried and weighed to determine seed yield.

Statistical analyses

Data were analyzed using the General Linear Model procedure (SAS Institute, Inc. 1999). The Univariate procedure and Shapiro-Wilk statistic were used to evaluate variance and normality. To stabilize the variance among treatments, flea beetle damage was transformed using the arcsine square root function before analysis of variance (ANOVA). Shoot dry weights and shoot biomass on each sampling date were transformed using natural logarithms before ANOVA. Field data were analyzed as a split-split-plot design with years as main plots, cultivars as subplots and treatments as subsubplots. Comparisons were done on pooled data when associated interactions were not significant ($P \geq 0.05$). ANOVA or Fisher's protected LSD test ($P = 0.05$) was used to compare means among years, cultivars and seed treatments. Data were back-transformed for presentation.

RESULTS AND DISCUSSION

Yearly comparisons

Flea beetle damage, seedlings/row, shoot dry weight, shoot biomass and seed yield of Polish canola varied significantly from year to year (Tables 1 and 2). Flea beetle damage after 21 days was lower in 2005 (13% damage) than in 2003 (19% damage) or 2004 (19% damage). Seedling counts after 14, 21 and 28 days were higher in 2005 than in 2003 or 2004. Stand establishment after 28 days averaged 79% in 2005 compared with 67% in 2003 and 70% in 2004. Shoot dry weights and shoot biomass after 14, 21, 28 and 35 days were substantially higher in 2005 than in 2003 or 2004. Seed yields averaged 244.4 g/m^2 (43.5 bu/acre) in 2005 compared to 79.6 g/m^2 (14.2 bu/acre) in 2003 and 134.4 g/m^2 (23.9 bu/acre) in 2004.

Cultivar comparisons

Flea beetle damage, seedlings/row, shoot dry weight and shoot biomass were not significantly different in the open-pollinated cultivar and synthetic cultivar on most sampling dates (Tables 1 and 2). However, the year by cultivar interaction on seedlings/row, shoot dry weight and shoot biomass was significant on most sampling dates. The interactions indicated that the relative performance of the two cultivars varied from year to year. Seedling counts, shoot weights and shoot biomass were significantly higher in the synthetic cultivar than in the open-pollinated cultivar when flea beetle damage was relatively high in 2003. However, seedlings counts and shoot growth were not significantly different in the two cultivars when flea beetle damage was below the economic threshold in 2004 and 2005. Seed yields over 3 years were 5% higher in the synthetic cultivar (156.5 g/m^2) than in the open-pollinated cultivar (149.0 g/m^2).

Seed treatment comparisons

Seed treatments had a significant effect on flea beetle damage and agronomic performance of *B. rapa* (Tables 1 and 2). The year by treatment interaction on damage, seedlings/row, shoot dry weight and shoot biomass was significant on most sampling dates and indicated that differences among treatments varied from year to year. In contrast, the cultivar by treatment interaction on damage and performance was not significant on all sampling dates. The interactions indicated that treatment effects on damage and performance were similar in the two cultivars. With the exception of shoot dry weight and shoot biomass after 35 days, the year by cultivar by treatment interaction on damage and performance was also not significant on all sampling dates. The three-way interaction indicated that treatment effects in the two cultivars were consistent from year to year.

Flea beetle damage

Seed treatments had a significant effect on flea beetle damage after 14 days in 2003, 2004 and 2005 (Table 3). In each cultivar, damage was highest in seedlings grown from untreated seed and seeds treated with Foundation Lite®. Damage to seedlings grown from untreated seed was higher in 2003 (20-26% damage) than in 2004 (4-5% damage) or 2005 (4-6% damage). In treatments containing a neonicotinoid insecticide, damage was highest with Assail®. The treatment reduced damage to 12-15% in 2003, 4-7% in 2004 and 3-7% in 2005. Gaucho®, applied at a 400 g rate, provided slightly better protection than Assail®, reducing damage to 7-8% in 2004, 5% in 2004 and 3-5% in 2005. Seeds treated with Prosper®400 or Helix XTra® had the least flea beetle damage. Treatments reduced damage to 3-4% in 2003, 2-3% in 2004 and 1% in 2005. Damage in the Prosper®200 and Helix® treatments was also very low, averaging 4-5% in 2003, 3-4% in 2004 and 2-3% in 2005.

Seed treatments had a significant effect on flea beetle damage after 17-18 days in 2003, 2004 and 2005 (Table 4). Untreated seed and seeds treated with Foundation Lite® usually had the highest damage. Damage to seedlings from untreated seed averaged 29-31% in 2003, 14% in 2004 and 5-10% in 2005. Assail® provided relatively poor protection, reducing damage to 20-25% in 2003, 14-15% in 2004 and 6-10% in 2005. Gaucho® reduced damage to 12-15% in 2003, 14-16% in 2004 and 7-9% in 2005. Seedlings grown from seed treated with Prosper®400 or Helix® XTra had the least damage. Treatments reduced damage to 5-8% in 2003, 7-11% in 2004 and 1-3% in 2005. In most instances, Prosper®200 and Helix® provided a similar level of protection, reducing damage to 8% in 2003, 9-15% in 2004 and 3-6% in 2005.

Seed treatments had a significant effect on flea beetle damage after 21 days in 2003, 2004 and 2005 (Table 5). Damage was highest in the check, Foundation Lite® and Assail® treatments. Damage averaged 21-32% in 2003, 19-23% in 2004 and 11-15% in 2005. Damage exceeded the economic threshold in 2003 but not in 2004 or 2005. Damage was also relatively high in the Gaucho® treatment, averaging 14-23% in 2003, 19-21% in 2004 and 13-15% in 2005. Seeds treated with Prosper®200, Prosper®400, Helix® or Helix®XTra had the least damage. Treatments reduced damage to 10-15% in 2003, 15-19% in 2004 and 10-13% in 2005.

The effects of seed treatments on flea beetle damage to Polish canola over in 2003-2005 are summarized in Figure 1. On each of the three sampling dates, damage was highest in the check, Foundation Lite® and Assail® treatments. Gaucho® provided an intermediate level of protection. Compared to untreated seed, Gaucho® reduced damage by 5% after 14 days, by 4% after 17-18 days and by 3% after 21 days. Helix XTra® followed by Prosper®400, Helix® and Prosper®200 provided the best protection against flea beetle damage. Compared to untreated seed, treatments reduced damage by 7-9% after 14 days, by 8-12% after 17-18 days and by 6-8% after 21 days. In the Prosper® and Helix® treatments, the 400 g rate provided better flea beetle protection than the 200 g rate after 14-18 days but not after 21 days.

Emergence and establishment

The effect of seed treatments on seedlings/row 14 days after seeding varied yearly depending on moisture conditions and flea beetle damage (Table 6). Emergence of untreated seed of the two cultivars ranged from 58% with relatively high flea beetle damage and dry conditions in 2003 to 84% with very low flea beetle damage and moist conditions in 2005. Emergence of untreated seed over 3 years averaged 70% in the open-pollinated cultivar and 72% in the synthetic cultivar. Foundation Lite® and Assail® had little or no effect on seedling emergence. Over 3 years, emergence of seed treated with Foundation Lite® or Assail® averaged 70-71% in the open-pollinated cultivar and 68-72% in the synthetic cultivar. Compared to untreated seed, Assail® improved emergence by 5-9% in 2003 but had no effect on emergence in 2004 or 2005. Emergence improved significantly with other neonicotinoid seed treatments. Emergence of the open-pollinated cultivar over 3 years averaged 74-75% with Gaucho®, Prosper®200 or Helix® and 78% with Prosper®400 or Helix XTra®. Compared to untreated seed, Gaucho®, Prosper®200 and Helix® improved emergence by 9-11% in 2003, by 0-10% in 2004 and by 0% in 2005. Prosper®400 and Helix XTra® improved emergence by 15% in 2003, by 6-7% in 2004 and by 0-4% in 2005. Emergence of the synthetic cultivar over 3 years averaged 75-76% with Gaucho® or Helix® and 78-80% with Prosper®200, Prosper®400 or Helix XTra®. Compared to untreated seed, Gaucho® and Helix® improved emergence by 12-15% in 2003 and by 0-2% in 2004 and 2005. Prosper®200, Prosper®400 and Helix XTra® improved emergence by 16-18% in 2003, by 0-5% in 2004 and by 1% in 2005. Contrary to patent claims, neonicotinoid seed treatments did not promote faster emergence of Polish cultivars when flea beetle damage averaged less than 5% in 2004 and 2005.

The effect of seed treatments on seedlings/row 21 days after seeding varied yearly (Table 7). Establishment of untreated seed of the open-pollinated cultivar after 21 days averaged 56% in 2003, 68% in 2004 and 85% in 2005. Establishment of untreated seed of the synthetic cultivar averaged 61%, 68% and 83%, respectively. Establishment of untreated seed over 3 years averaged 70% in the open-pollinated cultivar and 71% in the synthetic cultivar. Foundation Lite® and Assail® had little effect on seedling establishment. Establishment of seeds treated with Foundation Lite® or Assail® over 3 years averaged 69% in the open-pollinated cultivar and 68-70% in the synthetic cultivar. Compared to untreated seed, Assail® improved establishment by 4-7% in 2003 and by 2% or less in 2004 and 2005. Establishment of the open-pollinated cultivar over 3 years averaged 74% with Gaucho®400, Prosper®200 or Helix® and 77% with Prosper®400 or Helix XTra®. Compared to untreated seed, Gaucho® Prosper®200 and Helix improved establishment of the open-pollinated cultivar by 8-10% in 2003, by 5-11% in 2004 and 0% in 2005. Prosper®400 and Helix XTra® improved establishment by 14% in 2003, by 6-10% in 2004 and by 0-1% in 2005. Establishment of the synthetic cultivar over 3 years averaged 73-76% with Assail®400, Prosper®200 or Helix® and 78% with Prosper®400 or Helix XTra®. Gaucho®, Prosper®200 and Helix® improved establishment of the synthetic cultivar by 10-15% in 2003 and by 3% or less in 2004 and 2005. Prosper®400 and Helix XTra® improved establishment by 15-18% in 2003 and by 3-8% in 2004. Neonicotinoid seed treatments had no positive effect on establishment of the two cultivars in 2005 when flea beetle damage averaged 20% or less.

The effect of seed treatments on seedlings/row after 28 days varied depending on the year and flea beetle damage (Table 8). Stand establishment of untreated seed of the two cultivars averaged 55-61% in 2003, 66-68% in 2004 and 81% in 2005. Stand establishment of untreated seed over 3 years averaged 68% in the open-pollinated cultivar and 70% in the synthetic cultivar. In most instances, Foundation Lite® and Assail®400 had no effect on stand establishment. Establishment of seeds treated with Foundation Lite® or Assail® over 3 years averaged 68% in the open-pollinated cultivar and 66-70% in the synthetic cultivar. Compared to untreated seed, Assail® improved establishment by 4-5% in 2003 and by 4% or less in 2004 and 2005. Stand establishment was higher with other seed treatments. Establishment of the open-pollinated cultivar over 3 years averaged 72% with Gaucho®400, Prosper®200 or Helix® and 75% with Prosper®400 or Helix XTra®. Compared to untreated seed, Gaucho®, Prosper®200 and Helix® improved establishment of the open-pollinated cultivar by 7-8% in 2003, by 4-10% in 2004 and by 1% or less in 2005. Prosper®400 and Helix XTra® improved establishment of the open-pollinated cultivar by 14-16% in 2003, by 2-6% in 2004 and by 3% or less in 2005. Establishment of the synthetic cultivar over 3 years averaged 72-74% with Gaucho®400, Prosper®200 or Helix® and 76% with Prosper®400 or Helix XTra®. Compared to untreated seed, Gaucho®, Prosper®200 and Helix® improved stand establishment of the synthetic cultivar by 9-13% in 2003 and by 5% or less in 2004 and 2005. Prosper®400 or Helix XTra® improved stand establishment by 13-16% in 2003 and by 3-7% in 2004. Neonicotinoid seed treatments had no significant effect on establishment of the two Polish cultivars when flea beetle damage averaged 15% or less in 2005.

Seed treatments had a significant effect on overall emergence and establishment of Polish canola in 2003-2005 (Fig. 2). Untreated seeds and seeds treated with Foundation Lite® or Assail® had the poorest emergence and establishment. Emergence of untreated seed of the two cultivars averaged 71% after 14 days; establishment averaged 69% after 28 days. Compared to untreated seed, Gaucho®400, Prosper®200 and Helix® improved emergence by 4-6% after 14 days and establishment by 3-4% after 28 days . Prosper®400 and Helix XTra® improved emergence by 7-8% and establishment by 5-6%. Seed treatments improved emergence and establishment when flea beetle damage exceeded 25% but not when damage averaged 15% or less.

Shoot growth

Seed treatments had little or no effect on the shoot dry weight of Polish cultivars after 14 days (Table 9). In the open-pollinated cultivar, shoot weights of untreated seed and treated seeds were not significantly different in 2003, 2004 and 2005. In the synthetic cultivar, shoot weights of seed treated with Gaucho®, Helix® or Helix XTra® were 1.3 times higher than shoot weights of untreated seed in 2003. Shoot weights of Helix® -treated seed over 3 years were 1.2 times higher than those of untreated seed.

Seed treatments had a significant effect on shoot dry weight after 21 days (Table 10). In each cultivar, untreated seeds and seeds treated with Foundation Lite® or Assail® had the lowest shoot weights. Seeds treated with Helix® or Helix XTra® had the highest shoot weights in the open-pollinated cultivar. Compared to untreated seed, Helix® and Helix XTra® improved shoot weights of the open-pollinated cultivar by 2.2-2.3 times in 2003, by 1.5-1.6 times in 2004, by 1.2-1.3 times in 2005 and by 1.4-1.5 times over 3 years. Prosper® 200 and Prosper® 400 improved shoot weights of the open-pollinated cultivar by 1.9-2.1 times in 2003, and by 1.2-1.3 times over 3 years. In the synthetic cultivar, Gaucho®, Prosper®200 and Prosper®400 improved shoot weights by 1.6-1.9 times in 2003, by 1.1-1.2 times in 2005 and by 1.2-1.3 times over 3 years. Seeds treated with Helix® or Helix XTra® had the highest shoot weight after 21 days. Compared to untreated seed, Helix®and Helix XTra® improved shoot weights by 1.9-2.5 times in 2003, by 1.3-1.5 times in 2004, by 1.2-1.4 times in 2005 and by 1.4-1.5 times over 3 years. Improvements in shoot weight of seed treated with 200 g or 400 g rates of Prosper®and Helix® were greater when flea beetle damage was high in 2003 than when flea beetle damage was low in 2004 and 2005. The latter data support the patent claim that neonicotinoid seed treatments promote seedling vigour and canopy development when flea beetle damage averages 20% or less.

Seed treatments had a pronounced effect on shoot dry weight after 28 days(Table 11). In each cultivar, shoot weights of untreated seed and seeds treated with Foundation Lite® or Assail® were not significantly different in most tests. Seeds treated with low or high rates of Prosper® or Helix® had the highest shoot weights. Compared to untreated seed, Prosper®200 or Prosper®400 improved shoot weights of the open-pollinated cultivar by 1.5-1.9 times in 2003, by 1.2-1.4 times in 2004, by 1.2-1.4 times in 2005 and by 1.3-1.4 times over 3 years. The low or high rate of Prosper® improved shoot weights of the synthetic cultivar by 2.3-2.4 times in 2003, by 1.2-1.3 times in 2004, by 1.4-1.5 times in 2005 and by 1.6 times over 3 years. Helix® and Helix®XTra improved shoot weights of the open-pollinated cultivar by 1.7-2.0 times in 2003, by 1.3-1.4 times in 2004, by 1.2-1.4 times in 2005 and by 1.3-1.5 times over 3 years. Helix® and Helix XTra® improved shoot weights of the synthetic cultivar by 2.4-2.7 times in 2003, by 1.3-1.6 times in 2004, by 1.3-1.4 times in 2005 and by 1.5-1.6 times over 3 years. Improvements in shoot weight were greater when flea beetle damage was high than when flea beetle damage was low. Results indicated that low or high rates of Prosper® and Helix® promote shoot growth when flea beetle damage is below the economic threshold.

Seed treatments had a significant effect on shoot dry weight after 35 days (Table 12). In each cultivar, shoot weights of untreated seed and seeds treated with Foundation Lite®, Assail® or Gaucho® were not significantly different in 2003, 2004 and 2005. Seeds treated with the low or high rate of Prosper®, Helix® or Helix XTra® had the highest shoot weight. Compared to untreated seed, treatments improved shoot weights of the open-pollinated cultivar by 1.7-2.1 times in 2003, by 1.2-1.5 times in 2004 and by 1.2-1.3 times over 3 years. Treatments improved shoot weights of the synthetic cultivar by 1.5-2.0 times in 2003 and by 1.1-1.4 times over 3 years. In most tests, seeds treated with Helix XTra® had the highest shoot weight after 35 days.

Seed treatments had a significant effect on shoot dry weights of Polish canola after 14-35 days in 2003-2005 (Fig. 3). Untreated seeds and seeds treated with Foundation Lite® or Assail® had the lowest shoot weights 21, 28 and 35 DAS. Conversely, seeds treated with Prosper®200, Prosper®400, Helix® or Helix XTra® had the highest shoot weights after 21, 28 and 35 days. Compared to untreated seed, low or high rates of Prosper® improved shoot weights after 21, 28 and 35 days by 1.2-1.5 times. Helix® and Helix XTra® improved shoot weights after 21, 28 and 35 days by 1.3-1.5 times. Seeds treated with Helix XTra® had the highest shoot weight after 35 days. Results indicated that Helix XTra® had the greatest positive effect on shoot growth of Polish canola when flea beetle damage was above and below the action threshold.

Biomass accumulation

Seed treatments had little effect on the shoot biomass of Polish cultivars after 14 days (Table 13). In most instances, the shoot biomass of untreated seeds was not significantly different from that of treated seeds. However, there were several exceptions. Compared to untreated seed, Helix® improved shoot biomass of the open-pollinated cultivar by 1.5 times in 2003. Gaucho®, Prosper®200, Prosper®400, Helix® and Helix XTra® improved shoot biomass of the synthetic cultivar by 1.7-2.1 times in 2003. Prosper®200, Prosper®400, Helix® and Helix XTra® improved shoot biomass of the synthetic cultivar by 1.1-1.3 times in 3 years of testing.

Seed treatments had a significant effect on the shoot biomass of Polish cultivars after 21 days (Table 14). In all tests, the shoot biomass of untreated seeds and seeds treated with Foundation Lite® or Assail® were not significantly different. Shoot biomass was higher in seeds treated with Gaucho®, Prosper® or Helix®. Compared to untreated seed, Gaucho® improved the shoot biomass of the open-pollinated cultivar by 1.5 times in 2004 and the shoot biomass of the synthetic cultivar by 2.2 times in 2003. Low or high rates of Prosper® improved the shoot biomass of the open-pollinated cultivar by 2.8 times in 2003, by 1.4 times in 2004 and by 1.1-1.3 times over 3 years. Prosper® treatments improved the shoot biomass of the synthetic cultivar by 2.3-2.6 times in 2003 and by 1.3 times over 3 years. Helix® and Helix XTra® improved the shoot biomass of the open-pollinated cultivar by 3.0-3.5 times in 2003, by 1.8-1.9 times in 2004, by 1.1-1.3 times in 2005 and by 1.3-1.5 times over 3 years. The treatments improved the shoot biomass of the synthetic cultivar by 2.7-3.2 times in 2003, by 1.3-1.6 times in 2004, by 1.2-1.4 times in 2005 and by 1.4-1.5 times over 3 years. Compared to untreated seed, Helix XTra® was the only neonicotinoid seed treatment that provided a significant increase in biomass in all field tests. Improvements in shoot biomass were greater with high flea beetle damage in 2003 than with low flea beetle damage in 2004 or 2005. The latter data support the claim that Helix XTra® promotes canopy development when flea beetle damage is below the economic threshold.

Seed treatments had a substantial effect on shoot biomass after 28 days (Table 15). In the open-pollinated cultivar, the shoot biomass of untreated seed and seeds treated with Foundation Lite®, Assail® or Gaucho® were not significantly different in 2003, 2004 or 2005. Seeds treated with low or high rates of Prosper®, Helix® or Helix XTra® had the highest shoot biomass. Compared to untreated seed, Prosper treatments improved the biomass of the open-pollinated cultivar by 1.9-2.5 times in 2003, by 1.4-1.6 times in 2004 by 1.2-1.4 times in 2005 and by 1.4 times over 3 years. Helix® and Helix XTra® improved biomass of the open-pollinated cultivar by 2.1-2.7 times in 2003, by 1.5-1.6 times in 2004, by 1.2-1.4 times in 2005 and by 1.3-1.6 times over 3 years. In the synthetic cultivar, the shoot biomass of untreated seed and seeds treated with Foundation Lite® or Assail® were not significantly different in most tests. Compared to untreated seed, Gaucho improved shoot biomass by 3.2 times in 2003. Low or high rates of Prosper® improved the shoot biomass of the synthetic cultivar by 2.8-3.1 times in 2003, by 1.5 times in 2005 and by 1.7 times in 2003-2005. Helix® and Helix XTra® improved the shoot biomass of the synthetic cultivar by 3.2-3.4 times in 2003, by 1.3-1.6 times in 2004, by 1.3-1.4 times in 2005 and by 1.6-1.7 times in 2003-2005. Results indicated that the latter treatments had the greatest positive effect on biomass accumulation when flea beetle damage was above and below the economic threshold.

Seed treatments had a significant effect on the shoot biomass after 35 days (Table 16). In most tests, the shoot biomass of untreated seed and seeds treated with Foundation Lite®, Assail® or Gaucho® were not significantly different. In the open-pollinated cultivar, low or high rates of Prosper® improved shoot biomass by 2.2-2.4 times in 2003, by 1.3-1.4 times in 2004 and by 1.2-1.3 times in 2003-2005. Helix® and Helix XTra® improved the shoot biomass of the open-pollinated cultivar by 2.0-2.6 times in 2003, by 1.4-1.6 times in 2004, and by 1.2-1.4 times in 2003-2005. Low or high rates of Prosper® improved the shoot biomass of the synthetic cultivar by 1.8-1.9 times in 2003, by 1.4-1.5 times in 2004 and by 1.2 times in 2003-2005. Helix® and Helix XTra® improved the shoot biomass of the synthetic cultivar by 1.9-2.5 times in 2003, by 1.5 times in 2004, by 1.1-1.3 times in 2005 and by 1.3-1.5 times in 2003-2005. Helix XTra® had the greatest positive effect on biomass accumulation when flea beetle damage was above and below the economic threshold.

Seed treatments had a significant effect on the shoot biomass of Polish canola after 14, 21, 28 and 35 days in 2003-2005 (Fig. 4). Untreated seed and seeds treated with Foundation Lite® or Assail® had the lowest biomass on each of the four sampling dates. Compared to untreated seed, Gaucho® improved shoot biomass after 21, 28 and 35 days by 1.0-1.1 times. Low or high rates of Prosper® improved biomass on the three sampling dates by 1.2-1.6 times. Helix® and Helix XTra® improved biomass 1.3-1.6 times. Over 3 years of testing, seeds treated with Helix XTra® had the highest shoot biomass after 35 days.

Seed yield

Seed treatments had a significant effect on the yield of Polish cultivars in 2003, 2004 and 2005 (Table 17, Fig. 5). In each cultivar, yields of untreated seed were not significantly different from those of seeds treated with Foundation Lite®, Assail® or Gaucho®. Compared to untreated seed, low or high rates of Prosper® improved yields of the open-pollinated cultivar by 13-19% in 2003, by 16-22% in 2004, by 0-6% in 2006 and by 7-11% in 2003-2005. Treatments improved yields of the synthetic cultivar by 4-26% in 2003, by 11-19% in 2004, by 5-6% in 2005 and by 7-13% in 2003-2005. Yields were not significantly different with 200 g and 400 g rates of Prosper® in 4/6 tests. Yields of the two cultivars over 3 years improved by 7% with the 200 g rate of Prosper® and by 12% with the 400 g rate of Prosper®. Helix® and Helix XTra® improved yields of the open-pollinated cultivar by 38-39% in 2003, by 15-30% in 2004, by 5-7% in 2005 and by 13-18% in 2003-2005. Helix® and Helix XTra® improved the yields of the synthetic cultivar by 16-25% in 2003, by 13-26% in 2004, by 5-7% in 2005 and by 9-16% in 2003-2005. Yields were not significantly different with Helix® and Helix XTra® in 5/6 tests. Yields of the two Polish cultivars over 3 years improved by 11% with Helix® and by 17% with Helix XTra®. The latter treatment provided the highest yield over 3 years.

Low or high rates of Prosper® and Helix® had a significant effect on yield and economic return of Polish canola in 2003-2005 (Table 18). Seed yield over 3 years was significantly higher with the 400 g rate of Prosper® (28.7 bu/acre) than the 200 g rate of Prosper® (27.5 bu/acre). Based on $7.00/bu canola, economic returns over 3 years averaged $13.30/acre with the 200 g rate of Prosper® and $21.70/acre with the 400 g rate of Prosper®. The high rate of Prosper® provided better returns than the low rate of Prosper® when flea beetle damage exceeded the economic threshold in 2003 and when damage was below the economic threshold in 2004 and 2005. Seed yield over 3 years was also higher with Helix XTra® (29.9 bu/acre) than with Helix® (28.5 bu/acre). Returns averaged $20.30/acre with Helix® and $28.00/acre with Helix Xtra®. Helix XTra® provided the highest yield and best returns when flea beetle damage was above the economic threshold in 2003 and when damage was below the action threshold in 2004 and 2005. The 400 g rate of Prosper, Helix® and Helix XTra® were the only neonicotinoid seed treatments that improved yield significantly when flea beetle damage was above or below the economic threshold.

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Table 1. Overall flea beetle damage and seedlings/row of open-pollinated and synthetic Polish canola on selected days after seeding in 2003-2005.

	Damage (% area)			Seedlings/row		
Variable	14 DAS	17-18 DAS	21 DAS	14 DAS	21 DAS	28 DAS
year						
2003	10a	16a	19a	141.4a	136.2a	133.2a
2004	4b	13a	19a	142.0a	142.2a	139.7a
2005	3b	5b	13b	163.1b	160.4b	157.1b
SE	1	1	1	2.5	2.7	2.9
cultivar						
op	5a	11a	17a	147.6a	145.8a	142.5a
synthetic	6b	11a	16a	150.1a	146.8a	144.1a
SE	1	1	1	1.1	1.3	1.2
F value						
Year (Y)	13.8**	37.5***	19.5***	50.9***	43.0***	35.8***
Cultivar (C)	9.4*	2.2	0.4	4.7	0.7	1.6
Y x C	1.1	1.9	1.1	34.5***	32.0***	33.7***
Treatment (T)	41.3***	46.5***	20.8***	16.9***	15.0***	11.8***
Y x T	10.3***	10.6***	8.9***	5.0***	4.2***	4.0***
C x T	0.8	1.9	1.2	0.9	0.5	0.6
Y x C x T	0.5	0.8	0.9	1.5	1.2	1.4

a-b For each variable, means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, ANOVA, $P \geq 0.05$). Damage data were transformed (arcsine square root) before analysis. DAS, days after seeding. *, **, *** F value significant at P = 0.05, 0.01 and 0.001, respectively.

Table 2. Overall shoot dry weight, shoot biomass and seed yield of open-pollinated and synthetic Polish canola on selected days after seeding in 2003-2005.

Variable	Shoot dry weight (mg/plant)				Shoot biomass (g/m-row)				Seed yield (g/m^2)
	14 DAS	21 DAS	28 DAS	35 DAS	14 DAS	21 DAS	28 DAS	35 DAS	
year									
2003	8.7b	55.7b	300.2b	904.6b	1.8b	10.7b	58.1b	187.8b	79.6a
2004	4.9a	20.0a	122.6a	362.7a	0.8a	3.3a	24.0a	113.7a	134.4b
2005	16.7c	160.0c	659.5c	2453.7c	4.7c	44.5c	201.5c	909.0c	244.4c
SE	0.6	2.8	31.9	129.2	0.2	0.7	8.5	46.5	4.7
cultivar									
op	9.5a	78.2a	357.2a	1278.4a	2.3a	19.7a	95.8a	423.3a	149.0a
synthetic	10.6b	78.9a	364.3a	1202.3a	2.5b	19.4a	93.3a	383.7a	156.5b
SE	0.2	1.6	15.8	65.6	0.1	0.5	5.2	26.3	3.1
F value									
Year (Y)	188.0***	612.9***	304.5***	300.7***	271.9***	784.3***	350.3***	236.3***	643.4***
Cultivar (C)	25.7***	3.0	0.2	0.1	6.8*	3.0	0.1	0.1	5.8*
Y x C	1.3	5.6*	5.5*	5.0*	4.3*	12.6**	8.3**	7.6*	7.3*
Treatment (T)	3.8***	22.7***	19.5***	24.1***	8.1***	27.2***	27.3***	28.5***	16.8***
Y x T	1.2	4.0***	2.8**	4.1***	2.4**	5.6***	3.4***	3.6***	1.6
C x T	0.8	0.2	1.3	1.5	0.8	0.2	1.4	1.3	0.4
Y x C x T	0.7	0.7	1.5	1.8*	0.9	0.9	1.8	2.0*	0.7

a-b For each variable, means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, ANOVA, $P \geq 0.05$). Shoot weight and shoot biomass were transformed (natural logarithm) before analysis. DAS, days after seeding. *, **, *** F value significant at P = 0.05, 0.01 and 0.001, respectively.

Table 3. Effect of seed treatments on flea beetle damage to cotyledons of open-pollinated and synthetic Polish canola 14 days after seeding in 2003-2005. [1]

Treatment	Rate	Damage - op (%)				Damage - syn (%)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	20ab	4ab	4a	9a	26a	5ab	6ab	12a
Foundation Lite®	-	23a	5a	3a	10a	22a	5ab	5b-d	10a
Assail 50 SF®	400	15b	4a	3a	7ab	12b	7a	7a	9a
Gaucho CS FL®	400	7c	5a	3a	5bc	8bc	5ab	5a-c	6b
Prosper®	200	4c	3a-c	2ab	3de	5cd	4bc	3c-e	4c
Prosper®	400	4c	2c	1b	2e	4d	3c	1e	3d
Helix®	200	5c	4a	2ab	4cd	4d	4bc	2de	3cd
Helix XTra®	400	3c	2bc	1b	2e	4d	3c	1e	3d
	SE	3	1	1	1	3	1	1	1

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Rate expressed as g AI/100 kg seed. In this and subsequent tables, open-pollinated (op), synthetic (syn).

Table 4. Effect of seed treatments on flea beetle damage to cotyledons of open-pollinated and synthetic Polish canola 17-18 days after seeding in 2003-2005. [1]

		Damage - op (%)				Damage - syn (%)			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	29ab	14a	5a-c	16b	31a	14ab	10a	18a
Foundation Lite®	-	32a	16a	8a	19a	27a	16a	5a-c	16ab
Assail 50 SF®	400	25b	15a	6a	15b	20b	14ab	10a	14ab
Gaucho CS FL®	400	15c	14a	7a	12b	12c	16a	9ab	12bc
Prosper®	200	8d	12ab	3bc	8c	8c	15ab	6a-c	10cd
Prosper®	400	8d	9c	2cd	6c	8c	11b	2d	7e
Helix®	200	8d	9bc	5ab	7c	8c	12ab	5b-d	8de
Helix XTra®	400	5d	7c	1d	4d	7c	10b	3cd	6e
	SE	3	2	2	1	3	2	2	1

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Rate expressed as g AI/100 kg seed.

Table 5. Effect of seed treatments on flea beetle damage to cotyledons of open-pollinated and synthetic Polish canola 21 days after seeding in 2003-2005. [1]

Treatment	Rate	Damage - op (%)				Damage - syn (%)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	27ab	19a-c	15a	20ab	30a	20a	11b	20a
Foundation Lite®	-	32a	20ab	15a	22a	28a	20a	13ab	20a
Assail 50 SF®	400	28ab	23a	15a	21ab	21b	19a	12ab	17ab
Gaucho CS FL®	400	23b	19a-c	13a	18b	14c	21a	15a	17bc
Prosper®	200	15c	16bc	13a	14c	12c	19a	13ab	15b-d
Prosper®	400	13c	16bc	11a	13c	13c	19a	11ab	14cd
Helix®	200	11c	16bc	12a	13c	11c	19a	12ab	14d
Helix XTra®	400	10c	15c	12a	12c	11c	17a	10b	13d
	SE	4	2	2	2	3	2	2	1

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Rate expressed as g AI/100 kg seed.

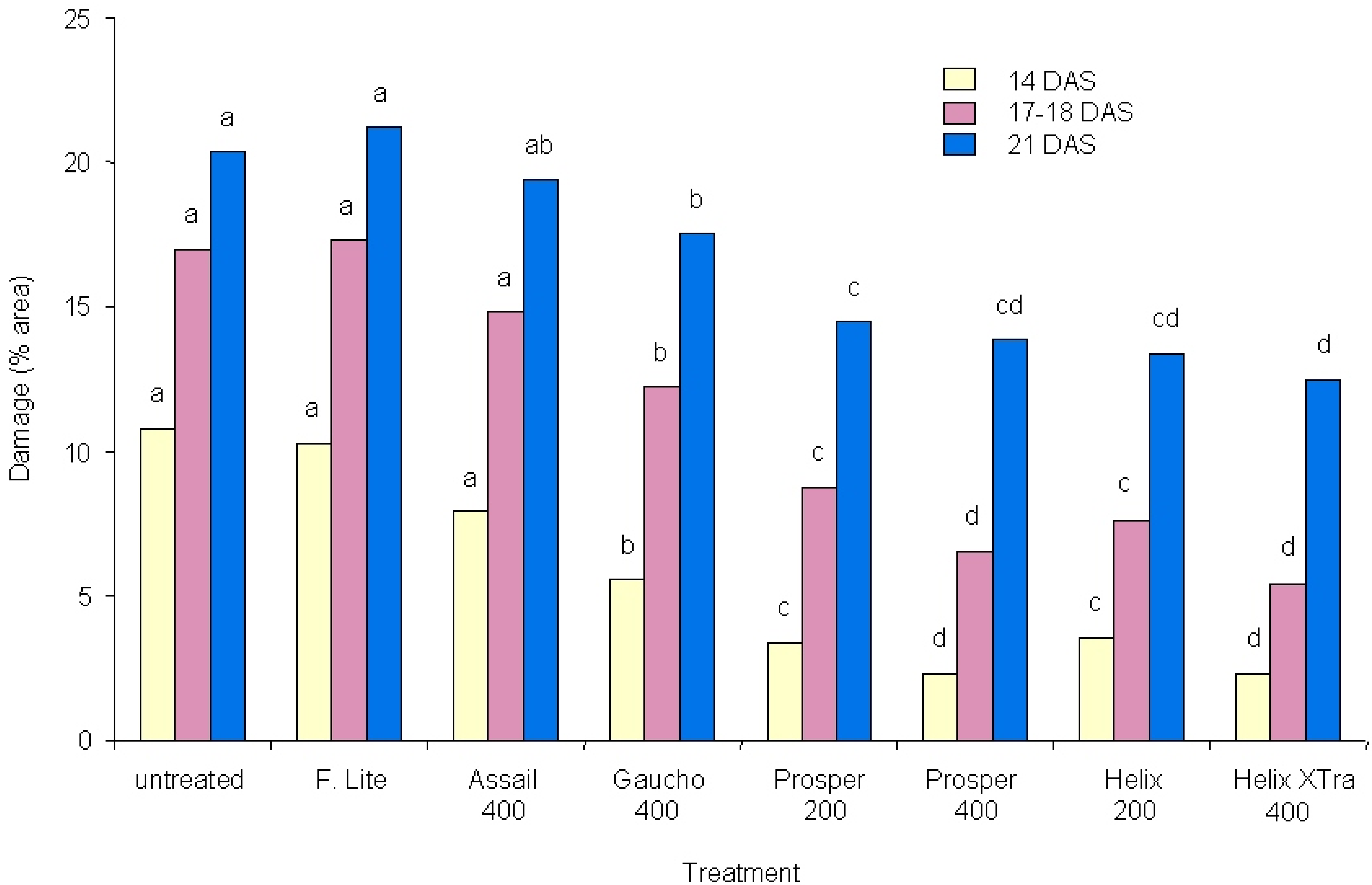

Figure 1. Flea beetle damage to cotyledons of untreated and treated Polish canola (n=2 cultivars) after 14, 17-18 and 21 days in 2003-2005. For each sampling time, vertical bars with the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$).

Table 6. Effect of seed treatments on numbers of seedlings/row of open-pollinated and synthetic Polish canola 14 days after seeding in 2003-2005. [1]

Treatment	Rate	Seedlings/row - op				Seedlings/row - syn			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	115.5a	138.8ab	168.3ab	140.8a	125.3a	139.8bc	168.0c	144.3b
Foundation Lite®	-	126.8b	130.0a	161.0ab	139.3a	141.8b	125.3a	143.8a	136.9a
Assail 50 SF®	400	126.3b	138.8ab	159.3ab	141.4a	143.8b	136.3a-c	154.0ab	144.7b
Gaucho CS FL®	400	133.3bc	157.8c	161.5ab	150.8bc	155.0c	144.8bc	153.3ab	151.0bc
Prosper®	200	137.3cd	138.8ab	170.0b	148.7b	157.5c	144.0c bc	170.0c	157.2cd
Prosper®	400	146.8d	150.5bc	168.3ab	155.2bc	159.5c	149.3c	169.5c	159.4d
Helix®	200	137.5cd	152.0c	156.5a	148.7b	150.5bc	135.3ab	165.0bc	150.3bc
Helix XTra®	400	145.3d	151.5c	171.0b	155.9c	161.3c	138.8a-c	170.3c	156.8cd
	SE	4.9	5.8	6.2	3.3	5.4	6.6	6.0	3.5

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, P ≥0.05). Varieties were seeded at 200 seeds per 6.1 m row.

Table 7. Effect of seed treatments on numbers of seedlings/row of open-pollinated and synthetic Polish canola 21 days after seeding in 2003-2005. [1]

		Seedlings/row - op				Seedlings/row - syn			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	112.0a	136.8ab	169.3bc	139.3a	121.8a	136.5bc	165.8c	141.3ab
Foundation Lite®	-	121.8a-c	132.0a	160.0a-c	137.9a	140.0bc	122.3a	143.3a	135.2a
Assail 50 SF®	400	119.0ab	140.0ab	153.0a	137.3a	136.5b	131.0ab	154.3a-c	140.6ab
Gaucho CS FL®	400	128.0bc	157.8c	159.3a-c	148.3b	148.5b-d	141.5c	150.8ab	146.9bc
Prosper®	200	132.8cd	146.5bc	163.8a-c	147.7b	152.0cd	141.8c	163.0bc	152.3cd
Prosper®	400	141.5d	155.5c	163.3a-c	153.4b	152.3cd	152.3d	165.8c	156.8d
Helix®	200	132.3cd	154.8c	156.3ab	147.8b	141.0bc	136.0bc	162.3bc	146.4bc
Helix XTra®	400	142.5d	148.5bc	172.0c	154.3b	158.0d	142.8cd	164.8bc	155.2d
	SE	6.0	6.2	7.1	3.7	6.4	4.9	7.1	3.6

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Varieties were seeded at 200 seeds per 6.1 m row.

Table 8. Effect of seed treatments on numbers of seedlings/row of open-pollinated and synthetic Polish canola 28 days after seeding in 2003-2005. [1]

		Seedlings/row - op				Seedlings/row - syn			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	109.5a	136.5ab	161.8ab	135.9a	122.5a	132.3b	162.5bc	139.1b
Foundation Lite®	-	120.0ab	133.5a	154.0ab	135.8a	140.5bc	117.0a	136.3a	131.3a
Assail 50 SF®	400	117.3ab	138.8ab	153.0a	136.3ab	132.0ab	140.3bc	149.5b	140.6b
Gaucho CS FL®	400	123.0b	152.3cd	155.0ab	143.4bc	143.8bc	141.0bc	150.0bc	144.9bc
Prosper®	200	126.5bc	144.0a-d	163.3ab	144.6c	147.0bc	137.8bc	161.5bc	148.8c
Prosper®	400	138.5cd	148.8b-d	162.0ab	149.8c	147.8c	146.0c	162.5bc	152.1c
Helix®	200	126.8bc	155.0d	152.0a	144.6c	141.0bc	132.8b	160.8bc	144.8bc
Helix XTra®	400	141.5d	140.8a-c	167.3b	149.8c	153.5c	138.0bc	162.8c	151.4c
	SE	6.0	6.4	6.8	3.7	7.5	4.7	6.4	3.6

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Varieties were seeded at 200 seeds per 6.1 m row.

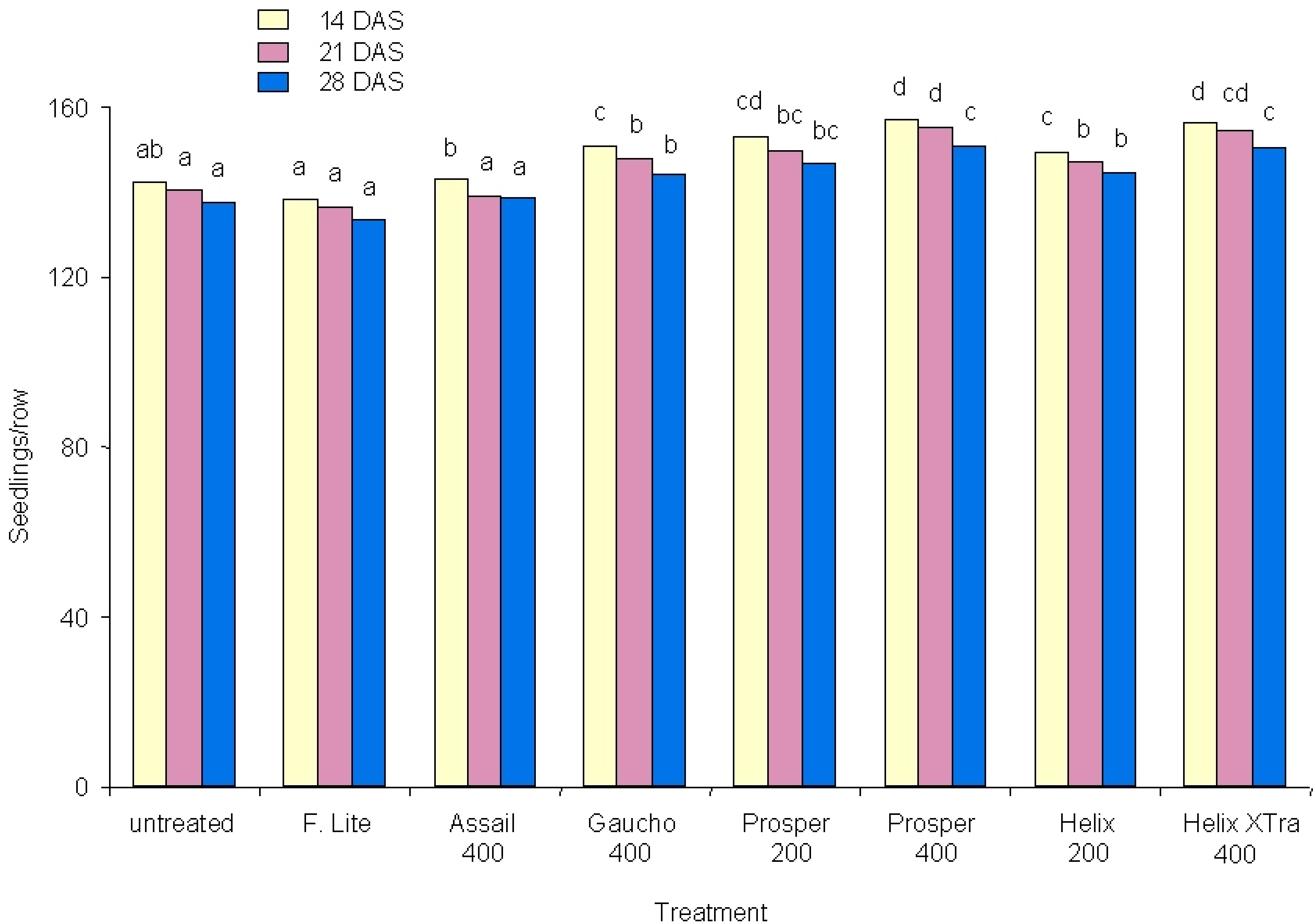

Fig. 2. Number of seedlings/row of untreated and treated Polish canola (n=2 cultivars) after 14, 21 and 28 days in 2003-2005. For each sampling time, vertical bars with the same letter are not significantly different (Fisher's protected LSD test, P>0.05). Entries were seeded at 200 seeds per 6.1 m row.

Table 9. Effect of seed treatments on shoot dry weight of open-pollinated and synthetic Polish canola 14 days after seeding in 2003-2005. [1]

Treatment	Rate	Shoot dry wt. - op (mg/plant)				Shoot dry wt. - syn (mg/plant)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	8.7ab	4.8a	16.0a-c	9.8ab	7.8a	5.5ab	17.3ab	10.2ab
Foundation Lite®	-	7.8ab	4.1a	17.0bc	9.6a	8.7ab	4.3a	17.8ab	10.3a
Assail 50 SF®	400	7.2a	5.0a	14.1a	8.8a	8.9ab	5.4ab	16.2a	10.2ab
Gaucho CS FL®	400	7.5a	4.6a	15.7a-c	9.2a	10.4b	4.5ab	15.7a	10.2ab
Prosper®	200	8.8ab	4.3a	15.6a-c	9.6a	9.8ab	4.7ab	16.5ab	10.3ab
Prosper®	400	7.1a	4.5a	15.0ab	8.9a	8.7ab	5.1ab	17.1ab	10.3ab
Helix®	200	9.6b	5.0a	18.9c	11.2b	10.4b	5.9b	19.6b	12.0c
Helix XTra®	400	7.2a	4.7a	16.0a-c	9.3a	10.4b	5.4ab	18.9ab	11.6bc
	SE	0.9	0.6	1.5	0.6	1.1	0.7	1.5	0.7

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

Table 10. Effect of seed treatments on shoot dry weight of open-pollinated and synthetic Polish canola 21 days after seeding in 2003-2005. [1]

Treatment	Rate	Shoot dry wt. - op (mg/plant)				Shoot dry wt. - syn (mg/plant)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	31.8a	15.9a	157.2bc	68.3ab	38.4a	17.8ab	138.9ab	65.0a
Foundation Lite®	-	28.5a	16.9a	129.4a	58.3a	38.3a	17.6ab	134.4a	63.4a
Assail 50 SF®	400	32.6a	18.7ab	154.7bc	68.7ab	44.0ab	16.2a	129.3a	63.2a
Gaucho CS FL®	400	41.4ab	19.6ab	152.3ab	71.1bc	60.4bc	18.8ab	159.2bc	79.5b
Prosper®	200	66.3c	19.6ab	174.2b-d	86.7de	72.4cd	21.5a-c	155.4bc	83.1bc
Prosper®	400	60.7bc	18.7ab	163.6bc	81.0cd	66.6cd	18.7ab	163.5c	82.9b
Helix®	200	69.3c	25.1b	183.3cd	92.5e	94.5d	23.8bc	167.5c	95.3c
Helix XTra®	400	72.0c	24.0b	201.7d	99.2e	74.0cd	26.6c	195.9d	98.8c
	SE	10.4	3.0	13.2	5.7	12.8	3.1	11.1	5.7

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, P ≥ 0.05). Means in 2003, 2004 and 2005 based on 40 plants.

Table 11. Effect of seed treatments on shoot dry weight of open-pollinated and synthetic Polish canola 28 days after seeding in 2003-2005. [1]

		Shoot dry wt. - op (mg/plant)				Shoot dry wt. - syn (mg/plant)			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	183.5ab	114.4a-c	581.8a	293.2a	175.0a	99.8ab	514.3a	263.0ab
Foundation Lite®	-	186.0ab	95.3a	635.0ab	305.4a	156.0a	77.2a	640.3a-c	291.1a
Assail 50 SF®	400	164.8a	107.1ab	628.3ab	300.0a	294.3b	105.1ab	500.3a	299.9b
Gaucho CS FL®	400	218.5a-c	107.1ab	645.0ab	323.5a	427.0bc	111.4bc	573.5ab	370.6c
Prosper®	200	281.0b-d	163.7d	785.3c	410.0b	426.0bc	119.6bc	731.3c	425.6c
Prosper®	400	338.8cd	140.1b-d	703.0bc	394.0b	394.5bc	128.6bc	747.8c	423.6c
Helix®	200	316.0cd	149.7cd	707.8bc	391.1b	468.3c	130.7bc	692.5bc	430.5c
Helix XTra®	400	362.3d	156.4d	802.0c	440.2b	411.3bc	155.1c	664.3bc	410.2c
	SE	60.4	20.8	46.8	26.4	70.5	17.7	70.7	34.3

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

Table 12. Effect of seed treatments on shoot dry weight of open-pollinated and synthetic Polish canola 35 days after seeding in 2003-2005. [1]

		Shoot dry wt. - op (mg/plant)				Shoot dry wt. - syn (mg/plant)			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	579.0a	346.8b	2434.0a	1119.9b	716.8a	301.5ab	2234.8a	1084.3a
Foundation Lite®	-	482.0a	338.0b	2516.3a	1112.1ab	749.5a	216.8a	2041.5a	1002.6a
Assail 50 SF®	400	490.5a	254.0a	2446.3a	1063.6a	719.8a	360.0b	2033.8a	1037.8ab
Gaucho CS FL®	400	604.8a	325.0ab	2813.0a	1247.6b	889.5ab	227.0a	2168.5a	1095.0a
Prosper®	200	1136.0b	455.3c	2760.3a	1450.5cd	1088.3bc	410.8b	2306.3ab	1268.4c
Prosper®	400	1096.5b	412.5bc	2550.3a	1353.1c	1104.3bc	377.3b	2140.8a	1207.4bc
Helix®	200	993.5b	406.5bc	2787.3a	1395.8c	1200.5c	429.3b	2467.3ab	1365.7cd
Helix XTra®	400	1201.1b	508.8c	2743.5a	1484.4d	1422.0c	434.0b	2816.0b	1557.3d
	SE	130.8	48.0	297.1	109.4	146.0	59.4	237.7	95.1

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

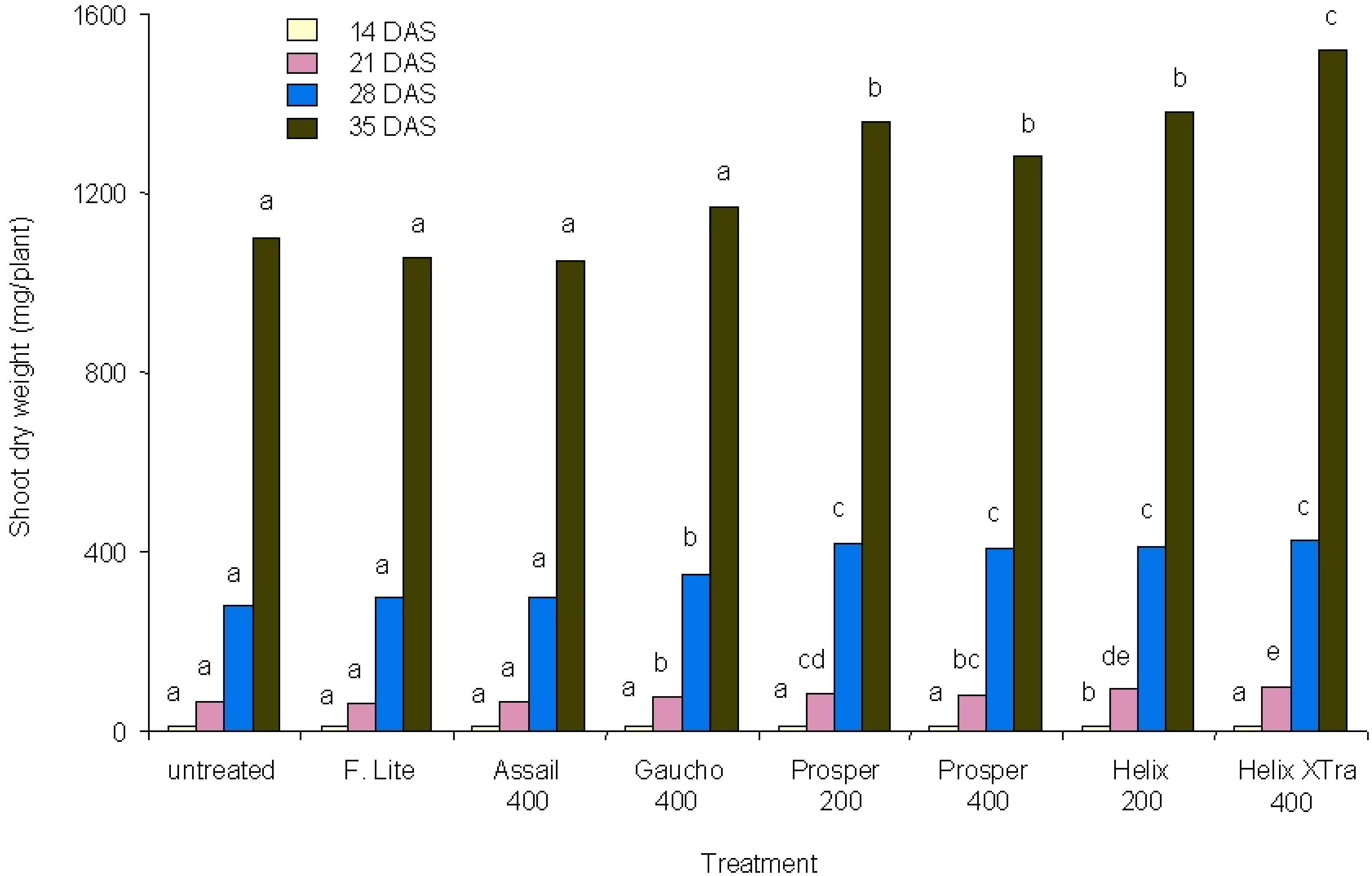

Fig. 3. Shoot dry weight of untreated and treated Polish canola (n=2 cultivars) after 14, 21, 28 and 35 days in 2003-2005. For each sampling time, vertical bars with the same letter are not significantly different (Fisher's protected LSD test, P>0.05). Means are based on 240 plants.

Table 13. Effect of seed treatments on shoot biomass of open-pollinated and synthetic Polish canola 14 days after seeding in 2003-2005. [1]

Treatment	Rate	Shoot biomass - op (g/m-row)				Shoot biomass - syn (g/m-row)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	1.3ab	0.7ab	4.5ab	2.2ab	1.2a	0.8b	4.7a-c	2.3a
Foundation Lite®	-	1.4ab	0.6a	4.7ab	2.2ab	1.6ab	0.6a	4.3ab	2.2a
Assail 50 SF®	400	1.4a	0.8ab	3.9a	2.0a	1.7bc	0.8ab	4.1a	2.2ab
Gaucho CS FL®	400	1.5ab	0.8ab	4.4ab	2.2ab	2.2cd	0.7ab	4.0a	2.3a-c
Prosper®	200	1.8bc	0.7ab	4.5ab	2.4ab	2.3d	0.7ab	4.7a-c	2.6cd
Prosper®	400	1.6a-c	0.8ab	4.5ab	2.3ab	2.0b-d	0.8b	4.9a-c	2.6b-d
Helix®	200	2.0c	0.9b	5.2b	2.7c	2.3d	0.9b	5.4bc	2.9d
Helix XTra®	400	1.6a-c	0.9b	4.9ab	2.5bc	2.5d	0.8b	5.6c	3.0d
	SE	0.2	0.1	0.5	0.2	0.3	0.1	0.5	0.2

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

Table 14. Effect of seed treatments on shoot biomass of open-pollinated and synthetic Polish canola 21 days after seeding in 2003-2005. [1]

Treatment	Rate	Shoot biomass - op (g/m-row)				Shoot biomass - syn (g/m-row)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	4.3a	2.4a	46.5b	17.7a	6.0a	2.9a	39.4ab	16.1a
Foundation Lite®	-	4.5a	2.7ab	36.4a	14.5a	6.9a	2.6a	34.1a	14.5a
Assail 50 SF®	400	5.2a	3.1ab	41.6ab	16.6a	8.1ab	2.5a	34.6a	15.1a
Gaucho CS FL®	400	6.7a	3.6b-d	42.1ab	17.5a	13.0bc	3.0a	40.7ab	18.9b
Prosper®	200	11.9b	3.4b-d	49.7bc	21.7c	15.6c	3.6ab	43.8b	21.0b-d
Prosper®	400	12.2b	3.3a-c	45.0b	20.2bc	14.0c	3.1ab	45.4bc	20.8bc
Helix®	200	12.7b	4.6d	50.1bc	22.5cd	19.4c	3.8ab	46.7bc	23.3cd
Helix XTra®	400	15.1b	4.2cd	60.8c	26.7d	16.3c	4.6b	55.1c	25.3d
	SE	2.1	0.5	4.6	1.7	3.1	0.7	4.0	1.7

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

Table 15. Effect of seed treatments on shoot biomass of open-pollinated and synthetic Polish canola 28 days after seeding in 2003-2005. [1]

		Shoot biomass - op (g/m-row)				Shoot biomass - syn (g/m-row)			
Treatment	Rate	2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	27.7a	20.8ab	184.0a	77.5a	28.3a	18.4ab	155.7a	67.5ab
Foundation Lite®	-	30.4a	17.1a	193.5ab	80.3a	28.0a	12.5a	165.3ab	68.6a
Assail 50 SF®	400	27.0a	20.3ab	184.0a	77.1a	55.7b	20.1b	140.8a	72.2b
Gaucho CS FL®	400	36.9ab	22.1a-c	194.7ab	84.6a	90.1c	21.2bc	161.4ab	90.9c
Prosper®	200	52.4bc	33.6cd	250.4cd	112.2b	88.0c	22.5bc	226.8c	112.4c
Prosper®	400	68.2c	29.3b-d	226.2b-d	107.9b	80.3bc	27.1bc	234.7c	114.0c
Helix®	200	57.0c	33.6d	218.1bc	102.9b	95.5c	24.1bc	219.6c	113.1c
Helix XTra®	400	74.0c	30.6b-d	266.2d	123.6b	90.0c	30.1c	203.0bc	107.7c
	SE	11.4	5.1	16.5	6.9	15.8	3.8	20.8	8.8

1 Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

Table 16. Effect of seed treatments on shoot biomass of open-pollinated and synthetic Polish canola 35 days after seeding in 2003-2005. [1]

Treatment	Rate	Shoot biomass - op (g/m-row)				Shoot biomass - syn (g/m-row)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	101.9a	102.9ab	908.6a	371.2ab	132.5a	87.3bc	834.1a-c	351.3ab
Foundation Lite®	-	83.6a	99.8ab	903.7a	362.4ab	158.0ab	55.3a	639.5a	284.3a
Assail 50 SF®	400	90.3a	76.4a	845.8a	337.5a	142.9ab	110.4c	706.7ab	320.0b
Gaucho CS FL®	400	112.9a	109.5bc	1021.7a	414.7b	187.0bc	67.2ab	753.5a-c	335.9ab
Prosper®	200	224.4bc	147.5d	1081.9a	484.6cd	238.2cd	130.7c	883.6b-d	417.5cd
Prosper®	400	239.8bc	138.4cd	946.3a	441.5cd	247.3cd	123.5c	845.0bc	405.3c
Helix®	200	200.4b	144.4cd	1036.3a	460.4c	252.5cd	131.0c	942.5cd	442.0cd
Helix XTra®	400	267.7c	164.9d	1109.0a	513.9d	324.8d	130.0c	1086.4d	513.7d
	SE	28.3	18.6	140.2	48.1	36.5	21.7	103.6	37.3

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$). Means in 2003, 2004 and 2005 based on 40 plants.

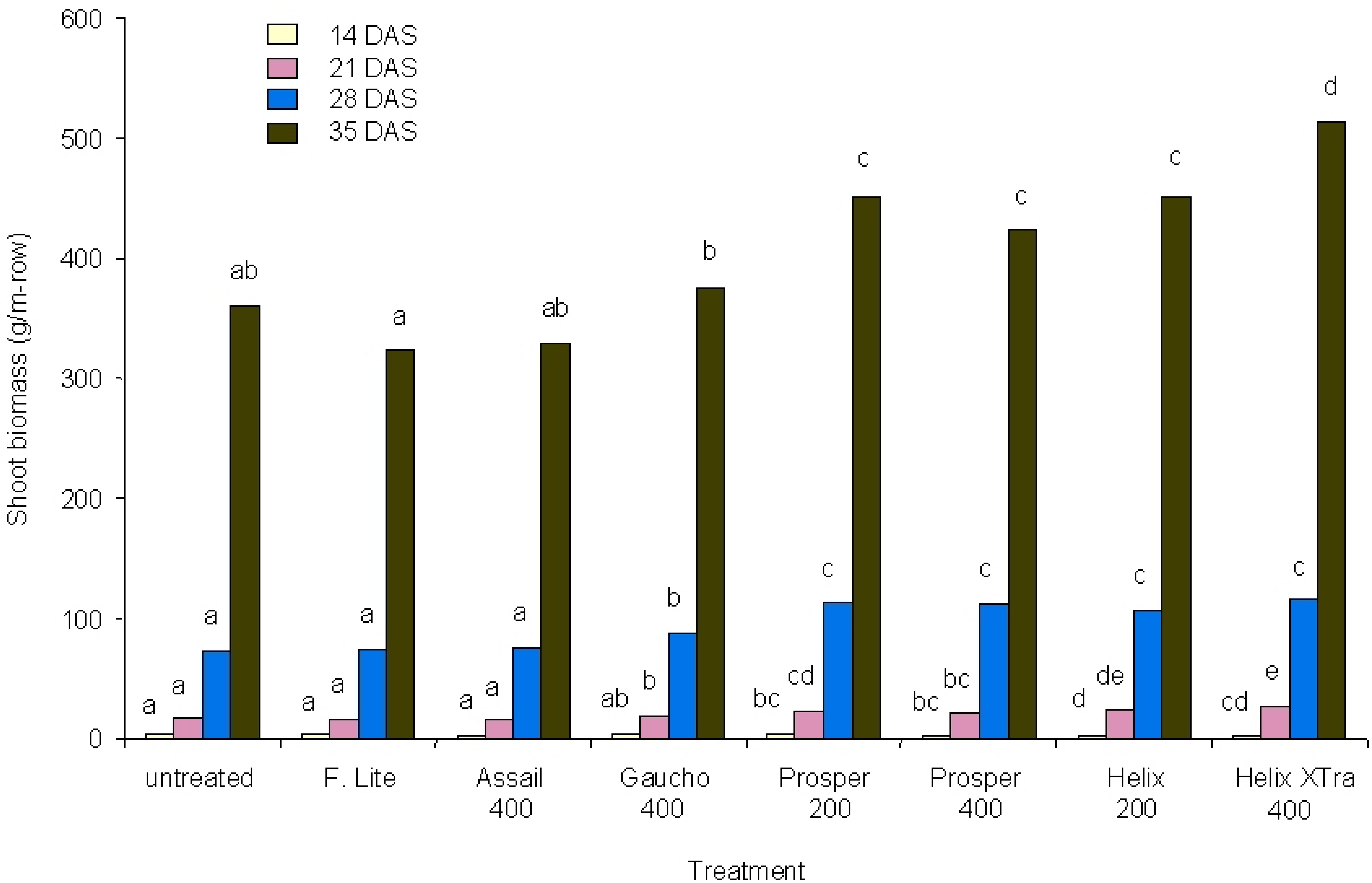

Fig. 4. Shoot biomass of untreated and treated Polish canola (n=2 cultivars) after 14, 21, 28 and 35 days in 2003-2005. For each sampling time, vertical bars with the same letter are not significantly different (Fisher's protected LSD test, P≥0.05). Means are based on 240 plants.

Table 17. Effect of seed treatments on yield of open-pollinated and synthetic Polish canola in 2003-2005. [1]

Treatment	Rate	Yield - op (g/m^2)				Yield - syn (g/m^2)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	64.2a	111.6a	244.6ab	140.2a	75.8a	134.4ab	234.4ab	148.2a
Foundation Lite®	-	60.8a	112.6a	240.9a	138.1a	74.3a	132.3ab	231.6ab	146.1a
Assail 50 SF®	400	70.9a	119.3ab	237.1a	142.4ab	84.4a-c	128.9a	224.4a	145.9a
Gaucho CS FL®	400	73.5a-c	108.8a	245.0ab	142.4ab	85.6a-c	131.8ab	240.5ab	152.6ab
Prosper®	200	76.7a-c	129.8bc	242.7a	149.8bc	78.5ab	149.8a-c	248.6b	158.9bc
Prosper®	400	72.4ab	136.0cd	258.2bc	155.5cd	95.5c	159.9c	245.9b	167.1cd
Helix®	200	89.4c	128.8bc	257.7bc	158.7de	88.0a-c	151.5bc	246.4b	162.0b-d
Helix XTra®	400	88.4bc	144.9d	261.5c	164.9e	94.9bc	169.3c	250.2b	171.5d
	SE	8.2	6.0	6.7	4.0	8.1	10.3	9.2	5.3

[1] Means within columns followed by the same letter are not significantly different (Fisher's protected LSD test, $P \geq 0.05$).

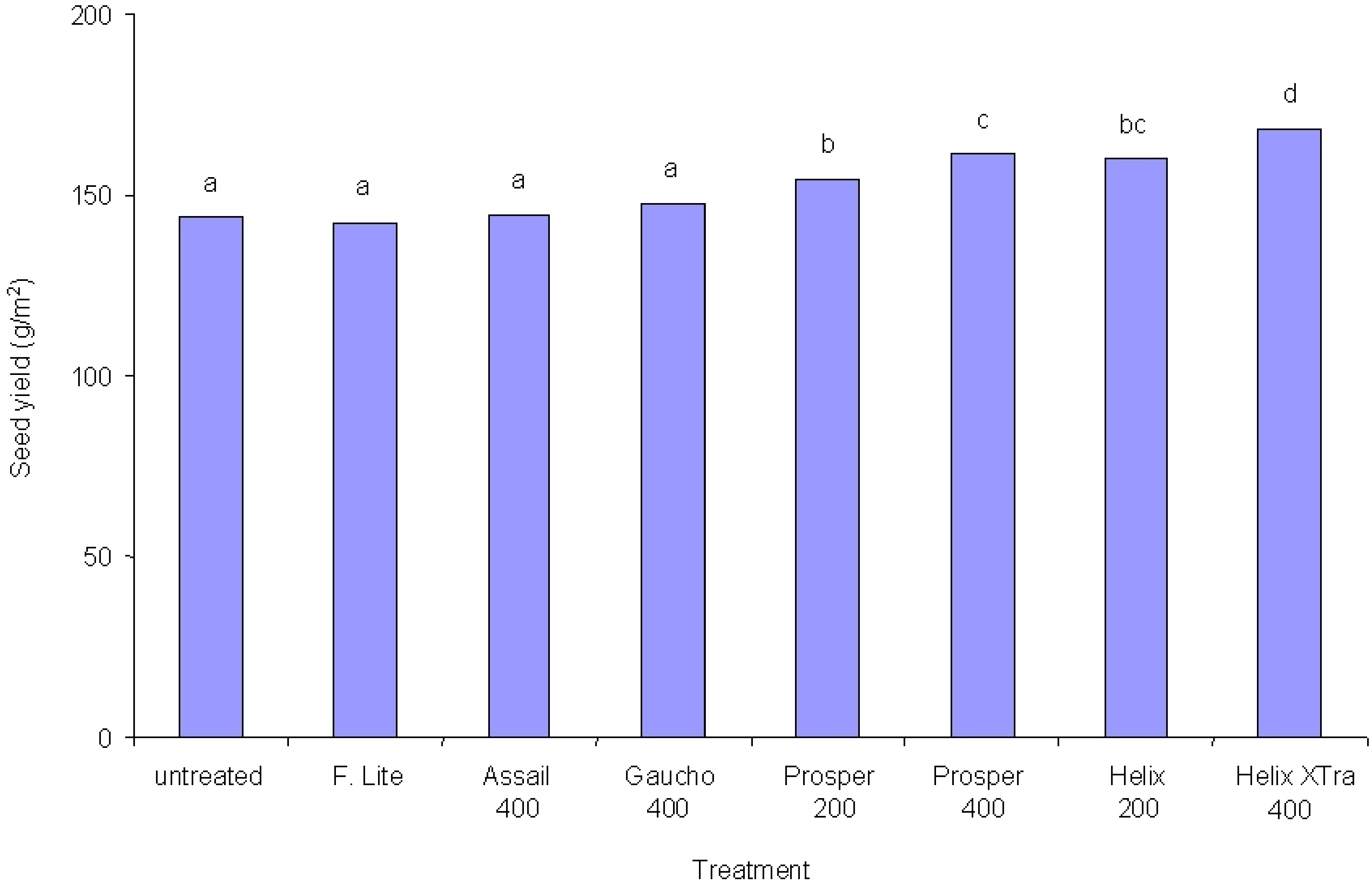

Fig. 5. Seed yield of untreated and treated Polish canola (n=2 cultivars) in 2003-2005. Vertical bars with the same letter are not significantly different (Fisher's protected LSD test, P>0.05).

Table 18. Effect of seed treatments on seed yield and economic returns of Polish canola in 2003-2005. [1]

Treatment	Rate	Yield (bu/acre)				Economic return ($/acre)			
		2003	2004	2005	mean	2003	2004	2005	mean
untreated	-	12.4	21.9	42.6	25.6	-	-	-	-
Foundation Lite®		12.0	21.8	42.1	25.3	-	-	-	-
Assail 50 SF®	400	13.8	22.1	41.1	25.7	$ 9.80	$ 1.40	-	$ 0.70
Gaucho CS FL®	400	14.2	21.5	43.2	26.3	$ 11.90	-	$ 4.20	$ 4.90
Prosper®	200	13.8	**24.9**	43.7	**27.5**	$ 9.80	$ 21.00	$ 7.70	$ 13.30
Prosper®	400	**14.9**	**26.3**	**44.9**	**28.7**	$ 18.20	$ 30.80	$ 16.10	$ 21.70
Helix®	200	**15.8**	**25.0**	**44.9**	**28.5**	$ 23.80	$ 21.70	$ 16.10	$ 20.30
Helix XTra®	400	**16.3**	**28.0**	**45.5**	**29.9**	$ 27.30	$ 42.70	$ 20.30	$ 28.00
	LSD	2.1	2.2	2.2	1.2				

[1] Yields in bold print significantly higher than untreated seed (Fisher's protected LSD test, $P \geq 0.05$). Economic return relative to untreated seed based on $7.00/bu canola.