PROJECT DETAILS

- **Title**: Reducing seedling blight to improve stand establishment in hybrid canola
- **Funders:** SaskCanola and Alberta Canola
- **Research program:** Canola Agronomic Research Program (CARP)
- **Principal investigator:** Sheau-Fang Hwang
- **Collaborators/additional investigators:** Stephen Strelkov, Hafiz Ahmed, Murray Hartman, G.D. Turnbull
- **Year completed:** 2011

Final report

Reducing seedling blight to improve stand establishment in hybrid canola
Project Code: CARP 2007-1
March 31, 2011
SUMMARY

Recent observations of inconsistent protection of seedlings by seed protectant fungicides indicate that successful canola establishment continues to be one of the greatest challenges for canola producers in Alberta. Changes in canola production may have caused some fundamental shifts in susceptibility to seedling blight and root rot. Rising seed costs of new cultivars have also made it more important to efficiently achieve target plant populations. A total of 13 fields of canola were surveyed and Fusarium root rot was identified as the predominant pathogen in association with the increased incidence of root rot in hybrid canola crops. Seedling establishment was reduced in plants seeded at the early date in 2007, but not in 2008. Seed ranging from 0.7 – 2 mm in size showed greater yield compared to seed smaller than 0.7 mm. In 2008, seed greater than 0.7 mm in size had greater seedling establishment and yield compared to seed smaller than 0.7 mm. Seedling establishment decreased with each successive increase in seeding depth although yield was not significantly affected. Delaying harvest resulted in increased viability of canola seed and increased vigour of the resulting seedlings. Dynasty + Helix improved emergence in *Rhizoctonia*-inoculated plots. In an assessment of seed treatments to control Rhizoctonia seedling blight, Rovral, G 7078 + Rovral, Helix Xtra + Dynasty (1 g/100 kg seed) and Prosper FX resulted in greater emergence and yield compared to the inoculated control. In a separate experiment, treatment with Dynasty + Helix Xtra showed greater emergence and yield compared to plots inoculated with *R. solani*. Treatment with Rancona resulted in improved emergence in *Fusarium*-inoculated soils.

The project will benefit canola producers, many of whom have suffered severe plant population losses due to root rot and seedling blight in hybrid canola.

INTRODUCTION

Recent observations indicate that successful canola establishment continues to be one of the greatest challenges for canola producers in Alberta. In 2003, crop losses from rhizoctonia infestations were very significant in southern Alberta and the Peace region. In 2005 and 2006, over 20% of fields surveyed in central Alberta suffered poor seedling establishment (DeMilliano, Orchard, pers. comm.).

Canola production has changed so that 80% of canola grown in Canada now carries selective resistance to specific herbicides (Clayton et al. 2002). These new canola varieties have differing vigour and oil composition than conventional varieties, and this may affect their sensitivity to seedling blight. Past work on canola seedling pathogens is already over 20 years old (Hwang et al 1986, Gugel et al. 1987). Since then, new pathogen strains may have appeared, or the new cultivars may be sensitive to pathogens that were benign to conventional canola cultivars. In addition, cropping practices have changed in the past 20 years, so that now rotations have been shortened and crops are seeded directly into stubble, into cooler, damper soils (Kutcher & Brandt 2004). Shorter rotations may also have increased the inoculum density of soilborne pathogens (Yitbarek et al. 1988). Hwang et al. 2007 did extensive research on seedling blight in pulse crops, focusing on the impact of rhizoctonia seedling blight in field pea and has shown that *R. solani* isolated from pulse crops can kill canola seedlings. Kutcher and Brandt (2004, 2005), in year 5 of an 8-yr rotation study, reported the effects of fungicides, but on foliar diseases. No data on soil-borne diseases have been collected.

Producers have noted much more severe infestations of seedling blight and root rot in canola fields. In the Peace River and central regions, most fields are affected, with up to 80-100% infected plants. Rising seed costs of new cultivars have also made it more important to efficiently achieve target plant populations.

Traditionally, crop rotations have been one of the primary tools used to control diseases (Ahmed et al.,2003; Azooz and Arshad, 1998; Christen and Sieling, 1995). Research has shown that weeds and diseases combine to reduce canola yields when crops are grown less than 3 years apart in the semi-arid prairie, and 4 to 5 years apart in the parkland area. However, low cereal crop prices have led to pressure for increased frequency of canola in the rotation. Herbicide resistant varieties and greater disease resistance have encouraged this trend. Canola rotations have been shortened in many areas, at the risk of major pathogen build-up in the soil. A separate study indicated that populations of *Pythium* tended to build up under continuous cropping with canola. The impact of these changes on seedling blight severity and pathogen dynamics needs evaluation. Evidence suggests that timing of glyphosate application can influence development of root rot and seedling blight (Johnson et al 2002; Clayton et al. 2002; Descalzo et al. 1998). Smiley (1992) suggests that the volunteers and weeds serve as a "green bridge" that maintains *Rhizoctonia solani* between one crop and the next. During the period between water uptake prior to germination and the two to four leaf stage, canola seedlings are vulnerable to seedling blight caused by several soilborne pathogens. Direct seeding and early seeding date cause canola seedlings to germinate into colder, wetter soils. This may contribute to the increased seedling blight experienced by producers. Early seeding or seeding in the previous fall, tends to optimize yield, but slows emergence, increasing vulnerability to root rot pathogens.

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Environment and seed quality both regulate seed germination. Gusta et al (2004) showed that seed size and the maturity of the seed at harvest both affect seed quality. Seeding date has the greatest effect on the quality of environment, since soil temperatures rise from 5 to 20°C during the planting period and moisture levels drop. Both low temperature and dry soil delay and reduce germination and seedling emergence (Kondra et al. 1983). Early seeding and reduced tillage result in colder, wetter soils during germination and thus may contribute to increased seedling blight (Sims et al. 1998). This project will study the effects of soil temperature, seeding date, seeding depth and seed size on seedling establishment. Seeding date also influences the interaction of soil microflora with germinating seedlings (Hwang et al., 2000 a,b).

Crop sequence research in western Canada has indicated that more diverse rotations tended to have less pest problems and lower production risk than rotations that were heavily cereal or broadleaf-based (Johnston et al. 2005). The recommendation to grow canola or field pea only once every four years is based primarily on the need to manage disease and weed pests. Growers frequently question whether improved weed control technology and cultivars with improved disease resistance can overcome these limitations. A 10% yield loss due to short rotation may more than compensate for a 20% price spread between canola and cereals in the short term. However, greater long-term yield losses may justify longer rotation periods.

This project was established to identify the organisms associated with the increased incidence of root rot in hybrid canola crops and to improve seedling establishment, seedling vigour and seed yield of canola by optimizing chemical and cultural methods to reduce the impact of seedling blight and root rot on canola seedling populations and on plant yield.

Objectives of this project are to: 1) To conduct surveys and to isolate, culture, identify and assess the virulence of pathogens causing seedling blight of canola under field conditions in Alberta; 2) To determine the impact of direct seeding and various residue types on root rot in canola; 3) To determine the effects of the timing of glyphosate application on pathogen populations, canola establishment and root rot severity; 4) To determine the impact of inoculum density on seedling establishment and seedling vigour of canola under greenhouse conditions; 5) To determine the effect of date of seeding and soil temperatures on susceptibility of canola seedlings to seedling blight and root rot; 6) To determine the effect of seed size on the susceptibility of canola to seedling blight and root rot and 7) To determine the effect of seeding depth on the susceptibility of canola to seedling blight.

MATERIALS & METHODS

Surveys and sampling - survey of canola diseases in southern Alberta

A total of 13 fields of canola were surveyed on August 19 and 20, 2008 mostly in the southern and central part of Alberta near highways 36, 525 and 875 and near highway 21 at Camrose. The surveys were conducted following the method described by Pearse et al., 2007. In 2010, 110 fields were surveyed in the area surrounding Edmonton. Soil samples were collected from each of the fields. The fields were surveyed between growth stages 5.2 and 5.3 (Canola Council of Canada) before swathing. Disease assessments were made in each field by collecting 20 plants from each of five sites at least 20 m from the edge of

the field and separated from each other by at least 20 m. Disease incidence was determined based on the number of plants infected out of the total plants observed for foot rot (*Rhizoctonia* spp., *Fusarium* spp.) and Fusarium wilt (*F. oxysporum* f. sp. *conglutinans*). Similarly, when other diseases were observed in a field, but not in the sample of 100 plants, the disease was recorded as "trace".

Following the 2010 survey, canola plants were grown in soil collected from each survey site. Plants were uprooted 14 days after planting and diseased portions of the plant roots were plated onto acidified potato dextrose agar and *Rhizoctonia* colonies were isolated. The procedure was repeated with *Fusarium*-selective medium (Nash-Snyder medium) and *Pythium*-selective medium (CMPVP); the roots selected for the Nash-Snyder medium were collected 21 days after planting. After isolation, the pathogens were transferred to water agar and purified by hyphal-tip culture.

Inoculum production

Inoculum consisted of pathogens isolated from previous studies for first year field studies, produced by growing the isolates on potato dextrose agar (PDA) Petri plates until completely overgrown. The resulting mycelium was introduced to sterilized wheat and incubated until completely colonized by mycelium. The colonized grain was dried and ground for use as inoculum.

Inoculum density

Small plot trials were seeded on May 17, 2010 in a randomized complete block design at CDC North to assess the impact of inoculum density on establishment and yield of canola. Inoculum was distributed at rates of 5, 10, 15 or 20 mL per 6-m row.

Date of seeding

Small plot trials were seeded in a randomized split plot design at CDC North to assess the impact of seeding date on seedling blight, establishment and yield of canola. The main plot treatments (*Pythium*, *Rhizoctonia* and *Fusarium* vs. noninoculated control) were seeded as subplots on May 8, 22, and June 4, 2007 and May 8, 20 and 30, 2008 and May 5, 15 and 25, 2009.

Effect of seed size on seedling blight and root rot

Seed lots of canola cv. 3465 RR with high germination were sorted into three size categories (<0.7 mm, 0.7 – 2.0 mm, >2.0 mm) and seeded into field plots in a randomized split plot design. Inoculation treatment (*Pythium*, *Rhizoctonia*, and *Fusarium* vs. noninoculated) served as main plots and seed size as sub-plots. Inoculum was distributed at a rate of 30 mL/row for *Fusarium* and *Rhizoctonia* and at 40 mL/row for *Pythium*. Field plots were established on May 15, 2007, May 20, 2008 and May 8, 2009. Seedling establishment and yield were recorded.

The experiment was repeated under greenhouse conditions in 2009. ProMix was used to fill 10, 450-mL cups, which were seeded with 10 canola seeds per cup, covered with *R. solani*, *F. avenaceum*, or *Pythium* spp. inoculum diluted 1:10 with sterilized sand, or with sterilized sand as a control. The cups were placed on a greenhouse bench and watered as necessary. Seedling emergence was counted 10 days after

planting and seedling damping-off was assessed 1 wk later. Plant height was measured at this time, seedlings were uprooted and root rot severity was assessed. The seedlings were dried and weighed to assess growth. The experiment was repeated and the results were pooled between the experiments.

Depth of seeding

Seed of canola cv. 3465 RR was seeded into field plots in a randomized split plot design. Seed treatment (Dynasty, Dynasty + Helix, or non-treated seeds vs. noninoculated) served as main plots and seeding depth (1.2, 2.4 or 3.6 cm) as sub-plots. Plots were inoculated with *R. solani* at 30 mL/row. Field plots were established on May 20, 2008 and inoculated with *F. avenaceum* at a rate of 30 mL/row. Seedling establishment and yield were recorded. A greenhouse experiment was conducted in 2009 using the procedure described above. Field plots at CDC North were again seeded on May 18, 2010 using canola cv. 45H-28. Plots were seeded in a split-split plot design with inoculation as main plots, fungicide treatments as sub-plots and seeding depth as sub-sub plots. Emergence was counted on June 14, 2010 and plants were harvested by small plot combine on September 26, 2010.

Effect of harvest date on seedling vigour and viability

Field plots were sown to canola cv. 71-45RR on May 27, 2009 and maintained throughout the summer. The plots were harvested on one of six dates: September 3, 6, 11, 14, 17, or 22. Seed from each date was tested for germination on moistened filter paper and the 1000-seed weight was measured from four sub-samples of each seedlot. Ten seeds from each seedlot were planted into 13-cm pots and grown in a greenhouse. The pots were replicated 10 times for each seedlot. Seedling vigour was assessed on a 0-4 scale where 0=non-germinating and 4=seedling vigour comparable to the most vigourous seedlings in the experiment. Seedling height was measured after 3 wk growth. The plants were uprooted, washed and dried. Shoot dry weight, root dry weight and total dry weight were compared among the treatments.

Effect of residue type and residue management

Field plots were sown to cereal, canola or pea stubble in 2007. A second plot area was given a similar treatment in 2008. Main plots received an application of *R. solani* inoculum at 30 mL/row during planting or were left without inoculum. In 2008, a canola crop was sown into each of the plots using direct seeding or conventional tillage. Seedling emergence was counted three weeks after seeding. The plots were harvested and seed yield calculated. The experiment was re-initiated in 2008. Drought in the 2009 season and flooding in the 2010 season prevented collection of usable data.

Effect of glyphosate application timing on disease susceptibility

Field plots were sown with barley crop in 2007. Main plots received a heavy application of inoculum and before planting the cereal crop or were left without inoculum. A canola crop was seeded directly into the stubble in 2008. Sub-plots had a pre-seeding application of glyphosate, post-seeding application of glyphosate, pre and post-seeding applications of glyphosate, or no herbicide. Seedling emergence was counted three weeks after seeding. Plots were harvested and seed yield calculated. The experiment was re-initiated in 2008. Drought in the 2009 season and flooding in the 2010 season prevented collection of usable data.

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Assessment of fungicidal seed treatments for the control of rhizoctonia seedling blight of canola in Alberta
Experiment 1
Seed of canola cv. Invigor 5020 was treated with Allegiance at 23.6 mL/100 kg seed, alone or combined with Rovral at 6.25 mL/100 kg seed, Dynasty at 1 or 2 mL/100 kg seed; with Helix Xtra at 1500 mL/100 kg seed alone or with Dynasty at 2 mL/100 kg seed; with G 7078-01 at 1400 mL/100 kg seed, alone or combined with Rovral at 62.5 mL/ 100 kg seed; or with Prosper FX at 1400 mL/100 kg seed. An experimental plot was established on May 12, 2008 at Edmonton, AB, in a black chernozemic loam soil. The plot was seeded in a randomized complete block design with four replications. Each subplot consisted of four, 6 m rows of plants spaced 25 cm apart. Seeds were planted 1.5 cm deep at a rate of 1.0 g of seed per row. *Rhizoctonia solani* was grown on sterilized oat and rye grains for 14 days, air dried and ground, and incorporated at the time of seeding at the rate of 30 mL/row. Allegiance-treated seeds were planted as inoculated and non-inoculated controls. Emerged seedlings were counted on June 11. At maturity (September 11), plants were harvested and seed was weighed to determine yield. Data were subjected to analysis of variance using a General Linear Models Procedure (SAS) and, where appropriate, Duncan's New Multiple Range Test was performed for means comparison.

Experiment 2.
Seed of canola cv. RR179 was treated with Dynasty at 5, 10 and 20 g ai/100 kg seed, alone or combined with Helix Xtra at 434 g ai/100 kg seed; with Helix Xtra 434 g ai/100 kg seed alone or combined with Dynasty Premix at 444 g ai/100 kg seed; and with Prosper at 625 g ai/100 kg seed. An experimental plot was established on May 20, 2008 at the CDC North research site near Edmonton, AB in a black chernozemic loam soil. The plot was seeded in a randomized complete block design with four replications. Each subplot consisted of four, 6 m rows of plants spaced 25 cm apart. Seeds were planted 1.5 cm deep at a rate of 0.6 g seed per row. *Rhizoctonia solani* was grown on sterilized oat and rye grains for 14 days air dried and ground, and incorporated at the time of seeding at the rate of 30 g/row. Non-treated seeds were planted as inoculated and non-inoculated controls. Emerged seedlings were counted on June 10. At maturity (October 9), plants were harvested and seed was weighed to determine yield. Data were subjected to analysis of variance using a General Linear Models Procedure (SAS) and, where appropriate, Duncan's New Multiple Range Test was performed for means comparison.

Assessment of fungicidal seed treatments for the control of fusarium seedling blight of canola in Alberta
Seeds of canola cvs. Canterra 1818, Rugby, 71-45 RR and *Brassica juncea* were treated with RANCONA 3.8 FS at 22.4 mL/ 100 kg seed or with VITAVAX RS at 833 mL/ 100 kg seed along with inoculated and non-inoculated controls. The experiments were established under greenhouse conditions at CDC North, Edmonton, AB. Ten replicate cups for each treatment were filled with Promix soil mixture, and 10 seeds were seeded in each cup. *Fusarium avenaceum was* grown on sterilized oat and rye grains for 14 days, air dried and ground. The inoculum was diluted with sterilized sand at 1x, 2x and 10x concentrations. The diluted inoculum was incorporated at the time of seeding at the top of the seeds at the rate of 5 mL/cup. After inoculation the seeds were covered with 20 mL Promix. Data on seedling emergence, damping off and plant height were recorded 10 days after seeding, and root rot severity was noted 14 days after seeding. Root rot severity

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was scored following a 0-5 scale by plants of each replicate, where 0= no disease 5= severe rotting or the plant was dead. Plants from each pot (replicate) were dried and weighed.. Data were subjected to analysis of variance using a General Linear Models Procedure (SAS) and, where appropriate, Duncan's New Multiple Range Test was performed for means comparison.

Effects of seed treatments on Rhizoctonia and *Fusarium* seedling blight

Seed of canola cv. Rugby was treated with HELIX XTRA at 1500 mL/100 kg seed or PROSPER + PONCHO at 1250 + 417 mL/100 kg seed, respectively. Experimental plots were established on May 7 and May 22, 2009 at Edmonton, AB, in a black chernozemic loam soil. The plots were seeded in a randomized complete block design with four replications. Each subplot consisted of four, 6 m rows of plants spaced 25 cm apart. Seeds were planted 1.5 cm deep at a rate of 1.0 g of seed per row. *Fusarium avenaceum* was grown on sterilized wheat grains for 14 days, air dried and ground , and incorporated at the time of seeding at the rate of 30 mL/row. Untreated seeds were planted as inoculated and non-inoculated controls. Emerged seedlings were counte and flooding in the 2010 season d on May 29, June 8 and June 15. At maturity (September 24), plants were harvested and seed was weighed to determine yield. Data were subjected to analysis of variance using a General Linear Models Procedure (SAS) and, where appropriate, Duncan's New Multiple Range Test was performed for means comparison.

RESULTS

A. Surveys and sampling - survey of canola diseases in southern Alberta

A total of 13 fields of canola were surveyed. Among the diseases, blackleg was the predominant disease (70 % of the fields surveyed) followed by fusarium wilt and foot rot. Fusarium wilt was found in 30% fields and foot rot in 15% of the fields.

After the 2010 survey, 100 isolates of *Rhizoctonia* were purified, and will be used for future research on a grant secured from ACIDF.

Inoculum Density

All of the inoculum treatments reduced seedling establishment by over 98% and yield by over 90% compared to the non-inoculated control (Table 1). There were no significant differences in establishment or yield among treatments.

Date of seeding

Seedling establishment was reduced in plants seeded at the early date compared with the later two dates in 2007, similar among seeding dates in 2008 and lower for plots seeded at the first two dates compared to the later date in 2009 (Table 2). Yield was similar among seeding dates in 2007 and 2009 and greater for early-seeded plots in 2008 compared to both later seeding dates. There were inoculum x seeding date interactions for plant counts in 2007 and 2008 but not in 2009; there were no interactions for yield. *Rhizoctonia* inoculum

reduced s seedling establishment and yield by the greatest amount, followed by *Fusarium* and then by *Pythium.*

Effect of seed size on seedling blight and root rot

There was a trend toward greater seedling establishment from larger seeds. Results were statistically significant only in 2008 and 2009 (Table 3), where the two larger seed sizes showed greater establishment compared to the smallest seed size. There was no interaction between inoculum and seed size, except in 2009. Yield from medium sized seed was greater than that from small seed in site B in 2007 and in the plots seeded in 2008. Yield was lower for the smallest seed size in 2009, compared to the two larger seed sizes. *Rhizoctonia* inoculum reduced seedling establishment and yield by the greatest amount, followed by *Fusarium* and then by *Pythium.*

In the 2009 greenhouse experiment, seeding depth did not affect seedling emergence in *Fusarium* or *Pythium*-inoculated pots, but *Rhizoctonia*-inoculated pots seeded with 0.7-2.0 mm seed showed greater emergence compared to either small or large seed (Table 4). Plant height increased with seed size for all three inocula. Root rot was lower in *Rhizoctonia*-inoculated pots seeded with mid-sized seed compared to those seeded with large seed, but otherwise, no significant differences in root rot occurred among seed sizes. Shoot weight increased with seed size for all three inocula, but the difference between *Rhizoctonia*-inoculated pots seeded with small and mid-sized seed was not significant.

Depth of seeding

In the 2008 field trial, seedling establishment was lower with each successive increase in seeding depth, although yield was not significantly affected (Table 5). Inoculated plots treated with Dynasty + Helix showed greater establishment compared to those treated with Dynasty alone, or the inoculated control.
In the 2009 greenhouse trial, emergence was greater for the shallowest seeding depth compared to the two deeper treatments (Table 6). Damping-off was most severe for the pots seeded at the greatest depth. Plant height and shoot weight was greater for the deepest seeding depth compared to the two shallower treatments. Root rot was unaffected by seeding depth.

In the 2010 field trial, seedling establishment was greater for the shallowest seeding depth compared to the two deeper treatments (Table 5). Inoculated plots had significantly lower seedling establishment and yield compared to non-inoculated plots. Fungicide-treated plots (Helix + Dynasty) showed greater seedling establishment compared to non-fungicide treated plots, but yield was similar between the two treatments. Yield was also similar among the seeding depths.

Effect of harvest date on seedling vigour and viability

Seedling germination improved as harvest was delayed (Table 7). Thousand-seed weight increased with delay in harvest date. The greatest seed weight was observed with the latest harvest. Seedling vigour and height and root and shoot dry weights were significantly lower for the first two harvests compared to the subsequent

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harvests. Total dry weight was lower for the first two harvests compared to all subsequent harvests, and was greater for the last harvest compared to all previous harvests.

Assessment of fungicidal seed treatments for the control of rhizoctonia seedling blight of canola in Alberta
Experiment 1
Treatment of seed with Rovral, G 7078 + Rovral, Helix Xtra + Dynasty (1 g/100 kg seed) or Prosper FX resulted in significantly ($P \leq 0.05$) greater emergence compared to the Helix Xtra, Helix Xtra + Dynasty (2 g), Dynasty + Allegiance, and the Allegiance treatment alone (Table 8). Yield was greater compared to the inoculated control for all treatments except G 7078 and the low rate of Dynasty + Allegiance. Yield was greater compared to Dynasty + Allegiance for Rovral + Allegiance, and G 7078 + Rovral.

Experiment 2.
The fungicide treatments with Dynasty in combination with Helix Xtra resulted in significantly ($P \leq 0.05$) greater emergence and seed yield compared to the inoculated control, although the seedling emergence was reduced by 5-6 fold compared to the non-inoculated control (Table 9). Compared to the inoculated control, the highest seedling emergence was obtained when the seeds were treated with Dynasty + Helix XTRA at 5 + 434 g ai/100 kg seeds, and the highest yield was obtained when treated with Dynasty + Helix premix at 444 g ai/100 kg seeds. Plots treated with Prosper alone showed significantly greater yield compared to the inoculated control.

Assessment of fungicidal seed treatments for the control of fusarium seedling blight of canola in Alberta

Emergence:
At the high inoculum concentration, neither of the chemical seed treatments affected emergence compared to the inoculated control for Canterra 1818 or Rugby (Table 10). Treatment of seed with Rancona resulted in greater emergence for cv. 71-45 RR and both treatments resulted in greater emergence compared to the inoculated control for *B. juncea.* At the intermediate concentration, Rancona resulted in greater emergence compared to the inoculated control for Canterra 1818, both seed treatments increased emergence for Rugby and *B. juncea*, and neither of the treatments affected emergence for 71-45 RR. At the low concentration, both treatments improved emergence for Canterra 1818 and 71-45 RR, neither of the treatments affected emergence for cv. Rugby, and Rancona improved emergence for *B. juncea*.

Plant height:
At the highest inoculum concentration, plant height was unaffected by seed treatment for cvs. Canterra 1818 or Rugby. Both treatments improved plant height for the other two cultivars. At the intermediate inoculum concentration, both treatments improved plant height for cvs. Canterra 1818 and Rugby; Rancona improved plant height for *B. juncea* and neither of the treatments affected plant height for 71-45 RR. At the lowest inoculum concentration, plant height was improved by both seed treatments for cvs. Canterra 1818 and Rugby. Rancona improved plant height for *B. juncea*, but neither of the treatments affected plant height for 71-45 RR.

Root Rot:
For the highest inoculum concentration, root rot was unaffected by seed treatment for cvs. Canterra 1818 or Rugby. Root rot was reduced by treatment of 71-45 RR or *B. juncea* with either of the seed treatments. For the intermediate inoculum concentration, root rot was unaffected by seed treatment for cvs. Canterra 1818 and 71-45 RR. Root rot was reduced by Rancona for *B. juncea* and by both seed treatments (albeit a significantly greater reduction with Rancona) for cv. Rugby. At the lowest inoculum concentration, root rot was reduced by both seed treatments for all cultivars except *B. juncea*, where the root rot severity was reduced only by Rancona.

Root Dry Weight:
At the highest inoculum concentration root dry weight was unaffected by either seed treatment for cvs. Canterra 1818 and Rugby. Application of Vitaflo 280 improved root dry weight for cv. 71-45 RR and *B. juncea*. At the intermediate inoculum concentration, root dry weight was unaffected by either seed treatment for cvs. Canterra 1818 and 71-45 RR. Both treatments improved root dry weight for cv. Rugby and Rancona improved dry weight for *B. juncea*. At the low inoculum concentration, root dry weight was improved by both treatments for cvs. Canterra 1818 and Rugby, by Rancona for 71-45 RR and for neither treatment for *B. juncea*. Root dry weight was reduced by Rancona for *B. juncea*.

Shoot Dry Weight:
At the highest inoculum concentration, shoot dry weight was unaffected by either treatment for cvs. Canterra 1818 and Rugby. Shoot dry weight was improved by Rancona for cv. 71-45 RR and by both treatments for *B. juncea*. At the intermediate inoculum concentration, shoot dry weight was improved by both treatments for all three canola cultivars but was unaffected by either treatment for *B. juncea*. At the low inoculum concentration, shoot dry weight was improved by both treatments for cvs. Canterra 1818 and Rugby, by Vitaflo 280 for 71-45 RR and by neither treatment for *B. juncea.*

Effects of seed treatments on *Rhizoctonia* and *Fusarium* seedling blight:
In both early and late-seeded plots, Rhizoctonia seedling blight was unaffected by application of either Prosper + Poncho or Helix, whereas both treatments improved emergence in *Fusarium*-inoculated plots (Table 11). In the late seeded plots, those treated with Helix showed greater emergence compared to those treated with Prosper + Poncho.

Yield was unaffected by seed treatment, except in the late-seeded, Rhizoctonia-inoculated plots, where it was improved by both treatments.

DISCUSSION and CONCLUSIONS

This study showed that inoculation with *Rhizoctonia solani* severely reduced seedling emergence and yield in canola in both greenhouse and field studies. The degree of losses observed after inoculation with this pathogen

was greater than for either *Fusarium* or *Pythium*. This pathogen may be responsible for many of the losses experienced by canola producers.

Earlier seeding dates have resulted in seedlings germinating into cooler, moister soils. Most producers consider the added stress at germination to be offset by reduced stress during reproductive growth (Clayton et al, 2004, Angadi et al., 2004, Kirkland & Johnson 2000). However, earlier seeding modifies the interaction with germinating seedlings with soil microflora (Hwang et al., 2000 a,b) and also influences seedling vigour (Gusta et al. 2004). This study found lower seedling establishment associated with earlier seeding in two of three station-years of field data.

Lower seedling establishment was observed for seeds that were under 0.7 mm in diameter compared to seeds of a larger size in for *Rhizoctonia,Fusarium* and *Pythium*.

Canola seed planted at greater depth showed reduced establishment in both greenhouse and field studies. Yield was unaffected in the field studies.

Experiments with fungicidal seed treatments showed that Rovral and Dynasty + Helix combinations reduced seedling blight in Rhizoctonia-inoculated soils, while Rancona was more effective in reducing seedling blight in *Fusarium*-inoculated soils. Treatment effects in *Fusarium*-inoculated soils varied with the concentration of inoculum and also with the cultivar of canola.

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ACKNOWLEDGEMENTS

We are very grateful to V. Manoli, Y. Yong and J. Tieulie for technical assistance in collecting soil samples. The Saskatchewan Canola Development Commission and the Canola Agronomic Research Program provided portions of the funding for this project.

Table 1. Effects of inoculum density with *R. solani* on seedling emergence and yield of canola in 2010.

Inoculum density (mL/plot)	Seedling emergence (plants/m^2)	Seed yield (t/ha)
Non-inoculated	53.5 a	6.16 a
20 mL	0.3 b	0.40 b
40 mL	0.7 b	0.56 b
60 mL	0.3 b	0.64 b
80 mL	0.1 b	0.34 b

Table 2. Effects of seeding date and soil pathogens on seedling survival and yield of canola cv. 3465 RR near Edmonton, AB in 2007, 2008 and 2009.

Seeding Date 2007	**Plants/m^2**	**Yield (t/ha)**	**Seeding Date 2008**	**Plants/m^2**	**Yield (t/ha)**	**Seeding Date 2009**	**Plants/m^2**	**Yield (t/ha)**
May 8	18.4 b	1.58 a	May 8	20.1 a	1.75 a	May 5	8.7 b	1.73 a
May 22	41.3 a	1.46 a	May 20	15.4 a	0.90 b	May 15	7.5 b	1.76 a
June 4	37.7 a	1.49 a	May 30	19.0 a	0.89 b	May 25	20.9 a	2.34 a
Inoculum								
Control	57.5 a	2.11 a		46.8 a	1.83 a		35.1 a	2.62 a
Pythium	42.2 b	1.97 b		15.4 b	1.53 a		7.0 b	1.91 ab
Fusarium	28.0 c	1.58 c		8.0 c	1.06 b		6.4 b	2.36 a
Rhizoctonia	2.2 d	0.38 d		1.0 d	0.24 c		1.0 b	0.92 b

Means in each column and treatment category followed by the same letter do not differ significantly according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Table 3. Effects of seed size and soil pathogens on seedling survival and yield of canola cv. 3465 RR near Edmonton, AB in 2007, 2008 and 2009.

	2007				2008		2009	
	Site A		Site B					
Seed size	**Plants/m²**	**Yield (t/ha)**	**Plants/m²**	**Yield (t/ha)**	**Plants/m²**	**Yield (t/ha)**	**Plants/m²**	**Yield (t/ha)**
Small < 0.7 mm	24.1 a	1.27 a	24.8 a	1.18 b	8.0 b	0.85 b	2.7 b	1.02 b
Medium 0.7 – 2 mm	25.7 a	1.45 a	26.3 a	1.58 a	10.3 a	1.29 a	4.9 a	1.68 a
Large > 2 mm	28.0 a	1.44 a	26.1 a	1.40 ab	11.2 a	1.34 a	4.7 a	1.86 a
Inoculum								
Control	47.9 a	1.98 a	46.6 a	2.00 a	35.8 a	2.61 a	12.3 a	3.36 a
Pythium	32.2 b	1.69 b	29.5 b	1.69 a	3.7 b	1.18 b	2.1 b	1.60 b
Fusarium	20.0 c	1.48 b	21.7 c	1.24 b	2.2 bc	0.96 b	1.6 b	1.11 c
Rhizoctonia	3.7 d	0.39 c	5.0 d	0.55 c	0.1 c	0.05 c	0.3 b	0.01 d

[x] Means in each column and treatment category followed by the same letter do not differ significantly according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Table 4. Effects of seed size and soil pathogens on seedling survival and yield of canola cv. 3465 RR under greenhouse conditions

	Fusarium				*Rhizoctonia*			
Seed size	**Plants/pot**	**Height (cm)**	**Root rot (0-4)**	**Shoot wt. (mg)**	**Plants/pot**	**Height (cm)**	**Root rot (0-4)**	**Shoot wt. (mg)**
< 0.7 mm	8.5 a	2.4 c	1.2 a	41 c	7.4 b	2.2 c	1.9 ab	27 b
0.7 – 2.0 mm	8.9 a	2.8 b	1.1 a	50 b	8.0 a	2.6 b	1.8 b	36 b
> 2 mm	8.7 a	3.4 a	1.1 a	70 a	7.3 b	3.0 a	2.0 a	47 a
Concentration								
0	9.9 a	3.1 a	0.0 b	59 a	9.6 a	3.0 a	0.0 b	47 a
10	7.5 b	2.7 b	2.2 a	49 b	5.5 b	2.2 b	3.8 a	27 b

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Seed size	*Pythium* Plants/pot	Height (cm)	Root rot (0-4)	Shoot wt. (mg)
< 0.7 mm	8.8 a	2.4 c	0.7 a	24 c
0.7 – 2.0 mm	9.1 a	2.8 b	0.7 a	33 b
> 2 mm	9.1 a	3.3 a	0.7 a	39 a
Concentration				
0	9.6 a	3.1 a	0.0 b	35 a
10	8.4 b	2.5 b	1.3 a	29 b

Table 5. Effects of seeding depth and chemical seed treatment on seedling survival and yield of canola cv. 3465 RR in plots inoculated with *Rhizoctonia solani* near Edmonton, AB in 2008.

	2008	
	Plants/m^2	Yield
Seeding depth		(t/ha)
1.6 cm	12.9 a	2.02 a
2.4 cm	8.5 b	1.82 a
3.6 cm	5.4 c	1.63 a
Seed Treatment		
Non-inoculated	31.7 a	4.21 a
Dynasty + Helix	3.0 b	1.76 b
Dynasty	0.9 c	0.83 c
Inoculated	0.2 c	0.48 c
	2010	
Seeding depth		
1.6 cm	25.5 a	2.87 a
2.4 cm	20.6 b	2.85 a
3.6 cm	16.4 b	2.72 a
Inoculation		
Inoculated	1.5 b	1.06 b
Non-inoculated	40.2 a	4.57 a
Seed Treament		
No fungicide	18.3 b	2.67 a
Helix + Dynasty	23.3 a	2.96 a

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Table 6. Effects of seeding depth and inoculation with *Rhizoctonia* on seedling survival and yield of canola cv. 3465 RR in a greenhouse trial in 2009.

Greenhouse, 2009					
Seeding depth	**Plants/pot**	Damping Off (/pot)	Height (cm)	Root rot (0-4)	Shoot wt. (mg)
0.8 cm	8.2 a	0.6 b	2.7 b	1.7 a	26 b
1.6 cm	7.0 b	0.5 b	2.8 b	1.7 a	28 b
2.4 cm	6.9 b	1.9 a	3.1 a	1.6 a	36 a
Concentration					
0	9.7 a	0.0 b	3.2 a	0.0 b	40 a
10	5.0 b	2.0 a	2.5 b	3.3 a	19 b

[x] Means in each column and treatment category followed by the same letter do not differ significantly according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Table 7. Effects of harvest date on vigour of canola seedlings in a greenhouse trial

Harvest Date 2009	Germination (%)	1000-seed weight (g)	Seedling vigour (0-4)	Seedling height (cm)	Root dry weight (mg)	Shoot dry weight (mg)	Total dry weight (mg)
September 3	34.7 d	4.40 d	1.9 b	1.96 d	67 b	318 c	385 c
September 6	31.0 d	4.92 c	1.8 b	2.17 c	64 b	312 c	376 c
September 11	75.8 c	4.92 c	3.8 a	2.96 ab	105 a	509 ab	614 b
September 14	79.7 c	5.00 bc	3.8 a	2.88 b	118 a	496 b	614 b
September 17	88.3 b	5.12 ab	4.0 a	3.03 a	106 a	510 ab	616 b
September 22	95.2 a	5.22 a	4.0 a	3.06 a	128 a	555 a	683 a

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Table 8. Effect of seed treatments on number of emerged seedlings and seed yield of canola cv. Invigor 5020 grown in soil inoculated with *Rhizoctonia solani* at Edmonton, Alberta in 2008.

	Treatment Description	Dosage (mL/100 kg seed)	Emergence (Plants/2m^2)	Yield (t/ha)
			June 11	
1	ALLEGIANCE + R	23.6	0.3 d	0.47 g
2	G 7078 + R	1400	0.6 d	0.81 g
3	DYNASTY + ALLEGIANCE + R	1 + 23.6	1.1 d	1.50 fg
4	DYNASTY + ALLEGIANCE + R	2 + 23.6	1.8 d	2.36 def
5	ROVRAL + ALLEGIANCE + R	625 + 23.6	12.0 b	4.46 bc
6	HELIX XTRA + R	1500	1.9 d	2.24 ef
7	HELIX XTRA + DYNASTY + R	1500 + 1	7.9 b	4.00 bcde
8	PROSPER FX + R	1400	11.4 b	3.51 cde
9	HELIX XTRA + DYNASTY + R	1500 + 2	7.1 c	3.82 cde
10	G 7078 + ROVRAL + R	1400 + 625	12.4 b	4.27 bc
11	ALLEGIANCE no inoculum	23.6	50.7 a	6.22 a

1 Means within a column followed by the same letter are not significantly different
2 using Duncan's New Multiple Range Test (P 0.05).

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Table 9. Effect of seed treatments on number of emerged seedlings and seed yield of the canola cv. Invigor 5020 grown in a field plot inoculated with *Rhizoctonia solani* at Edmonton, AB in 2008

Treatment Description	Dosage (g ai/100 kg seed)	Emergence (plants/m^2)	Yield (t/ha)
UNTREATED		46.5 a[1]	3.79 a
UNTREATED[2]		0.4 cd	0.41 de
DYNASTY	5	0.1 d	0.13 e
DYNASTY	10	0.3 d	0.15 e
DYNASTY	20	1.1 cd	1.10 bcde
DYNASTY + HELIX XTRA	5 + 434	7.3 b	2.44 abc
DYNASTY + HELIX XTRA	10 + 434	5.5 bc	2.23 abcd
DYNASTY + HELIX XTRA	20 + 434	6.6 b	2.66 ab
HELIX XTRA	434	0.9 cd	0.55 cde
HELIX XTRA + DYNASTY PREMIX	444	5.1 bcd	3.16 a
PROSPER 400	625	3.3 bcd	2.37 abc

[1] Means within a column followed by the same letter are not significantly different using Duncan's New Multiple Range Test (*P*□0.05).

[2] This, and all subsequent treatments were inoculated with *Rhizoctonia solani* at the time of seeding.

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Table 10. Effects of chemical seed treatments on fusarium seedling blight on three cultivars of canola and *Brassica juncea*.

	Emergence			Plant Height (cm)		
	Undiluted	1:2	1:10	Undiluted	1:2	1:10
Canterra 1818						
Control	3.7 b	5.7 c	7.8 b	6.9 a	5.8 b	7.0 b
Rancona	3.1 b	7.4 b	9.1 a	7.7 a	7.9 a	8.2 a
Vitaflo 280	3.5 b	5.4 c	9.5 a	6.9 a	7.6 a	8.1 a
Non-inoculated	8.9 a	9.8 a	8.8 a	8.2 a	7.3 a	8.3 a
Rugby						
Control	3.3 b	4.2 d	8.8 b	7.8 ab	8.5 b	8.8 b
Rancona	3.5 b	8.0 b	9.5 ab	6.7 b	9.3 a	10.9 a
Vitaflo 280	2.3 b	6.6 c	9.5 ab	8.1 ab	9.9 a	10.4 a
Non-inoculated	9.9 a	9.9 a	9.8 a	9.4 a	8.9 a	9.0 b
71-45 RR						
Control	1.5 c	5.5 b	8.1 b	4.8 b	8.8 b	9.3 a
Rancona	3.9 b	6.9 b	9.4 a	9.1 a	9.0 ab	9.6 a
Vitaflo 280	2.7 bc	5.5 b	9.2 a	8.9 a	9.5 a	9.1 a
Non-inoculated	9.7 a	10.0 a	9.7 a	9.4 a	8.5 b	9.2 a
Brassica juncea						
Control	0.9 c	3.7 c	7.2 c	1.4 c	5.7 bc	8.7 b
Rancona	3.1 b	5.0 b	8.7 ab	6.0 b	6.9 b	11.1 a
Vitaflo 280	2.1 b	2.2 d	7.9 bc	6.0 b	4.1 c	8.8 b
Non-inoculated	9.2 a	9.3 a	9.5 a	13.4 a	9.4 a	8.3 b

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Table 10, continued

	Root rot			Root dry wt. (mg)			Shoot dry wt. (mg)		
	Undiluted	1:2	1:10	Undiluted	1:2	1:10	Undiluted	1:2	1:10
Canterra 1818									
Control	4.1 a	4.3 a	2.6 a	48 b	79 b	50 b	280 b	366 c	392 c
Rancona	4.2 a	4.1 a	1.5 b	47 b	94 b	80 a	324 b	570 ab	490 b
Vitaflo 280	4.3 a	4.5 a	1.3 b	41 b	68 b	74 a	274 b	499 b	509 b
Non-inoculated	0.0 b	0.0 b	0.0 c	138 a	188 a	88 a	697 a	694 a	643 a
Rugby									
Control	4.3 a	3.8 a	2.4 a	69 b	77 b	73 b	308 b	458 b	549 b
Rancona	4.1 a	2.0 c	0.7 b	60 b	127 a	99 a	313 b	766 a	666 a
Vitaflo 280	4.5 a	2.8 b	1.1 b	35 b	116 a	104 a	215 b	685 a	690 a
Non-inoculated	0.0 b	0.0 d	0.0 c	165 a	125 a	120 a	773 a	720 a	710 a
71-45 RR									
Control	4.6 a	3.4 a	2.8 a	29 c	91 b	80 c	160 b	545 b	545 c
Rancona	4.0 b	3.3 a	2.0 b	54 bc	88 b	109 b	962 a	420 c	563 bc
Vitaflo 280	4.2 b	3.6 a	2.3 b	63 b	94 b	78 c	390 ab	417 c	604 b
Non-inoculated	0.0 c	0.0 b	0.3 c	162 a	155 a	150 a	874 ab	761 a	725 a
Brassica juncea									
Control	4.8 a	4.0 a	3.2 a	18 c	37 b	108 ab	84 c	283 bc	513 b
Rancona	4.0 c	3.3 b	2.5 b	54 bc	112 a	78 c	368 b	405 b	592 ab
Vitaflo 280	4.5 b	4.4 a	3.1 ab	73 b	53 b	91 bc	346 b	239 c	564 b
Non-inoculated	0.0 d	0.0 c	0.0 c	264 a	111 a	118 a	795 a	603 a	683 a

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	Emergence (plants/m^2)		Yield (t/ha)	
	Early	Late	Early	Late
Rhizoctonia				
Inoculated control	0.0 b	0.1 b	0.000 b	0.043 c
Prosper + Poncho	0.8 b	4.3 b	0.173 b	1.093 b
Helix	0.1 b	1.3 b	0.006 b	0.493 b
Non-inoculated control	25.5 a	43.2 a	3.769 a	4.214 a
Fusarium				
Inoculated control	4.5 c	16.7 c	1.582 a	2.694 a
Prosper + Poncho	36.0 b	58.1 b	2.181 a	2.839 a
Helix	33.5 b	75.0 a	2.910 a	3.606 a
Non-inoculated control	53.5 a	61.8 b	2.978 a	3.123 a

Table 11 (above). Effects of seed treatments on emergence and yield of canola cv. Rugby inoculated with *Rhizoctonia solani* or *Fusarium avenaceum* and grown under field conditions near Edmonton, AB in 2009.

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Fig. 1. Roots collected in a field survey showing root rot symptoms

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Fig. 2. Roots infected by *Rhizoctonia* sp. in a greenhouse study showing symptoms of root rot

Fig 3. Roots infected by *Fusarium* sp. in a greenhouse study showing symptoms of root rot

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