Canadian Weed Science Society
Société canadienne de malherbologie

Proceedings of the 2004 National Meeting

58th Annual Meeting
November 28 - December 1st, 2004
The Fairmont Winnipeg
Winnipeg, Manitoba, Canada

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Compiled, assembled and produced by

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Société canadienne de malherbologie
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Introduction

Canadian Weed Science Society
Société canadienne de malherbologie
2004 National Meeting
Réunion nationale 2004
Winnipeg, MB

There were 206 registered participants at the meeting and a symposium took place. Eleven presentations were made in the symposium titled: Soil Residual Herbicides: Science, Management and Implications for Canada. During the regular sessions of the meeting, there were 11 graduate students oral presentations and 32 posters were displayed.

The Bayer CropScience Best Student Presentation Award was awarded to to Leanne C. Wilson, University of Manitoba, for her presentation titled "Unravelling the mystery of seed dormancy breaking in black medic (*Medicago lupulina*)" by L. C. Wilson and M. H. Entz.

The poster titled "Patch management of herbicide-resistant wild oat (*Avena fatua* L.)" by Beckie, H.J.[1], Hall, L.M.[2], and Schuba, B.[1] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development/University of Alberta, Edmonton, AB won first place. The poster titled "Has herbicide-tolerant canola altered weed diversity in Western Canada?" by Thomas, A.G.[1], Leeson, J.Y.[1], Hall, L.M.[2], Beckie, H.J.[1], Van Acker, R.C.[3], Brenzil, C.A.[4] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development, Edmonton, AB; [3]Department of Plant Science, University of Manitoba, Winnipeg, MB; [4]Saskatchewan Agriculture, Food and Rural Revitalization, Regina, SK, won second place. The poster titled "Alberta field survey of herbicide-resistant weeds" by Beckie, H.J.[1], Hall, L.M.[2], Leeson, J.Y.[1], and Thomas, A.G.[1] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development / University of Alberta, Edmonton, AB, won the third place.

Several awards and scholarships were awarded at the Winnipeg meeting:

The Monsanto Canada Scholarships were awarded to Arvel Lawson (M.Sc.) from the University of Manitoba and to Kris Mahoney (Ph.D) from the University of Guelph.

The Dow AgroSciences Canada Travel Awards were awarded to Jonathan Horsman (M.Sc.) from the University of Guelph and to Jamshid Ashigh (Ph.D.) from the University of Guelph.

The Syngenta Crop Protection Canada Travel Awards were awarded to Kristen Hacault (M.Sc.) from the University of Manitoba and to Christie Stewart (Ph.D.) from the University of Western Ontario.

Mahesh Upadhyaya, Professor and Associate Dean, Faculty of Agricultural Sciences at the University of British Columbia, received the Dow AgroSciences Canada Excellence in Weed Science Award.

There were no applicants for the Outstanding Industry Member Award for 2004.

Six Working Group sessions and four commercial displays rounded off the conference. A total of over 80 photo entries brilliantly showcased agriculture, weeds, and weeds in action.

The committee members and their responsibilities were:

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Agenda
2004 Meeting

Canadian Weed Science Society
Société canadienne de malherbologie
2004 National Meeting
Réunion nationale 2004
The Fairmont Winnipeg
Winnipeg, Manitoba

Agenda

Sunday, November 28, 2004

9:00 am – 5:00 pm	Board Meeting
4:00 pm – 8:00 pm	Registration
4:00 pm – 8:00 pm	Poster and Commercial Display Setup
5:00 pm – 10:00 pm	CWSS "Experimenting with Residuals" mixer

Monday, November 29, 2004

7:30 am – 8:30 am	Registration
7:30 am – 8:30 am	Commercial Display Setup
7:30 am – 8:30 am	Poster Setup

Symposium - Soil Residual Herbicides: Science, Management and Implications For Canada

8:30 am – 8:45 am	CWSS Welcome and Announcements – Gary Turnbull, Dow AgroSciences and John O'Donovan, AAFC – Beaverlodge, AB
8:45 am – 9:30 am	The Science of Soil Residual Herbicides – Charles Helling, USDA – Beltsville, Maryland
9:30 am – 10:10 am	The Science of BASF's Soil Residual Herbicides in Canada – *Dale Shaner, USDA – Fort Collins, Colorado*
10:40 am – 11:20 am	The Science of Dupont's Soil Residual Herbicides in Canada – *Harry Strek, Dupont – Newark, Delaware*
11:20 am – 12:00 am	The Science of Arvesta's Soil Residual Herbicides in Canada – *Patrick Haikal, Arvesta Corporation – Denver, Colorado*

1:00 pm – 1:30 pm Interactions between Landscape and Soil Residual Herbicide Activity – *Jeff Schoenau, University of Saskatchewan*

1:30 pm – 2:00 pm Herbicide Stacking and Soil Residues – *Eric Johnson, AAFC – Scott, SK*

2:00 pm – 2:30 pm Managing Soil Residual Herbicide Use in Western Canada – *Denise Maurice, Westco – Calgary, AB*

2:30 pm – 3:00 pm Managing Soil Residual Herbicide Use in Eastern Canada – *Peter Sikkema, University of Guelph – Ridgetown, ON*

3:20 pm – 3:45 pm Deconstructing Herbicide Residue Problems: An Agronomist's Approach – *Richard Lussier, Agricore United – Grande Prairie, AB*

3:45 pm – 4:10 pm Soil Residual Herbicide Assays: Science and Practice – *Paul Watson, Alberta Research Council*

4:10 pm – 4:35 pm A Simple and Practical Soil Residual Assay for Special Crops – *John O'Sullivan, University of Guelph – Simcoe, ON*

4:35 pm – 4:45 pm Closing Remarks – Rene Van Acker, University of Manitoba

Other activities

4:45 pm – 6:15 pm Poster and Commercial Display Viewing

Tuesday, November 30, 2004

Graduate Student Presentations

8:00 am – 8:20 am Biomass partitioning in corn as influenced by weeds.
Joanne Liu and Clarence J. Swanton – University of Guelph

8:20 am – 8:40 am Stress and fitness: using ALS-inhibitor resistant Eastern-black nightshade as a model.
Jamshid Ashigh and Francois Tardif – University of Guelph

8:40 am – 9:00 am Adaptive strategies of common lamb's-quarters in a corn canopy.
Kris J. Mahoney and Clarence J. Swanton – University of Guelph

9:00 am – 9:20 am Modeling the agronomic implications of herbicide tolerant spring wheat in western Canadian cropping systems.
Ryan Nielson, Linda Hall and Keith Topinka – University of Alberta

9:20 am – 9:40 am Biosafety of plant-made pharmaceuticals: Control of transgenic safflower volunteers in barley and canola.
Marc A. McPherson, Ross H. McKenzie, Allen G. Good, A. Keith C. Topinka, and Linda M. Hall – University of Alberta

9:40 am – 10:00 am	Unraveling the mystery of seed dormancy breaking in black medic (Medicago lupulina). Leanne Wilson and M. H. Entz. – University of Manitoba
10:20 am – 10:40 am	Emergence timing and management of volunteer canola (Brassica napus L.) in spring wheat fields. Arvel N. Lawson and Rene C. Van Acker – University of Manitoba
10:40 am – 11:00 am	Crop residue effect on weed populations and community dynamics in no-till agriculture. Christie L. Stewart, Paul B. Cavers, Peter H. Sikkema and Darren E Robinson – University of Western Ontario
11:00 am – 11:20 pm	Emergence timing and control of dandelion (Taraxacum officinale) using fall or spring applications of glyphosate and florasulam in spring wheat fields. Kristin M. Hacault and Rene C. Van Acker – University of Manitoba
11:20 am – 11:40 pm	Physiological characterization of picloram safening in transgenic tobacco expressing an anti-picloram antibody. Jonathan S. Horsman, M. D. McLean, F. C. Olea-Popelka, and J. C. Hall – University of Guelph
11:40 am – 12:00 pm	Reduced Herbicide Use in Flax Under a No-Till Annual-Based Rotation. Scott Gillespie, B. Irvine, and M. H.Entz – University of Manitoba

Other activities

12:00 pm – 2:00 pm	Awards Luncheon
2:15 pm – 3:30 pm	Working Group Sessions Integrated Weed Management Application Technology
3:45 pm – 5:00 pm	Herbicide Resistance Extension and Noxious Weeds
5:00 pm – 6:00 pm	Poster and Commercial Display Viewing
6:00 pm – 7:00 pm	Dismantle Posters and Commercial Displays
6:30 pm – 11:00 pm	CropLife Canada Reception
5:00 pm – 6:30 pm	CWSS/SCM Database Committee Meeting
6:30 pm – 11:00 pm	Crop Life Canada Reception

Tuesday, December 2, 2003

8:30 am – 10:00 am	Working Group Session **Integrated Weed Management Working Group** - Organic Weed Control in Integrated Weed Management Systems Physical Weed Control Working Group - Business meeting
10:30 am – 12:00 am	Poster and Commercial Display Viewing Reports by Provincial Representatives
12:00 pm – 2:00 pm	Awards Luncheon

Invasive Weeds in Canada - Present and Future Needs

Chair: Leslie Huffman,OMAFRA, Ontario

2:00 pm – 2:05 pm	**Introduction** – Leslie Huffman,OMAFRA, Ontario
2:05 pm – 3:30 pm	An Overview of Invasive Weeds in Canada How weeds become invasive and why Canada should be concerned - Stephen Darbyshire, *Agriculture and Agrifood Canada, Ottawa* Invasive Weeds in British Columbia - David Clements, *Trinity Western University, British Columbia* Invasive Weeds series in Canadian Journal of Plant Science- Paul Cavers, *University of Western Ontario, London*
3:30 pm – 4:10 pm	National Policy Development on Invasive Plants/Weeds Marcel Dawson, Grain & Field Crops, Plant Health Division, CFIA Claire Wilson, Weed Risk Assessment, Science Division, CFIA
4:10 pm – 4:40 pm	The Challenge of Regulating Invasive Weeds: An example from Quebec - Managing Wooly Cupgrass (*Eriochloa villaso*) Danielle Bernier, Weed Specialist, MAPAQ Marcel Dawson, Plant Health Division, CFIA
4:40 pm – 6:00 pm	Discussion: Priorities for Invasive Weeds in Agriculture Leaders: Danielle Bernier, Weed Specialist, MAPAQ Clark Brenzil, Weed Specialist, SAFRR

Wednesday, December 3, 2003

7:30 am – 9:30 am	**CWSS Annual Breakfast Meeting**
9:30 pm – 11:30 pm	**New Pesticide Products and Herbicide Characterization Working Group Session** 1. Mesotrione for weed control in corn - *Syngenta Crop Protection Canada* 2. Weed control in rangeland and pasture - *Dupont Canada* 3. Roundup Ready Wheat - *Monsanto* 4. Minor Crop registration - *Mike Downs, PMRA*

Symposium

Soil Residual Herbicides: Science and Management

Manuscripts from this symposium in Winnipeg were published as Volume 3 in the series "Topics in Canadian Weed Science"

Van Acker, R. C., ed. 2005. Soil Residual Herbicides: Science and Management. Topics in Canadian Weed Science, Volume 3. Sainte-Anne-de Bellevue, Québec: Canadian Weed Science Society – Société canadienne de malherbologie. 125 pp. ISBN 0-9688970-3-7.

The papers in this volume of Topics in Canadian Weed Science were presented at a symposium held during the Canadian Weed Science Society - Société canadienne de malherbologie (CWSS-SCM) meeting held in Winnipeg, Manitoba in November 2004. The science and management of soil residual herbicides was chosen as the symposium theme because it had become very topical. In farming operations across Canada, pressures of time and scale, and the need for cropping flexibility have heightened interest in the nature and management of soil residual herbicides. Residual weed control, landscape and weather effects on herbicide persistence, crop sensitivity to herbicide residues, re-cropping intervals, bioassays and residual herbicide stacking are all issues weed scientists, agronomists and farmers have to deal with in regard to soil residual herbicides. The symposium hosted international, national and regional experts from government, industry and universities to present the current state of science and management knowledge on this topical issue. The papers presented in this symposium provide an excellent basis for those wishing to gain an understanding of the scientific nature of the persistence of herbicides in the soil. They also offer sound and practical advice for farmers and agronomists who are charged with managing soil residual herbicides to both capture the opportunities they offer while avoiding the challenges they bring.

Graduate student presentations

Biomass partitioning in corn as affected by weed-induced reduction in red-to-far-red light during the critical period of weed control

Joanne G. Liu[1], Peter Sikkema[2] and Clarence J. Swanton[1]
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[2]Ridgetown College, University of Guelph, Ridgetown, Ontario, Canada N0P 2C0

Abstract

The causes of yield loss in corn (*Zea mays* L.) as a result of early season weeds are thus far unknown. Corn yield loss in excess of 5% is possible even when weeds are removed at an early developmental stage such as the fourth leaf tip. At this stage of development there is no direct competition for resources. Researchers believe that plants have adapted to anticipate competition for light by perceiving changes in the light spectrum prior to shading. This research investigates the effect of reduced ratios of red-to-far-red light (R:FR) on dry matter partitioning in corn, and specifically whether early weeds influence how corn partitions dry matter. A 2-year field study was conducted in a hydroponic system with corn and redroot pigweed (*Amaranthus retroflexus* L.) plants, which were used to establish specific periods of low R:FR: 1) weed-free check; pigweed removal at 2) four leaf tips; 3) six leaf tips; 4) eight leaf tips; 5) and ten leaf tips; and 6) weedy-until-silking. Corn was harvested at silking and at the eight leaf tip stage of development. In 2003, root : shoot biomass at silking decreased 27% in corn with weeds present until the tenth leaf tip compared to non-weedy corn. In 2004, root : shoot biomass at 8 leaf tips was 15% less in weedy corn compared to non-weedy corn. Our data suggest that early weeds have lasting effects on corn, shifting biomass partitioning from the roots to the shoots. Such a shift could predispose corn to water and nutrient deficiencies later in the growing season, causing significant yield loss. Also, a decrease in total dry weight at silking suggests that there is a cost associated with this shift.

Introduction

Early season weed control is important because weeds emerging with the crop cause greater yield loss than those emerging later. There can be rapid yield loss in corn if weeds are not controlled beyond the three to four leaf tip stage of development (Figure 1). Yield loss occurs even though weeds are present for only a short period early in development, and resources are usually plentiful for some time after the weeds are removed. What effect are weeds having on corn in these early stages of development?

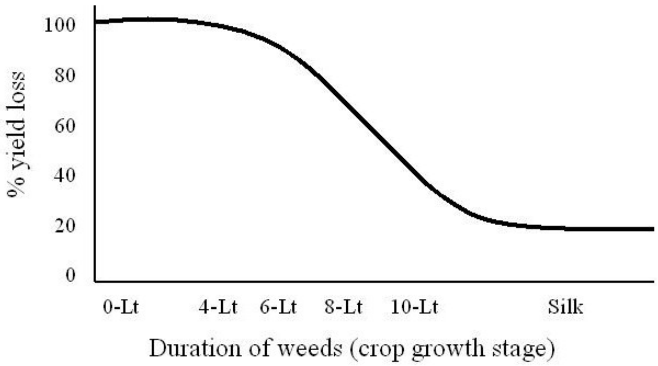

Figure 1. Typical corn yield loss curve.

The ratio of red-to-far-red light (R:FR) is believed to warn of approaching competition. Plants are thought to detect their neighbors before shading becomes important by perceiving low R:FR reflected from nearby plants(Ballaré et al. 1987; 1990). Low R:FR alters plant biomass partitioning: in corn, it promotes greater shoot biomass, and a lower root : shoot ratio (proportionately less roots are produced compared to shoots) (Rajcan et al. 2004; Kasperbauer and Karlen 1994). Our hypothesis is that yield losses in corn caused by early season weeds are the result of changes in biomass partitioning in response to a weed-induced reduction in R:FR. Low R:FR has not been linked to weed management, except for a study by Rajcan et al. (2004) on which this study is built. Thus far, all experiments on corn have been harvested when corn is between eight and ten leaf tips in stage of development: none have taken corn as far as silking.

Materials and Methods

The study was conducted in 2003 and 2004 at the Arkell Research Station near Guelph, Ontario using the corn hybrid Pioneer 3902. It was run on a hydroponic system to control the uniformity of water and nutrients, and to be able to harvest the roots of the corn. The hydroponic system consisted of nutrient solutions and injectors, and automatic irrigation running to 22 L plastic pails filled with Turface. Turface is an inert baked clay medium. Redroot pigweed was grown in plastic cups inserted in a ring around the space for the corn plant. Corn was planted after four leaves appeared on the pigweed. Trimming the pigweed minimized shading of the lower corn leaves. With this experiment setup there was no nutrient effect, no water limitations, and no root competition; we isolated above-ground competition, focusing on the effect of low R:FR reflected from pigweed. At the time of harvest, Turface was washed from the corn roots, and the organs of each plant were separated and dried in a dryer.

There were six treatments of weed removal: weeds were removed at four, six, eight and ten leaf tips of corn, as well there was a weed-free check and a weedy-until-silking treatment. Corn was harvested at silking. Based on the results of 2003 we added an additional harvest at eight leaf tips in 2004, for which we took the weed-free check and weedy-until-eight-leaf-tips treatments.

The experimental design was a randomized complete block. In 2003 the experiment was replicated four times, and there were seven corn plants in each experimental unit. The total number of corn plants was 168. In 2004 the experiment was replicated seven times, and there were five corn plants in each experimental unit. The total number of corn plants was 280 (weed-free check and weedy-until-eight-leaf-tips treatments were doubled to allow for the additional harvest). The number of replications and subsamples had been changed in 2004 to give the experiment greater ability to detect differences based on 2003 results. Thus, the results of the silking harvest were not pooled. The analysis of variance (ANOVA) was performed for all responses using PROC GLM in SAS. Treatments were compared using single degree of freedom contrasts. The type I error rate was set at 0.05.

Results

The root : shoot dry weight ratio decreased (proportionately less dry weight allocated to roots than shoots) after the sixth leaf tip treatment in corn harvested at silking (Figure 2A, 2B). The root : shoot of the ten-leaf-tip treatment was 27% less than the control, and the root : shoot of the silking treatment was 30% less than the control in 2003 (Figure 2A). The root : shoot of late weed removal treatments were less than those of early weed removal treatments in 2004 (Figure 2B).

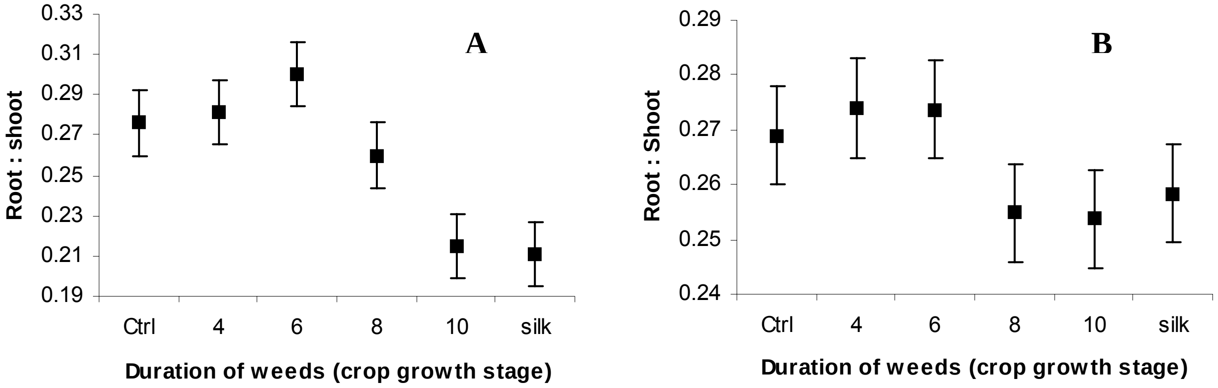

Figure 2. Root : shoot of corn at silking. (A) 2003. (B) 2004. Error bars represent standard errors.

The dry weight of the whole plant decreased with increasing weed duration at silking (Figure 3A, 3B). The loss of total dry weight was apparent at the four-leaf-tip treatment, an effect seen much earlier than the change in root : shoot.

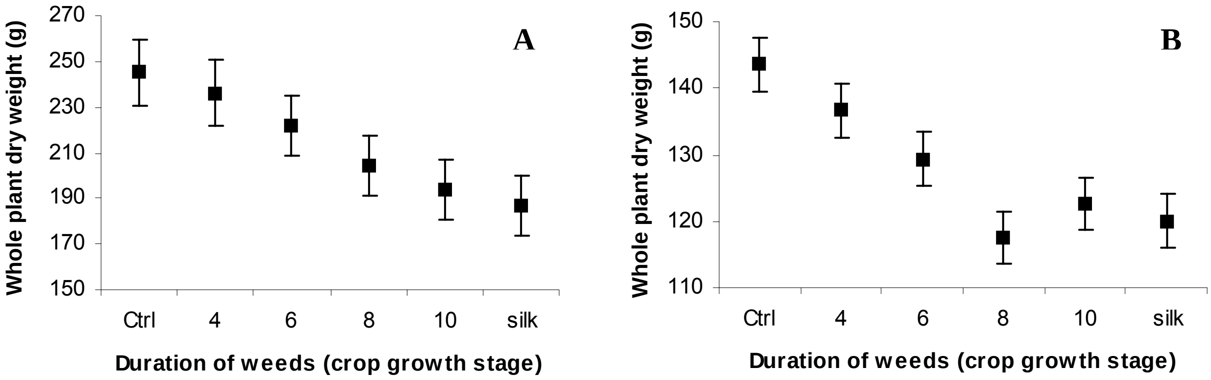

Figure 3. Whole plant dry weight of corn at silking. (A) 2003. (B) 2004. Error bars represent stsandard errors.

Shoot and root dry weights decreased with increasing weed duration at silking (Figure 4A, 4B). Thus the reduced root : shoot was not simply due to a swapping of biomass partitioning between above- and belowground plant parts, nor was it due to a decrease in dry weight of only above- or belowground organs. Lower shoot weights at silking contrast with other studies that harvested corn at earlier stages of development and found shoot weights to increase (Rajcan et al. 2004, Kasperbauer and Karlen 1994).

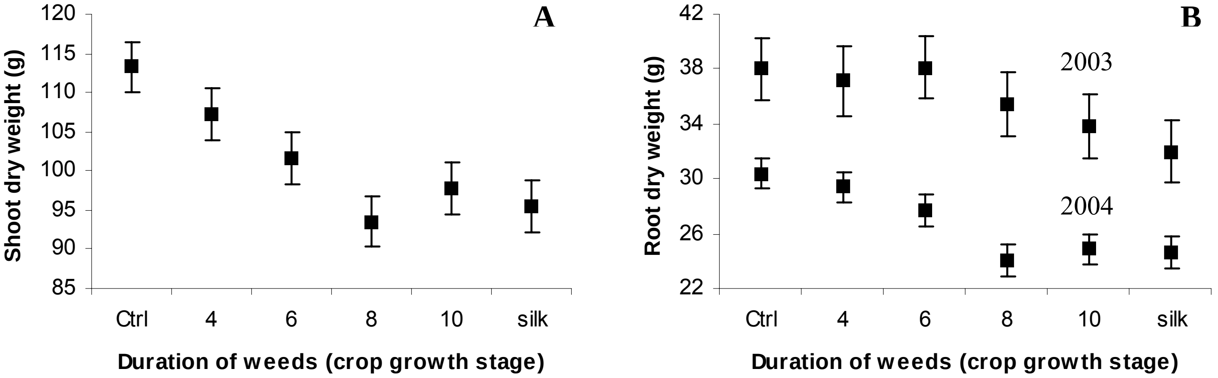

Figure 4. (A) Shoot dry weight of corn at silking in 2004. (B) Root dry weight of corn at silking in 2003 and 2004. Error bars represent standard errors.

The root : shoot dry weight ratio at eight leaf tips was 15% lower in the weedy-until-eight-leaf-tips treatment compared to the control (Figure 5). By silking the same year, the numerical difference had dropped to 5%.

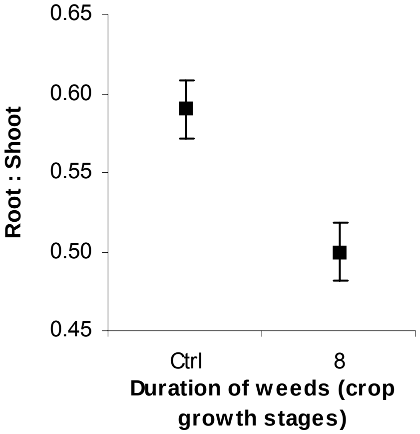

Figure 5. Root : shoot of corn at the eight leaf tip stage of development. Error bars represent standard errors.

Discussion

Low R:FR during corn seedling development clearly have both immediate and long term effects on root : shoot, decreasing the proportion of biomass allocated to roots versus shoots. A low root : shoot could predispose corn to belowground stresses, especially during flowering and grain filling. Total dry weight, and the dry weights of roots and shoots was lower at silking, and those effects appeared in much earlier treatments of weed removal than the decrease in root : shoot. This suggests that low R:FR not only altered biomass partitioning, but may also have affected photosynthesis. This is interesting because corn that has received low reflected R:FR and harvested around eight leaf tips has greater shoot biomass, but if the low R:FR signal is subsequently removed and corn is allowed to reach silking it then has comparatively less shoot biomass. The initial vigour to produce more shoots may have cost the corn plant in establishing a root system large enough to sustain greater shoot growth, which may then have limited photosynthesis and root biomass accumulation.

The implications of this research are that it contributes to our understanding of why early weeds cause yield loss in corn. It gives a physiological explanation for the importance of early season weed control.

References

Ballaré, C. L., Sanchez, R. A., Scopel, A. L., Casal, J. J. and Ghersa, C. M. 1987. Early detection of neighbour plants by phytochrome perception of spectral changes in reflected sunlight. Plant Cell Environ. 10:551-557.

Ballaré, C. L., Scopel, A. L., and Sanchez, R. A. 1990. Far-red radiation reflected from adjacent leaves: an early signal of competition in plant canopies. Science 247:329-332.

Kasperbauer, M. J. and Karlen, D. L. 1994. Plant spacing and reflected far-red light effects on phytochrome-regulated photosynthate allocation in corn seedlings. Crop Sci. 34:1564-1569.

Rajcan, I., Chandler, K. J. and Swanton, C. J. 2004. Red—far-red ratio of reflected light: a hypothesis of why early-season weed control is important in corn. Weed Sci. 52:774-778.

Stress and fitness: using acetolactate synthase-inhibitor resistant eastern-black nightshade (*Solanum ptycanthum* Dun.) as a model

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Abstract

Relative fitness has been stated as one of the major factors influencing the evolution of herbicide resistance. While it is well established that weeds resistant to triazines suffer from an important fitness penalty in the absence of herbicides, the situation is less clear for plants resistant to ALS inhibitors. The objective of this study is to determine the relative fitness of Eastern-black nightshade populations from Ontario resistant due to the $\text{Ala}_{205}\text{Val}$ ALS substitution under water and light stress. Four resistant (R) populations were compared to four susceptible (S) populations and were subjected to water availability stress by exposing them to watering regimes ranging from one-day to five-day interval in a greenhouse. Plants were also exposed to different light quality and quantity regimes in growth cabinets. Under optimal water availability condition (two-day interval) the S populations produced more fruit and seed compare to the R populations despite no difference in aboveground vegetative biomass. Under higher (watering every other day) or lower (watering up to every six days) water availability the reproductive ability of both R and S populations declined, however, this was more pronounced for the S populations so that there was no differences between R and S. These results were in consistence with the preliminary results of light regime experiments. Under a regime of high irradiance (550 $\mu\text{mol m}^{-2}\text{ s}^{-1}$) and a 1.2 ratio of red/far-red (R/FR), S plants produced more berries than the R plants while aboveground vegetative biomass was the same. Any reduction of the light intensity or of the R/FR ratio resulted in reduction in productivity and no difference between R and S. Under optimal light and watering conditions, the S populations always had a higher reproductive output than the R plants which very likely would cause them to have a higher fitness than the R plants in the absence of herbicide selection pressure.

Introduction

Evolution of resistance to ALS inhibiting herbicides has been rapid, and possibly faster than for several other modes of action herbicides (Saari et al. 1994). Relative fitness of resistant biotypes is one of the major factors influencing the evolution of herbicide resistance (Maxwell et al. 1990; Mortimer et al. 1992). While it is well established that triazine resistant weeds suffer an important fitness penalty in the absence of herbicides, the situation is less clear for plants resistant to ALS inhibitors. Results of experiments with ALS-inhibitors resistant plants have shown little if no fitness penalty due to resistance (Saari et al. 1994). However, some have questioned the validity of such a conclusion stating that experimental procedures followed may have prevented identifying small but otherwise biologically significant differences (Gressel, 2002, Cousens et al, 1997).

From an evolutionary point of view, in the absence of herbicides the resistant populations should have some fitness penalty compared to their susceptible counterparts. If the fitness loss of a mutant were to be negligible, there should be some populations that are resistant before selection ever occurs (Gressel, 2002). The main problem in many previous experiments is that plants were grown in the absence of environmental stresses and without taking into account genetic diversity among different populations (Gressel, 2002, Bergelson and Purrington, 1996).

The occurrence of ALS inhibitors resistance in several populations of Eastern-black nightshade in Ontario has been documented since 2001. The result of dose response experiments has shown that, compared to a susceptible (S) population, one of the resistant (R) populations had 726-, 31-, 6-, and 4-fold resistance to post applied imazethapyr, imazamox, primisulfuron, and flumetsulam, respectively. Resistance to imazethapyr was also confirmed in six other R populations from other Ontario locations. The chloroacetamide herbicides metolachlor, dimethenamid, and flufenacet all provided at least 90% control of the R population when applied in pre-emergence and there was no difference with the S population suggesting resistance being confined to the ALS inhibitors only. Sequencing of the *ALS* gene of these R populations revealed the same point mutation coding for an $\text{Ala}_{205}\text{Val}$ substitution. This gave us the opportunity to test what effects this mutations would have on fitness using different populations.

Materials and Methods

Plant Materials.

Four R and four S populations of Eastern-black nightshade from southern Ontario were chosen for this study. All the R plants had the $\text{Ala}_{205}\text{Val}$ substitution in their *ALS*. All the S plants had wild-type *ALS* and were known to be susceptible to ALS inhibitors. In each experiment, ten seeds were planted in 13 by 13-cm pots filled with potting soil. After germination, pots were thinned to one plant per pot, and fertilized weekly.

Watering Regimes.

Pots were placed in a greenhouse with a 16-h photoperiod at 26°C and an 8-h dark period at 22°C with photosynthetically active radiation of 700-µmol m^{-2} s^{-1}. Treatments consisted of five moisture regimes: watering at 1, 2, 3, 4, and 5 days interval, and were initiated when the plants had reached the eight- to ten-leaf stage. The experimental design was a split plot with four replications and it was repeated. Whole plot treatments were five watering regimes and sub-plot treatments were S or R populations.

Light Regimes.

Pots were placed in four growth chambers with 16-h photoperiod at 26°C and an 8-h dark period at 22°C. Using cool white fluorescent and incandescent light sources, four treatments varying in light quantity and quality were established (Table1). The experimental design was a split-plot with three replications. Whole plot treatments were four spectrally distinct light environments and sub-plot treatments were S or R populations.

Data Collection.

For both experiments, plants were cut at soil level 72 days after planting and separated into vegetative parts, mature berries and immature berries before drying in an oven at 80 C for four days. The variables measured were mature berry biomass (MBB), total berry biomass (TBB), aboveground vegetative biomass (AVB), and total aboveground biomass (TAB).

Table 1: Treatments for the Light Regime Experiment.

Treatment	PPFD μmol m^{-2} s^{-1}	Red: far-red ratio
HH[1]	550	1.2
MH	350	1.0
MM	200	0.75
LL	100	0.55

[1] The letters refer to the relative intensity of the treatments (PPFD and ratio): H = high, M = medium and L = low.

Results and Discussion

There are differences in relative fitness of the R and S populations of Eastern-black nightshade. While there was no difference in the aboveground vegetative biomass, the R populations produced less berries than the S. The S plants had berries that matured more rapidly than those of the R plants, however, these differences tended to vary under varying environmental conditions.

Under the two-day interval, watering regime, all S and R populations had the highest productivity. However, the S populations had significantly higher MBB, TBB (Fig 1) and TAB (data not shown) compared to the R populations. Furthermore, AVB were the same for both S and R populations under two-day watering regime, indicating that the differences were due to the decreased reproductive capability of R populations compared to S populations. Moreover, the difference between the above mentioned variables tend to become minimal under the higher (one-day) and lower (three-, four-, and five-day intervals) watering regimes (Fig 1).

Under optimal light conditions (HH), both R and S populations of Eastern-black nightshade had highest MBB, TBB, AVB, and TAB, compare to the other treatments. However, MBB, TBB, (Fig 2) and TAB (data not shown) were significantly higher in S populations. Moreover, the AVB were not significantly different between the S and R populations indicating lower reproductive ability in R populations compared to S populations. Furthermore, the differences in reproductive ability between the S and R populations tended to decrease and become not significant under lower light environments (MH, MM, and LLT) (Fig 2).

The $Ala_{205}Val$ ALS substitution, in addition to conferring resistance to ALS inhibitors, comes at a fitness cost to the plants that bear it. This fitness cost does not involve a reduction in aboveground vegetative biomass accumulation but rather total berries production as well as a delay in the maturation of berries and this was consistent across all S and all R populations. This would mean that at any given time the R plants would produce fewer seeds than the S plants (assuming that seed content per berry is identical).

The fact that increasing stress levels resulted in less difference in the plants' productivity is unexplained yet. The exact link between the mutation in *ALS* and the effects on reproduction also need to be explained. It is possible that the changes in conformation that produce a resistant enzyme slightly affect its kinetic properties. Any change in feedback regulation or in substrate affinity likely results in perturbations of the highly finely regulated branched chain amino acids biosynthetic pathway. This might affect supply of those amino acids in some developmental phases when they are in particularly high demands. This will need to be tested in the future.

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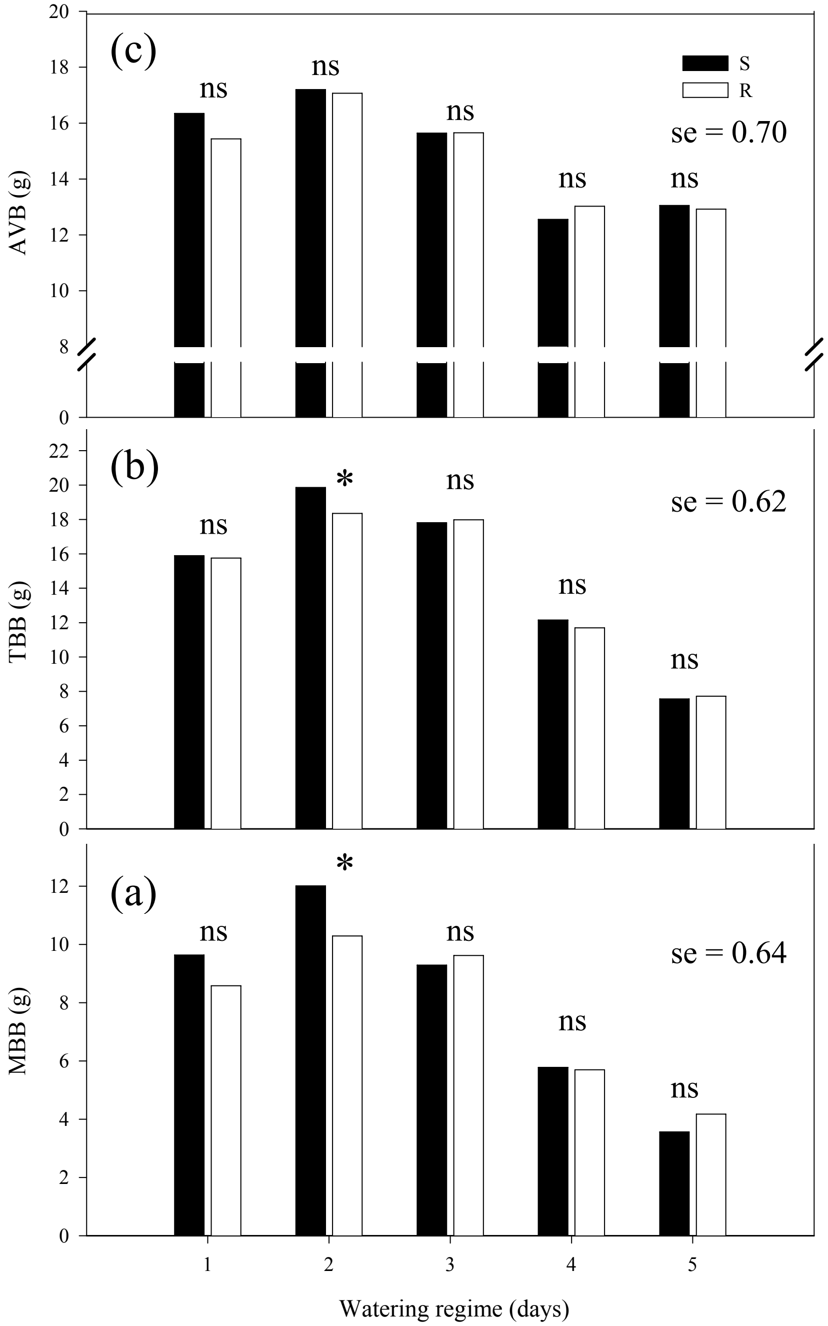

Figure 1. Effect of watering regimes on mature berry biomass (MBB) (a), total berry biomass (TBB) (b) and total aboveground biomass (AVB) (c). All bars are the average of four R or four S populations and the experiment was repeated. Asterisks indicate significant differences ($P < 0.05$).

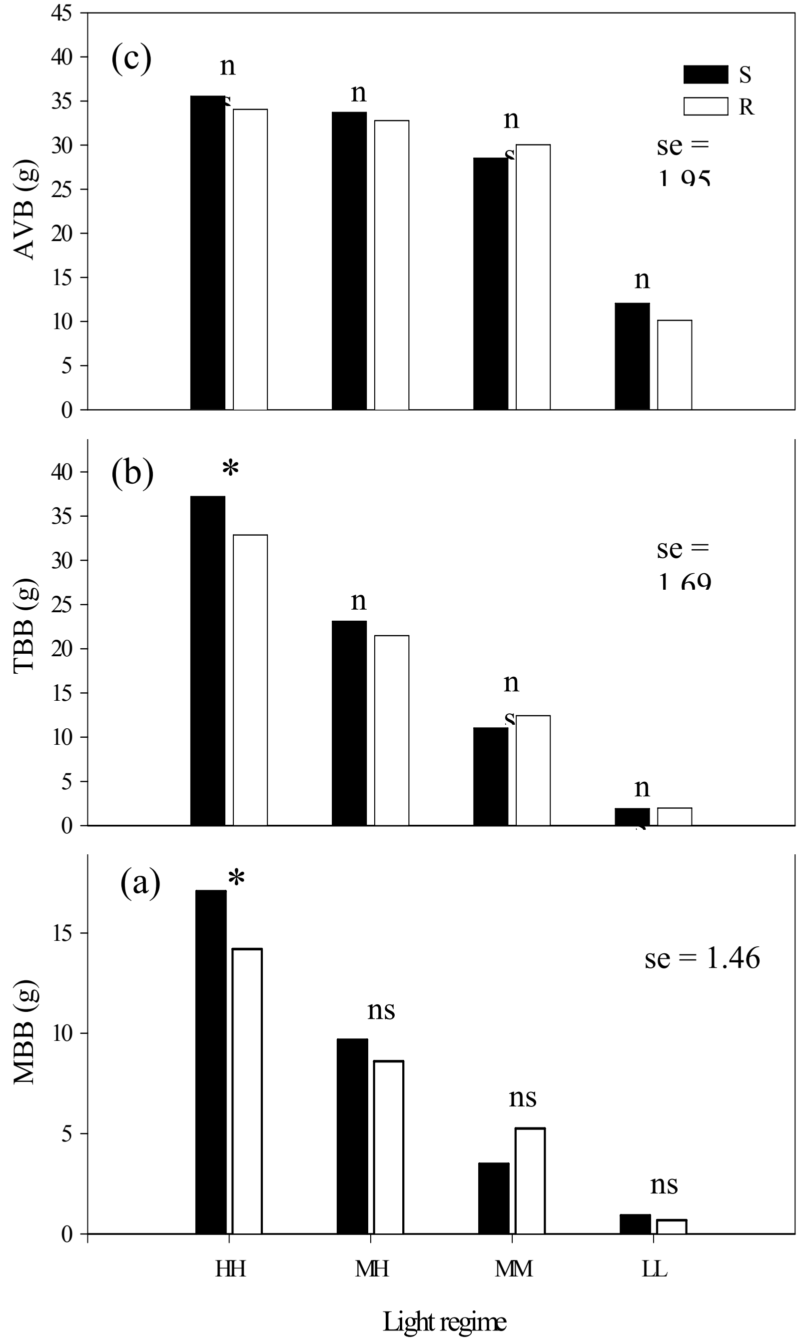

Figure 2. Effect of light regimes on mature berry biomass (MBB) (a), total berry biomass (TBB) (b) and total aboveground biomass (AVB) (c). All bars are the average of four R or four S populations in one experiment. Asterisks indicate significant differences ($P < 0.05$).

Adaptive strategies of common lambsquarters in a corn canopy

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Abstract

Like many species, common lambsquarters adapts to canopy shade conditions by growing taller and by altering biomass allocation in order to project leaves into open daylight. Recently, we demonstrated that light quantity influences how plants respond to light quality. In growth cabinet studies, common lambsquarters height increased due to low light quantity while stem weight decreased due to low light quality; but total leaf area and main-stem leaf number were unaffected by light quantity or quality. Consequently, we believe that leaf area and main-stem leaf number may be adaptive traits for survival in a canopy environment. How plants respond to light, however, is influenced by other factors such as nutrient availability. Therefore, field studies were conducted to determine the effect of corn canopy and nitrogen (N) supply on biomass allocation and seed production of common lambsquarters. Corn was grown at 60,000 and 20,000 plants ha^{-1} to create "Low $_{\text{Light}}$" and "High $_{\text{Light}}$" canopy treatments, respectively. Common lambsquarters were seeded in pots buried at soil level and irrigated with nutrient solutions containing either a "high" (15 mM N) or "low" (1.5 mM N) level of N. At floral initiation and seed set plant height and leaf area were measured, and plants were partitioned into leaves, stems, roots, and inflorescences. Under the closed canopy environment, stem weight and seed production of common lambsquarters plants decreased. In addition, at floral initiation, total leaf area and main stem leaf number were similar across canopy environments and N availability. These findings lend credence to our belief that maintaining similar total leaf area and main stem leaf number are adaptive strategies that allow for common lambsquarters to survive and persist in agricultural systems. Weeds spend a majority of their life cycle within a crop canopy; therefore, it is crucial to understand weed adaptive strategies in a competitive environment in order to predict invasiveness potential.

Introduction

Crop canopy foliage decreases the quantity (photosynthetic photon flux density or PPFD) and quality (ratio of red to far-red light wavelengths or R/FR) of light available for weeds growing beneath it (Holmes and Smith 1977a; 1977b). Many weeds, including common lambsquarters, adapt to canopy shade conditions by growing taller and by altering biomass allocation patterns in order to project leaves into open daylight (Röhrig and Stützel 2001a; 2001b; Smith and Whitelam 1997). Recently, we demonstrated that light quantity influences how plants respond to light quality (Mahoney and Swanton 2004). In growth cabinet studies, common lambsquarters height increased due to low light quantity while stem weight decreased due to low light quality; but total leaf area and main-stem leaf number were unaffected by light quantity or quality. Consequently, we believe that leaf area and main-stem leaf number may be adaptive traits for survival in a canopy environment.

Nutrient availability can also influence plant responses to light (Causin 2004; Wulff et al. 1999; Aphalo and Lehto 1997). Within a crop canopy environment, a nutrient availability stress, such as limited nitrogen (N) supply, can occur (McCullough et al. 1994). Weeds that accumulate more nutrients than crops, for example by increasing height or shoot biomass, can gain a competitive advantage for light (Di Tomaso 1995). However, low nutrient supply reduces overall plant growth with a concurrent increase in dry matter allocation to roots (Aphalo and Lehto 1997). Specifically, N controls biomass production through its effects on leaf area (van Oosterom et al. 2001; Rousseaux et al. 1999; Aphalo and Lehto 1997) and leaf number (Lawlor 2002).

Common lambsquarters height and biomass increases with increasing N (Tilman 1986). Leaf size, leaf number, and lateral shoot production also increases with N availability (Sage and Pearcy 1987). In addition, the shoot/root partitioning of common lambsquarters changes in response to nutrient regime (McConnaughay and Coleman 1998). In high nutrient environments, common lambsquarters had higher growth rates, total biomass, and shoot/root ratio than those grown in low nutrient environments (Gedroc et al. 1996). When competing with a crop, Stoller and Myers (1989) reported that shoot/root ratio increased as PPFD decreased; however, McConnaughay and Coleman (1999) found the opposite.

Despite the fact that alterations in light quality, light quantity and N availability occur within crop canopies, there is little research on light quality by N interactions for common lambsquarters (see Causin 2004). Both low R/FR (Holmes and Smith 1975; 1977c) and low nutrient availability (McConnaughay and Coleman 1999) decrease leaf area in common lambsquarters and could severely affect growth and biomass production. Therefore, the objectives of this field study are to determine the effects of the interaction between R/FR and N supply of common lambsquarters on dry matter accumulation and allocation and seed production.

Materials and Methods

Field studies were conducted in 2003 and 2004 at the Arkell Research Station, Arkell, Ontario, Canada to determine the effect of corn canopy and N supply on biomass allocation and seed production of common lambsquarters. The experiment was a randomized complete block (RCB) with four replications. A suitable corn hybrid was planted at a population of 70,000 plants ha^{-1} in a 76-cm row width, and adequately fertilized to meet typical yield goals. Plots were 4 rows wide by 5.5 m long. Corn seedlings were hand-thinned in the middle two rows to 60,000 and

20,000 plants ha^{-1} to create plots with a "Low $_{Light}$" and "High $_{Light}$" canopy treatment, respectively. The light environment of the Low $_{Light}$ canopy was a R/FR of 0.53 and 280 PPFD, whereas the High $_{Light}$ canopy R/FR and PPFD was 0.79 and 590, respectively.

When the corn seedlings reached approximately the 13 leaf-tip stage, 20-cm diameter plastic pots containing a baked clay growth medium (Turface MVP, Profile Products LLC) were buried at soil level at 0.5 m intervals in the centre of the plots. Common lambsquarters were seeded to a depth of 0.5 cm in these pots prior to burial. Plants were irrigated daily with water, and supplied twice weekly with 500 mL of nutrient solutions containing either a "high" (15 mM N) or "low" (1.5 mM N) level of N (McCullough et al. 1994).

At floral initiation and seed set, plant height and leaf area were measured on randomly selected plants which were then harvested and partitioned into leaves, stems, roots, and inflorescences. Light measurements within the different corn density treatments were taken at solar noon ±1.5 h with a R/FR sensor (SKR 110, Skye Instruments Ltd., Llandrindod Wells, Powys, UK) and a 1-m line quantum sensor (LI-191SB, LI-COR Inc., Lincoln, Nebraska, USA). All common lambsquarters plants not sampled remained in the field and seed traps were used to catch maturing seeds. All seeds collected were bulked within treatment for evaluation of average production per plant and 100-seed weight.

To examine the effect the maternal light and N environments on the seeds collected, we conducted a reciprocal planting experiment. The experiment was a RCB with four replications and was arranged as a split-block. Corn was planted and light treatments were established as previously described. The “high” and “low” nutrient solutions were supplied once weekly. Seeds from the four light – N combinations were sown into individual trays and placed between the corn rows. The placement pattern resulted in seeds germinating, emerging, and growing in similar and contrasting environments to the maternal plant. Emergence data was collected daily for 6 wk, at the end of which time, randomly selected plants from each planting combination were harvested and shoot biomass was measured.

Results and Discussion

Common lambsquarters plants at floral initiation in 2004 performed similarly to our growth cabinet studies. For example, stem weight was lower in plants grown under Low $_{Light}$ High $_{N}$ (LH) (Table 1). However, unlike our previous research, leaf and shoot dry weight at floral initiation was also lower in LH plants. At seed set, common lambsquarters plants were taller for the High $_{Light}$ treatments. This confirms our observation that low PPFD such as that used in our previous growth cabinet experiment is responsible for increases in plant height (Mahoney and Swanton 2004).

Table 1. Effect of corn canopy density and nitrogen fertilizer supply treatments on common lambsquarters stem, leaf, and shoot weights at first harvest and height at second harvest in 2004.

Treatment†	Stem weight (g)‡		Leaf weight (g)		Shoot weight (g)		Height (cm)	
H_{Light} L_N	0.22	a	0.44	a	0.70	a	62	a
H_{Light} H_N	0.12	b	0.26	b	0.39	b	50	ab
L_{Light} L_N	0.10	b	0.22	b	0.33	b	45	bc
L_{Light} H_N	0.07	b	0.11	b	0.19	b	33	c

† H_{Light} = high light; L_{Light} = low light; H_N = high N fertilizer availability; L_N = low N fertilizer availability.
‡ Means within a column followed by the same letter are not significantly different at α = 0.05.

At both harvests, total leaf area and main stem leaf number were similar across canopy environments and N availability (data not shown). This information lends credence to our belief that maintaining similar total leaf area and main stem leaf number are adaptive strategies that allow for common lambsquarters to survive and persist in agricultural systems. This adaptive strategy may be a photosynthetic compensatory mechanism allowing weeds to produce similar biomass across optimal (H_{Light} H_N) and stressful (L_{Light} L_N) growth conditions.

Due to high plant mortality in 2003, biomass harvests were not conducted but seeds from surviving plants were collected. Similar to our growth cabinet studies, seed production decreased for common lambsquarters plants under the Low $_{Light}$ treatments (Table 2). However, unexpectedly, Low $_{Light}$ Low $_N$ (LL) plants produced heavier seed. These results contradict Causin (2004) who reported that common lambsquarters seed production and average seed weight increased with low light quality and high N availability. However, the Causin study used artificial shading to impose light treatments and thus may not accurately represent field conditions.

Table 2. Effect of corn canopy density and nitrogen fertilizer supply treatments on common lambsquarters seed production and weight in 2003.

Treatment†	Seed production‡		Seeds per plant		100-seed weight (mg)	
H_{Light} L_N	6000	a	900	a	5.9	b
H_{Light} H_N	8800	a	1300	a	5.5	b
L_{Light} L_N	800	b	100	b	7.1	a
L_{Light} H_N	1000	b	100	b	5.9	b

† H_{Light} = high light; L_{Light} = low light; H_N = high N fertilizer availability; L_N = low N fertilizer availability.
‡ Means within a column followed by the same letter are not significantly different at α = 0.05.

The first run of the reciprocal planting experiment was conducted in 2004. Preliminary analyses indicated that the maternal environment did affect progeny fitness. For example, the seed matured in the LH environment germinated faster and more frequently across all progeny environments, especially the High Light High N (HH) treatment. We hypothesize that the HH environment should provide optimal conditions for weeds. Plants grown under the HH treatment produced, on average, more biomass across all maternal seed environments. Plants derived from the LH maternal environment produced the most biomass across both High Light treatments. We feel the LH environment simulates typical canopy light and nutrient availability for weeds in current agricultural systems. Based on these results, we could conclude that perhaps seeds produced from environments similar to the LH treatment have better fitness and adaptability than the other seeds tested which may ultimately allow for survival and persistence.

Summary

Crop canopy light and N environments influence common lambsquarters growth and seed production. The maternal environment also influences subsequent progeny. Common lambsquarters when grown under typical agronomic conditions for weeds ($L_{Light}\ H_{N}$) exhibit the adaptive strategies of maintaining leaf area, main-stem leaf number, and shoot, stem, and leaf weights similar to plants grown under optimal conditions for weeds ($H_{Light}\ H_{N}$). In addition, seeds matured in the $L_{Light}\ H_{N}$ maternal environment produce progeny which emerge faster and produce more shoot biomass. Weeds spend a majority of their life cycle within a crop canopy; therefore, it is crucial to understand weed adaptive strategies in a competitive environment in order to predict invasiveness potential.

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Unraveling the mystery of seed dormancy breaking in black medic (Medicago lupulina)

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Abstract

Cover crops are an important innovation in sustainable crop production systems. The successful use of black medic as a cover crop in grain production systems requires a better understanding of how different environmental conditions, particularly temperature, affect its dormancy and its yearly capacity to regenerate. The key to the success of black medic as a self-regenerating legume is its use of the seed dormancy mechanism, hardseededness. In order to 'soften' this hard seed coat, it has been suggested that a 2-stage seed softening process is required. Unlike the high temperatures that are required for the softening of legume species in Australia (e.g. Stage 1: 20 to 60ºC, Stage 2: 60/15ºC), in western Canada, a series of low temperature stages (e.g. Stage 1: 5ºC, Stage 2: 15/6ºC) appear to be required. However, the exact conditions involved in the seed softening of black medic remain unknown. In order to better understand whether or not a 2-stage process is involved in the softening of black medic, and if so, what the stage 1 requirements are, a field experiment and a controlled environment study were established. The results from the studies confirmed that a 2-stage process involving low temperatures is required to soften black medic seed. Also, exposure of seed to temperatures between –5ºC and 5ºC for at least 4 weeks was sufficient to meet stage 1 requirements. If these temperature or time requirements for Stage 1 are not met, softening will not occur. This research has provided us with valuable information about black medic seed dormancy loss under western Canada conditions.

Introduction

Cover crops can play an important role in sustainable crop production systems because they can provide a number of benefits to a cropping system, such as reducing soil erosion or weed suppression, while at the same time still allow a cash crop to be produced. On the Canadian Prairies, the cover crop species black medic is drawing particular interest because of its self-regenerating nature. This means that the farmer only has to establish the black medic crop and after that it will regenerate on its own year after year from its soil seedbank reserve. This allows the farmers to get the yearly benefits of having a cover crop without having the yearly cost of cover crop reseeding. However, before this species can be widely adopted in western Canada we need to learn more about its seed dormancy. This is because it is the use of the seed dormancy mechanism, hardseededness, which allows black medic to form long-lived seedbanks, which is the key to the success of black medic as a self-regenerating legume (Cavers 1995).

Before germination can occur, the hard seed coat must be "softened", and it has often been cited that temperature plays an important role in this dormancy breaking. Research in Australia has shown the importance of a 2-stage temperature mediated softening process for many legumes species. The first stage in this process is a high temperature phase (e.g. 20ºC to 60ºC), while the second stage is a short period (3 to 7 days) of high alternating temperatures (e.g. 60/15ºC) (Taylor 1981). Research by Van Assche et al. (2003) and Braul (2004) suggests that a 2-stage seed softening process is also required for the softening of black medic when it is grown in a temperate environment, such as western Canada. However, unlike the results from Australia, stage 1 is believed to be a chilling period (e.g. 5ºC), while stage 2 is a low fluctuating temperature stage (e.g. 15ºC/6ºC). However, whether or not a 2-stage process is actually required for black medic softening, and if so, what the actual stage 1 requirements are still remains uncertain. Therefore, the specific objectives of this study were to:

1) Determine whether a 2-stage process is required for the softening of black medic in western Canada
2) Determine what temperature/time combinations were sufficient to meet stage 1 requirements for black medic in western Canada

Materials and Methods

1) Field experiment

A field experiment was established in the summer of 2003 at two locations in western Canada: Winnipeg and Indian Head. At each of these sites, black medic was grown and the seed from these plants was harvested in the fall. Immediately following harvest, this seed was placed into a number of small pouches, which were subsequently placed in three locations: Winnipeg, Indian Head and Lethbridge. At each of these locations, temperature-sensing devices (HOBOs) were placed alongside the pouches to continually monitor soil temperature. Throughout the year (November, January, February, March, April, June, August) sub-samples of these pouches were removed from the three locations. For each removed pouch, half the seed was placed under a normal germination temperature (20ºC), while half was placed under a low fluctuating germination temperature (15/6ºC) meant to simulate stage 2 conditions. At each of these sampling times a control treatment (seed stored at room temperature (20ºC)) was also subjected to these two germination temperatures. After allowing the seed to germinate for 2 weeks, the percentage of softened/germinated seed in each of these treatments was determined and the viability of the remaining hard seed was checked.

2) Controlled Environment Study

In order to better understand the stage 1 requirements for black medic, a controlled environment study was established. Black medic seed was exposed to two temperatures (5ºC and –5ºC) for a period of time (2, 4, 6, 8 or 10 weeks). For each temperature/time combination, the seed was allowed to germinate under stage 2 conditions (i.e., 15/6ºC) in order to determine whether or not the particular temperature/time combination was sufficient to meet stage 1 requirements.

Results and Discussion

1) Field Experiment

Over the course of the winter sampling period, no significant softening occurred at any of the sites. By late winter/early spring, significant softening was observed at both Lethbridge and Winnipeg when seed was removed from the soil and subjected to the stage 2 conditions. Since softening only occurred after the seed had been subjected to the stage 1 conditions in the field and the stage 2 conditions in the lab, a 2-stage process involving low temperatures was confirmed. Temperature data from both of these sites supports this conclusion. For example, at Winnipeg we found that the black medic seed was exposed to a constant chilling temperature (approximately -5ºC) for a period of ~ 46 days, and this was followed by a period of low fluctuating temperatures (Figure 1).

By the end of the sampling period, approximately 20% of the black medic seed had softened at Lethbridge and Winnipeg, which was significantly more than at Indian Head (Table 1).

Table 1. Mean Percentage of Black Medic Seed Softened by August

Site	% Softened*
Indian Head	5.13b
Winnipeg	20.25a
Lethbridge	18.93a
Control	3.38b
LSD(0.05)	2.14

*Means followed by the same letter are not significantly different

At Indian Head, significant softening did not occur (Table 1). The reason for this appeared to be that unlike at Winnipeg and Lethbridge, at Indian Head there was a period of cold temperatures (<-5ºC) during the winter (Figure 2). This may have prevented softening from occurring for two reasons: 1) the period of time spent at the cold temperatures resulted in the seed only being exposed to the stage 1 temperatures (-5ºC) for ~23 days, which may not have been long enough to meet stage 1 requirements, 2) the cold temperatures may have caused something to occur in the seed that prevented it from softening.

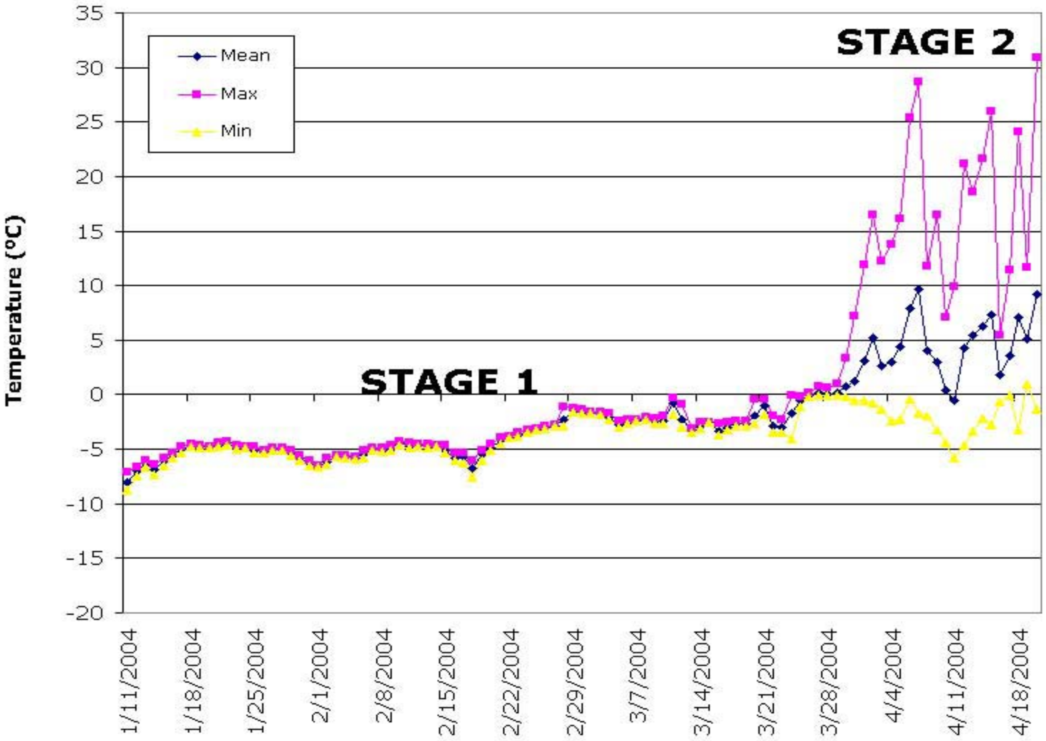

Figure 1. The daily mean, maximum and minimum soil temperatures in Winnipeg

2) Controlled Environment Study

The results from the controlled environment study showed that both –5ºC and 5ºC are acceptable stage 1 or "chilling" temperatures, but that the seed must be exposed to these temperatures for at least 4 weeks before softening can occur (data not shown). These results may help explain the lack of seed softening at the Indian Head site. At Winnipeg and Lethbridge the black medic seed was exposed to –5ºC for > 5 weeks, and softening occurred, while in Indian Head the seed was exposed to –5ºC for < 4 weeks. Since it appears that at least 4 weeks is needed to meet stage 1 requirements, the low level of softening at Indian Head may be attributed to insufficient exposure to stage 1 conditions.

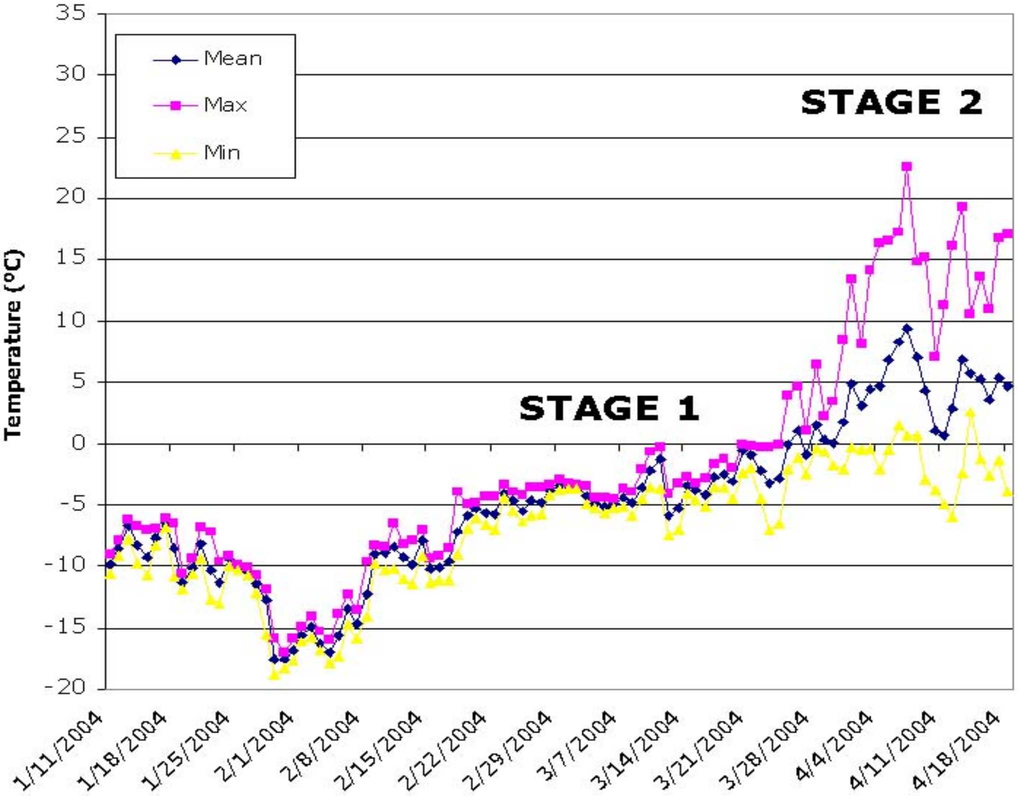

Figure 2. The daily mean, maximum and minimum soil temperatures in Indian Head

Conclusions

This research has provided strong evidence that a 2-stage process is required for black medic seed to soften (i.e., break physical dormancy). Unlike the high temperatures that are required in Australia, in western Canada a series of low temperature stages appear to be involved. In order for the stage 1 requirements to be met, it appears as though exposure to temperatures between –5ºC to 5ºC for approximately 4 weeks is sufficient. If seed is exposed to these chilling temperatures for less than 4 weeks, softening will not occur. Although this research has answered a number of questions regarding black medic seed dormancy, there are still a number of questions that remain. For example, it is important to determine what role cold temperatures (<-5ºC) may play in the softening of black medic seeds and also what the exact conditions (e.g. amplitude and frequency of temperature fluctuations) are needed to meet stage 2 requirements.

Acknowledgments

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Emergence timing and management of volunteer canola *(Brassica napus* L.) in spring wheat fields.

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Abstract

Volunteer canola is commonly observed in western Canadian cropping systems but characterization of the emergence timing of this species to date has been largely anecdotal or superficially quantitative. The emergence period of volunteer canola was tracked *in situ* in spring wheat fields located in southwestern Manitoba. Monitoring of volunteer canola emergence commenced prior to wheat crop seeding and ended four weeks after in-crop herbicide application. There has been no published record of overwintering volunteer canola plants in western Canada. Thus, the volunteer canola plants observed in this study were assumed to have originated from seed germination in the spring. The production fields examined represented three common tillage regimes: conventional tillage (fall tillage and spring tillage), low disturbance direct seeding (narrow openers), and high disturbance direct seeding (wide sweeps). Results from two years of study indicate that the emergence of volunteer canola is seasonal in nature, with the majority of emergence occurring prior to seeding or in-crop herbicide application. Fields subjected to high disturbance direct seeding had the highest densities of volunteer canola, while the conventionally tilled fields had the lowest densities of this weed. Observations from a controlled field plot study were in agreement with the observations from the production fields. Despite high overall observed volunteer canola densities, the timing of management events (pre-seed herbicide application, seeding, and in-crop herbicide application), in combination with spring frost events and intense flea beetle (*Phyllotreta* spp.) pressure, resulted in very little volunteer canola biomass accumulation in the wheat crop. Flowering canola plants were observed in a small number of fields after the in-crop herbicide application; however, the flowering canola was found in strips, indicating a sprayer miss. Based on the observed emergence period of this species, current management practices in spring wheat appear to be well timed for the control of volunteer canola.

Introduction

Volunteer canola populations (unwanted populations in arable fields) are commonly observed in years following a sown canola crop but generally have not been considered difficult to control (Gulden 2003). The production of GE herbicide resistant *B. napus* varieties, in combination with an increase in the annual acreage of seeded canola over the past two decades, provides a partial explanation for the increase in the occurrence of volunteer canola in western Canada. Based on results of a Manitoba Weed Survey, volunteer canola moved up in rank from 19th in 1997 to 10th in 2002, based on relative abundance (Leeson et al. 2002; Thomas et al. 1998). The increase in relative abundance was due primarily to an increase in frequency, not density. Volunteer canola was found in more of the fields surveyed in 2002 as compared to 1997. The rise in frequency of volunteer canola may be related to an increase in reduced tillage acres (Gray et al. 1996) and an increase in crops such as oilseeds and pulses being grown in rotation where effective volunteer canola control is more difficult than in cereals (Friesen et al. 2003; Thomas and Wise 1983; Thomas et al. 1998). The presence of GE herbicide resistant volunteer canola, even at low densities, introduces several complications for crop production including the limitation of certain crops and herbicides in the years following a canola crop, the existence of a potential pollen source for the dispersal of transgenes to neighboring canola crops, weedy relatives, and subsequent canola crops (Beckie el al. 2001; Rieger et al. 2002), and the contamination of canola seedlots (Downey and Beckie 2002; Friesen at al. 2003). High seed shatter potential and small seed size can result in large harvest losses of *B. napus* (Brown et al. 1995; Thomas and Donaghy 1991). Studies by Gulden et al. (2003) in western Canada have shown average harvest losses in canola to be 5.9%, which equates to 3600 seeds m^{-2} or 107 kg ha^{-1}. Characterizing the emergence period of volunteer *B. napus* is important because there are agronomic, ecological, and economic implications that result from the presence of volunteer canola populations in subsequent crops.

Objectives

The four main objectives of this study were,

(1) To determine empirically, the emergence timing for volunteer canola, as related to growing degree days;

(2) To determine whether or not the current management techniques for volunteer canola, implemented by farmers are effective, specifically in different tillage regimes;

(3) To determine the potential competitive impact of volunteer canola in spring wheat fields;

(4) To determine empirically, what proportion of autumn shed canola seed germinates and emerges as successful spring seedlings.

The first three objectives were achieved by tracking the emergence period of volunteer canola *in situ* in spring wheat fields within the Aspen Parkland ecoregion of Manitoba. Monitoring of volunteer canola emergence commenced prior to wheat crop seeding and ended four weeks after in-crop herbicide application. There has been no published record of overwintering canola plants in western Canada. Thus, the volunteer canola plants observed in this study were assumed to have originated from seed germination in the spring. Canola shoot biomass samples were collected both prior to and 2 weeks post in-crop herbicide application, to provide an indication of the potential competitive impact of volunteer canola.

The fourth objective was achieved by setting up three experimental field sites (Winnipeg, Kelburn, and Carman) in the autumn of 2003 in areas where canola had not been grown for at least four years. Highly germinable canola seed was broadcast at 3600 seeds per square meter and four tillage treatments were established (fall till and spring till; fall till only; spring till only; no till). Volunteer canola emergence was tracked in the spring of 2004, beginning prior to wheat crop seeding and ending one week after in-crop herbicide application.

Results

The production fields monitored represented three common tillage regimes: conventional tillage (fall tillage and spring tillage), low disturbance direct seeding (narrow openers), and high disturbance direct seeding (wide sweeps). In 2003, conventional tillage resulted in earlier emergence of volunteer canola while direct-seed low soil disturbance and direct-seed high disturbance resulted in delayed emergence (Fig. 1).

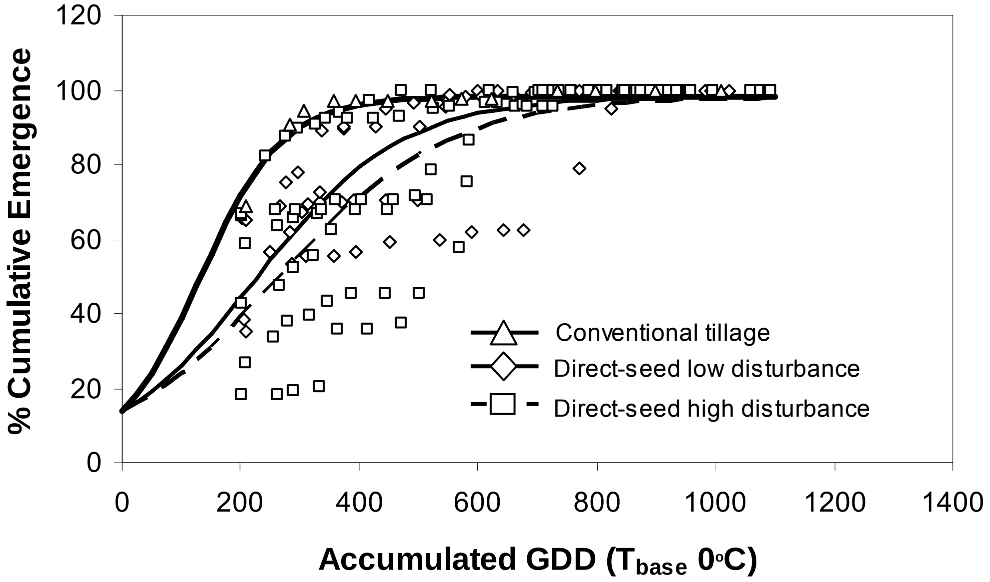

Figure 1. Volunteer canola emergence period in commercial production fields in 2003 as related to soil growing degree days (GDD, base 0°C, 2.5 cm from the soil surface). Markers represent field data and lines represent the fitted regression equations. Data were fitted to a logistic model.

In 2004, data from fields in the conventional tillage and direct-seed high disturbance categories combined statistically to form one emergence curve. Direct-seed low soil disturbance resulted in earlier emergence of volunteer canola while conventional tillage/direct-seed high soil disturbance resulted in delayed emergence (Fig. 2). However, the emergence curve was much steeper for conventional tillage/direct-seed high soil disturbance; cumulative emergence reached 100% over a very small span of accumulated growing degree days.

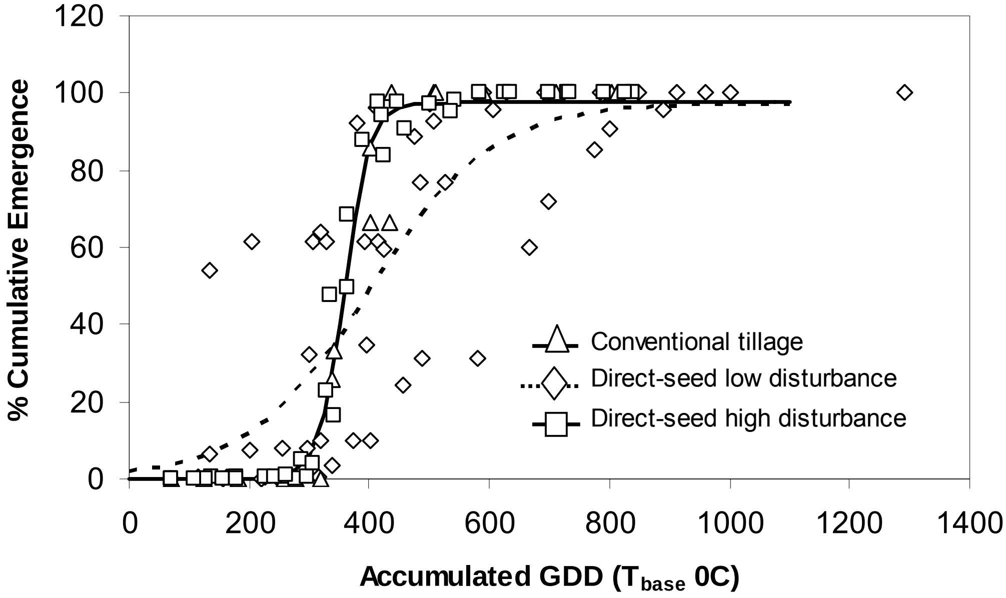

Figure 2. Volunteer canola emergence period in commercial production fields in 2004 as related to soil growing degree days (GDD, base 0°C, 2.5 cm from the soil surface). Markers represent field data and lines represent the fitted regression equations. Data were fitted to a logistic model

Conventionally tilled fields had the lowest densities of volunteer canola while fields subjected to high disturbance direct seeding had the highest densities (Table 1). Total emerged volunteer canola seedlings ranged from 6 to 2015 seedlings per square meter. In 2003, a significant amount of emergence occurred prior to crop planting, due to warm temperatures in April. These seedlings were controlled with the seeding operation alone, or in combination with a pre-seed herbicide burnoff application. In 2004, very little emergence occurred prior to crop planting due to cooler temperatures in April and May. Despite high overall observed volunteer canola densities, the timing of management events (pre-seed herbicide application, seeding, and in-crop herbicide application), in combination with spring frost events and intense flea beetle (*Phyllotreta* spp.) feeding pressure, resulted in very little volunteer canola shoot biomass accumulation in the wheat crop. In 2003, volunteer canola emergence was observed after the in-crop herbicide application (Table 1); however this emergence was extremely limited and of little concern since none of these seedlings resulted in flowering plants. Flowering canola plants were observed in a small number of fields after the in-crop herbicide application; however, the flowering canola was found in strips, indicating an unsprayed area (a missed strip during herbicide application).

For the experimental field sites, site was not significant as a factor and therefore results were pooled. Tillage treatment was highly significant, with canola densities and percentage spring recruitment being lowest in treatments that included fall tillage (comparable to the conventional tillage production fields) (Tables 2 and 3). The highest canola densities and percentage spring recruitment occurred in the fall no till spring till treatment (comparable to the direct-seed high disturbance production fields). Proportional spring recruitment values ranged from 1.3% to 9.4%.

Table 2. Final Cumulative Emergence of Volunteer Canola (Seedlings m^{-2}) in 2004 Field Experiments, as Affected by Tillage Treatment. Data was Pooled across Three Field Sites. Values in Parentheses are Standard Errors.

Tillage treatment	Total emerged canola seedlings (no. m^{-2})
Fall till spring till	96 (24.1)a[a]
Fall till spring no till	47 (10.9)a
Fall no till spring no till	228 (39.2)b
Fall no till spring till	338 (48.9)c
LSD (0.05)	90

[a] Means followed by different letters are significantly different according to Fishers protected LSD ($p<0.05$).

Table 3. Proportional Emergence of Volunteer Canola in 2004 Field Experiments, as Affected by Tillage Treatment. Data was Pooled across Three Field Sites. Proportional Emergence is a Percentage Based upon Initial Seedbank Additions of 3600 seeds m^{-2}. Values in Parentheses are Standard Errors.

Tillage treatment	Proportional canola emergence (percentage of 3600 seeds m^{-2})
Fall till spring till	2.7 (0.7)a[a]
Fall till spring no till	1.3 (0.3)a
Fall no till spring no till	6.3 (1.1)b
Fall no till spring till	9.4 (1.4)c
LSD (0.05)	2.5

[a] Means followed by different letters are significantly different according to Fishers protected LSD ($p<0.05$)

Table 1. Field Characteristics and Cumulative Emergence of Volunteer Canola (seedlings m^{-2}) in 2003 and 2004, Relative to Management Period.

		Emerged canola seedlings							
Tillage system/Year-field designation	Soil texture[a]	Total		Prior to crop planting		Prior to in-crop herbicide application		After in-crop herbicide application	
		2003	2004	2003	2004	2003	2004	2003	2004
		no. m^{-2}							
Direct-seed low disturbance									
2003-H	Clay	351 (226)[b]		198 (125)		146 (112)		7 (1.5)	
2003-K	Clay to silty clay	313 (187)		220 (190)		93 (45)		0	
2003-T	Clay loam	211 (200)		117 (138)		50 (55)		44 (15.6)	
2003-U	Loam to clay loam	145 (48)		94 (25)		51 (45)		0	
2004-A	Clay		234 (362)		1 (2)		233 (360)		0
2004-D	Clay loam		13 (12)		8 (8)		5 (6)		0
2004-X	Loam to clay loam		418 (314)		0		418 (314)		0
2004-Y	Clay loam		221 (62)		69 (24)		152 (51)		0
Direct-seed high disturbance									
2003-L	Clay loam	838 (472)		568 (65)		270 (460)		0	
2003-M	Clay loam	2015 (731)		720 (201)		1295 (709)		0	
2003-N	Clay loam	1722 (555)		1163 (300)		559 (332)		0	
2003-P	Clay loam	1016 (229)		935 (256)		81 (38)		0	
2003-R	Clay loam	603 (79)		426 (101)		177 (115)		0	
2003-S	Clay loam	831 (408)		378 (266)		453 (323)		0	
2004-E	Clay loam		451 (169)		0		451 (169)		0
2004-F	Clay loam		279 (137)		2 (4)		277 (134		0
2004-V	Clay loam		253 (107)		1 (2)		252 (106)		0
Conventional tillage									
2003-Q	Clay loam	129 (124)		125 (123)		4 (3.3)		0	
2004-I	Clay loam		6 (5)		0		6 (5)		0
2004-J	Clay loam		35 (15)		0		35 (15)		0
Tillage system means[c]									
Direct-seed low disturbance		255 (47)[d]	222 (83)	157 (31)	20 (17)	143 (47)		13 (11)	0
Direct-seed high disturbance		1171 (230)	328 (62)	698 (125)	1 (1)	423 (120)		0	0
Conventional tillage		129[e]	21 (15)	125	0	15 (10)		0	0
LSD (0.05) for tillage system totals		1007	NS	547	NS	339		-	-

[a] According to Manitoba Department of Agriculture 1956a, 1956b.

[b] Standard deviations in parentheses for means of four 1.0 m^{-2} quadrats per field (original quadrat size was 0.25 m^{-2} and data was expressed on a 1.0 m^{-2} basis prior to ANOVA).

[c] In 2003, means for total no. m^{-2} and means for the management period 'Prior to crop planting' differed between tillage systems according to Fishers protected LSD ($p<0.05$).. In 2004, means for total no m^{-2} and means for the management period 'Prior to crop planting' did not differ between tillage systems according to Fishers protected LSD ($p<0.05$). For the management period 'Prior to in-crop herbicide application', results of ANOVA indicated that year was not significant and disturbance was significant according to Fishers protected LSD ($p<0.05$). For the management period 'After in-crop herbicide application', the dataset did not meet the assumptions of ANOVA.

[d] Standard errors in parentheses for tillage system means.

[e] Standard errors could not be calculated for the conventional tillage class in 2003 for the total no m^{-2} and for the management period 'Prior to crop planting' as there was only one field within this class.

Conclusions

Results from two years of study indicate that the emergence of volunteer canola is seasonal in nature, with the majority of the emergence occurring prior to seeding or in-crop herbicide application in spring wheat, regardless of tillage category. However, seedling densities can vary significantly between tillage systems. It appears that although avoiding fall tillage results in higher volunteer canola populations in the spring immediately following a canola crop, this may be an effective management strategy in limiting the long-term persistence of volunteer canola populations. Based on the observed emergence period of volunteer canola, current management practices in spring wheat appear to be well timed for effective control. Nevertheless, strips missed during herbicide application do allow volunteer canola plants to become part of the species' metapopulation and these plants also have the potential to contribute seed to the seedbank. Growing a competitive crop such as wheat, which has a wide range of herbicide options available to control canola volunteers, appears to decrease the overall negative impact of volunteer canola in the year immediately following a canola crop. Proportional recruitment values from the field experiment sites indicate that producers can expect from 1 to 9% of canola harvest losses to emerge in the spring immediately following a sown canola crop. Field based characterization of the emergence timing of volunteer canola will allow for further development of practical management plans for volunteer canola. Such management plans are necessary in most cropping systems in western Canada, where the ubiquitous presence of herbicide resistant volunteer canola affects many aspects of agricultural production.

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Crop residue effects on weed population and community dynamics in no-till agriculture

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Abstract

Efficient weed management in agro-ecosystems requires knowledge of the effects of the management system in use on plant community interactions (weeds and crops), weed population dynamics and individual weed species responses. Despite the increase in the use of conservation tillage practices in the last 30 years, an information gap still remains. The objective of these studies is to gain insight into the responses of weeds to crop residues in no-till agriculture for the purpose of improving weed management. Overall, these studies will examine the effects of different crop litters (corn, soy, wheat), each tested at varying percentages of soil surface cover, in no-till plots, on weed seedling emergence, survival and reproduction, and weed seed-bank dynamics.

Introduction

The overall challenge in agro-ecosystems is to change competitive interactions between the target crop and weed species in the plant community. This can be achieved either by increasing the competitive ability of the crop through genotypic selection, crop densities and spatial arrangements; or by decreasing the weeds competitive ability by limiting resource and microsite availability, through tillage and cultivation practices and by control agents. Weed management practices require that they be effective; both in labour and cost, and protect ecosystem health. Control of weeds through herbicides has been the dominant weed management strategy, particularly in conservation/reduced tillage regimes. Recent concerns regarding chemical dependence for weed control include loss of effectiveness as a result of developed resistance, environmental degradation, negative effects on non-target species and input costs. Conservation tillage provides many benefits as a result of the crop residue left on the soil surface after harvest (Fawcett and Towery, 2002). These benefits include the reduction of soil erosion, soil moisture evaporation and soil compaction; increases in organic matter; and reductions in fuel consumption, equipment costs and greenhouse gas emissions (Fawcett and Towery, 2002, Phillips *et al*, 1980). One can wonder if the benefits of conservation tillage outweigh the negative effects of chemical dependence through increased use of herbicides with this tillage system. An important aspect of conservation tillage that has had minimal attention in agro-ecosystems is the affect of crop residue (stubble/leaf litter) on weed population and community dynamics. Leaf litter has been shown to significantly affect weed seed production and seed-bank dynamics (Downs and Cavers, 2002), as well as weed seedling emergence, survival and vigour (Mohler and Calloway, 1992). It is possible that a greater understanding of the ecological principles governing weed responses to crop residues may help tailor weed management practices that will allow for a decrease in chemical dependence.

Objectives

The objective of my proposed study is to gain insight into the responses of weed populations to crop litter in no-till agriculture for the purpose of improving weed management. Overall, these studies will examine the effects of different crop litters (corn, soy, wheat), combined with varying proportions of soil surface cover by crop litter in no-till plots, on weed seedling emergence, survival and reproduction, and weed seed-bank dynamics.

Methods

The composition of weeds in the agricultural seed bank in no-till fields is being determined through greenhouse emergence studies. This will help determine if different crop litters, and their rotation arrangement, affect agricultural seed-bank composition and in what direction weed species selection occurs, if at all.

Measurement of the percent cover of crop litter that occurs in farmers' fields will be collected to provide a realistic comparison to the levels of percent cover used in the experiments.

In the experimental portion of the study, a standard seed bank with known numbers of weed species common in no-till fields will be used. Germination studies of the standard seed bank species, performed in growth chambers, will help in characterizing patterns of species emergence and germination percentages that may be observed in the field and greenhouse experiments.

The experiments being performed in the greenhouse, as well as in field plots, expose the standard seed bank to different types and percent cover of litter, representing the variations found in field situations. Weed seedling emergence and survival will be observed intensively by recording the number of seedlings of each species through weekly counts.

One field experiment will incorporate competing cash crops and several rotations of crop litter build-up to determine the effects of crop litter (amount and type) on crop relationships with weed populations.

A final experiment will determine if viable weed seeds that become attached to crop litter are a major factor in annual seed input, as well as if any one crop-litter type contributes to annual weed-seed carry-over to a greater extent than others. Investigating the mechanism(s) of the effect that crop litter has on weed populations is beyond the scope of the study. However, theories of regulation through allelopathy and competitive plant interactions will be visited and evaluated.

Preliminary results

A small scale field trial performed between October 2003 and August 2004 focused on the effect of varying the percent cover of soybean litter on weed emergence in a no-till soybean field. The soybean residue on the soil surface ranged from 0% to 200% cover. Statistical analysis has not yet been performed on the data. However, observationally, the trend seems to indicate an inversely proportional relationship between litter percent cover and number of weed plants. The relationship shows that increasing the percent cover of litter dramatically decreases the establishment of weed species in treatment plots.

Several other greenhouse experiments have been conducted over the last year, but data collection is not yet complete. This includes a seed bank study from several no-till research locations, a litter study observing weed emergence in response to different litter types established in varying densities and two germination studies.

Conclusion and significance

This research is of importance, not only because of the recent increase in no-till agriculture, but also because knowledge of weed population dynamics in agriculture leads to efficient weed management strategies, which is vital for crop success. Efficient weed management can reduce herbicide dependence in conservation tillage practices, thereby increasing the attractiveness of implementing these systems where the benefits of conservation tillage have not yet been realized. This research also provides new insight into the use of ecological principles in weed management. My intent is that this research will enable farmers to reduce management costs while, at a minimum, maintain cash-crop yield.

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Emergence timing and control of dandelion (*Taraxacum officinale*) using fall or spring applications of glyphosate and florasulam in spring wheat fields

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Abstract

The control of dandelion (*Taraxacum officinale* Weber in Wiggers) in annual field crops can vary tremendously but the cause for this variation is mostly unknown. The abundance of dandelion in annual crops has increased greatly in Manitoba over the past decade. Determining whether a dandelion plant in spring is arising from a newly established seedling or from a fall rosette is important because it influences the competitive ability of dandelion and impacts control strategies. Field studies were conducted on dandelion recruitment biology in terms of emergence timing from either seed or rootstock. The efficacy on dandelion of florasulam (a new ALS inhibitor with short soil residual activity) and glyphosate versus other herbicidal compounds applied at various rates in the fall (post-harvest) or spring (pre-seed) was investigated. Dandelion is a simple perennial that reproduces from either seed or rootstock, but the source of population spread is seed. Targeting the source of population spread is crucial in managing infestations. Results from our study show that dandelion rootstock emergence was greatest early in the spring and diminished throughout the remainder of the season, while the majority of seedlings emerged after the time when in-crop (post-emergence) herbicides would normally be applied. Therefore, in-crop weed control targets over-wintering dandelion rosettes and shoots regenerating from established rootstock but misses true seedlings which are the cause of population spread. Pre-seed herbicide applications target over-wintered rosettes of dandelion (large and small), but the herbicide soil residual activity of spring applied glyphosate + florasulam or glyphosate + tribenuron were insufficient to provide control of dandelion seedlings emerging in early summer. In our study, fall treatments overall were more efficacious than spring treatments. Fall applications controlled both large dandelion rosettes and true seedlings which emerged in mid-summer and early fall (seedlings emerging after the normal in-crop herbicide application).

Introduction

The control of dandelion (*Taraxacum officinale*) in annual field crops can vary tremendously but the cause for this variation is mostly unknown (Froese, 2001). Dandelion was ranked 9th on the 2002 Manitoba Weed Survey, up from a rank of 13th in 1997, with a frequency of 20.6% in fields surveyed and a relative abundance of 7% (Leeson et al., 2002). This increase in dandelion abundance may be due to above average rainfall in Manitoba over the past few years (Van Acker et al., 2002), as moist soil conditions favour dandelion seedling recruitment (Boyd and Van Acker, 2003), the fact that there are few good control options available to manage this weed, and the reduced soil disturbance associated with minimum tillage practices provides an ideal niche for dandelion establishment and growth (Stevenson and Johnson, 1999; Van Acker and Hacault, 2005). Dandelion is a simple perennial species that is capable of reproducing from either seed or rootstock but the source of population spread is via seed alone (Solbrig and Simpson, 1974). A greater understanding of the biology and ecology of dandelion, and herbicide efficacy on this species, especially under western Canadian environmental and agricultural conditions, will aid in devising more effective management strategies for dandelion in annual field crops. For example, it is uncertain whether dandelion rosettes that producers observe in the spring are rosettes that survived over the winter, shoots emerging from pieces of rootstock, or new seedlings. This information would aid in developing control practices that are synchronized with the life cycle of dandelion. Investigating the emergence periodicity of dandelion plants from either seed or rootstock may enhance management decisions and provide an explanation why dandelion plants differ in their tolerance to herbicides applied at various times throughout the growing season, and why dandelion infestations spread in some field crop situations.

The specific objectives of this project are to:

(1) investigate dandelion recruitment biology, in terms of dandelion emergence from either seed or rootstock throughout the growing season
(2) determine the efficacy of glyphosate alone and glyphosate + florasulam versus other herbicidal compounds applied at various rates in either the fall (post-harvest) or the spring (pre-seed) on dandelion infestations in spring wheat fields (*Triticum aestivium* L.).
(3) relate the efficacy of the herbicide applications on dandelion to recruitment biology and recruitment timing.

Methods

Field trials were conducted at 3 locations in 2003 and at 2 locations in 2004 in annually cropped fields situated in southern Manitoba. The 2003 experimental sites were established in the fall of 2002 while the 2004 experimental sites were established in the fall of 2003. Minimum tillage practices were used at all sites in the year of establishment, with soil disturbance only occurring during crop planting. The experimental design was a randomized complete block split plot design, replicated four times with herbicide treatments as the main plots and herbicide application timing (post-harvest in fall or pre-seed in spring) as the subplots. Main plot treatments consisted of various rates of glyphosate alone and in combination with florasulam (a new ALS inhibitor with a short soil half-life of 2 to 18 days) or tribenuron, and an untreated control (refer to Table 1). An in-crop herbicide application in both years was made at the 3 to 4 leaf stage of the wheat crop and consisted of 280 g a.i. ha^{-1} of bromoxynil + 280 g a.i. ha^{-1} of

MCPA ester + 5 g a.i. ha^{-1} of thifensulfuron:tribenuron (2:1) + 56 g a.i. ha^{-1} of clodinafop-propargyl. Dandelion plant density counts (plants m^{-2}) distinguishing between seed or rootstock were performed throughout the course of the growing season in each treatment. Assessments occurred: prior to the pre-seed herbicide application in the spring, prior to the in-crop herbicide application, post-in-crop herbicide application, prior to crop harvest, and post crop harvest. In addition, dandelion shoot biomass and wheat shoot biomass was measured approximately one month after the in-crop herbicide application and post crop harvest (dandelion biomass only) to assess dandelion interference in the wheat crop. To statistically separate the influence of herbicide treatment on dandelion density (rootstock or seedling), dandelion shoot biomass, and wheat shoot biomass, data was subjected to analysis of variance (ANOVA) and means separated using Fisher's Protected LSD test at the 0.05 significance level. The SAS General Linear Model (Proc GLM) procedure was used to model treatment effects for all response variables.

Dandelion recruitment from either seed or rootstock was assessed on a weekly basis in permanent quadrats established in the untreated control plots at the experimental sites using the coloured ring method (Bullied et al., 2003). Quadrats were monitored from early in the spring (end of April) until the end of dandelion emergence from either seed or rootstock. Soil temperature was also monitored on an hourly basis using small self-contained data loggers located 2.5 cm below the soil surface. Cumulative growing degree days (GDD) were calculated from summed daily mean soil temperature recordings. Emergence periodicity was analyzed using nonlinear (logistic model) regression analysis as a function of cumulative soil GDD using the SAS NLIN procedure.

Results

Emergence Periodicity

Site year was not a significant factor and therefore data was pooled across site years for dandelion emergence from rootstock and dandelion emergence from seed (Fig. 1).

Based on soil thermal time (accumulated GDD), dandelion emergence from rootstock occurred mainly in the early spring and diminished throughout the remainder of the growing season. A substantial proportion of dandelion plants emerging from rootstock were plants that had over-wintered. Over 65% of the dandelion plants observed to have originated from rootstock were from the previous year based on the April assessment date (Table 2). Cumulative emergence from rootstock reached 100% at approximately 1250 GDD. Dandelion seedling emergence began at approximately 400 to 500 GDD. In 2003, this thermal time corresponded to the last week in May whereas in 2004 this period occurred during the second week in June. The emergence curve for dandelion originating from seed is quite steep since peak seedling emergence occurred approximately over a 2-week period at all five sites-years. In 2003, peak seedling emergence was observed from mid-June until mid-July with seedling emergence ending in mid-August at approximately 2000 GDD. Peak seedling emergence in 2004 took place from mid-July to mid-August. An in-crop herbicide application was applied in both years at approximately 750 GDD. The in-crop herbicide application did not coincide with peak dandelion seedling emergence and hence many seedlings were not controlled. Dandelion seed production was quite prolific in both years with over 1000 seedlings per m^{-2} emerging in a single growing season in the untreated control plots (Table 3). In 2003, seedling survivorship at the end of the growing season was quite low, while in 2004 seedling survivorship was significantly higher than in 2003, especially at the Carman UM site where dandelion seedling survivorship, as assessed at the end of the growing season, was over 90% (Table 3). High seedling survivorship in 2004 is attributed to moist and cool environmental conditions that characterized the entire growing season, considering that dandelion is a surface recruiter and recruitment is promoted in moist soils (Boyd and Van Acker, 2003).

Table 1: Post-harvest and pre-seed herbicide treatment list.

Treatment	Application dose	Application timing[a]
	g ha^{-1}[b]	
Untreated control	---	---
Glyphosate	450	Fall Spring
Glyphosate	675	Fall Spring
Glyphosate	1350	Fall Spring
Glyphosate + Florasulam	450 + 5	Fall Spring
Glyphosate + Florasulam	675 + 7.5	Fall Spring
Glyphosate + Florasulam	900 + 5	Fall Spring
Glyphosate + Tribenuron	450 + 7.5	Fall Spring

[a] Fall applications made post crop harvest. Spring applications made prior to crop seeding.
[b] Dosage of glyphosate expressed as g a.e. ha^{-1}, dosage of florasulam expressed as g a.i. ha^{-1}, dosage of tribenuron expressed as g a.i. ha^{-1}.

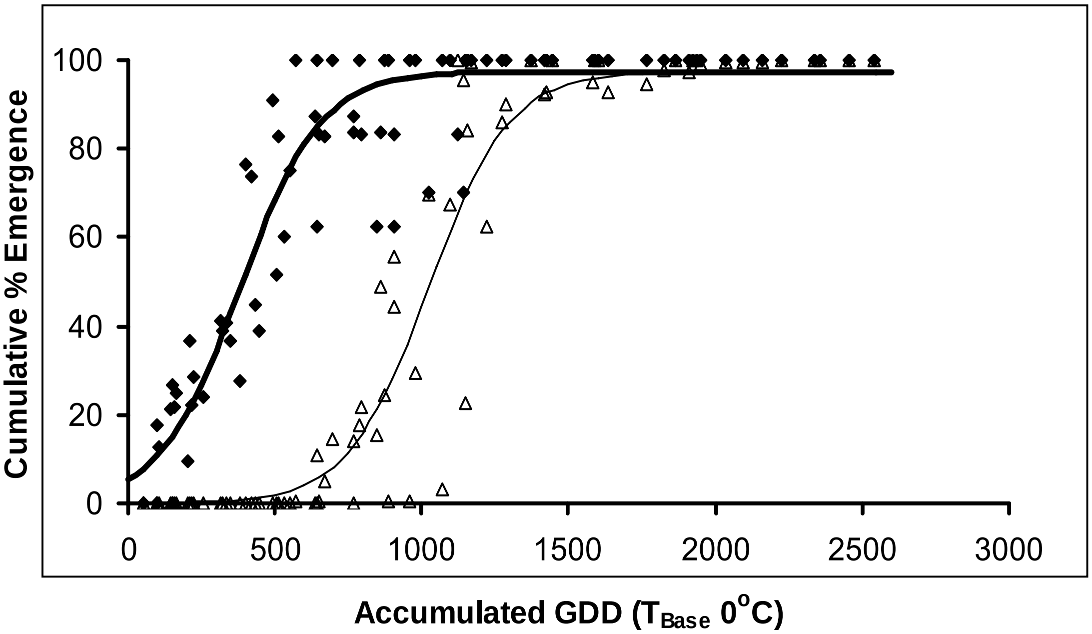

Figure 1: Emergence periodicity of dandelion from rootstock and seed pooled over 5 site-years as related to soil growing degree days (accumulated GDD). Markers represent field data points and lines represent fitted regression equations.

Table 2. Mean number of dandelion plants (plants m^{-2}) emerged from rootstock on the first sampling date[a] of the growing season (standard errors in parentheses).

Site	Year	Rootstock	
		Average	Percentage of total[b]
		— plants m^{-2} —	— % —
Oak Bluff 1	2003	30.3 (9.7)	65.6 (5.8)
Oak Bluff 2	2003	37.0 (11.8)	67.1 (8.3)
Carman	2003	59.7 (25.5)	72.7 (3.4)
Roland	2004	20.0 (1.7)	87.8 (5.1)
Carman UM	2004	37.7 (13.8)	82.9 (6.6)
LSD (0.05)		48.5	18.6

[a] First sampling date occurred approximately at the end of April.

[b] Total dandelion plants from rootstock represent a cumulative total for the growing season as assessed in late September.

Table 3. Mean total number of dandelion seedlings (plants m^{-2}) emerged throughout the growing season and percent dandelion seedling survivorship as assessed at the end of the growing season (standard errors in parentheses).

Site	Year	Total seedlings[a]	Seedling survivorship[b]
		—— plants m^{-2}——	—— % ——
Oak Bluff 1	2003	1545.7 (443.6)	12.5 (9.7)
Oak Bluff 2	2003	1083.3 (179.4)	18.9 (7.6)
Carman	2003	1055.7 (201.8)	13.4 (2.3)
Roland	2004	1914.8 (94.3)	49.3 (5.2)
Carman UM	2004	2862.4 (243.9)	91.5 (1.6)
LSD (0.05)		800.0	17.6

[a] The total number of dandelion seedlings emerged throughout the entire growing season.

[b] Dandelion seedling survivorship in 2003 was assessed in late August. Dandelion seedling survivorship in 2004 was assessed in early October.

Herbicide Efficacy

Site year was determined to be a significant factor for most response variables and therefore data was analyzed by site-year and results for each site-year presented separately. Dandelion plants originating from or preparing to over-winter on rootstock were the plants that actually received the herbicide treatments and consequently are a most reliable indicator of herbicide efficacy (Table 4) as there were few dandelion seedlings present at the time of the fall treatments in both 2002 and 2003.

The fall herbicide treatments were generally more efficacious (even though not always statistically significant) than the spring herbicide treatments in terms of reducing dandelion (from rootstock) densities (Table 4). This trend was observed in all five site-years. Treatments including glyphosate + florasulam or glyphosate + tribenuron were not necessarily statistically more efficacious than glyphosate alone, but in many cases were numerically superior. At Oak Bluff 1 in 2003, fall applied glyphosate + florasulam at the low rate (450 g a.e.ha^{-1} + 5 g a.i. ha^{-1}) significantly reduced dandelion rootstock densities when compared to fall applied glyphosate alone (450 g a.e. ha^{-1}). There were no consistent herbicide treatment effects on dandelion seedling density (data not shown). Spring herbicide treatments including florasulam or tribenuron apparently had insufficient residual activity to influence dandelion seedling emergence. The major effect on dandelion seedling density was a massive site-year effect due to differences in prevailing weather conditions in 2003 versus 2004 (data not shown).

Table 4. Mean density of dandelion from rootstock (no. m^{-2}) measured post wheat harvest for each herbicide treatment and for each site year (standard errors in parentheses).

Treatment[a]	Appl. dose	Appl. timing[b]	Site-years Oak Bluff 1 2003	Oak Bluff 2 2003	Carman 2003	Roland 2004	Carman UM 2004
	$g\ ha^{-1}$[c]		no. m^{-2}				
Untreated control	---	---	31.7 (6.1)	23.6 (8.1)	30.1 (14.2)	19.5 (2.7)	18.7 (2.0)
Glyph	450	Fall	11.4 (5.7)	4.9 (4.9)	1.6 (1.6)	4.9 (3.1)	4.9 (2.1)
		Spring	11.4 (2.8)	12.2 (3.6)	22.0 (5.8)	5.7 (2.4)	10.6 (3.4)
Glyph	675	Fall	0.0 (0.0)	6.5 (6.5)	3.3 (3.3)	3.3 (2.3)	1.6 (0.9)
		Spring	16.3 (3.3)	15.5 (4.3)	36.6 (13.5)	8.9 (1.6)	14.6 (6.0)
Glyph	1350	Fall	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2.4 (1.6)	0.8 (0.8)
		Spring	3.3 (2.3)	9.8 (9.8)	20.3 (10.2)	1.6 (0.9)	7.3 (2.0)
Glyph + Flor	450 + 5	Fall	0.0 (0.0)	7.3 (7.3)	0.0 (0.0)	5.7 (4.7)	4.0 (2.4)
		Spring	7.3 (4.3)	8.9 (5.8)	35.0 (9.2)	5.7 (3.6)	13.8 (2.8)
Glyph + Flor	675 + 7.5	Fall	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.8 (0.8)	0.0 (0.0)
		Spring	8.1 (2.1)	8.1 (5.4)	25.2 (7.9)	5.7 (1.6)	11.4 (3.9)
Glyph + Flor	900 + 5	Fall	0.8 (0.8)	0.0 (0.0)	0.0 (0.0)	2.4 (2.4)	0.0 (0.0)
		Spring	6.5 (4.0)	13.8 (5.5)	22.8 (13.8)	1.6 (0.9)	3.3 (1.3)
Glyph + Triben	450 + 7.5	Fall	1.6 (0.9)	2.4 (2.4)	2.4 (1.6)	1.6 (0.9)	1.6 (1.6)
		Spring	8.1 (4.3)	13.8 (5.0)	9.8 (7.7)	5.7 (2.8)	8.1 (2.8)
LSD (0.05)			8.9	12.3	22.6	6.9	6.9

[a] Abbreviations: Glyph, glyphosate; Flor, florasulam; Triben, tribenuron.

[b] Fall applications made post crop harvest. Spring applications made prior to crop seeding.

[c] Dosage of glyphosate expressed as g a.e. ha^{-1}, dosage of florasulam expressed as g a.i. ha^{-1}, dosage of tribenuron expressed as g a.i. ha^{-1}.

Conclusions

Dandelion emergence from rootstock was greatest very early in the spring and tapered off throughout the remainder of the growing season. Dandelion seedling emergence in 2003 began in the middle of June, whereas in 2004 seedling emergence was delayed with peak emergence occurring in mid-July. However, in terms of thermal time, seedling emergence in both years commenced at approximately 500 GDD. The delay in emergence, based on calendar day, can be attributed to abnormally low temperatures and wet conditions in 2004 which hindered the growth of most plant species, including the wheat crop. Peak dandelion seedling emergence in both years occurred after the in-crop herbicide application and seedlings were not controlled. In 2004, a significant portion of the dandelion seedlings that emerged throughout the growing season survived and produced fall rosettes, which have the ability to over-winter on a rootstock and produce established plants the following spring. The difference in seedling survivorship between the two years indicates that cool, wet environmental conditions favour the proliferation and spread of dandelion, as observed in 2004. Dandelion is a simple perennial weed species and population spread is by seed alone. Targeting not only seed dispersal but also the source of population spread (seedlings) is crucial in managing infestations. Fall (post-harvest) herbicide applications (assessed approximately 11 months after application) restricted the spread of dandelion as these applications controlled both large dandelion rosettes and true seedlings. Spring (pre-seed) herbicide applications affected the previous year’s rosettes (from rootstock and seedling) but control was reduced as compared to the fall treatments. The addition of florasulam to glyphosate offers a broadened spectrum of weed control and this combination also results in reduced inputs of active ingredient into the environment due to the low dose chemistry of florasulam. Differing environmental conditions between the two years of this study had a massive effect on dandelion rootstock and seedling emergence periodicity in terms of calendar day (not soil thermal time), seedling survivorship, post-harvest biomass production, and flowering patterns.

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Physiological characterization of picloram safening in transgenic tobacco expressing an anti-picloram antibody

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Abstract

Transgenic tobacco (*Nicotiana tabacum*) plants expressing an anti-picloram single-chain variable fragment (scFv) antibody have been created as a model system for the development of herbicide resistant crops. The objective of this research was to characterize resistance levels by selection and development of a homozygous line expressing anti-picloram scFv, and to investigate the physiological mechanism of resistance. A picloram dose-response assay on agar medium was used to select plants with the highest levels of resistance to picloram and homozygosity was verified by studying the inheritance of a linked marker gene (*npt*II; *i.e.*, kanamycin resistance) among offspring. The best homozygous line was further characterized by a single foliar application of picloram (0, 0.05, 0.1, 0.5, 1, 5, or 10 g ai ha^{-1}). Twenty-one days after treatment, transgenic plants survived 5 g ai ha^{-1} of picloram while wild-type plants died. A six-fold resistance factor was determined by comparing the GR_{50} (growth reduction of 50%) values for plant height between wild-type (GR_{50}=0.72 g ai ha^{-1}) and transgenic (GR_{50}=4.5 g ai ha^{-1}) plants. An uptake and translocation study found that [^{14}C]picloram translocation to the apical meristem was reduced in transgenic versus wild-type plants. Transgenic plants contained nearly three times the level of [^{14}C]picloram in the treated leaf compared to that found in wild-type plants, 24 HAT (hours after treatment). These results suggest that sequestration of [^{14}C]picloram in the treated leaf reduced the translocation of [^{14}C]picloram to the apical meristem. Metabolism studies are being completed to further investigate the effects of the anti-picloram scFv on picloram resistance in tobacco.

Introduction

Genetically modified crops have rapidly transformed agriculture over the past decade. The global area of transgenic crops increased by 20% from 2003 to 2004, or up 13.3 M ha to a total area of 81.0 M ha. The global market value of genetically modified crops in 2004 was $4.70 billion (James, 2004). Projections suggest that there will be 150 M ha of genetically modified crops by 2010. The most popular trait introduced into genetically modified crops is herbicide resistance, with 60% of genetically modified hectares being seeded with herbicide resistant varieties in 2004 (James, 2004). Herbicide resistant crops are a widely used strategy for controlling several weed species with a single herbicide application, with glyphosate and glufosinate resistance being the most popular, respectively. Crops resistant to new herbicides may be necessary with the possible onset of weeds resistant to glufosinate and glyphosate.

There are three main strategies for engineering plants for herbicide resistance: (i) overproduction of a herbicide-binding target, (ii) structural alteration of a biochemical herbicide target site, and (iii) detoxification or degradation of a herbicide prior to binding to the target site (Strauch *et al.*, 1988; Stalker *et al.*, 1988). A fourth strategy involving antibodies could be used as a novel strategy to develop herbicide resistant crops by attenuating the effects of a herbicide *in planta*, which would protect plants from herbicides by sequestration, reduced translocation, and/or altered metabolism.

An antibody is a protein that is produced by a vertebrate animal in response to a foreign substance such as a protein, polysaccharide, nucleic acid or, in some cases, simple small molecule, including herbicides (Hall *et al.*, 1990). Antibodies can bind these substances with great specificity and affinity. Traditionally, antibodies have been utilized in weed science for the *in vitro* detection of herbicides in soil, water, plants, urine, and blood using immunoassays (Hall *et al.*, 1990).

In 1989, Hiatt *et al.* was the first to express antibodies in transgenic plants. Since their initial demonstration, antibody research in plants has focused on two areas: (1) large-scale production therapeutic antibodies and (2) antibodies for modulation of plant physiology. Scientists are now investigating the application of antibodies for the benefit of weed science.

One research question that has concerned our group is whether antibodies can attenuate the effects of a herbicide *in planta*. The Hall laboratory has been investigating this hypothesis using previously characterized antibodies against the herbicide picloram (Yau *et al.*, 1998). An antibody against picloram was expressed in tobacco (*Nicotiana tabacum*; Almquist *et al.*, 2004). In this study, reduced symptoms were observed in transgenic tobacco expressing an anti-picloram antibody compared with control plants. However, resistance levels were low and further optimization of the system was required by increasing antibody expression in the plant. This was done by utilizing the cauliflower mosaic virus 35S promoter and gene synthesis employing codon optimization (Olea-Popelka, 2005). Over 100 new transgenic tobacco plants have been produced and the amounts of anti-picloram scFv produced by them has been characterized biochemically.

The first objective of this research was to develop homozygous lines from the best expressers of anti-picloram scFv, and to utilize these in the characterization of antibody-mediated resistance. The second objective was to investigate the mechanism of antibody-mediated resistance in transgenic tobacco plants by an uptake and translocation study.

Materials and Methods

Homozygous line selection scheme

The two highest expressing primary transgenic tobacco plants produced by Olea-Popelka (2005) that had single T-DNA loci were studied. A picloram resistance biossay was conducted on T_1 seeds from these two self-pollinated primary transgenic plants. Seeds were surface sterilized and placed on Murashige and Skoog (MS) agar media plates containing picloram at concentrations ranging from 10^{-9} to 10^{-7} M (*i.e.*, 10^{-9}, 10^{-8}, 2.5×10^{-8}, 5×10^{-8}, 7.5×10^{-8}, 10^{-7} M). The T_1 plants surviving 2.5×10^{-8} M of picloram were rescued from plates, transplanted to soil, grown to maturity, self-pollinated and T_2 seed were collected. The T_2 seed were used to determine the genotype of the T_1 progenitors (*i.e.*, homozygous versus hemizygous) using two subsequent assays. The first assay was a kanamycin resistance bioassay, where T_2 seeds were surface sterilized, placed on MS plates containing kanamycin (100 μg/mL) and the ratios of green (resistant) to white (susceptible) plantlets were compared to expected Mendelian ratios of 1:0 (homozygous) and 1:1 (hemizygous) for single T-DNA loci. The second assay was a picloram resistance bioassay, where T_2 seeds were surface sterilized, placed on MS plates containing picloram at 10^{-8} M and ratios of healthy (resistant) to epinastic (susceptible) were compared to expected Mendelian ratios of 1:0 (homozygous) to 1:1 (hemizygous) for single T-DNA loci.

The level of resistance was determined using a picloram resistance bioassay on T_2 seedlings. Surface sterilized T_2 seeds were place on MS plates containing picloram ranging from 10^{-9} to 10^{-7} M and observations taken 21 days later. The best T_1 homozygous line was used for the following experiments.

Picloram field spray simulation dose-response

Wild-type and T_2 homozygous transgenic tobacco plants were germinated in plug mix (ProMix BX) in a growth room that was at a constant 16 h daylight cycle with constant diurnal temperatures of 23 and 18ºC for day and night, respectively. Once the plants reached a uniform growth at the 5-leaf stage, they were sprayed with picloram in water containing 10% ethanol and 0.5% Tween 20 using an automatic hood sprayer (RC-5000-100EP Mandel Scientific) using a flat fan nozzle (SS80015E Spraying Systems). The spray volume used was equivalent to 110 l/ha of spray solution delivered at 240 kPa. Photographs were taken and plant height was measured 21 days after treatment of six replicates. Five replicates were harvested and dried in an oven at 60ºC for 72 hours to determine above ground dry weight 21 days after treatment. The remaining replicate was grown until carpel formation.

Uptake and translocation study

Wild-type and homozygous transgenic tobacco plants were germinated and grown in plug mix for two weeks then transplanted to 8-cm square pots containing crushed particulate expanded baked clay (Turface MVP®). Plants were watered every second day with Hoagland's solution (Hoagland and Arnon, 1950). Plants were grown to the four leaf developmental stage prior to removal of cotelydons, as well as 1st, 2nd, and 3rd leaves.

Radiolabeled [^{14}C]picloram was obtained from Dow Chemical Company. Plants were treated at the 4-leaf stage with 50,000 dpm in 10 µl of [^{14}C]picloram in water containing 10% ethanol and 0.5% Tween 20 (a polyoxyethylene based nonionic detergent). The solution was adjusted to pH 2 using HCl. Treatment method was similar to the method used by Ramsey *et al*. (2002). A Hamilton syringe (50 µl) was stabilized so that the end of the needle was directly in front of an air stream. The release of 1 µl droplets of treatment solution into the air stream produced a fine spray. A template with a rectangular hole measuring 800 mm^2 (20 by 40 mm) was placed on the treated leaf prior to spraying to ensure each plant had the same treated area.

Plants were harvested 6, 12, 24, 48, and 72 h after treatment. The treated leaf was removed and rinsed with an aqueous 10% ethanol, 0.5% Tween 20 solution. The treated leaf was sectioned into treated and untreated leaf portions. The remainder of the plant was sectioned into meristem and root tissue. All harvested plant sections were wrapped in Kimwipes®EX-L and dried at 60ºC for 48 h. Plant sections were oxidized in a biological oxidizer (OX 500, R.J. Harvey instrument), where $^{14}CO_2$ was trapped in scintillation cocktail (R.J. Harvey Instrument) and measured by liquid scintillation spectrometry (LSS; Beckman LS6000SC). The efficiency of combustion and recovery was greater than 90%. Leaf rinses were collected and ^{14}C content was quantified by LSS. Uptake data are expressed as a percentage of ^{14}C recovered from the plant.

Results and Discussion

Two different assays were used to confirm the successful selection of a homozygous line. A kanamycin resistance assay was used to determine the presence of the *npt*II marker gene that was inserted as part of the T-DNA. Wild-type plants turned white 21 days after seeding, since they are susceptible to kanamycin. The T_1 plants from a self-pollinated primary transgenic segregated 3:1, resistant to susceptible, respectively, indicating the primary transgenic contained one locus of the *npt*II marker gene. All T_2 plants from the homozygous selection scheme were resistant to kanamycin, indicating a T_1 homozygous line. A similar picloram resistance assay was used to confirm the selection of a T_1 homozygous line. All wild-type plants placed on picloram at 10^{-8} M showed symptoms characteristic of picloram: curling of the cotelydons and the inability to produce true leaves. The T_1 plants from a self-pollinated primary transgenic segregated 3:1, resistant to susceptible, respectively. Plants were considered resistant if they showed no symptoms to picloram and susceptible if they showed symptoms identical to wild-type plants. All of the T_2 homogeneous plants were resistant to picloram at 10^{-8}M, confirming that selected homogeneous lines that would be suitable to further experimentation.

A single foliar application of picloram was used to characterize the resistance of the best homozygous line. Visual differences between this line and wild-type plants were striking: 21 days after treatment, transgenic plants survived 5 g ai ha^{-1} of picloram while wild-type plants died. Wild-type plants had severe symptoms of epinasty and hypertrophy at 0.5 g ai ha^{-1} while transgenic plants only had minor symptoms at 5 g ai ha^{-1}. Previous work by Almquist *et al.* (2004) demonstrated tobacco plants expressing an anti-picloram antibody could resist 0.5 g ai ha^{-1}. A 10-fold improvement to resistance can be estimated by comparing the work of Almquist *et al.* (2004; 0.5 g ai ha^{-1}) to the results from the best homozygous line (5 g ai ha^{-1}). A conservative resistance factor of six was calculated by comparing the GR_{50} (growth reduction of 50%) values for plant height between wild-type (GR_{50}=0.72 g ai ha^{-1}) and transgenic (GR_{50}=4.5 g ai ha^{-1}) plants. An even more conservative resistance factor of three was calculated by comparing GR_{50} values of above ground biomass for wild-type (GR_{50}=1.7 g ai ha^{-1}) and transgenic (GR_{50}=4.8 g ai ha^{-1}) plants.

An uptake and translocation study found that sequestration of $[^{14}C]$picloram in the treated leaf of transgenic plants altered the translocation to the apical meristem when compared to wild-type plants. In contrast there were no differences in uptake of $[^{14}C]$picloram between transgenic and wild-type plants. Transgenic plants contained nearly three times the quantity of $[^{14}C]$picloram in the treated leaf compared to that found in wild-type plants, 24 HAT. The sequestered $[^{14}C]$picloram was not able to translocate to the meristem where the site of action of picloram is located. These results suggest that sequestration of $[^{14}C]$picloram is a major mechanism of resistance for plants expressing anti-picloram antibodies. Autoradiography studies are currently being performed to further investigate the effect of the anti-picloram scFv on the distribution of $[^{14}C]$picloram in tobacco with and without anti-picloram scFv.

Conclusions

The level of resistance to picloram was improved by increasing expression of the anti-picloram antibody in tobacco plants. Following application of picloram, visual observations, plant dry weight, and plant height all showed the T_1 homozygous line to be significantly different from wild-type plants. A visual comparison of symptoms gave a 10-fold improvement in resistance compared to previous work by Almquist *et al.* (2004). The level of resistance is still low for practical use as a herbicide resistant crop, so methods to further improve resistance, involving increasing expression of the antibody, increasing the affinity of the antibody, or compartmentalization of the antibody to other cellular organelles should be performed.

Translocation of picloram from the treated leaf to the meristem is necessary for phytotoxic symptoms to occur at the growth point. Antibodies may "buffer" translocation of picloram to the meristem by sequestration in the treated leaf. Antibodies bind, as well as release picloram to create a dynamic pool of free and bound picloram. Following treatment of picloram, most of the herbicide is bound to the antibody, preventing the translocation to the meristem. Once picloram reaches the meristem it may be bound to the antibody, preventing the herbicide from acting. This establishes at two dynamic pools of free and bound picloram at a source, in this case the treated area, and the sink, in this case the meristem. Other pools could be established at sinks such as the roots that would further buffer translocation to the meristem.

Anti-picloram antibodies may also alter picloram metabolism in tobacco. Bound picloram may be protected from enzymatic action necessary for the formation of picloram metabolites in plants, namely a mixture of picloram-glucose esters, and a minor fraction of picloram-gentiobiose esters (Frear *et al.*, 1989). A metabolism study has been initiated to investigate differences in picloram metabolism due to the anti-picloram antibody in tobacco.

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Reduced herbicide use in flax under a no-till annual-based rotation

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Abstract

Farmers interested in reducing pesticide use in no-till annual-based systems need to have reliable farming methods that aren't dependent on pesticides and that are still able to generate good economic returns. Flax is a good candidate for reduced pesticide systems as it is known as a health food. A system that requires the elimination of in-crop pesticides was used as the model for pesticide reduction in this experiment. Flax is not very competitive against weeds but its competitiveness can be enhanced through a delayed seeding date and a high seeding rate. Light disturbance with a rotary harrow and early nitrogen application were added to try to encourage as much weed growth as possible before planting. Rotary harrowing was found to have a significant effect in stimulating weed germination. This is to be expected as weed seeds in a no-till system tend to stratify in the top layers of the soil. Early spring nitrogen placement did not have consistent results in stimulating weed germination although the disturbance did have an effect in some cases. Weed populations were similar among all treatments 25 days after planting indicating the treatments were not effective in controlling weeds. All reduced pesticide yields were significantly lower than the conventional controls which indicates pesticide reduction would not have been profitable in this trial.

Introduction

Many farmers are interested in reducing pesticide use but are not ready to commit to an entirely organic system. Organic farming requires three years with no pesticides or synthetic fertilizers before certification (OCIA, 2004). Consequently, even one application of pesticides results in loss of certification for the following three years and subsequent loss of the price premium usually found for organic products. Organic certification also requires that the entire farm be certified or in transition to certification within five years from the first field being certified (OCIA, 2004).

The advantage of reduced pesticide systems is flexibility. A farmer can easily switch between conventional systems and reduced pesticide systems on a year to year basis. Pesticide Free Production™ (PFP™) was used as the framework for this experiment. PFP™ eliminates in-crop pesticides but still allows synthetic fertilizers. Pre-seed burn-off is permitted provided there is no residual activity of the chemical (Pesticide Free Production Canada, 2004).

In a recent farm survey of PFP^{TM} crops, flax had the lowest certification among farmers. This was attributed to its lack of competitiveness against weeds which discouraged farmers from reducing herbicide use (Nazarko et al. 2003). Flax is a good candidate for reduced pesticide systems as it already has a reputation as a healthy food. Some of the strategies named by farmers included using forages in the rotation just prior to flax, increasing the seeding rate, and planting at a later date (Nazarko et al. 2003).

Although forages provide the cleanest field for PFP^{TM} flax production, there are not many producers currently using forages nor do they have a need for them (Entz et al. 1995 and Small and McCaughey 1999, *In* Entz et al. 2002). Since many producers are switching to no-till in western Manitoba (Thomas et al. 1999, *In* Nazarko et al. 2003) there is a need to develop a method for PFP^{TM} flax under a no-till annual-based rotation.

Objective

The objective of this experiment is to increase the effectiveness of the later planting date. Two strategies were used: applying nitrogen early to stimulate weed growth and lightly disturbing the surface with a rotary harrow (Figure 1 and 2). By increasing weed germination before planting it is expected that there will be less weed competition for the crop after crop planting.

Figure 1. Rotary harrow.

Figure 2. Plot after rotary harrow.

Materials and methods

The trial was set up in 2003 at a research station 25km north of Brandon, MB. Oats were harvested for green feed at the late milk stage and the regrowth treated with glyphosate at 675 g ai ha^{-1} to control regrowth and other perennial weed species. Oat seed was broadcast in the fall on all PFP^{TM} plots prior to fall rotary harrowing plots at a rate of 50 kg ha^{-1} to simulate a uniform volunteer crop of oats.

Fall rotary harrowing was conducted on September 30, 2003. Spring rotary harrowing and nitrogen treatments were conducted on April 22, 2004. Early plots were planted on May 18, 2004 and late plots were planted on June 3, 2004. AC Lightning flax was planted at 60 kg ha^{-1} using a 225 mm row spacing. All plots received 70 kg ha^{-1} actual nitrogen in the form of 46-0-0 and 25 kg ha^{-1} actual phosphorus in the form of 11-52-0. Fertilizer was side-banded at seeding except in the case of two treatments where the nitrogen was applied early with the seeder.

All plots were sprayed with glyphosate just prior to seeding. The early plots received 450 g ai ha^{-1} and the late plots received 675 g ai ha^{-1}. The higher rate was used for the late plots because of greater weed pressure. Conventional control plots had trifluralin (5% w/w) applied on October 30th, 2003 at a rate of 22 kg ha^{-1}. The plots also received an in-season treatment of sethoxydim (217 g ai ha^{-1}), clopyralid (present as acid) (103 g ai ha^{-1}), MCPA (present as 2-ethylhexyl ester) (576 g ai ha^{-1}), and adjuvant with surfactant blend 50% / solvent (petroleum hydrocarbons) 50% (1.0 L ha^{-1}) at the 50mm flax stage.

Table 1 shows a summary of experimental treatments and timing of operations. All plots except for the conventionally managed plots (1,6) were managed using the PFP^{TM} system. Two of the PFP^{TM} plots were left untouched (2,3). Six plots were rotary harrowed in the fall (4,5,9-12). Four of these plots had further treatments in the spring: two were disturbed with the seeder (one with nitrogen and one without as a control), and two were disturbed with a rotary harrow (one packed and the other not). Two plots had no rotary harrowing but were disturbed with the seeder similar to above (7,8).

Table 1. Treatment matrix.

Planting Date	Late									Early		
Treatment Number	12	11	9	10	7	8	3	5	6	2	4	1
Side Band			♦	♦	♦	♦						
Early Nitrogen			♦		♦							
Spring Rotary Harrow	♦	♦										
Spring Packing		♦										
Fall Rotary Harrow	♦	♦	♦	♦				♦			♦	
PFP Standard	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	
Conventional Control									♦			♦

Weed counts were completed just prior to seeding and when the flax was 50 mm tall. Biomass of flax and weeds were assessed just after full flower. Plots were swathed on September 23, 2004 and harvested on October 7, 2004.

Results and discussion

Rotary harrowing increased weed emergence significantly over the standard PFP^{TM} plot (Figure 3) in the time period before late planting. This is to be expected because weed seeds in a no-till system tend to stratify in the top layer. The early side-band application of nitrogen had mixed results. With fall rotary harrowing weed growth was not significantly higher than the PFP^{TM} standard but with no fall rotary harrowing it was significantly different. There is no significant difference between the early side-band nitrogen (7,9) and the controls (8,10) indicating the disturbance had a greater effect than the nitrogen. The conventional control had a significantly lower weed density than all of the treated PFP^{TM} plots.

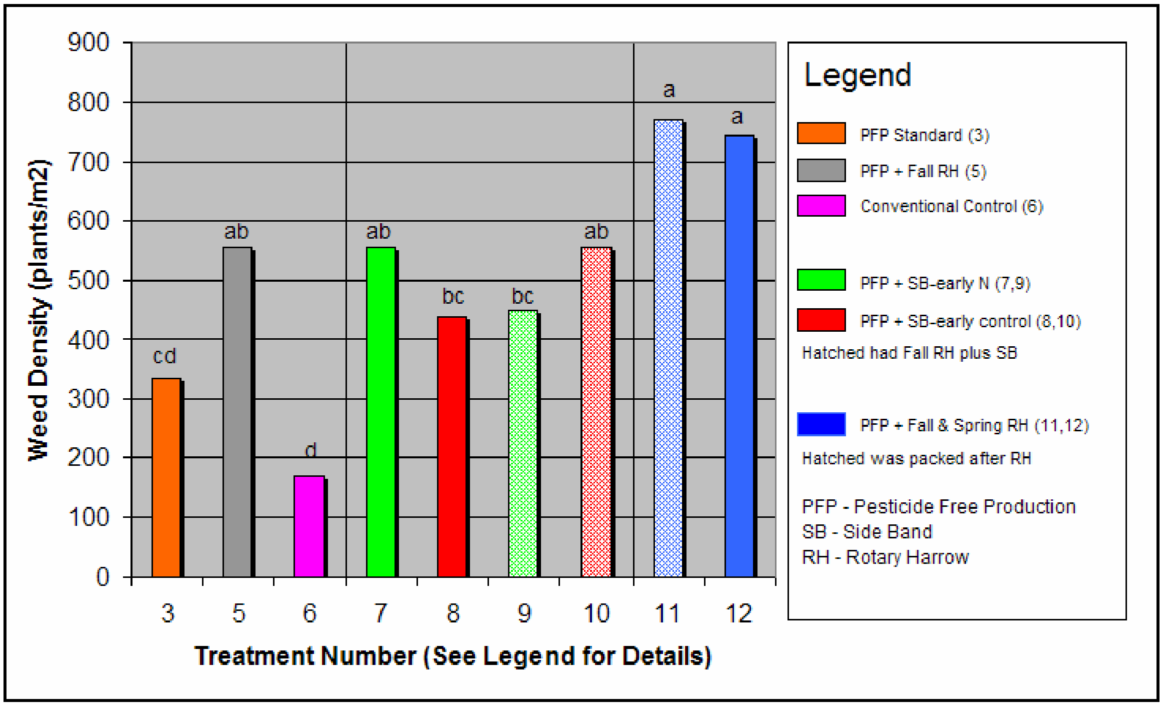

Figure 3. Pre-seed weed counts for the late seeded flax. Bars with different letters are statistically significant at the $P < 0.05$ level.

Increased weed emergence prior to seeding did not affect post seeding weed emergence (Figure 4). All of the late PFP^{TM} treatments (3, 5, 7-12) had significantly higher weed numbers at the 50mm stage of flax as compared to the conventional control (6). There was no discernable difference between late PFP^{TM} plots indicating treatments had no effect on post-seed weed emergence. Early planted PFP^{TM} treatments (2 and 4) had significantly higher weed numbers than both conventional controls (1 and 6) and all of the late PFP^{TM} treatments.

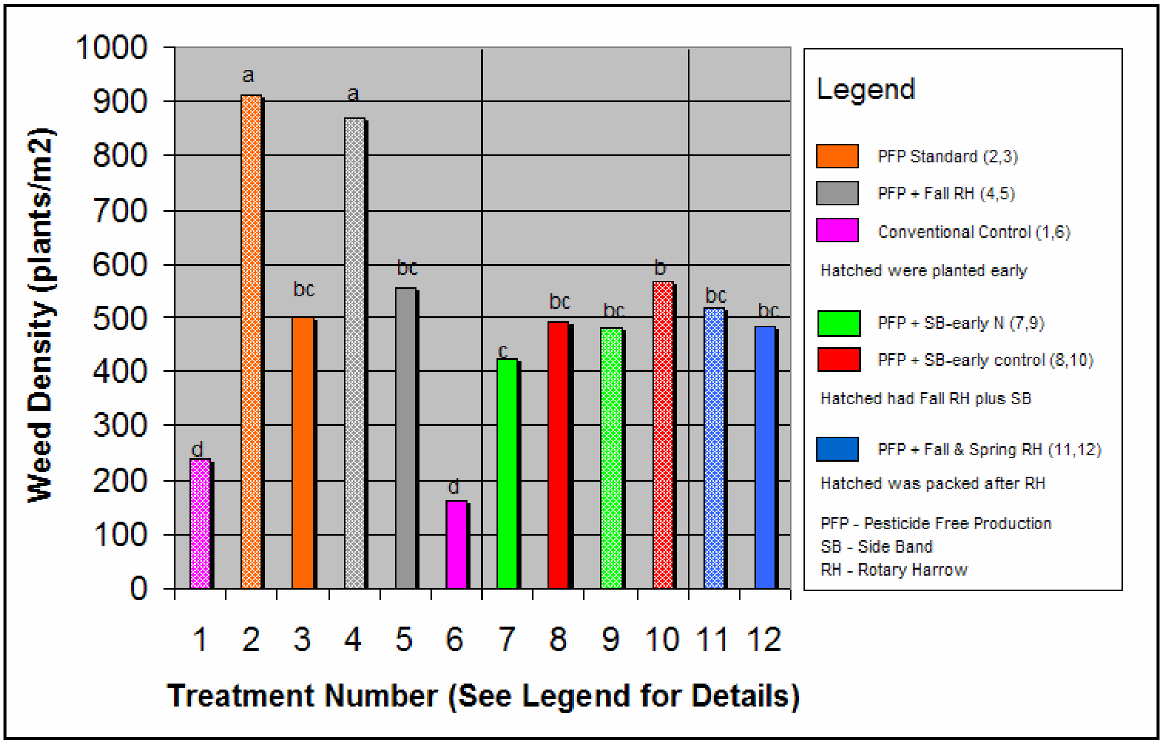

Figure 4. Weed counts at 5cm flax stage for all plots. Bars with different letters are statistically significant at the $P < 0.05$ level.

Conventional controls had the highest crop biomass and lowest weed biomass while the early planted PFP^{TM} plots had the lowest crop biomass and highest weed biomass (Table 2). The late PFP^{TM} treatments had similar biomass levels for both crop and weeds with a few significant differences indicating that the treatments were not effective in controlling weeds.

All PFP^{TM} systems (early and late) had significantly lower grain yields than the controls (Table 2). Early planted PFP^{TM} systems had significantly lower yields than any late planted PFP^{TM} systems. There is no discernable difference between late planted PFP^{TM} yields indicating that yield was not affected by treatments.

Further analysis on weed species emergence patterns should shed some light on the effect of nitrogen and rotary harrowing and more years of data should increase the accuracy of the results.

PFP^{TM} would not have been profitable this year due to the drastic decreases in yield compared with the conventional weed control options even if there were significant market premiums.

Table 2. Biomass and Grain Yield Data for All Plots. Values with Different Letters are Statistically Significant at the $P < 0.05$ level. Note: PFP = Pesticide Free Production, SB = Side Band, and RH = Rotary Harrow.

Treatment Number	Planting Date	Treatment Description	Biomass (g m^{-2})		Grain Yield (g m^{-2})
			Crop	Weed	
1	E	Conventional control	451.1 *a*	16.4 *e*	116.0 *a*
2	E	PFP	91.2 *d*	692.8 *a*	5.4 *d*
3	L	PFP	227.6 *c*	389.7 *cd*	28.8 *bc*
4	E	PFP + Fall RH	119.4 *d*	581.4 *b*	10.7 *d*
5	L	PFP + Fall RH	224.2 *c*	436.9 *c*	27.1 *bc*
6	L	Conventional control	502.0 *a*	0.6 *e*	124.4 *a*
7	L	PFP + SB-early N	296.4 *b*	351.4 *cd*	36.5 *bc*
8	L	PFP + SB control	275.1 *bc*	338.6 *cd*	25.0 *c*
9	L	PFP + SB-early N + Fall RH	280.9 *bc*	309.6 *d*	38.7 *b*
10	L	PFP + SB-early control + Fall RH	266.5 *bc*	366.9 *cd*	26.9 *bc*
11	L	PFP + Fall & Spring RH + Pack	270.9 *bc*	365.3 *cd*	32.5 *bc*
12	L	PFP + Fall & Spring RH	262.2 *bc*	430.1 *c*	31.2 *bc*

Future Research

Trials were initiated in 2004 for the 2005 growing season near Carman, MB and Brandon, MB. Spring only rotary harrowing and fall packing after rotary harrowing were added as treatments.

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Poster Abstracts

The IR-4 Project: Update on Herbicide Registration in Specialty Crops in the United States. M. Arsenovic, F. P. Salzman, D. L. Kunkel, J. J. Baron, R. E. Holm, IR-4 Project, Rutgers, The State University of New Jersey, North Brunswick, New Jersey, USA

The IR-4 Project is a publicly funded effort to support the registration of pest control products on minor or specialty crops. The IR-4 Project continues to actively work on providing growers with weed control options despite a climate in which there are fewer herbicides to evaluate. Over the past few years, IR-4 has worked closely with Canada in the development and exchange of food crop residue and performance data. Residue trials have been conducted in Canada as a regular part of joint studies. In addition, data packages developed for U. S. registrations have been provided to the Pest Management Regulatory Agency (PMRA) of Canada in support of MRLs that allow use in Canada and for MRLs that supports the importation of U. S. agricultural products. As the Food Quality Protection Act (FQPA) of 1996 threatens to restrict or eliminate many long-standing pest control products, the IR-4 is focusing on “reduced risk” and safer chemistry to ensure that producers of minor crops have an adequate number of pest control products, both traditional and biopesticides. Herbicide petitions submitted to the EPA by IR-4 from October 2003 to October 2004 include: metribuzin on garlic; s-metolachlor on vegetable root subgroup, oriental radish, tuberous and corm vegetable subgroup, oriental radish, horseradish, dry bulb onion, head and stem *Brassica* subgroup, spinach and collards; flumioxazin on tuberous and corm vegetable subgroup, dry bulb onion, and mint; carfentrazone on multiple crops and crop groups; clethodim on herb subgroup; flumioxazin on strawberry; 2,4-D on potato (Pacific Northwest); dimethenamid on green onion; tribenuron-methyl on sunflower; and pronamide on Austrian pea, and phenmedipham on spinach. From October 2003 through September 2004, EPA has published Notices of Filing in the Federal Register for: flumioxazin on the tuberous and corm subgroup and mint; DCPA on oriental radish, basil, chives, coriander, dill, marjoram, ginseng, celeriac, chicory, radicchio, and parsley; carfentrazone on multiple crops and crop groups; s-metolachlor on head stem *Brassica* subgroup, onion (dry bulb, and green), garlic, shallot; vegetable root subgroup (except sugarbeet), tuberous and corm vegetable subgroup, leaf petiole subgroup 4B, edible-podded legume vegetable subgroup, fruiting vegetable group, sweet corn, popcorn, dried shelled pea and bean subgroups, peanut, safflower, and grain sorghum; thifensulfuron on canola and flax. EPA established tolerances from October 2003 to 2004 on: DCPA on basil, celeriac, chicory, chives, coriander, dill, ginseng, marjoram, parsley, radicchio, and oriental radish; flumioxazin on grape, almond; pistachio, sugarcane, mint, dry bulb onion, garlic, shallot, and tuberous and corm vegetable; dimethenamid on tuberous and corm vegetable subgroup, sugar beet, garden beet, horseradish, dry bulb onion, garlic, and dry bulb shallot; carfentrazone on multiple crops and crop groups.

Microbial weed control of broadleaf weeds in turfgrass. Bailey K.L.[1], Derby J.[1], Pitt W.M.[1], Falk S.[2], Augustin B.[2]. [1] Agriculture and Agri-Food Canada, Saskatoon, SK; [2] The Scotts Company, Marysville, OH

A good, healthy stand of turfgrass is pleasing to the eye, but also provides numerous other benefits to people and the environment. The occurrence of broadleaf weeds disrupts the uniformity and vigour of turfgrass by competing for light, nutrients, moisture, and physical space. Integrated weed management advocates pest prevention, using reduced risk products, and applying pesticides only when necessary. Biological weed control uses living organisms or their naturally-occurring products to kill or suppress weeds and is an alternative practice emerging as a reduced risk technology. The fungus, *Phoma macrostoma*, was discovered on diseased Canada thistle (*Cirsium arvense* L.) plants growing across Canada. When applied to the soil surface before weed emergence, the fungus causes the plants to come up white and eventually die. It also significantly reduces the foliar biomass of established weeds. Host range testing showed that various broadleaf weeds such as Canada thistle, dandelion (*Taraxacum officinale* Weber ex F.H. Wigg.), scentless chamomile (*Matricaria perforata* Mérat)**,** chickweed (*Stellaria media* (L.) Vill.**),** and white clover (*Trifolium repens* L.) were damaged by the fungus, but wild oat (*Avena fatua* L.) and green foxtail (*Setaria viridis* (L.) Beauv.) were not harmed. Crop testing showed that barley, wheat, oat, millet, canary seed, and various cultivars of grass were not affected, but broadleaf crops had varying degrees of susceptibility. Field testing is being conducted at several sites across Canada and the USA. The trials will determine application parameters and other conditions for use. Environmental fate studies on the dispersion and survival of the fungus in soil and plant tissues have shown little dispersion from the area of placement and a low risk of survival after one year.

Optimal timing and control treatments for Scotch broom. Becker, A., Clements, D.R., and Kunstar, H. Department of Biology, Trinity Western University, Langley, BC

Scotch broom (*Cytisus scoparious* L.) is an invasive plant that has been shown to be detrimental to many British Columbian ecosystems. In this study we examined the effect of both timing of cutting and 2,4-D application on the regeneration of Scotch broom. Five treatments were carried out in 2002 in each of 10 plots, 15 m × 3 m in size, located on a restoration site in Abbotsford, British Columbia. These treatments were: 1) early cut, 2) early cut with 2,4-D applied to the cut stem, 3) late cut, 4) late cut with 2,4-D applied to the cut stem, and 5) control (uncut). The early cut coincided with flowering (May) and the late coincided with seed set (July). Regrowth was assessed in June 2003 and 2004. For plants without 2,4-D application, 16 out of 52 early-cut plants, and 8 out of 47 late-cut plants had regrowth by the second year. For plants with 2,4-D application, 6 out of 48 early-cut plants and 11 out of 62 late-cut plants had regrowth by the second year. Interestingly, after the first year, only 1 of the early-cut plants and 3 of the late-cut plants treated with 2,4-D had regrown, whereas 23 early-cut and 7 late-cut plants without 2,4-D had regenerated by the first year (some early-cut seedlings with regrowth died between years). The 15% regrowth from late cut plants after one year was slightly higher than the 9% level recorded at another study in Victoria, British Columbia. The herbicide treatment greatly increased the efficacy of control, as did the later cut when presumably more of the plant's resources were being allocated to reproduction. These results suggest that the removal of Scotch broom using both chemical and mechanical means is much more effective that mechanical means alone.

Alberta field survey of herbicide-resistant weeds. Beckie, H.J.[1], Hall, L.M.[2], Leeson, J.Y.[1], and Thomas, A.G.[1] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development/University of Alberta, Edmonton, AB

A survey of weeds resistant to herbicides in 236 randomly selected fields was conducted across the major ecoregions of Alberta in 2001. This baseline survey determined the incidence of herbicide resistance, and will serve as a reference for future surveys. All residual weed species with viable seeds were mapped and sampled before harvest. Selected fields were cropped to cereals, oilseeds, or pulses (field pea). Samples of 20 weed species were subsequently screened in the greenhouse with high-risk herbicides belonging to Groups 1 and 2. Producers provided information on herbicide use and resistance awareness by means of a management questionnaire. Nearly 20% of surveyed fields had a herbicide-resistant weed biotype. Of 190 fields where wild oat (*Avena fatua* L.) samples were collected, 11% had Group 1-resistant wild oat (9% of all fields surveyed) and 13% had Group 2-resistant wild oat (10% of all fields surveyed). Half of the fields with either resistant biotype originated in the Aspen Parkland ecoregion, which was attributed to historically high frequency of use of products from these groups. Most Group 1-resistant wild oat populations exhibited resistance to both aryloxyphenoxypropionate and cyclohexanedione herbicides. Group 2-resistant populations exhibited broad cross resistance across three classes of Group 2 herbicides. Of 16 broadleaf weed species, Group 2 resistance was detected only in chickweed [*Stellaria media* (L.) Vill.] (four fields in the Aspen Parkland ecoregion) and spiny annual sow-thistle [*Sonchus asper* (L.) Hill] (four fields in the Moist Mixed Grassland, Fescue Grassland, or Aspen Parkland ecoregions). Only 5% of producers with resistant biotypes previously suspected or were aware of their occurrence. This low level of awareness was consistent with findings from previous surveys, and may be attributed, in part, to the relatively small infestation area of resistant biotypes in most fields.

Manitoba field survey of herbicide-resistant weeds. Beckie, H.J.[1], Leeson, J.Y.[1], Thomas, A.G.[1], Andrews, T. [2], Brown, K.R. [2], and Van Acker, R. C. [3] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Manitoba Agriculture, Food and Rural Initiatives, Carman, MB; [3]University of Manitoba, Winnipeg, MB

A survey of weeds resistant to herbicides in 150 randomly selected fields was conducted across the major agricultural ecoregions of Manitoba in 2002. All residual weed species with mature seeds were mapped and sampled before harvest. Selected fields were cropped to cereals or oilseeds. Samples of 17 weed species were subsequently screened in the greenhouse with high-risk herbicides belonging to Groups 1 and 2. Producers provided information on herbicide use and resistance awareness by means of a management questionnaire. One-third of surveyed fields had a herbicide-resistant weed biotype. Of 84 fields where wild oat (*Avena fatua* L.) were collected, 40% had Group 1 resistance (22% of all fields surveyed) and 13% had Group 2 resistance (7% of fields surveyed). Most Group 1-resistant wild oat populations exhibited resistance to both aryloxyphenoxypropionate and cyclohexanedione herbicides. Group 2-resistant populations exhibited broad cross resistance across three classes of Group 2 herbicides. Of 59 fields where green foxtail [*Setaria viridis* (L.) Beauv.] seeds were collected, 22% had Group 1 resistance (9% of fields surveyed). Group 2 resistance was confirmed in one population - the first case in western Canada. Of 11 broadleaf weed species, Group 2 resistance was detected only in redroot pigweed (*Amaranthus retroflexus* L.) in one field in the Aspen Parkland ecoregion. Similar to green foxtail, Group 2 resistance in this species had not been reported previously in western Canada. Only 10% of producers with resistant wild oat previously suspected or were aware of their occurrence; no producers with resistant green foxtail suspected resistance. This low level of awareness was consistent with findings from previous surveys, and may be partly attributed to the relatively small infestation area of resistant biotypes in most fields.

Patch management of herbicide-resistant wild oat (*Avena fatua* L.). Beckie, H.J.[1], Hall, L.M.[2], and Schuba, B. [1] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development/University of Alberta, Edmonton, AB

A study was conducted at a 64-ha site in western Canada to determine how preventing seed shed from herbicide-resistant wild oat affects patch expansion over a 6-yr period. Seed shed was prevented in two patches and allowed to occur in two patches (untreated controls). Annual patch expansion was determined by seed bank sampling and mapping. All crop management practices were performed by the producer. Area of treated patches increased by 35% over the 6-yr period, whereas untreated patches increased by 330%. Patch expansion was attributed mainly to natural seed dispersal or seed movement by equipment at time of seeding. Extensive seed shed from plants in untreated patches before harvest or control of resistant plants by alternative herbicides minimized seed movement by the combine harvester. Although both treated and untreated patches were relatively stable over time in this cropping system, preventing seed production and shed in herbicide-resistant wild oat patches can markedly slow the rate of patch expansion.

Application method of N fertilizer affects weed competition with winter wheat. Blackshaw, R.E. and Molnar, L.J. Agriculture and Agri-Food Canada, Lethbridge, AB

The management of crop fertilization may be an important component of integrated weed management systems. A field study was conducted to determine the effect of various application methods of nitrogen (N) fertilizer on weed growth and winter wheat yield in a zero-tillage production system. Nitrogen fertilizer was applied at 50 kg ha^{-1} at the time of planting winter wheat in four consecutive years to determine annual and cumulative effects. Nitrogen treatments consisted of granular ammonium nitrate applied broadcast on the soil surface, banded 10 cm deep between every crop row, banded 10 cm deep between every second crop row, and point-injected liquid ammonium nitrate placed between every second crop row at 20 cm intervals and 10 cm deep. An unfertilized control also was included. Density, shoot N concentration and biomass of weeds was often lower with sub-surface banded or point-injected N than with broadcast N. Winter wheat density was similar with all N fertilizer application methods but wheat shoot N concentration and yield were consistently higher with banded or point-injected N compared with broadcast N. Surface broadcast N did not increase weed-infested wheat yield above that of the unfertilized control in several instances, indicating that it was the least preferred N application method. Depending on the weed species, the weed seed bank at the conclusion of the four-year study was reduced by 29 to 62% with point-injected N compared with broadcast N. Information gained in this study will be utilized to develop more integrated weed management programs in winter wheat.

Crop management decisions for long term weed control. Blackshaw, R.E.[1], Moyer, J.R.[1], Harker, K.N.[2], and Clayton, G.W.[2] [1]Agriculture and Agri-Food Canada, Lethbridge, AB; [2]Agriculture and Agri-Food Canada, Lacombe, AB

A field study was conducted to determine the combined effects of seed date (April or May), seed rate (recommended or 150% of recommended), fertilizer timing (fall- or spring-applied), and in-crop herbicide rate (50% or 100% of recommended) on weed growth and crop yield. Treatments were applied in four consecutive years within a barley-field pea-barley-field pea rotation in a zero-till production system. Both barley and field pea phases of the rotation were grown each year. Weed biomass was often lower with May than with April seeding due to more weeds being controlled with preplant glyphosate. However, despite fewer weeds being present with May seeding, barley yield was only greater in 1 of 4 years and field pea yield was actually lower with May than with April seeding in 3 of 4 years, indicating that optimum seed date is highly dependent on crop species and environmental conditions. Higher crop seed rates reduced weed biomass and increased crop yield in 2 of 4 years in each of barley and field pea. Fertilizer timing had little effect on weed competition in barley but spring- compared with fall-applied fertilizer reduced weed biomass and increased field pea yield in 2 of 4 years. In-crop herbicides applied at 50% compared with 100% rates sometimes resulted in greater weed biomass and lower crop yields with recommended crop seed rates but few differences were noted at high crop seed rates. Indeed, the weed seed bank at the conclusion of the 4-year study was not greater with the 50% compared with 100% herbicide rate when high crop seed rates were utilized. This study demonstrates the combined merits of early seeding (April), higher crop seed rates, and spring-applied fertilizer in conjunction with timely but limited herbicide use to manage weeds and maintain high yields in rotations containing barley and field pea.

Influence of soil moisture stress on growth and preference of *Trichoplusia ni* on broccoli and two agricultural weeds. Cameron, J.H., Isman, M.B. and Upadhyaya, M.K. Faculty of Agricultural Sciences, University of British Columbia, Vancouver, BC.

The growth and feeding preferences of the cabbage looper, *Trichoplusia ni* (Lepidoptera: Noctuidae), were investigated on broccoli, common groundsel (*Senecio vulgaris* L.), and shepherdspurse (*Capsella bursa-pastoris* L.) grown at three soil moisture levels. Plants were grown in a greenhouse in soil-less potting mix at field capacity (FC), 70% FC, and 40% FC. The different soil moisture levels affected fresh weight and leaf area of broccoli and fresh weight of common groundsel in all experiments, but shepherd's purse was affected only in two of six experiments. In a seven-day growth trial, *T. ni* larvae grew larger on excised broccoli leaves from the 40% FC treatment compared to treatments receiving higher watering rates. Insect survival was not affected by the three treatments. In a leaf disc choice bioassay, 4th instar larvae did not prefer leaf material from one watering regime over another. Adult insects showed a weak (p-values 0.06-0.08) preference for shepherd's purse leaves from the 40% FC treatment compared to the 100% FC treatment as a site for oviposition. Changes in leaf chemistry brought about by soil moisture stress appear to affect the growth rate of this insect, but not the signaling compounds which indicate to the insect that one plant is a better source of food than another.

Using a Whole Plant Bioassay to Detect Herbicide Residues. S. Checkel and P.R. Watson*, Alberta Research Council, P.O. Bag 4000, Vegreville AB.
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Soil residual herbicide activity can cause crop injury ranging from minimal to complete crop loss. Factors such as drought, low soil organic matter and pH can increase the risk of economic loss or extend this risk beyond the recommended re-crop interval. Injury evaluation compares growth of target and sensitive plant species in a submitted soil sample versus a herbicide free soil. Since 1999, 868 samples have been submitted by producers, agrologists, researchers and herbicide companies for residue testing. Group 2 herbicides were requested in >85% of samples submitted. Canola was the most requested target species, comprising of 62% of target species planted. Plant bioassays indicate the biological activity of the herbicide residue on the crop and can detect concentrations of herbicide residue at lower concentrations than chemical analysis. Results from the bioassay may not directly relate to the field conditions and the effect on the sensitive species must be taken into consideration. Bioassay results should be used with other information such as; herbicide label restrictions, soil organic matter and pH, and precipitation.

UV-B exposure of houndstongue (*Cynoglossum officinale* L.) plants influences the inhibitory activity of leaf leachates on forage grasses. Furness, N.H.[1], Upadhyaya, M.K.[1], and Adomas, B.[2] [1]Faculty of Agricultural Sciences, University of British Columbia, Vancouver, BC; [2]Department of Plant Protection, University of Warmia and Mazury, Olsztyn, Warmia-i-Mazury

Inhibition of crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) Idaho fescue (*Festuca idahoensis* Elmer), and prairie Junegrass (*Koeleria macrantha* (Ledeb.) JA Schultes) seedling emergence by aqueous leaf leachate, leaf residue and leached-leaf residue of houndstongue, and influence of ultraviolet-B (UV-B) radiation exposure during houndstongue growth on leaf leachate inhibitory activities were studied. Greenhouse-grown houndstongue leaves were dried, ground, and aqueous extracts prepared. Soil-applied 4% leachate (8ml/20 g) inhibited crested wheatgrass and prairie Junegrass seedling emergence by 21 and 62%, respectively after 14 d. Soil-applied leaf residue and leached-leaf residue (2% w/w) delayed emergence of all three grasses. Little difference in emergence persisted after 14 d. Soil-surface leaf residue (2% w/w) reduced emergence by 29, 35, and 65% after 14 d in crested wheatgrass, Idaho fescue and prairie Junegrass, respectively. Effects of leaf leachates (0.5, 1, 2, or 4%) from houndstongue grown in a greenhouse at 0, 4 (field ambient), 7 (18% ozone depletion), and 11 (37% ozone depletion) kJ m^{-2} d^{-1} of biologically effective UV-B (UV-B_{BE}) radiation on seed germination were monitored in petri plates. Idaho fescue and prairie Junegrass germination were the most, and crested wheatgrass the least inhibited by houndstongue leaf leachates. No consistent UV-B trends on crested wheatgrass or Idaho fescue germination was observed among leaf leachates. Germination inhibitory activity of leaf leachates generally increased with increasing UV-B dose for prairie Junegrass. Seedling growth was investigated by incubating pregerminated seeds in 0.5, 1, or 2% leachates as described above. Root length declined and shoot:root ratio increased upon incubation in leaf leachates from UV-B-exposed seedlings. UV-B-absorbing compounds (A_{300} nm) increased in leaf leachates of plants grown at 11, compared with 0, 4, or 7 kJ m^{-2} d^{-1} UV-B_{BE} radiation levels. Results suggest that UV-B radiation levels may influence allelopathic potential of houndstongue on some forage grasses.

Reduced Herbicide Use in Flax Under a No-Till Annual-Based Rotation. Gillespie, S.C.[1], Irvine, B.[1], Entz, M.H.[2] [1]Brandon Research Centre, Agriculture and Agri-Food Canada, Brandon, MB; [2]Plant Science Department, University of Manitoba, Winnipeg, MB

Farmers interested in reducing pesticide use in no-till annual-based systems need to have reliable farming methods that aren't dependent on pesticides and that are still able to generate good economic returns. Pesticide Free Production (PFP^{TM}) was developed in 1999 by individual farmers along with research scientists and extension workers from the University of Manitoba, Brandon Research Centre (Agriculture and Agri-Food Canada), and Manitoba Agriculture and Food. For PFP^{TM}, residual pesticides cannot be active in the soil when the crop is planted and pesticides cannot be applied while the crop is growing. Since flax is not very competitive against weeds, the goal in this experiment is to encourage as much weed growth as possible before planting. A late seeding date and a high seeding rate are known by farmers and researchers as effective ways to make the crop more competitive. With this in mind, two further strategies were used to try to enhance weed germination in this period. Rotary harrowing, a light disturbance to a depth of 1-3cm, was found to have a significant effect in germinating more weeds. This is to be expected as weed seeds in a no-till system tend to stratify in the top layers of the soil. Early spring nitrogen placement did not have consistent results in germinating more weeds although the disturbance did have an effect in some cases. Weed populations were similar among all treatments 25 days after planting. Despite this, early nitrogen treatments had the highest crop biomass and grain yield among all PFP^{TM} treatments, although the results were not statistically significant. All PFP^{TM} yields were significantly lower than the conventional control which indicates PFP^{TM} would not have been profitable this year.

Quantification and persistence of root derived corn and soybean recombinant DNA in leachate water. Gulden, R. H. [1], Lerat, S. [2], Hart, M. [2], Powell, J. [3], Trevors, J.T. [2], Pauls, P. [1], Klironomos, J. [3], Swanton, C.J. [1] [1]Department of Plant Agriculture, University of Guelph (U of G), Guelph, ON; [2]Department of Environmental Biology, U of G, Guelph, ON; [3]Department of Environmental Biology, U of G, Guelph, ON.

Roundup Ready ™ genetically-modified (GM) corn and soybean currently comprise a large portion of the annual planted acreage of these crops. Plant growth and subsequent decomposition introduces large amounts of recombinant DNA (rDNA) into the soil environment where its fate has not been researched. Little is known of the temporal and spatial distribution of plant derived rDNA in the soil environment. The objectives of this study were to determine whether sufficient quantities of plant rDNA are released by roots during growth and decomposition to be detected in free water collected after percolating through a soil profile and to determine the persistence of rDNA in leachate water at different incubation temperatures. Individual plants of Roundup Ready ™ corn and soybean were grown in modified cylinders in a growth room. Soil moisture was maintained between 50 and 80% of field capacity throughout the study and the cylinders were flushed weekly with 1.1 times the soil pore volume of rainwater. Immediately after collection, the leachate was subjected to DNA purification followed by rDNA quantification using real time polymerase chain reaction. To test the effects of temperature on rDNA persistence, leachate water was spiked with a known quantity of soybean and corn rDNA and rDNA persistence was examined at 5, 15 and 25 C. Mean quantities of rDNA released by roots of individual corn plants were as high as 2.5×10^6 copies rDNA L^{-1} leachate water, whereas in soybean few samples were positive and a maximum of only 2.6×10^3 copies rDNA L^{-1} were detected. Our results suggest that rainfall events may distribute plant rDNA throughout the soil and into leachate water. Half-lives of rDNA in leachate water were calculated and ranged from 2.2 hrs at 25 C to 32.9 hrs at 5 C, indicating rapid degradation of rDNA in leachate water.

On the importance of crop health. Harker, K.N.[1], Clayton, G.W.[1], Turkington, T.K.[1], O'Donovan, J.T.[2], Lupwayi, N.Z.[2], Irvine, R.B.[3], and McLaren, D.[3] [1]Agriculture and Agri-Food Canada (AAFC), Lethbridge, AB; [2]AAFC, Beaverlodge, AB; [3]AAFC, Brandon, MB

Field studies were conducted to determine the impact of crop health on weed management. In the first experiment, N-rate and N-placement treatments were applied in direct-seeded barley at different plot locations each year. In the second experiment (also direct-seeded), treatments were applied in four consecutive years in continuous barley or in a barley-canola-barley-field pea rotation at four locations (Lacombe, AB; Beaverlodge, AB; Fort Vermilion, AB; Brandon, MB). Treatment variables in the latter experiment were herbicide rate, seeding density and barley cultivar in addition to rotational diversity treatments. Wild oat (*Avena fatua* L.) biomass and seed numbers were indicators of crop health and weed management levels. In the first experiment, placing too much N in the seed-row led to barley canopies with poor health. Digital photos at Lacombe indicated barley canopy cover near the end of June averaged 78% with 90 kg ha of N banded below and beside the seed as opposed to 22% when the same rate of N was placed with the seed. In the same plots, wild oat biomass was reduced five-fold in the banded N versus seed-placed N plots. In the second experiment, a combination of higher seeding rates, tall barley cultivar, and rotational diversity dramatically reduced wild oat biomass and seed numbers in 25% herbicide-rate treatments at Lacombe. Results at three other locations indicated similar trends at 50% herbicide rates, but these sites were less responsive to rotational diversity. Continuous barley led to substantially high levels of leaf disease in barley, but flag- and penultimate-leaves were not substantially diseased every year. Improving crop health by careful N placement and by combining higher crop density and competitive cultivars with greater rotational diversity augments herbicidal weed management.

Seeding date, row spacing, crop density, and glyphosate application time effects on transagenic soybeans (*Glycine max* L. Merr.).

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Yield in glyphosate tolerant soybeans can be affected by management factors such as crop seeding date, row spacing, crop density, and weed removal time. We evaluated the interaction of these factors with time of glyphosate application at Charlottetown, PEI in 2001 and 2003. Soybean cultivar 2601-RR (group 0) was no-till planted into barley stubble in 12 row plots in a split plot design with 4 replications. Glyphosate was applied at the unifoliate and 1st , 2nd , 3rd, or 4th trifoliate leaf stages of the soybean in 200 L/ha spray solution at 214 kPa using a tractor mounted sprayer. Soybean responded differently between the two years to time of seeding with late seeding giving highest yield in 2001 and early seeding giving highest yields in 2003. There was no interaction between time of seeding and time of herbicide application. Glyphosate applied at the unifoliate or 1st trifoliate sometimes gave lower yields than application at the 2nd trifoliate stage due to late emerging weeds. Soybean responded similarly in the two years to row spacing with wide spacing at 34 cm having lower yields than narrow spacing at 17 cm. There was no interaction between row spacing and time of herbicide application. Soybean responded similarly in the two years to planted density with densities of 75% and 50% of full density having lower yields than full density. There was an interaction between density and time of herbicide application. In both years and at all seeding times, row spacing, and crop densities, soybean yield was progressively reduced as glyphosate application was delayed. (IvanyJ@agr.gc.ca)

Development of a prototype propane flamer for weed control in horticulture

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The first prototype of flamers was developed in 1852. The use of flamers increased up to the 1960’s when there were over 25,000 flamers on farms in the USA. Later, the technique decreased in popularity with the advent of herbicides. In Europe, it has regained popularity in the late 1980’s with the increase in organic production. Propane flamers are environmentally friendly since their combustion produces water and CO_2, and it does not leave any residues in the soil or in the water. The mode of action of the flamer is not by burning the plant but by increasing cell temperature for a fraction of a second which is sufficient to disrupt the cell wall and denature the proteins, thereby killing the cells and eventually the plant. An experiment was initiated in 2004 in Québec to study the use of propane flamers in the field as a potential alternative to herbicides. The preliminary trial involved 5 tractor speeds, two type of propane torches with two different rates (kg h^{-1}), enabling us to develop a dose response curve with weed control and propane quantity in kg ha^{-1}. The quantity of propane used varied between 20 to 52 kg ha^{-1} (depending on speed and rate) and the average monocotyledonous and dicotyledonous weed density was 470 m^{-2} and 69 m^{-2} , respectively, in the experimental area. The LD50 was 37 and 19 kg ha^{-1} for monocotyledonous and dicotyledonous weeds, respectively. The main dicotyledonous weed species were lamb's-quarters and redroot pigweed while the monocotyledonous weed species were barnyard grass, foxtail and witch grass. In this experiment, dicotyledonous weeds were better controlled with a single flaming than the monocotyledon weeds.

Group 2 herbicide use in the Prairie Provinces. Leeson, J.Y.[1], Thomas, A.G.[1], Beckie, H.J.[1], Hall, L.M.[2], Brenzil, C.A.[3], Van Acker, R.C.[4], Brown, K.R.[5], Andrews, T.[5] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development, Edmonton, AB; [3]Saskatchewan Agriculture, Food and Rural Revitalization, Regina, SK; [4]Department of Plant Science, University of Manitoba, Winnipeg, MB; [5]Manitoba Agriculture, Food and Rural Initiatives, Carman, MB

Group 2 (ALS inhibitor) herbicides are amongst the most commonly applied products in the Prairie Provinces, available for the control of grassy and broad-leaved weeds in annual cereal and broad-leaved crops. Application patterns for Group 2 herbicide are documented in the Prairie Provinces to determine: recent changes in Group 2 use, the risk of resistant weed selection, and the risk of herbicide carryover. Data are from the 2001 Alberta, 2002 Manitoba and 2003 Saskatchewan management questionnaires, distributed in conjunction with the provincial weed surveys of annual cereal, oilseed and pulse crops. Overall usage of Group 2 herbicides has remained relatively constant within each province since the late 1990s. Group 2 products were used more than the recommended one in three years on 32%, 28% and 42% of the acres in Alberta, Saskatchewan and Manitoba, respectively. The percentage of acres receiving Group 2 products more than one in three years varied by ecoregion, accounting for over half of the acres in the Saskatchewan and Manitoba Boreal Transition Ecoregion. The high acreage receiving Group 2 products more often than recommended suggests that there is a high risk for the selection of Group 2 resistant weeds. The acreage receiving residual Group 2 products has increased in Alberta and Manitoba since the late 1990s. In Manitoba in 2002, 41% of residual herbicides were applied back-to-back. Back-to-back residual Group 2 usage was less common in 2001 Alberta and 2003 Saskatchewan, accounting for 20 and 14% of residual herbicide applications, respectively. The majority of the back-to-back residual herbicide use occurred in the normally wetter areas of the prairies; however, producers need to be aware of the risks of carryover when selecting crops particularly if dry conditions exist. Research is necessary to determine potential effects of back-to-back residual Group 2 use in areas where this is a common practice.

Do Saskatchewan producers reduce in-crop herbicide rates? Leeson, J.Y.[1], Thomas, A.G.[1], Brenzil, C.A.[2], and Beckie, H.J.[1] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Saskatchewan Agriculture, Food and Rural Revitalization, Regina, SK

Management questionnaires were an integral component of the prairie weed survey projects. Previous information collected in Alberta and Manitoba demonstrated that producers used reduced in-crop herbicide rates. The management questionnaire used in Saskatchewan provided an opportunity to collect similar information on this practice for spring wheat, barley, and canola. In-crop herbicide rate data were obtained from 535 questionnaires completed in 2003. Producers indicated that they had reduced the rates of one herbicide on 26% of the sprayed area and an additional 12% of the area was not sprayed. However, 5% of the area received a herbicide at higher than recommended rates. Herbicides belonging to Groups 1, 2, 4 and 6 were used most frequently. Products containing Group 4 herbicides were used on 52% of the surveyed area and only 17% of the surveyed area had Group 4 products applied at reduced rates, resulting in the highest use intensity (0.24 kg ai ha^{-1}) for any Group. Groups 9 and 10 were each used on 16% and 6% of the area, respectively. Group 9 and 10 products were never applied at reduced rates. Reduction of herbicide usage varied among ecoregions with 21% of the Mixed Grassland and 30% of the Moist Mixed Grassland receiving a reduced rate application. The total amount of herbicide applied to wheat and barley in Saskatchewan was marginally less than would have been applied if all fields received the minimum recommended rates. The total amount for canola was higher. Further adoption of rate reductions will depend on the willingness of the regulatory, research, extension, and agri-business communities to assist producers by documenting the risks and benefits of these practices and demonstrating how preventive and integrated weed management options support reduced herbicide usage.

The curious incident of the missing weed species in the seedbank. Légère A.[1], Stevenson F. C.[2], Benoit D. L.[3], Samson N.[4] [1] Agriculture et agroalimentaire Canada (AAC), Sainte-Foy QC; [2] Saskatoon SK; [3]AAC Saint-Jean-sur-Richelieu; [4] Lac Beauport QC

The relationship between mid-season plant stands and autumn seedbanks were examined for 19 weed taxa over four years, in spring barley-red clover cropping systems that varied according to crop rotation, tillage and weed management. Presence data confirmed that very few species were ubiquitous over time or treatments, aboveground or in the seedbank. The perennial species, field horsetail (*Equisetum arvense* L.), quackgrass (*Elymus repens* (L.) Nevski), white clover (*Trifolium repens* L.) and perennial sowthistle (*Sonchus arvensis* L.) were present in the flora but less or not present in the seedbank. This was also observed for annuals such as common hempnettle (*Galeopsis tetrahit* L.), sun spurge (*Euphorbia helioscopia* L.), catchweed bedstraw (*Galium aparine* L.) and annual grasses [mainly yellow foxtail (*Setaria glauca* (L.) Beauv.), green foxtail (*Setaria viridis* (L.) Beauv.), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.)]. Perennial sowthistle was a striking example of a species with apparently no seedbank who seemed to depend entirely on external input of seed, likely air-borne, for their presence aboveground which was fairly important across treatment-years. For sun spurge, catchweed bedstraw, and annual grasses, the relative presence advantage aboveground over seedbanks was not affected by treatments. The relative presence advantage aboveground for field horsetail and white clover was greater in the monoculture than in the rotation. Relative aboveground presence of quackgrass was favored in the tilled treatments where fractionation of rhizomes generated more tillers than in NT treatments. Results suggest that, even for some annuals, the presence of a species in plant communities does not imply its presence in the seedbank. Persistence of such species thus requires seed input from external populations, vegetative reproduction, or else depends on transient seedbanks. This particular type of plant-seedbank relationship implies that seedbanks in certain cropping systems may not allow sound predictions of composition and abundance of future weed stands.

Responses of spreading atriplex (*Atriplex patula* L.) and lamb's-quarters (*Chenopodium album* L.) to soil compaction, drought, and waterlogging. Maganti, M., Weaver, S., Downs, M. Agriculture and Agri-food Canada, Harrow, ON

Root traits and growth of spreading atriplex and lamb's-quarters were compared in response to soil compaction, drought and waterlogging under controlled environment conditions. Based on the typical habitats occupied, the hypothesis was that spreading atriplex would be more tolerant of compaction and waterlogging, and lamb's-quarters more tolerant of drought. When grown in buckets with two soil bulk densities (1.2 and 1.6 g cm^{-3}) for 8 wks, the two species responded similarly to compaction, with the fraction of fine roots reduced by 10%, total root length by 70%, root and shoot dry weight and leaf area by 50 to 60%, and plant height by 30% at the high compared to the low bulk density. When grown for 6 wks in soil columns 1 m long that were watered daily or allowed to dry, lamb's-quarters was deeper rooted than spreading atriplex at both moisture levels, and better able to sustain growth in the drying columns. The watering regime did not alter the rooting depth of either species. Total root length in successive 10-cm increments declined exponentially from the top to the bottom of the watered columns, but root proliferation was reduced in the upper 20 cm of the drying columns. The average root diameter of both species decreased with drought and increased with soil compaction. When grown in waterlogged soil at 10 or 20 C for 4 wks, seedlings of spreading atriplex survived with little reduction in growth whereas survival and growth of lamb's-quarters were drastically reduced, particularly under cool soil conditions.

Regulatory Update on Resistance Management Labelling Based on Target Site/Mode of Action. Najib Malik and Wenming Zhang. Efficacy & Sustainability Assessment Division, Pest Management Regulatory Agency, Ottawa, Ontario

The Pest Management Regulatory Agency (PMRA) introduced a pesticide resistance-management labelling initiative in 1999 based on target site/mode of action for agricultural uses of herbicides, fungicides/bactericides and insecticides/acaricides. This initiative includes two components: (1). the labelling of site of action identification symbols in accordance with standard scheme of classification that is specific to pesticide class, and (2). the labelling of a standard set of resistance management guideline statements with the aim of reducing the development of resistance to pesticides. Presently, 45% of Canadian pesticide products eligible under this initiative include resistance management labelling. The percentage of eligible products by pesticide class that include resistance management labelling are: herbicides 51%, fungicides 57%, insecticides 33%, insecticide/acaracides 29%, fungicide/insecticide coformulations 41%. Within the herbicide class, implementation of the resistance management labelling for the two Groups most implicated in resistance development is as follows: ACCase-inhibitors 86%, ALS-inhibitors 88%. Whereas resistance management-labelling for existing (old) products is still voluntary, PMRA is now vigorously implementing this initiative for all new products as part of its sustainability assessment.

Mass-producing a weed biocontrol agent by growing houndstongue as a crop

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The recent success of the European root weevil, *Mogulones cruciger* Hbst. (Coleoptera: Curculionidae), as a biocontrol agent for the rangeland weed, houndstongue (*Cynoglossum officinale* L.) in British Columbia, Canada, has created a large demand for the weevil among ranchers and land managers. Numbers of the weevil sufficient to meet this demand cannot be easily collected from field sites, and mass-production of the agent in the laboratory is expensive and constrained by availability of host plant material. Hence, we have initiated a novel project to mass-produce the agent that involves growing houndstongue as a crop, releasing the weevil into the crop, and harvesting the progeny. Agronomic experiments at Lethbridge , AB. and Creston BC. indicate that for consistent houndstongue emergence and optimum growth, seeds should be planted in late fall at a depth of about 2 cm. In three of four experiments more houndstongue plants emerged from bare soil than soil with added straw mulch. Houndstongue root crowns also tended to be larger in bare soil. Nitrogen fertilizer did not affect emergence but did slightly increase root crown diameter. Houndstongue plants were very small when they were growing in competition with other annual weeds or volunteer crops. Selective herbicides were found for the control of annual grasses but effective control of other broadleaf weeds with herbicides was not obtained without injuring houndstongue. Initial results indicate that weevil production is positively correlated with root crown diameter. Therefore, agronomic methods that produce the largest healthiest houndstongue plants should be most effective for the mass production of the biocontrol agent.

Estimating barley plant density as a function of seeding rate in Alberta, Canada. O'Donovan, J.T[1]., Clayton, G.W., Harker, K.N.[2], and Turkington, T.K.[2]. Agriculture and Agri-Food Canada, Beaverlodge[1] and Lacombe[2], AB.

Our previous studies have indicated that seeding field crops to achieve relatively high plant densities can improve competition with weeds, enhance herbicide performance, and expedite crop maturity. Alberta provincial guidelines indicate that barley plant densities above 200 plants/m^2 are desirable, and can be achieved by assuming germination and mortality rates of 95 and 5%, respectively. This suggests that desired plant densities are achievable by increasing the barley seeding rate by as little as 10%. A survey of barley fields in Alberta, however, indicated that, in most cases, plant densities were < 150 plants/m^2 suggesting that growers may overestimate potential plant emergence as a function of seeding rate. Field experiments were conducted at Beaverlodge, Fort Vermilion and Lacombe, Alberta in 2002 and 2003 to determine the relationship between feed barley plant density, seed yield, and maturity as affected by variety and seeding depth, and to estimate required seeding rates to achieve desired plant densities. Regression analysis was used to determine seeding rates required to obtain optimal barley plant densities for a hulled (AC Harper) and a hull-less (Peregrine) seeded at 2.5 and 6.25 cm depths. The relationship between barley seeding rate, and both barley plant density and seed yield was variable and influenced by location, year, and barley variety and seeding depth. The likelihood of achieving desired densities increased when barley was seeded at the shallower depth, and deeper seeding tended to reduce plant density of the hull-less more than the hulled variety. Increasing the barley seeding rate resulted in earlier maturity but, in most cases, did not affect seed yield. Overall, the results indicate that if barley growers in Alberta are to achieve desired plant densities of over 200 plants/m^2, seeding rates will need to be increased considerably over those currently recommended. Hull-less varieties will need to be seeded at higher rates than hulled varieties, possibly due to greater seed damage caused by the absence of the hull.

Putting a complete field in the computer: A dream? Panneton, B.[1], Lemieux, C.[2] [1]Agriculture and Agri-Food Canada, Saint-Jean sur Richelieu, QC; [2]Agriculture and Agri-Food Canada, Sainte-Foy, QC.

Assessing weed populations usually relies on field sampling. This method allows for assessing weeds based on a small fraction of total population and hardly support extensive follow up of individual weeds (or patches) over time. It limits our capacity to study weed distribution and population shifts. This work is an attempt to overcome this limitation. We designed a device for capturing a series of digital images on-the-go for covering whole fields. Individual image location is precisely registered in a geographic information system (GIS) to support a multi-year study. The device comprises a capturing unit, a transfer unit, and a GIS. It is easily taken apart in 45 minutes and fits in a pick-up truck. The capture unit comprises a custom made support holding a Nikon™ D1X digital camera, alongside four functional modules for: controlling image acquisition (with 10% overlap of adjacent images); eliminating shade; generating diffuse light;

and propelling. The transfer unit comprises two temporary storage units (1 MB flashcards) to acquire images on the go, and two transfer units (80GB SmartDisk-FlashTrax™) to copy files from temporary storage units to portable hard drives. Data are finally entered in a GIS system (ArcView™ or MapWindow™). Capturing a 2 ha field at a pixel resolution of 1mm required less than 6 hr. Using the GIS system, one can point at any given location in the field and get instant access to that location. During the 2004 cropping season the device was used to generate detailed description of weed populations over the entire surface of two corn fields. These fields will be monitored at different periods over time (2005 to 2008) to document in details any weed population changes occurring over those periods.

Fall Control of Dandelions *(Taraxacum officinale)*……Don't wait too Long K.Sapsford[1], F.A. Holm[1], E.Johnson[2]. [1]University of Saskatchewan, Saskatoon, SK; [2]Agriculture and Agri-Food Canada, Scott, SK

The trial was conducted near Saskatoon, Sk.(2001), Scott, Sk.(2002) and Colonsay, Sk.(2004). Treatments were applied in September or October. All fall treatments received an application of glyphosate at 450 gai/ha 3 days prior to planting. Treatments were 1) *glyphosate* @ 900 gai/ha Sep. or Oct. or Pre-seed. 2) *2,4-D ester* @ 840 gai/ha Sep. or Oct. 3) *2,4-D ester* @ 1120 gai/ha Sep. or Oct. 4) Express® - *tribenuron methyl* @ 7.5 gai/ha Sep. or Oct. 5) Express Pack® - *tribenuron methyl* @ 7.5 gai/ha + *2,4-D ester* @ 420 gai/ha Sep. or Oct. 6) Spectrum® - *florasulam* @ 5 gai + *clopyralid* @75 gai + *MCPA* @ 420 gai/ha Sep. or Oct. 7) Amitrol 240® - *Amitrol* @ 960 gai/ha Pre-seed. Observations: Sept. applications of Express®, Express Pack® and Spectrum® controlled dandelions through all rating periods from May 11 to Aug. 11. Sept. applications of glyphosate @900 gai/ha controlled dandelion through July 8. Oct application of glyphosate controlled dandelion through June 9 only. The spring application of glyphosate did not control dandelion. Spring applied Amitrol 240® suppressed dandelions through June. Sept. applications of glyphosate @ 900 gai/ha, Express Pack® and Spectrum® significantly reduced dandelion count from the untreated check as assessed on May 13, 2004. Sept. application of Express®, Express Pack®, Spectrum® and Oct. application of Spectrum® and 2,4-D ester @ 1120 gai/ha and spring applied Amitrol 240® significantly reduced dandelion count on Sept. 29, 2004. Highest wheat yields were achieved with Sept. applications of glyphosate @ 900 gai/ha, Express®, Express Pack®, Spectrum® and the Oct. application of Spectrum®. Mean yield of all Sept. and Oct applications was 247% and 177% of the untreated check, respectively. Overall, dandelion control declined over the growing season due to regrowth of existing plants or germination of new dandelions. Conclusions: Fall treatment for control of dandelion should be applied in September for best results. Express®, Express Pack® and Spectrum® applied in September supplied the longest and most consistent control of dandelions. Long-term control of dandelion will not be achieved with a one-time treatment.

Fitness of double (imidazolinone + glufosinate; glyphosate + glufosinate; imidazolinone + glyphosate) vs. single herbicide resistant canola (*Brassica napus*). Simard M.-J.[1], Légère, A.[1], Séguin-Swartz, G.[2], Nair, H.[2] and Warwick, S.I.[3] [1] Agriculture and Agri-Food Canada (AAFC), Sainte-Foy, QC; [2]AAFC-Saskatoon, SK; [3]AAFC-Ottawa, ON.

In Canada, herbicide resistant (HR) canola currently available to producers include cultivars resistant to glyphosate, glufosinate and the imidazolinones. Double herbicide resistant (2HR) volunteers have been reported in canola-growing areas. In order to evaluate the effect of HR gene stacking on canola fitness, we compared the three 2HR combinations to each of their parent single HR (1HR) commercial lines in separate greenhouse experiments. The replacement series design included five ratios of 2HR vs. 1HR plants and three stress treatments: herbicide application according to the HR trait shared by the 2HR and 1HR plants, wheat competition, and a control. Fitness indicators included aboveground biomass, seed production and reproductive allocation. Although 2HR plants showed delayed reproductive growth, plant and seed biomass of 2HR canola was comparable or greater than 1HR canola. Glufosinate-R+glyphosate-R was the fittest combination. 2HR plants were as competitive as 1HRs. Herbicide application had little effect on 2HR plants, except for imazethapyr which reduced biomass and seed production by 30% for 2HR plants with imidazolinone-glyphosate resistance. The latter effect may have been due to the unsuspected presence of 2HR plants with only one of the two ALS mutations conferring high resistance to imidazolinones. Wheat competition reduced all fitness values of both 2HR and 1HR canola. In conclusion, there was little indication of reduced fitness in 2HR canola in spite of the more limited genetic background of the selected 2HRs compared to commercial 1HR varieties. Canola volunteers with two HR traits occurring in commercial fields are probably as fit as any single HR or conventional canola volunteer.

Response of Otebo Beans to Preemergence Applications of Dimethenamid, *S*-metolachlor, Clomazone, and Imazethapyr. Nader Soltani, Darren E. Robinson, and Peter H. Sikkema*. Ridgetown College, University of Guelph, Ridgetown, Ontario.

Weed management is a major production issue facing otebo bean growers in Ontario as currently there are no herbicides registered for weed control in this crop. Field trials were conducted at six Ontario locations in 2003 and 2004 to evaluate tolerance of otebo beans to the preemergence (PRE) application of dimethenamid (1250 and 2500 g ai/ha), *S*-metolachlor (1600 and 3200 g ai/ha), clomazone (1000 and 2000 g ai/ha), and imazethapyr (75 and 150 g ai/ha). Dimethenamid caused as much as 10, 10, and 5% visual injury and *S*-metolachlor caused as much as 7, 6, and 2% visual injury at 7, 14, and 28 days after treatment (DAT), respectively. However, these injuries were transient with no adverse effect on plant height, shoot dry weight, seed moisture content and yield of otebo beans. Clomazone caused as much as 17, 16, and 11% visual injury at 7, 14, and 28 DAT, respectively and reduced plant height by 11% and shoot dry weight by 16% compared to the untreated control. Imazethapyr caused as much as 2, 4, and 19% visual injury, at 7, 14, and 28 DAT, respectively. Crop injury was persistent over time and resulted in a decrease of up to 19, 31, and 16% in plant height, shoot dry weight, and yield of otebo beans, respectively. Based on these results, dimethenamid and *S*-metolachlor applied PRE have potential for weed management in otebo beans. Additional research is needed to determine if there is an adequate margin of crop safety in otebo beans to the PRE application of clomazone. However, there is not an adequate margin of crop safety for imazethapyr applied PRE in otebo bean production in Ontario.

Residual weed populations in the Prairie Provinces - 1973 to 2003. Thomas, A.G.[1], Leeson, J.Y.[1], Brenzil, C.A.[2], Hall, L.M.[3], Andrews, T.[4], Brown, K.R.[4], Van Acker, R.C.[5] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Saskatchewan Agriculture, Food and Rural Revitalization, Regina, SK; [3]Alberta Agriculture, Food and Rural Development, Edmonton, AB; [4]Manitoba Agriculture, Food and Rural Initiatives, Carman, MB; [5]Department of Plant Science, University of Manitoba, Winnipeg, MB

A comparison of the relative abundance of weeds in the Prairie Provinces from 2001-2003 with results from provincial surveys conducted in the 1990s, 1980s, and 1970s enables the identification of shifts in species rank, life form density and relative abundance. In the 2000s, 3806 fields of spring wheat, barley, durum, oats, canary grass, canola, flax, mustard, field peas, and lentils were surveyed. These fields were selected using a stratified random sampling procedure based on ecodistricts. Weeds were counted in 20 quadrats (50 by 50 cm) in late summer. Weed data were summarized using a relative abundance index based on frequency, field uniformity and density. Green foxtail (*Setaria viridis* (L.) P. Beauv.) was the most abundant weed, wild oats (*Avena fatua* L.) ranked second, wild buckwheat (*Polygonum convolvulus* L.) third, and Canada thistle (*Cirsium arvense* (L.) Scop.) fourth. The results from the 2000s surveys were compared to results from surveys of 2294 fields in 1995-1997, 2729 fields in 1986-1989 and 8878 fields in 1973-1981. Thirteen species have been ranked amongst the top 20 most abundant species in each survey. Six species, ranked in the top 20 species in the 1970's and/or 1980's, have since declined: cow cockle (*Vaccaria hispanica* (Mill.) Rauschert), corn spurry, (*Spergula arvensis* L.), bluebur *(Lappula squarrosa* (Retz.) Dumort.), night-flowering catchfly (*Silene noctiflora* L.), flixweed (*Descurainia sophia* (L.) Webb *ex* Prantl), and wild mustard (*Sinapis arvensis* L.). Five species have appeared in the top 20 list in the 1990s and/or 2000s: cleavers (*Galium aparine* L.), wheat (*Triticum aestivum* L.), kochia (*Kochia scoparia* (L.) Schrad.), barnyard grass (*Echinochloa crusgalli* (L.) P. Beauv.), and dandelion (*Taraxacum officinale* G.H. Weber *ex* Wiggers). Relative abundance of annual grasses and perennials has increased, while the relative abundances of annual broad-leaved species and facultative winter annuals have decreased. Densities of all life forms have decreased since the 1970's.

Has herbicide-tolerant canola altered weed diversity in Western Canada? Thomas, A.G.[1], Leeson, J.Y.[1], Hall, L.M.[2], Beckie, H.J.[1], Van Acker, R.C.[3], Brenzil, C.A.[4] [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development, Edmonton, AB; [3]Department of Plant Science, University of Manitoba, Winnipeg, MB; [4]Saskatchewan Agriculture, Food and Rural Revitalization, Regina, SK

Herbicide-tolerant (HT) canola, introduced in the 1990s, was rapidly adopted in Western Canada and now occupies >90% of the 4.6 million canola ha seeded annually. To determine the impact of this new technology on weed community composition, density and diversity, we compared residual weed survey data from 212 non-tolerant (NT) canola fields in 1995-1997 to 335 HT canola fields in 2001-2003. The HT canola acreage in the 2000s was 50% glyphosate, 27% imidazolinone and 23% glufosinate tolerant. Spring wheat was used as a reference crop to aid in the comparison of results between time periods. Data from 313 and 441 wheat fields (not on canola stubble) were used for the 1990s and 2000s respectively. The contribution of each of the major taxonomic families to the total relative abundance changed similarly in wheat and canola. Species originating in Eurasia accounted for 92% of the total relative abundance in both crops. Average weed density in canola declined from 43 to 27 plants m^{-2} and a similar decline occurred in wheat. Weed diversity in canola and wheat was measured by species richness, dominance and evenness indices. Both crops had similar changes between time periods: richness declined, dominance increased and evenness was unchanged. A multivariate redundancy analysis of the weed density data indicated that the main differences in species composition were between the 1990s and 2000s and the differences between NT and HT canola were of lesser importance. The temporal shifts in both crops can be attributed to below normal precipitation during the 2000s and management factors, including further adoption of conservation tillage and changes in herbicide application timing. The improved weed management is likely not of concern because the weed flora does not include any rare or endangered species; however, the consequences of these shifts on overall agro-ecosystem health needs to be further examined.

Influence of temperature and photoperiod on early development of *Papaver rhoeas.* Torra, J.[1]; Benoit, D.L.[2]; Bourgeois, G.[2]; Recasens, J.[1] [1]Dept. Hortofructicultura, Botànica i Jardineria. ETSEA. Universitat de Lleida, Spain. [2] Agriculture and Agri-Food Canada, Horticultural Research and Development Centre, Saint-Jean-sur-Richelieu, Quebec

The biology of the corn poppy *(Papaver rhoeas* L.), a cereal weed in Europe with strong potential for accidental introduction to North-America, is still not well known, a handicap for the timing of any kind of treatment. The main objective of this study was to develop a model to predict the appearance of leaves of the earlier stages of corn poppy. The growth and development of this annual broad-leaved weed was monitored for one growing season from a 2,4-D resistant population growing in winter barley or alone without crop in North-eastern Spain. All seedlings emerging within a short time frame were assigned to a cohort. Leaf numbers, BBCH stage and biomass of the different weed cohorts were recorded periodically until harvest. The data selected to model *P. rhoeas* were those for which plants were below a 50 BBCH stage (before reproduction onset) and/or had less than 50 leaves per rosette because above this value multiple rosettes occurred. The development was best described by a simple linear model and was closely related to the cumulative degree days and photoperiod length recorded during that period. The highest R^2 were obtained when the cumulative degree days were corrected by a function of the daylength. Six cohorts emerged in absence of crop and all behave similarly. Cohorts of *P. rhoeas* growing with barley had a slower development than the cohorts growing without crop. Average leaf appearance rate for all cohorts was 0.0524 leaves/Cum Corr. Daylength DD $_{\text{(opt. 25 °C).}}$ We concluded that a simple linear model can be used to predict the appearance of leaves of corn poppy at early vegetative stages irrespective of cohort emergence timing. This model may prove useful for the timing of chemical and mechanical treatments against this weed.

The biology of invasive alien plants in Canada Series. Warwick S.I., and Darbyshire S. Agriculture and Agri-Food Canada (AAFC)-ECORC, Ottawa, ON

A new series: *The Biology of Invasive Alien Plants in Canada* was initiated in 2003 in the Canadian Journal of Plant Science. To date, one species account has been published, two are in press and ten additional species have been assigned. The Series is designed to cover recently introduced plant species that pose a demonstrable economic or environmental risk. Invasive alien species are becoming a catastrophic problem to ecosystems throughout the world. Globalization and expansion of trade have greatly contributed to the increased rate at which species are being transported internationally. Presently an estimated 1-2 new alien plant species are becoming established in Canada each year and that rate of introduction and establishment will likely increase. Many of these new alien plants are likely to become widespread problematic weeds in the future. These new pests are generally poorly known and their weedy potential unrecognized by most Canadians. There is a need for information to assist with early detection and accurate identification of new infestations as well as diagnosis of their potential for detrimental effects. Contributions to the new series will serve as an alert of emerging problems, and will emphasize identification, occurrence, impact, effective control methods and future prognosis. The series will also engender research to fill important gaps in our knowledge of the biology and management of these species. For more information on the submission process and instructions to authors, see the Canadian Journal of Plant Science October 2003 issue or contact warwicks@agr.gc.ca for a pdf file.

Resistance in Canadian populations of wild mustard (*Sinapis arvensis*) to ALS-inhibiting herbicides. Warwick, S.I.[1], Sauder, C.[1], and Beckie, H.J.[2]. [1]Agriculture and Agri-Food Canada (AAFC), Ottawa, ON; [2]AAFC-Saskatoon, SK

The physiological extent and molecular basis of ALS resistance (R) were examined in four resistant populations of wild mustard from western Canada: a sulfonylurea (SU)-resistant population from Birch River, Manitoba detected in 1992; a SU-resistant population from Wetaskiwin, Alberta detected in 1993 and later reported to have a metabolism-based resistance mechanism; a recent SU-resistant population from Starbuck, Manitoba detected in 2002; and a recent SU- and imidazolinone (IMI)-resistant population from Theodore, Saskatchewan detected in 2002. Greenhouse spray experiments confirmed that the two Manitoba and the Alberta populations were resistant only to the SU herbicides ethametsulfuron and thifensulfuron:tribenuron mixture, whereas the Saskatchewan population was resistant to both SU herbicides and to imazethapyr, an IMI herbicide. Molecular sequence analysis of the ALS gene detected differences in target site mutations in three of the four resistant populations, with a single nucleotide mutation in domain A [Pro_{197} (**C**CT) to Ser_{197} (**T**CT)] of the gene in the two SU-resistant Manitoba populations, and a single nucleotide mutation in domain B [Trp_{574} (T**G**G) to Leu_{574} (T**T**G)] in the Saskatchewan population. In contrast, the Alberta SU-resistant population had the same ALS sequence as the susceptible control population at these two domains. No population differences were detected in domains C, D and E of the ALS gene. Two heterozygous individuals [Domain B (T**t/g**G)] were detected in the Saskatchewan population. Heterozygosity was confirmed with the observation of genetic segregation for resistance in the progeny derived from selfing of one of these plants. Population variation (nucleotide variation) was also observed in neutral regions of the ALS gene sequence in three of the four populations studied, with no intra-populational variation observed for the two Manitoba populations.

The Contribution of Seed, Seedling, and Mature Plant Traits to Barley Cultivar Competitiveness Against Weeds. P.R. Watson[1], D.A. Derksen[2], R.C. Van Acker[3], B. Irvine[2], M.C. Therrien[2], M.H. Entz[3]. [1]Alberta Research Council, P.O. Bag 4000, Vegreville AB, [2]Agriculture and Agri-Food Canada, P.O. Box 1000F RR#3, Brandon, MB, [3]University of Manitoba, Department of Plant Science, Winnipeg, MB

One integrated weed management tool is the use of competitive crops and cultivars. Barley is a competitive crop, but cultivar competitiveness varies. Competitive ability has been measured using different attributes at different developmental stages, often without considering the linkages. Consequently, the research objectives are to: 1) determine the contribution of seed, seedling, and mature plant traits to barley cultivar competitiveness against weeds and, 2) develop a framework to rank the competitive ability of barley cultivars. A screening trial was initiated to determine the range of competitive ability of 29 cultivars commonly grown in western Canada. Paired plots were sown with tame oats (weedy) and without (weed-free). Measurements were made at each developmental stage in the weed-free plots. A fungicide application trial was conducted to determine the effect of disease on the competitive ability of cultivars. Six cultivars from the screening trial were selected and a split-split plot design was employed with fungicide application (±), cultivar, and weed treatment (±) as the main, sub-plot, sub-plot and sub-sub-plot, respectively. Competitive ability has two components, the ability to withstand competition (AWC) and the ability to compete (AC). AWC is the ratio of the yield in weed-free to weedy plots, whereas AC is measured as 100 - % dockage. The screening trial shows considerable differences in cultivar AWC and AC, which can both be partially explained by greater emergence and early height increase. Fungicide application resulted in both increased yields and dockage. Since the dockage increase was proportional to the yield increase, AWC was unchanged and AC was increased by the application of fungicides. Results from both field trials and greenhouse trials suggest the outcome of competition is decided before competition begins.