Canadian Weed Science Society
Société canadienne de malherbologie

Proceedings of the 2006 National Meeting

60th Annual Meeting
November 27 – 29, 2006
Laurel Point Inn
Victoria, British Columbia

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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
2006 National Meeting
Réunion nationale 2006
Victoria, BC

There were 212 registered participants at the meeting and two symposia took place.

The 2006 Awards and Scholarships recipients were:

Monsanto Scholarship:
Ph.D.: Christian Willenborg, Characterizing the factors contributing to intraspecific gene movement between volunteer wheat (*Triticum aestivum* L.) populations and wheat crops. University of Manitoba.
M.Sc.: Julie Laplante, Characterization of resistance to Acetohydroxyacid Synthase (AHAS) inhibitor in giant foxtail (*Setaria faberii* Hermm.), University of Guelph.

Dow Agrosciences Travel Awards:
Ph.D.: Marc McPherson, Biological safety of biopharming plant-made pharmaceuticals. University of Alberta.
M.Sc.: Marie-Edith Cuerrier, Développement de stratégies de désherbage dans les cultures de millet perlé grain, fourrager et sucré (*Pennisetum glaucum* [L] R. Br.), Université Laval.

Syngenta Crop Protection Travel Awards:
Ph.D.: Evan Sivesind, Flame cultivation in vegetables: Efficacy as weed control and crop physiologic response. McGill University.
M.Sc.: Luke Bainard, Effect of allelopathic secondary metabolites of two invasive plant species on arbuscular mycorrhizal fungi. University of British Columbia.

Dow AgroSciences Excellence in Weed Science Award
The 2006 winner is Peter Sikkema, Assistant Professor at Ridgetown Campus, University of Guelph, Ontario.

Bayer CropScience Best Student Presentation Award
The Bayer CropScience Best Student Presentation Award was awarded to Marie-Edith Cuerrier, Laval University in Québec City, for her presentation titled “Weed control strategies in pearl millet (*Pennisetum glaucum* [L.] R. Br.).

BASF Canada Poster Award Winners
First Place:
Economic impact of alien weeds on wheat, barley and canola production
J.Y. Leeson, A.G. Thomas, J. O'Donovan, AAFC, Saskatoon and AAFC, Lacombe

Second Place:
How flowering synchrony affects canola outcrossing

M.J. Simard and A. Légère AAFC, Québec and Saskatoon

Third Place:
Weed Alert: Bromus secalinus L. in Ontario
S. Darbyshire and M. Cowbrough, AAFC, Ottawa and OMAFRA

E.I. DuPont Canada Photo Contest Winners
Brent Wright was the Photo contest chair for 2006.
Winners in Victoria were as follows:

General agriculture:
1) Rick Holm - Full of Holes
2) Art Yochim - Seeding
3) Christie Stewart - Corn Crop

Weeds:
1) Peter Smith - Bull thistle up close
2) Maryse Leblanc - Legume
3) Daniel Cloutier - Foxtail

Weeds in action:
1) Rick Holm -Big as a Ship
2) Lyle Drew - Goat'sbeard seed dispersal
3) Daniel Cloutier - Sowthistle dispersal

The committee members and their responsibilities were:

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CWSS-SCM 2006 Annual Meeting Agenda

Date	Time	Topic
Sunday November 26th	9:00 am – 5:00 pm	Board of Directors Meeting. Lunch served at noon
	1:00 pm – 5:00 pm	Eurosa Greenhouses and Arbutus Grove Nursery Tour
	5:00 pm – 9:00 pm	Registration – Marble Lobby
	5:00 pm – 9:00 pm	Poster and Commercial Display Setup – Breakout ABC
	5:00 pm – 9:00 pm	Reception – in Terrace Room
Monday November 27th	7:30 am – 8:30 pm	Poster and Commercial Displays (author in attendance)– Breakout ABC Continental Breakfast
	8:30 am – 6:00 pm	Poster and Commercial Display Viewing
	9:00 am – 12:00 pm	Symposium Session – Salons ABCD
	10:20 am – 10:40 pm	West Coast Break
	12:00 pm – 1:00 pm	Lunch – in Terrace Room
	1:00 pm – 5:00 pm	Symposium Session Salons ABCD
	3:00 pm – 3:20 pm	West Coast Break
Tuesday November 28th	6:30 am – 8:00 am	Breakfast Meeting for 2007 Program Committee
	6:30 am – 8:00 am	Continental Breakfast
	8:00 am – 6:00 pm	Poster and Commercial Display Viewing
	8:00 am – 12:15 pm	Graduate Student Presentations
	10:20 am – 10:40 pm	West Coast Break
	12:15 pm – 2:00 pm	Awards Banquet – in Terrace Room
	2:00 pm – 3:45 pm	Working Group Sessions – Herbicide Residue / Extension & Noxious Weeds
	3:45 pm – 4:00 pm	West Coast Break
	4:00 pm – 5:45 pm	Working Group Sessions – Integrated Weed Management / Herbicide Resistance
	6:30 pm – 12:00 am	CropLife Canada Reception in Terrace Room
Wednesday November 29th	7:30 am – 9:30 am	CWSS Annual Business Meeting Breakfast
	8:00 am – 12:00 am	Forestry Session in Breakout ABC
	9:30 am – 10:00 am	West Coast Break
	10:00 am – 12:00 pm	Working Group Sessions – Crop Life and Cereal & Oilseeds / Physical Weed Control
	12:00 pm – 2:00 pm	Board Member Meeting/ Lunch - Boardroom
	1:00 pm – 5:00 pm	Forestry Session in Breakout ABC
	3:20 pm – 3:40 pm	West Coast Break for Forestry Session

Invasive Plants : Inventories, Strategies and Action

Agenda

Time	Topic	Speaker	Affiliation
8:30 am – 8:40 am	**Welcome and Announcements**	**Anne Légère**	**Agri-food and Agriculture Canada, Saskatoon, SK**
8:40 am – 8:45 am	**Local Arrangements**	**Victoria Brookes**	**Agriculture and Agri-Food Canada, Agassiz, BC**
8:45 am – 8:55 am	**Welcome from BC Invasive Plant Council**	**Gail Wallin**	**Executive Director** **BC Invasive Plant Council**
8:55 am – 9:00 am	**Introduction to Symposium**	**David Clements**	**Trinity Western University, Langley, BC**
9:00 am – 9:30 am	**Invasive plants 'wins and losses' and lessons learnt: some Australian examples**	**Amanda Moncrieff**	**Dept of Environment and Conservation, Western Australia**
9:30 am – 10:00 am	**Australian risk assessment model: Does it work in Hawai'i? Would it work in Canada**	**Curt Daehler**	**University of Hawai'I, Honolulu, Hawai'i**
10:00 am – 10:30 am	**The good, the bad, and the ugly and how to tell them apart**	**Sarah Reichard**	**University of Washington, Seattle, WA**
10:30 am – 11:00 am	**West Coast Break**		
11:00 am – 11:20 am	**Tracking long-term changes in arable weed populations: the snubbed invasive aliens**	**Gord Thomas**	**Agriculture and Agri-Food Canada, Saskatoon, SK**
11:20 am – 11:40 am	**Eradicating (?) a new weed for Canada;** *Soliva sessilis*	**Dave Polster**	**Polster Environmental Services, Duncan, BC**
11:40 am – 12:00 am	**Toward an invasive plants strategy for Ontario's forests**	**Michael Irvine**	**Ontario Ministry of Natural Resources, Sault Ste. Marie**
12:00 am – 1:00 pm	**Lunch – Terrace Room**		
1:00 pm – 1:25 pm	**Applied bioncontrol, a look at *Mecinus janthinus* and *Rhinusa antirrhini* for biocontrol of Dalmation toadflax in BC**	**Susan Turner**	**BC Forest Service, Kamloops, BC**
1:25 pm – 1:50 pm	**A test case in weed bio-control insect production and delivery in Canada: Shifting the 'classical' paradigm**	**Rosemarie De Clerke-Floate**	**Agriculture and Agri-Food Canada, Lethbridge, AB**
1:50 pm – 2:10 pm	**Managing alien plant invasion in Eastern Canada: Challenges and the quest for solutions**	**Glen Sampson**	**Nova Scotia Agriculture College, Truro, NS**
2:10 pm – 2:30 pm	**Against the Law: How does legislation fit in the management of invasive alien plant species?**	**Clark Brenzil**	**Saskatchewan Agriculture & Food, Regina, SK**
2:30 pm – 3:00 pm	**West Coast Break**		
3:00 pm – 3:30 pm	**Thirteen ways of looking at invasive species: The spectrum from bad to good**	**Brendon Larson**	**University of Waterloo, Waterloo, ON**
3:30 pm – 4:30 pm	**Round table with speakers and audience questioning and discussing the days presentations and content**		

Today’s Silviculture: Tomorrow’s Forest
Agenda

08:00 – 08:30	Registration
08:30 – 08:50	Welcome
08:50 – 09:30	Lessons from a career in forest vegetation management **Robert Campbell**, retiring chair, Forestry and Industrial Working Group
09:30 – 10:00	West Coast Break
10:00 – 11:20	Ericads from coast to coast **Brian Titus,** Canadian Forest Service, Victoria **Nelson Thiffault,** Ministère des Ressources naturelles et de la Faune du Québec **Cindy Prescott,** University of British Columbia
11:20 – 11:40	Ericaceous shrubs: a forest management problem. Legend or reality? **Caroline Laberge Pelletier,** Université Laval
11 :40 – 12 :00	Biological control approach for management of competing vegetation **Simon Shamoun**, Canadian Forest Service, Victoria
12:00 – 13:00	Lunch
13:00 – 14:40	Modeling the future forest **Dave Coates**, B.C. Ministry of Forests **Phil Comeau**, University of Alberta **George Harper,** B.C. Ministry of Forests, Research Branch **Margeret Penner**, Forest Analysis Ltd
14:40 – 15:20	Vegetation management, future fibre flow and sustainability **Bob Wagner**, University of Maine
15:20 – 15:40	West coast break
15:40 – 16:00	Oxyfluorfen for short rotation intensively cultured poplar **Nancy Cain**, Cain Vegetation
16:00 – 16:20	Ecophysiological benefits of targeted herbaceous and woody competition control **Bill Parker**, Ontario Forest Research Institute
16:20 – 17:00	Vegetation management to maximize conifer production **Doug Pitt,** Canadian Forestry Service, Sault Ste Marie
17:00	Adjourn

Graduate Student Presentations

Time	Topic
8:00 am – 8:15 am	Inhibitory effect of tall hedge mustard allelopathic secondary metabolites on arbuscular mycorrhizal fungi - **Luke D. Bainard** – University of British Columbia
8:15 am – 8:30 am	Performance interactions among HPPD- and ALS-inhibiting herbicides for control of annual grasses. - **Allan Kaastra** - University of Guelph
8:30 am – 8:45 am	Optimal seeding rates for organic production of field peas and lentils - **Julia Baird** - University of Saskatchewan
8:45 am – 9:00 am	Resistance in giant foxtail (*Setaria faberii*) due to mutation in the AHAS gene - **Julie Laplante** - University of Guelph
9:00 am – 9:15 am	Emergence timing and persistence of Kochia (*Kochia scoparia*) in Manitoba fields - **Timothy Schwinghamer** - University of Manitoba
9:15 am – 9:30 am	Optimizing herbicide application in imidazolinone resistant lentil (*Lens culinaris* Medik.) - **Leah Fedoruk** - University of Saskatchewan
9:30 am – 9:45 am	Flame cultivation in vegetable crops - **Evan Sivesind** - McGill University
9:45 am – 10:00 am	Spectral analysis of UV induced fluorescence for the discrimination of grasses, dicot weeds and corn. - **Louis Longchamps** - Laval University
10:00 am – 10:30 am	West Coast Break – Poster and Commercial Display Viewing
10:30 am – 10:45 pm	Outcrossing frequency for transgenic safflower (*Carthamus tinctorius* L.) intended for plant-molecular farming - **Marc McPherson** - University of Alberta
10:45 am – 11:00 pm	Branching in peas: a strategy for reducing seeding rates and increasing crop competition - **Joshua Spies** - University of Saskatchewan
11:00 am – 11:15 pm	Intraspecific flowering synchrony and gene flow between volunteer and cropped wheat - **Christian J. Willenborg** - University of Manitoba
11:15 am – 11:30 pm	Impact of in-crop + soil residual herbicides on nodulation + effective N fixation in field pea + chickpea - **Angela D. Taylor** - University of Saskatchewan
11:30 am – 11:45 am	Développement de stratégies de désherbage dans les cultures de millet perlé grain et de millet perlé fourrager (*Pennisetum glaucum* [L.] R. Br.) - **Marie-Edith Cuerrier** - Université Laval

Invasive Plants : Inventories, Strategies and Action

The symposium has been published separately. The full reference is:

Clements, D. R. and S. J. Darbyshire, eds. 2007. Invasive plants: Inventories, strategies and action. Topics in Canadian Weed Science, Volume 5. Sainte Anne de Bellevue, Québec: Canadian Weed Science Society – Société canadienne de malherbologie. 165 pp. ISBN 978-0-9688970-5-8.

Graduate students presentations

Inhibitory effect of tall hedge mustard (*Sisymbrium loeselii* L.) allelopathic secondary metabolites on arbuscular mycorrhizal fungi

L. D. Bainard[1], P. D. Brown[2] and M. K. Upadhyaya[1]
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Abstract

The objectives of this study were to identify the glucosinolates and their subsequent degradation products in tall hedge mustard (*Sisymbrium loeselii* L.), investigate their effect on arbuscular mycorrhizal (AM) fungal spore germination and hyphal growth, and determine the effect of tall hedge mustard infestations on AM inoculum potential of soil. The two major GLSs identified in the root and shoot tissues of tall hedge mustard were isopropyl GSL and *sec*-butyl GSL. The shoots contained significantly higher concentrations of both GSLs. The degradation products of both these GSLs (isopropyl ITC and *sec*-butyl ITC) were identified in the root and shoot extracts. Tall hedge mustard aqueous root and shoot extracts and whole plant leachate inhibited spore germination and hyphal growth of *Glomus intraradices* Shenck & Smith. Isopropyl ITC and *sec*-butyl ITC inhibited spore germination, causing complete inhibition at 1.0 mM concentration; isopropyl ITC had a significantly stronger effect on spore germination at 0.5 and 0.1 mM concentrations. Hyphal growth was significantly inhibited by both ITCs at 0.5 and 1.0 mM concentrations, with isopropyl ITC causing greater inhibition. AM inoculum potential of tall hedge mustard infested soils was significantly lower compared to noninfested soils. The results of this study indicate that tall hedge mustard produces allelochemicals that inhibit AM fungi spore germination and hyphal growth, and tall hedge mustard infestations decrease the AM inoculum potential of soil.

Introduction

Allelopathy is defined as the chemical-mediated effect of a plant on the growth and distribution of other plants (Inderjit and Nilsen, 2003). This direct plant-plant chemical interaction has been widely used to explain of the success of some exotic plants. Recently it has been shown that allelochemicals could also affect interactions between native plants and soil organisms, such as arbuscular mycorrhizal (AM) fungi (Wolfe and Klironomos, 2005). AM fungi are symbiotic fungi that colonize the roots of most vascular plant species and improve soil nutrient uptake, particularly phosphorus (Bucking and Shachar-Hill, 2005). Many of the plants that form mycorrhizal associations with AM fungi are dependent on this association for survival (Stinson et al., 2006). Disruption of these mutualistic associations can have long-term effects on the dynamics of the plant species.

Recent studies have shown that allelochemicals have a negative effect on AM fungi. For example, garlic mustard (*Alliaria petiolata*) water leachates inhibited spore germination and AM colonization of tomato roots, and garlic mustard infestations reduced the AM inoculum potential of field soil (Roberts and Anderson, 2001). Phytochemicals produced by garlic mustard suppressed growth of native tree seedlings by disrupting mutualistic associations with AM fungi (Stinson et al., 2006). As a member of the Brassicaceae, garlic mustard produces glucosinolates. Glucosinolates are a class of secondary metabolites that produce biologically active compounds upon enzymatic degradation, including isothiocyanates, organic cyanides, oxazolidinethiones, and ionic thiocyanate (Brown et al., 1996). The enzyme myrosinase (thioglucosidase; EC 3.2.3.1.), found in the tissues of glucosinolate-containing species, hydrolyses glucosinolates to compounds with allelopathic and antifungal activities (Brown and Morra, 1997; Ludwig-Muller et al., 2002). These degradation products have been found to be inhibitory to AM fungi (Vierheilig and Ocampo, 1990; Schreiner and Koide, 1993).

Tall hedge mustard (*Sisymbrium loeselli* L.), a non-mycorrhizal (Harley and Harley, 1987) member of the Brassicaceae, has become naturalized across North America. It is commonly found on disturbed soils, cultivated fields, rangeland, and waste places in southern British Columbia and often appears like a yellow blanket covering fields and roadsides in early summer (Douglas et al., 1998; Parish et al., 1999). Like many weedy mustards, when well established it forms dense monocultures allowing few other plant species to grow. Tall hedge mustard has been shown to exhibit allelopathic properties as the aqueous extracts of its roots and shoots are highly inhibitory to seed germination and radicle elongation of several species, with little autotoxicity (Bainard et al., unpublished results). The allelopathic properties of tall hedge mustard are believed to be due to glucosinolates or more importantly their degradation products. The objectives of this study were to i) identify the glucosinolates and their degradation products in tall hedge mustard, ii) investigate their effects on AM fungal spore germination and hyphal growth and iii) determine the effect of tall hedge mustard infestations on AM inoculum potential of soil.

Materials and Methods

Glucosinolate (GSL) content was determined from root and shoot tissues of tall hedge mustard plants collected from natural populations in British Columbia. GSLs were extracted from dried tissues as desulfo-GSLs and quantified by high performance liquid chromatography. Identification of desulfo-GSLs was based on UV spectra and retention times. Degradation products were extracted from tall hedge mustard tissues by incubating root and shoot tissues in water to permit GSL hydrolysis and extracting with dichloromethane (Brown et al., 1994). The degradation products in the dichloromethane fraction were identified by gas chromatography-mass spectrometry.

Aqueous root and shoot extracts and a whole plant leachate were prepared from dried tall hedge mustard tissues collected from natural populations in British Columbia. Root and shoot extract were prepared by incubating their respective ground tissues in distilled water (4% w/v) on a rotary shaker (90 rpm) for 24 h. The whole plant leachate was prepared by incubating intact plants in distilled water (4% w/v) for 24 h. The incubation mediums were centrifuged (3000 rpm) for 10 min, and filter sterilized using a 0.2 μm millipore filter.

The effect of tall hedge mustard allelochemicals on AM fungal spore germination was investigated by incorporating aqueous root and shoot extracts, and whole plant leachate (1:1) and commercially available isopropyl ITC (0.001, 0.01, 0.1, 0.5, 1.0 mM) and sec-butyl ITC (0.001, 0.01, 0.1, 0.5, 1.0 mM) in 1% water agar in 60-mm petri dishes. Ten *Glomus intraradices* Shenck & Smith spores were acseptically transferred using a sterile blade to petri dishes and incubated in the dark at 21 C. Percent spore germination was recorded after 10 d. The dishes were arranged in a completely randomized design with four replicates per treatment, and the experiment was repeated. Data were arcsine-transformed and subjected to analysis of variance (ANOVA) and means separated by Tukey's test at 5% level.

The effect of tall hedge mustard allelochemicals on AM hyphal growth was investigated by incorporating aqueous root and shoot extracts, and whole plant leachate (1:1) and commercially available isopropyl ITC (0.001, 0.01, 0.1, 0.5, 1.0 mM) and sec-butyl ITC (0.001, 0.01, 0.1, 0.5, 1.0 mM) in 1% water agar in 60-mm petri dishes. Five *Glomus intraradices* spores were acseptically transferred using a sterile blade to petri dishes and incubated in the dark at 21 C. Hyphal length was recorded after 14 d using a dissecting microscope and ocular micrometer. The dishes were arranged in a completely randomized design with six replicates per treatment, and the experiment repeated. Data were subjected to analysis of variance (ANOVA) and means separated by Tukey's test at 5% level.

The effect of tall hedge mustard infestations on AM inoculum potential was investigated by growing spotted knapweed (*Centaurea maculosa*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) in tall hedge mustard infested and noninfested soil. Field soil was collected from two tall hedge mustard infested sites and two noninfested adjacent sites, primarily occupied by grasses, including bluebunch wheatgrass. Spotted knapweed and bluebunch wheatgrass plants were grown in these soils for 7 wks in a greenhouse, roots and shoots harvested and dried and their biomass measured. A root subsample was collected from each plant to measure AM colonization. Roots were cleared with 10% KOH and stained with 0.05% trypan blue in lactoglycerol. The root segments were examined under a microscope (200 X) and the percentage of root colonization determined using the modified line intersects method (McGonigle et al., 1991). The plants were placed in a completely randomized design on the greenhouse bench with eight replicates for each treatment soil and species.

Results and Discussion

The major glucosinolates (GSLs) found in both the root and shoot tissues of tall hedge mustard were isopropyl GSL and *sec*-butyl GSL (Table 1). Isopropyl was the predominant GSL having more than ten times the amount of any other GSL in the shoots and more than twice the amount in the roots. Tall hedge mustard shoot tissue contained the highest concentration of GSLs, ten fold more than that in the root tissue. The GSL degradation products found in the dichloromethane layer of the aqueous extracts were isopropyl isothiocyanate (ITC) and *sec*-butyl ITC, which corresponded with the major GSLs in the root and shoot tissues of tall hedge mustard.

Table 1. Glucosinolate content of tall hedge mustard root and shoot tissues

Glucosinolate	**Shoots (µmol/g)**	**Roots (µmol/g)**
Isopropyl	85.22	7.86
4-Hydroxy-3-indolylmethyl	2.77	0.35
sec-Butyl	6.43	0.51
3-Indolylmethyl	1.17	0.47
4-Methoxy-3-indolylmethyl	0.00	0.38
1-Methoxy-3-indolylmethyl	0.00	3.66

Tall hedge mustard aqueous root and shoot extracts and whole plant leachate significantly inhibited *G. intraradices* spore germination compared to the control. Shoot extract and whole plant leachate had a stronger effect inhibiting spore germination by 97% and 100% respectively, and the root extract by 83% compared to the control. Root extract had a significant effect on hyphal growth of *G.* intraradices by reducing the hyphal length by 74.6% compared to the control. No spores germinated in the shoot extract and whole plant leachate resulting in no hyphal growth. The results show that tall hedge mustard tissues contain allelochemicals that are highly inhibitory to spore germination and hyphal growth of *Glomus intraradices*. The greater inhibitory effect of shoot extract and whole plant leachate compared to the root extract could be due to their higher concentration of GSLs, especially isopropyl GSL and *sec*-butyl GSL.

The two major GSL degradation products in tall hedge mustard (isopropyl ITC and *sec*-butyl ITC) both strongly inhibited spore germination at 0.5 and 1.0 mM concentrations, with complete inhibition at 1.0 mM. Spore germination was significantly inhibited by isopropyl ITC at all concentrations tested compared to the control and showed a stronger effect than *sec*-butyl ITC. Compared to the control, hyphal length was significantly inhibited by both ITCs at 0.5 and 1.0 mM concentrations. Similar to spore germination, isopropyl ITC had a stronger effect on hyphal growth compared to sec-butyl ITC. Since isopropyl GSL is found at a much higher concentration than sec-butyl GSL in tall hedge mustard root and shoot tissue, isopropyl ITC most likely plays a more significant role in the inhibitory effect of aqueous extracts of this weed on spore germination and hyphal growth

AM inoculum potential of tall hedge mustard infested soil was significantly lower compared to noninfested soil for both bluebunch wheatgrass and spotted knapweed. Tall hedge mustard infested soils decreased the percent AM colonization compared to noninfested soils in site 1 by 48.1% for bluebunch wheatgrass and 43.1 % for spotted knapweed, and 53.6 % for bluebunch wheatgrass and 44.5 % for spotted knapweed in site 2. The total biomass of these species was also reduced in tall hedge mustard infested compared to noninfested soils. This could possibly be attributed to the lower level of AM colonization.

Conclusion

The results of this study indicate that tall hedge mustard produces allelochemicals that are not only inhibitory to the germination and growth of neighboring species, but also inhibit AM fungal spore germination and hyphal growth. Tall hedge mustard infestations also reduced the AM inoculum potential of soil. The results suggest that hedge mustard produces allelochemicals that inhibit AM fungi and may be responsible for the reduced AM inoculum potential of tall hedge mustard infested soil.

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Performance interactions among HPPD- and ALS-inhibiting herbicides for control of annual grasses

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Abstract

Topramezone and mesotrione are HPPD-inhibiting, postemergent herbicides registered for broadleaf weed control in corn. Minimal information is available for topramezone tank-mixes, but previous research has suggested that antagonistic interactions exist among combinations of mesotrione, atrazine, and several ALS-inhibiting herbicides. To determine performance interactions among HPPD-inhibiting and ALS-inhibiting herbicides, growth room experiments were conducted on three annual grass species: yellow foxtail (*Setaria glauca*), green foxtail (*Setaria viridis*), and barnyard grass (*Echinochloa crus-galli*). Grass species were treated at the 5- to 6-leaf stage. Dose-response curves were generated for nicosulfuron and foramsulfuron alone and in combination with topramezone (12.5 g ai ha^{-1}), topramezone plus atrazine (12.5 plus 500 g ai ha^{-1}), mesotrione (100 g ai ha^{-1}), and mesotrione plus atrazine (100 plus 280 g ai ha^{-1}). Combinations of mesotrione plus reduced rates of nicosulfuron were the only treatments in this study that caused a reduction in efficacy for yellow foxtail (20%) and green foxtail (10%), which can be overcome by the addition of atrazine. Reduced herbicide efficacy was not observed with any combinations of topramezone or topramezone plus atrazine with either nicosulfuron or foramsulfuron on yellow foxtail, green foxtail, or barnyard grass.

Introduction

With increasing farm size and energy costs, one-pass herbicide applications are desired for season-long, broad-spectrum weed control in field crop production systems including corn (*Zea mays* L.). Many of the new HPPD- and ALS-inhibiting herbicides control a defined weed spectrum with a very specific mode of action. The potential to tank-mix these groups of herbicides allows corn producers to control both broadleaf and annual grassy weeds. Further, these tank-mixes act as an excellent tool to delay the development of herbicide resistence by reducing weed selection pressure for individual modes of action.

Preliminary research has shown that mesotrione, an HPPD-inhibiting herbicide, may affect the activity of ALS-inhibiting herbicides such as nicosulfuron and foramsulfuron for the control of green foxtail (*Setaria viridis*), yellow foxtail (*Setaria glauca*), and shattercane (*Sorghum bicolor*) (Schuster et al., 2005). No information is available on the relative performance interactions among two HPPD-inhibiting (mesotrione and topramezone) and two ALS-inhibiting herbicides (nicosulfuron and foramsulfuron) on annual grass control in corn.

Through growth room studies, the objective of this research was to determine performance interactions when an HPPD-inhibiting herbicide is tank-mixed with nicosulfuron or foramsulfuron. This research was also conducted to determine if the addition of atrazine enhances or mitigates the performance interaction observed with tank-mixes of HPPD and ALS-inhibiting herbicides.

Materials and Methods

Yellow foxtail, green foxtail, and barnyard grass (*Echinochloa crus-galli*), were selected to express a range of sensitivity to mesotrione (100 g ai ha^{-1}) and topramezone (12.5 g ai ha^{-1}) for use in growth room experiments. These species also represent the most common annual grasses found in Ontario agriculture, as well as replication of experiments previously conducted with the use of mesotrione and ALS-inhibiting herbicides by Schuster et al. (2005).

Growth room studies followed a randomized complete block design with six replications, repeated twice to provide confidence in the data. Grass species were planted in Turface® for germination, and transplanted one plant per pot at the one-leaf stage into 8 cm^3 pots filled with PGX® soil mix. Growth room conditions maintained day/night temperatures of 27/23 ± 2 °C, and artificial lighting from flourescent and incandescent lights provided a 16:8 light:dark photoperiod. Plants were watered with a 20-20-20 fertilizer solution as needed to ensure maximum growth. Just prior herbicide application, course vermiculite was used to cover the soil surface in order to reduce possible effects related to herbicide soil residual. Grass species were treated at the 5- to 6-leaf stage with a laboratory track sprayer that delivers 210 L/ha at 276 kPa using an 8002E flat fan nozzle. A common adjuvant system was selected in order to focus this study on the differences between herbicide chemistries, thus appropriate adjuvants from either Canadian and/or American herbicide labels were used. Treated plants were returned to the growth room after vermiculite was removed from the soil surface.

Herbicide treatments were selected by preliminary experiments in order to develop separate dose-response curves for nicosulfuron and foramsulfuron. Six rates of the ALS-inhibiting herbicides were applied alone, and in combination with field rates of mesotrione (100 g ai ha^{-1}), mesotrione plus atrazine (100 plus 280 g ai ha^{-1}), topramezone (12.5 g ai ha^{-1}), and topramezone plus atrazine (12.5 plus 500 g ai ha^{-1}).

Statistical Analysis

Although dose-response curves have been generated following log-logistic methods of Seefeldt (1995), the actual dose-response analysis can get quite complex and is the focus of future studies. With the aid of SAS version 9.1 (SAS Institute), data was pooled across two trials for the growth room studies because no treatment by trial interaction was observed. The residuals for percent biomass of the untreated control were examined, which required the need for data transformation (arcsign squareroot) in order to meet the assumptions for homogeneity of variance and normal distribution of experimental errors. Treatment means were compared at the Type 1 error rate α=0.05 level of significance using Tukey's adjustment.

Results and Discussion

In order to determine a shift in the dose-response curve, treatments for this research established 10 dose-response curves to allow the following comparisons: nicosulfuron alone, nicosulfuron plus mesotrione, nicosulfuron plus mesotrione plus atrazine, nicosulfuron plus topramezone, nicosulfuron plus topramezone plus atrazine. Similarly with foramsulfuron in place of nicosulfuron.

Combinations of mesotrione with reduced rates of nicosulfuron were the only treatments in this study that caused a reduction in efficacy for yellow foxtail (20%) and green foxtail (10%). The addition of atrazine to mesotrione plus nicosulfuron overcame this reduction in efficacy for both yellow and green foxtail. Herbicide efficacy was not reduced in any combinations of topramezone or topramezone plus atrazine with either nicosulfuron or foramsulfuron on yellow foxtail, green foxtail, or barnyard grass.

Acknowledgements

Special thanks to Kevin Chandler and Peter Smith for technical insight into this research. Also to AMVAC and BASF Canada for research funding.

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Optimal seeding rates for organic production of field peas and lentils

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Abstract

Organic farms in Saskatchewan supply nearly all of the organic field peas and lentils produced in Canada. Organic producers do not have recommended seeding rates developed for their production system, and must rely on recommended seeding rates for conventional production. The optimal seeding rate for organic production may differ from the conventional rate as organic producers rely heavily on the competitive ability of the crop for weed suppression. Four sites were established in two years on certified organic farmland. Varying rates of field peas and lentils were sown, and weed and crop biomass was collected. Crop yield increased with decreasing weed biomass. Sites with lower weed densities had higher crop yields.. Beyond the recommended rate for conventional production (88 plants m^{-2}), little increase in crop yield and little decrease in weed biomass occurred for field peas. Lentils, however, showed increased yield and decreased weed biomass beyond the recommended rate for conventional production (130 plants m^{-2}). Lentils did not effectively decrease weed densities when weed pressure was high, and may not be a good choice of pulse crop for fields with high weed populations. Field peas showed greater competitive ability than lentils, and may be a better pulse crop choice when producers are faced with significant weed pressure.

Introduction

The province of Saskatchewan supports the largest number of certified organic farms in Canada, and produces the vast majority of organic field peas and lentils in the country (Canadian Organic Growers 2006). Organic farming differs from other production systems in that no synthetic fertilizers or chemical inputs are used. Organic producers, therefore, must rely on other methods to suppress weeds and maintain soil fertility. Common practices in organic systems are to use summerfallow and green manure ploughdown. These practices reduce weed populations and can increase soil fertility, but can increase soil erosion and do not yield a cash crop. There is also evidence to suggest that soil microbial populations decrease when land is bare during the growing season. Partial replacement of summerfallow and green manure ploughdown may be possible with pulse crops grown as a cash crop. Pulse crops can be effective in weed suppression, nitrogen fixation, and formation of associations between plant roots and arbuscular mycorrhizal fungi (AMF) which increase plant uptake of phosphorus, a nutrient that is commonly deficient in organic systems. Seeding rates for organic pulse production, however, have not been established and organic producers must use seeding rates determined for conventional production as their guideline. These rates may not be optimal given that weed management strategies differ greatly between conventional and organic production systems. The objective of this study is to determine the optimal seeding rate for organic field peas and lentils considering a number of factors including crop yield and weed suppression.

Materials and Methods

Randomized complete block trials were conducted during the 2005 growing season and will continue in 2006 near Vonda and Delisle, SK on certified organic farmland. Neither site had lain fallow for three years. Varying seeding rates were used ranging from 10 to 250 plants m^{-2} for peas and 15 to 375 plants m^{-2} for lentils. Green manure ploughdown and summerfallow treatments were included for each crop. In-crop harrowing was conducted approximately one month after planting. Weed counts and identification were performed after in-crop harrowing. Weed biomass was collected prior to the green manure ploughdown and at physiological maturity. Crop biomass was collected simultaneously, and an additional sampling time occurred at final harvest. Seed yield was determined by threshing the crop biomass collected at final harvest.

Results and Discussion

At physiological maturity, weed biomass decreased as crop biomass increased. Field peas and lentils showed this trend at all sites in both years. When weed pressure was low, lentil biomass increased beyond the conventional recommended seeding density of 130 plants m^{-2} (Saskatchewan Pulse Growers 2000). Weed biomass also decreased beyond the conventional recommended lentil density, suggesting that there may be a benefit to organic production to increase the seeding rate of lentils (Fig. 1a). Interestingly, the same was not true for field peas. Field pea biomass did not increase at the same rate or to the same degree that lentils did beyond the recommended conventional recommended seeding rate of 88 plants m^{-2} (Saskatchewan Pulse Growers 2000). In addition, weed biomass did not decrease substantially beyond the conventional recommended seeding density, suggesting that there were no additional benefits to increasing the seeding rate of field peas (Fig. 1b). Where weed pressure was high, both lentils and field peas showed a capacity for increased yield and decreased weed biomass beyond the recommended rate for conventional production (Fig. 1c, 1d).

The dominant weed species at Vonda were wild oats (*Avena fatua*) and wild mustard (*Sinapis arvensis*), and grassy weeds were more abundant than broadleaved ones. This site had the lowest mean weed biomass at the lowest seeding rate in both years at 250g m^{-2} and also had the highest yields in both years. The dominant weed species in Delisle were wild oats and lambsquarters (*Chenopodium album*), with broadleaved weeds most abundant. Mean weed biomass at the lowest seeding rate at Delisle was 300g m^{-2}, and crop yields were lower than Vonda with comparable crop densities. The dominant weed species in Vanscoy were wild oats, lambsquarters and Canada fleabane (*Conyza canadensis*). Broadleaved weeds were more abundant than grassy ones at this site, and the presence of perennial weeds was especially damaging to crop yields. The mean weed biomass at the lowest seeding rate at Vanscoy was 500g m^{-2}; much higher than the other two sites, and crop yields were the lowest.

Organic producers may benefit in terms of increased yield and decreased weed pressure from increasing seeding rates of lentils beyond the recommended conventional seeding rate. Increasing the seeding rate of lentils is especially important when weed pressure is high. Recommended seeding rates for conventional production of field peas, however, may also be appropriate for organic field pea production based on yield and weed suppression. Field peas are more effective in reducing weed abundance than lentils, and may be a better choice for a pulse crop in rotation when weed pressure is high. Further study will determine whether there is a correlation between seeding rate and plant nutrient uptake.

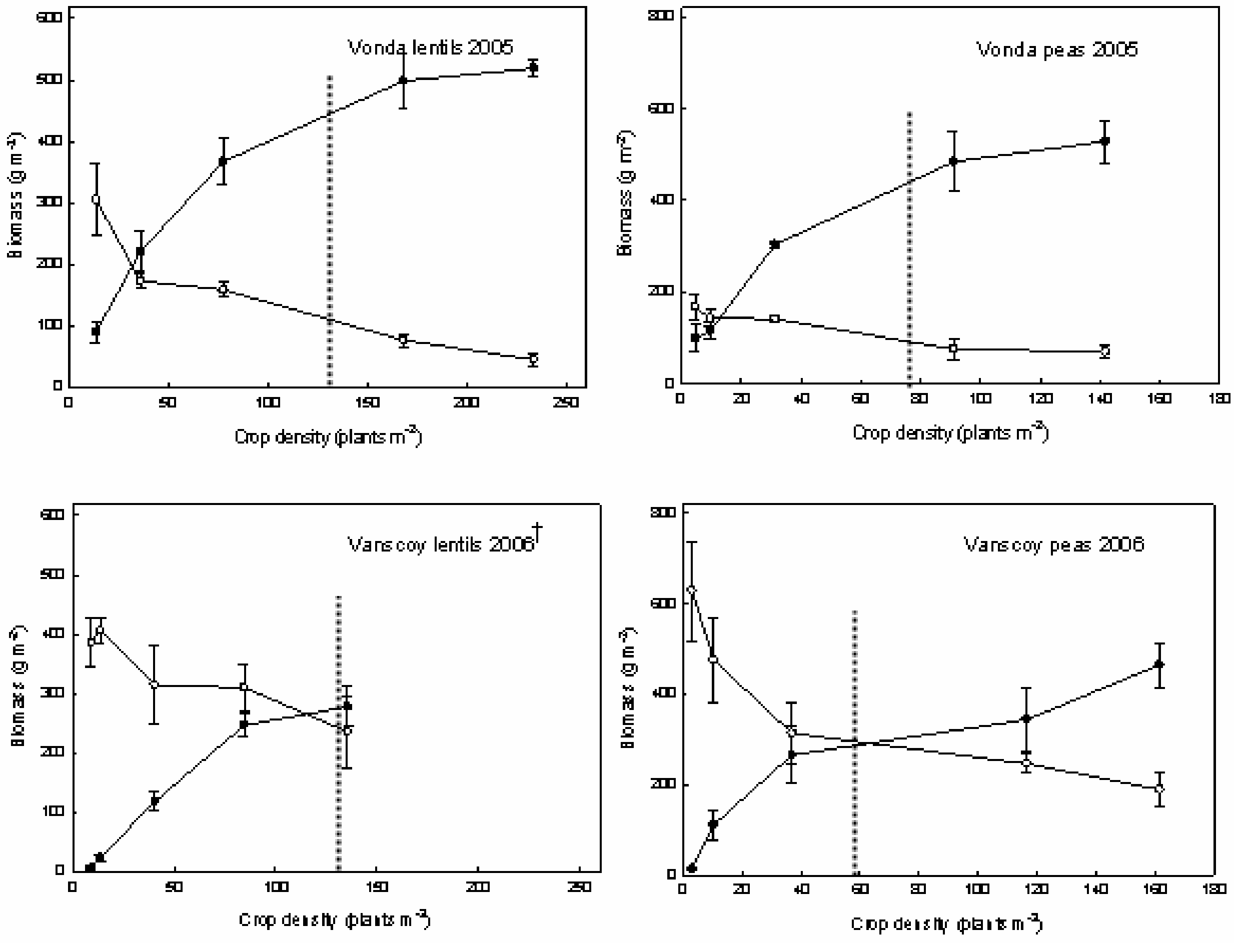

Figure 1. Low weed pressure in Vonda 2005 and high weed pressure in Vanscoy 2006. Dashed lines indicate recommended seeding rates for conventional production. Crop biomass indicated by solid markers; weed biomass indicated by open markers.
†Lentil emergence at both sites in 2006 was poor.

In the final portion of this study, an economically optimal seeding rate will be developed for organic production of lentils and field peas based on yield, weed suppression, soil fertility, and seed cost. This will give organic producers a seeding rate guideline to follow that has been developed specifically for their production system. The producers will be able to compare weed suppression at varying seeding rates and better understand how crop density affects a variety of factors in crop production.

Acknowledgements

The authors gratefully acknowledge Saskatchewan Pulse Growers for funding this study. We also wish to thank the farmer co-operators, technicians and summer students who have contributed much time and energy to this project.

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Resistance in giant foxtail (*Setaria faberii*) due to mutation in the *AHAS* gene

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Abstract

In 2003, a population of giant foxtail (*Setaria faberii*) from Ontario, Canada, was reported to survive field applications of imazethapyr, an acetohydroxyacid synthase (AHAS) inhibitor. The response to the herbicides imazethapyr (imidazolinone), nicosulfuron (sulfonylurea), pyrithiobac (pyrimidinyl-oxybenzoate), and flucarbazone (sulfonylamino-carbonyl-triazolinone) was determined at the whole plant and at the enzyme levels. Whole plant dose response analysis confirmed resistance. Compared to a susceptible population, the resistant population showed two- to twenty four-fold resistance to the four herbicides. Enzyme inhibition data correlated with whole plant results. *AHAS* genes were sequenced and Southern hybridization analysis was used to document *AHAS* gene copy number. DNA sequencing of the cloned PCR products detected two different *AHAS* amplicons (*AHAS* I and *AHAS* II). From Southern blot analysis, the presence of two distinct *AHAS* genes was confirmed. One of these two genes revealed a single base-pair mutation near the carboxy terminus that differentiated R and S. The serine at position 653 was replaced by an asparagine in *AHAS* II. The pattern of resistance observed in giant foxtail was consistent with results on other weed species.

Introduction

The acetohydroxyacid synthase enzyme (AHAS, EC 2.2.1.6; also known as acetolactate synthase, ALS) is involved in the biosynthesis of the branched-chain amino acids valine, leucine, and isoleucine. AHAS is the target of many classes of herbicides including imidazolinones, sulfonylureas, pyrimidinyl-oxybenzoates, triazolopyrimidines, and sulfonylamino-carbonyl-triazolinones. These herbicides inhibit the enzyme acetohydroxyacid synthase, preventing the biosynthesis of the branched-chain amino acids (Saari et al. 1994).

The repeated use of AHAS inhibitors has selected for resistance in many weed species. Currently, there are 93 species worldwide with confirmed resistance to AHAS inhibitors (Heap 2006). The mechanism of resistance is mostly caused by an insensitive AHAS enzyme due to point mutations in the *AHAS* gene coding for single amino acid substitution. Six conserved mutation points have been identified in *AHAS* in higher plants that are linked to resistance (Tranel and Wright 2002; Corbett et al. unpublished). Substitutions at Pro_{197} (*Arabidopsis thaliana* numbering) for any possible amino acid substitutions confer a high resistance level to SU herbicides and in some cases resistance to IMIs and TPs. The $\mathrm{Trp}_{574}\mathrm{Leu}$ and $\mathrm{Asp}_{376}\mathrm{Glu}$ substitutions confer resistance to all classes of AHAS inhibitors (Tranel and Wright 2002). Substitutions at $\mathrm{Ala}_{122}\mathrm{Thr}$, $\mathrm{Ser}_{653}\mathrm{Thr}$, or $\mathrm{Ser}_{653}\mathrm{Asn}$ confer resistance to IMIs and cross-resistance to POBs, but not to SUs and TPs (Duggleby et al. 2000). Finally, the $\mathrm{Ala}_{205}\mathrm{Val}$ substitution confers resistance to the IMIs, POBs, SCTs, and to some SUs (Wheeler 2005).

The *AHAS* gene is nuclearly encoded while the enzyme is active in the chloroplast (Duggleby et al. 2000). Generally, it has no introns, contains about 2000 nucleotides, corresponding to about 660 amino acids (Mazur et al. 1987). AHAS clones showed that plants are varying in gene copy number (Duggleby et al. 2000). For example, allotetraploid species such as tobacco (*Nicotiana tabacum*) has two *AHAS* copies (Mazur et al. 1987; Duggleby et al. 2000). Moreover, the *AHAS* gene number encoding for resistance varies among species (Pozniak et al. 2004).

In 2001, the first case of resistance in a grass species to AHAS inhibitors was reported in Ontario. As of 2006, five green foxtail (*Setaria viridis*) populations have been confirmed to be resistant to AHAS inhibitors in Ontario. Resistance in these populations was due to single base-pair mutation that alters different amino acids in the *AHAS* gene ($Ser_{653}Thr$, $Ser_{653}Asn$, $Ser_{653}Ile$, $Gly_{654}Asp$). All resistant populations have demonstrated resistance to imazethapyr with cross-resistance to nicosulfuron and flucarbazone while only three populations had cross-resistance to pyrithiobac (unpublished results). In 2003, a second grass species, giant foxtail, was reported on a farm in Bridgen (Ontario) to survive field applications of imazethapyr. It has been proposed that giant foxtail originated from a cross between green foxtail and an unknown diploid species (Dekker 2003).

The main objectives of this study were to confirm resistance to AHAS inhibitors in giant foxtail and to determine the genetic and biochemical basis of resistance. Since giant foxtail is an allotetraploid, having green foxtail as one of its ancestors, it was also hypothesized that this species has two *AHAS* copies, with only one copy involved in herbicide resistance.

Results

Resistance level and cross-resistance pattern

The Brigden population showed significant resistance to all herbicides tested compared to susceptible population. The highest resistance factor (RF) was observed with imazethapyr (24) whereas resistance was lower for nicosulfuron (2), pyrithiobac (4.5), and flucarbazone (2.9). Inhibition of extracted AHAS enzyme activity confirmed that resistance was due to target site modification as RFs were similar between whole plant and enzyme assays.

Sequence and southern blot analyses

DNA sequencing of the cloned PCR products detected two different amplicons (*AHAS* I and *AHAS* II) that showed polymorphisms at 36 nucleotides. Sequences comparison between green foxtail *AHAS* gene and giant foxtail *AHAS* genes showed polymorphisms at 20 nucleotides in *AHAS* I and polymorphisms at 43 nucleotides in *AHAS* II. From Southern blot analysis, the presence of two distinct *AHAS* genes was confirmed. This suggested that at least two *AHAS* genes could contribute to herbicide resistance. Sequence analyses comparing the susceptible population to resistant population of giant foxtail demonstrated a single-point mutation from G to A at nucleotide 1624 in *AHAS* II, conferring a $Ser_{653}Asn$ substitution. As reported in other plants, the *AHAS* gene of foxtail species is about 2kb (Mazur et al. 1987). Similar restriction enzyme fragments in giant foxtail *AHAS* genes corresponded to green foxtail *AHAS* gene, providing support of its origin from green foxtail.

This is the first documentation of resistance in giant foxtail in Canada. This is also the first time that *AHAS* sequences have been obtained for this species. Resistance was high enough to confer survival under field condition and illustrates that resistance can be selected for polyploid species such as giant foxtail.

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Emergence timing and persistence of kochia (*Kochia scoparia*) in Manitoba fields

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Abstract

This research addresses the ecological niche of kochia, *Kochia scoparia* (L.) Schrader (Chenopodiaceae), and how growers can close the ecological niche of kochia in Prairie cropland. The predictability of the spring emergence periodicity of kochia is a potentially exploitable attribute that may be applied to weed management. Emergence periodicity of kochia was monitored, during the spring and summer of 2005 and 2006, in 12 fields (high and low disturbance, no-till, alfalfa, barley/grass, beans, canola, corn, and wheat) in southern Manitoba, Canada. Kochia begins to emerge prolifically at only 50 cumulative growing degree days (GDD T_{base} 0 C) and kochia continues to emerge throughout the growing season into the late summer. Soil samples taken in the fall from quadrats in which emergence was monitored reveal a very limited kochia seedbank and supports other research which shows that kochia seeds have little or no dormancy. The effects of seeding depth (2, 10, 20, 40, and 80 mm) on emergence was observed, under controlled growth room conditions. Kochia seeds placed at the soil surface (2 mm) had the greatest emergence. Seeding depth reduced kochia emergence significantly. The results from this study indicate that kochia is a very early emerging seed limited weed species with seed that cannot emerge from great depths. This information will facilitate kochia control timing decisions and the data from this study can be used to create an emergence model for kochia.

Introduction

Kochia is an herbaceous annual warm-season dicot that reproduces and spreads by seed (Gates 1941, Frankton and Mulligan 1970, Milchunas et al. 1991). Kochia is also known as belvedere, summer cypress, and broom toad-flax.

The growth of kochia is indeterminate (Mulugeta 1991) and highly variable. Kochia can grow 3 m tall (Durham and Durham 1979). Kochia produces a main stem with abundant top growth (Davis et al. 1967). Gates (1941) described kochia as “freely branching.” Kochia branches are very leafy and either erect or ascending (Everitt et al. 1983). Kochia has a taproot system (Mulugeta 1991) with a large root profile. Kochia flowers are small, stalkless, inconspicuous, green (because they are apetalous) (Gates 1941, Frankton and Mulligan 1970, Eberlein and Fore 1984), and proterogynous (Stallings et al. 1995). Kochia is a short day plant (Bell et al. 1972) which flowers indeterminately (Stallings et al. 1995). The circular polypantoporate morphology of kochia pollen may facilitate long distance wind dispersion (Mulugeta et al. 1994*)*. Kochia has nonobligate allogamous mating behaviour (Guttieri et al. 1998), i.e., kochia is partially self-fertile (Bell et al. 1972a), but predominantly open pollinated (Thill et al. 1991). Kochia is capable of permanent autoreproduction (Holec et al. 2004). In most kochia plants, stigmas emerge up to one week before anthers (Mulugeta 1991, Stallings et al. 1995). Kochia is diploid (Cooper 1935 in Mulugeta 1991), the somatic chromosome number in all kochia biotypes is 2n = 18 (Májovský 1974, Thompson 1993). Kochia populations undergo a high degree of outbreeding (Mengistu and Messersmith 2002) and mating patterns approximate random mating (Guttieri et al. 1998). Kochia fruit is a reddish utricle (Gates 1941). Each kochia flower contains a single seed (Frankton and Mulligan 1970, Mulugeta 1991). Williams (1932) found mature kochia seeds on the same branches as unfertilized ovules. The kochia seed is 1.8 mm (Gates 1941) to 3 mm (Mulugeta 1991) long and about 1.0 mm in diameter (Everitt et al. 1983). A kochia plant typically produces over 14,000 seeds (Thill et al. 1991). Iverson and Wali (1981) found 50,000 seeds on kochia plants in favourable conditions.

In studies of kochia as a forage crop, the appropriate seeding depth was determined to be about 1 cm or less (Everitt et al. 1983 in Stepphun and Wall 1993). Stepphun and Wall (1993) and Al-Khatib et al. (1997) covered kochia seeds to a depth of 2 mm. Krishnan et al. (1998) covered kochia seeds to a depth of 5 mm. Seeds germinating in this layer interact with soil solutions of widely variable salinity, which decrease with influxes of water from precipitation, and increase with loss by evaporation (Stepphun and Wall 1993). Johnson (1990) found that kochia emergence decreased from seeds buried to a depth of 30 mm, and there was no kochia emergence from seeds buried to a depth of 90 mm. Seed germination is tolerant to high solute concentrations (Evetts and Burnside 1972 and Khan et al. 2001), moisture stress, and extreme acid or alkaline conditions (Everitt et al. 1983).

It is often said that kochia seeds have no innate dormancy (Everitt et al. 1983, Dyer 1993, and Thompson et al. 1994). Forcella et al. (1997) found no obvious microclimate thresholds that may induce dormancy in kochia.

Kochia is a very competitive weed. Davis et al. (1967) measured a dry matter weight of 771 g per plant. Kochia has the capacity to shade short crop plants (Nussbaum et al. 1985). Kochia is a problem in a wide range of crops (Mulugeta 1991), particularly early-planted crops. (Wicks et al. 1984). Sugarbeet (*Beta vulgaris*) root yield reduced according to the density of kochia plants. Early season control eliminates kochia's competitive advantage. Season-long competition by kochia densities of 0.3, 1, 3, and 6 plants m^{-1} of row decreased sunflower (*Helianthus annuus*) achene yield 7, 10, 20, and 27 percent, respectively (Durgan et al. 1990). Sunflower achene yield was reduced 6 and 10 percent by 2 and 4 weeks of kochia competition, respectively (Durgan and Dexter 1984 and Durgan et al. 1990). Kochia densities may exceed 2,100 seedlings m^{-2} and reduce soybean (*Glycine max*) yield more than 30 percent (Wolf et al. 2000). One wheat plant reduced herbicide-resistant kochia yield per plant equal to the effect of 4.8 herbicide-resistant kochia or 5.4 herbicide-susceptible kochia plants. Cool temperatures adversely affect kochia's ability to interfere with barley (Fischer et al. 2000). Yellow sweet clover (*Melilotus officinalis* Lam.) grown as a green manure fallow replacement crop controlled kochia (Blackshaw et al. 2001). Yellow sweet clover reduced kochia densities 96 to 99 percent.

Everitt et al. (1983) found the seedling emergence percentage for kochia seeds left exposed on the soil surface (74%) was significantly higher than for those planted at a depth of 3 mm (57%). Kochia also may emerge after postemergence herbicides are applied, resulting in substantial, uncontrolled populations (Mickelson et al. 2004).

Methods

Fields were selected from prairie cropland in southern Manitoba. The soils were uniformly clayey lacustrine black chernozems. Seven and six locations were observed in 2005 and 2006, respectively. Four 0.25 m^2 quadrats were marked in each field edge. Kochia emergence was measured from mid-April throughout the season. Newly emerged seedlings were counted and removed at each field visit. Farm practices were not interfered with. Seedlings were not protected from tillage or herbicides.

In each field, soil temperatures were recorded continuously throughout the observation period with the use of small, self-contained Stow Away® TidbiT$^{\mathrm{TM}}$ temperature loggers (Onset Computer Corporation, Box 3450, 536 MacArthur Blvd., Pocasset MA 02559-3450) (Bullied et al. 2003). One data logger was placed in each field 2.5 cm below the soil surface. This minimized soil disturbance around the data logger to facilitate accurate measurement of soil temperature. Because seeds of many small-seeded annual weeds germinate and emerge primarily from 0 to 2 cm soil depth (Buhler 1995 in Forcella et al. 1997), daily temperatures of these soil layers are more important in regulating plant behaviour than those at 5 to 10 cm soil depth. Data loggers were removed during tillage and seeding operations and replaced shortly afterwards. Because there is a strong association between soil temperature at shallow depths and air temperature (Marginet 2001 and Reimer and Shaykewich 1980 in Lawson et al. 2006), soil temperature data during these periods were replaced by air-temperature data obtained from a local Environment Canada weather station.

Cumulative soil growing degree days (GDD) were calculated for each site. Until soil-temperature data were available from the on-site soil-temperature data loggers, air-temperature data were used for the daily GDD calculation.

$$\mathrm{GDD}_{\mathrm{daily}} = [(\mathrm{T}_{\mathrm{max}} + \mathrm{T}_{\mathrm{min}})/2)]-\mathrm{T}_{\mathrm{base}} \qquad [1]$$

$$\text{Cumulative GDD} = \sum_{i=1}^{n} \mathrm{GDD}_{\mathrm{daily}} \qquad [2]$$

In the early fall of each year (August 22, 2005 and August 30, 2006) soil samples were taken from each field site quadrat using a soil core (8.50 cm diameter, 10.50 cm depth, 596 cm^3 soil core volume). Each sample was placed in plastic trays and subject to 3 periods of 6 weeks in a growth room (20 C day 15 C night), alternated with 2 periods of 3 weeks in a freezer (-20 C). The trays were watered regularly and monitored for kochia emergence to discover any residual seedbank.

For the seeding depth experiment, metromix and 2 soil : 2 sand : 1 peat were used as potting mixtures for respective replications during both runs. The pots were watered daily to keep the soil moist. Emergence was monitored daily by the removal of emerged kochia seedlings, which were counted.

With respect to the statistical analysis, emergence period data were expressed as a cumulative percent of total emergence. Fields 2006 I and J were excluded from emergence-period analyses because of the anomalously low density in these fields as compared to densities in the other fields. Initial analyses indicated that field site was not a significant factor ($P \leq 0.05$) influencing the emergence period of kochia. Therefore, the field data were pooled. Emergence-period data were analyzed by nonlinear regression analysis as a function of cumulative soil GDD with the NLIN procedure in SAS (SAS Institute Inc., Box 8000, Cary NC 27511-8000). The logisitic model fitted was

$$y = C + D/(1 + (x/E_{50})^{b} \qquad [3]$$

This equation describes an increasing sigmoid, where y is kochia cumulative percent emergence, x is cumulative soil GDD, C = lower limit (asymptote) of the response curve, D = upper asymptote (maximum emergence), E_{50} = the x value (GDD) at the mid-point or inflection point of the curve (not necessarily the GDD value at 50% emergence depending upon the values of the fitted C and D parameter estimates and the shape of the curve), and b = slope (Burke et al. 2005 in Lawson et al. 2006, Seefeldt et al. 1995). Individual curves were statistically tested systematically for each variable with lack-of-fit F tests (P=0.05).

Results and Discussion

While the data for this project are gathered and analyzed entirely, the discussion is preliminary.

Table 1. Parameter estimates (standard errors in parentheses) for emergence period response of kochia ($\mathrm{T}_{\mathrm{base}}$ 0 C) in 2005 and 2006 in southwestern Manitoba, Canada (Figure 1). Percentage cumulative kochia emergence was expressed as a function of cumulative growing degree days. A logistic model was fitted to the data (refer to Methods for a description of the model fitted).

Year	C	Standard Error	D	Standard Error	b	Standard Error	E_{50} (in cumulative GDD)	Standard Error	R^2
2005	-0.29	3.84	98.86	4.23	-2.20	0.28	175.6	10.3	0.83
2006	-0.29	3.84	98.86	4.23	-4.09	0.54	242.7	8.3	

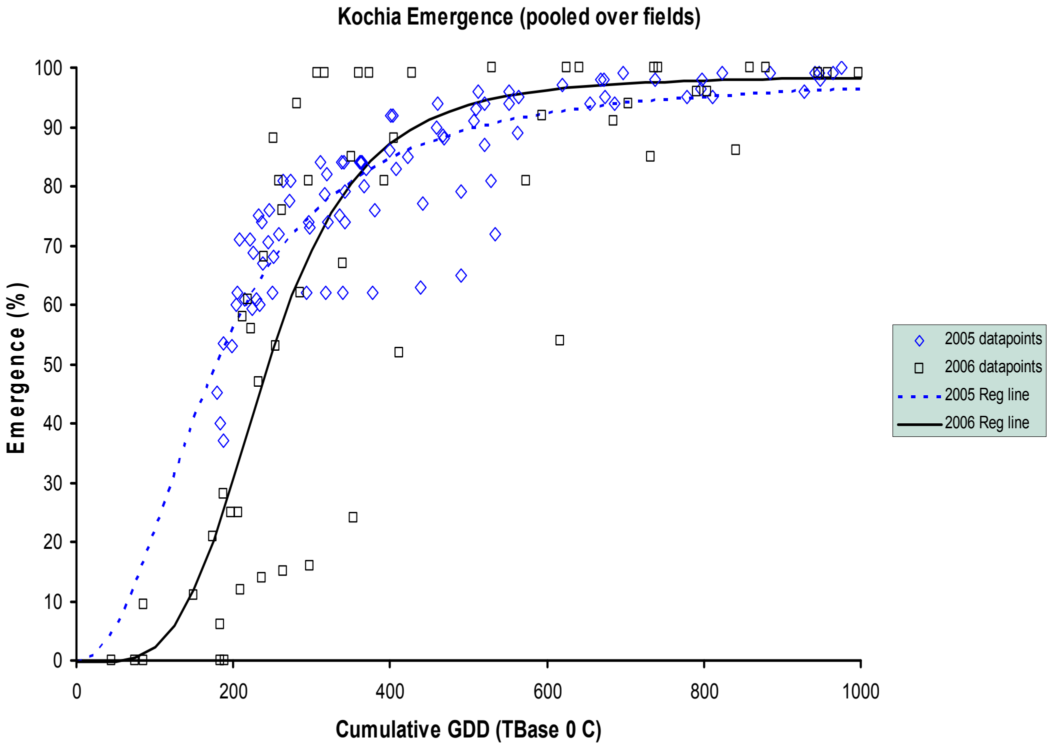

Figure 1. Kochia emergence in southwestern Manitoba, Canada in 2005 and 2006 as related to cumulative growing degree days (GDD) Tbase 0 C. Markers represent field data and lines represent the fitted logistic regression equations. Refer to Table 1 for parameter estimates.

Table 2. Percent kochia emergence at cumulative growing degree days.

Emergence	Cumulative GDD	
(%)	2005	2006
25	108 (April 13)	187 (April 21)
50	178 (April 19)	245 (April 27)
75	298 (May 10)	322 (May 4)

Table 3. Cumulative emergence of kochia in 2005 and 2006, as related to management period.

Year-field designation	Emerged kochia seedlings				
	Crop	Total (m^{-2})	Prior to crop seeding (m^{-2})	Prior to in-crop herbicide application (m^{-2})	After in-crop herbicide application (m^{-2})
2005-A	Canola	2794			
2005-B	NA	1207	1120	No Data[1]	87
2005-C	NA	2379			

2005-D	NA	2550			
2005-E	Canola	152	134		18
2005-F	Canola	973	966	No Data[1]	7
2005-G	Corn	536	266	No Data[1]	270
2006-B	NA	3073			
2006-C	NA	3397			
2006-H	Wheat	177		177	0
2006-I	Barley/grass	2			
2006-J	Wheat	21	11		10
2006-K	Alfalfa	12669*	12634**	24***	11
2006-L	Wheat	2161	2146		15

* prior to first cut of alfalfa, **prior to second cut of alfalfa, *** after second cut of alfalfa

[1] The farmer both seeded and applied herbicides in the time between field visits.

The total field density for kochia in the fields observed was 2292.2 (SD = 3226.2) m^{-2} and the field density minus I and J was 2672.3 (SD = 3346.3) m^{-2}.

With respect to the monitoring of the residual seedbank, year 1 (2005) growouts show a small end-of-season seedbank. Year 2 (2006) growouts are incomplete. Kochia emergence is early (≈ 50 GDD). The field observations indicate that kochia emergence is sustained throughout the season. Kochia may be a seed limited species. Cold weather can make weed control with herbicides difficult, in part due to farmers being not on the land that early, usually.

Nonherbicidal options for management include post harvest and pre-seed scouting. Shallow tillage removes kochia easily, kills pre-bud stage kochia, and forces kochia seed to sprout or decay (Becker 1968, Thill et al. 1991, and Boerboom 1993). Where cultivation or mowing before pollination is impractical, kochia pollen and seed dispersal can be reduced by cutting, pulling or hoeing (Gates 1941, Mulugeta 1991, and Boerboom 1993). Likewise, mature plants ought to be cut and burnt. Removing saline areas from annual cropping with the establishment of a competitive salt-tolerant forage. Avoid noncompetitive crops. Herbicidal options for management could include planting crops that have in-crop herbicide options: residual control such as trifluralin or ethalfluralin for established populations, or preseed glyphosate followed by an in-crop option such as fluroxypyr plus 2,4-D. Post-emergence control could involve dicamba tank mixes with 2,4-D or MCPA, or bromoxynil plus 2,4-D when kochia seedlings are small. However, Group 2 herbicide-resistant kochia generally render these products ineffective (Murray and Friesen, 2004, 2005 MB kochia survey – unpublished). Systemic options include hedgerows, which would both address salinity problems at the field edge and block tumbling weeds.

Acknowledgements

Dr. Rene Van Acker, Lyle Friesen, Arvel Lawson, Our Co-operating Farmers, Dr. Jane Froese, Dr. Mario Tenuta, the Department of Plant Science, NSERC, and the land and organisms of Manitoba.

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Optimizing herbicide application in imidazolinone tolerant lentil

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Abstract

Lentil is one of the least competitive crops grown in western Canada. Weed competition is a major cause of yield loss in lentil. Lentil varieties tolerant to imidazolinone herbicides have been developed by the Crop Development Center at the University of Saskatchewan. Three field studies were conducted in 2006 at Saskatoon and Vanscoy, SK. The results from these experiments indicate that multiple herbicide applications should take place when herbicides with little residual activity are applied early and weed density is high. Furthermore, the use of herbicides with residual activity is beneficial when applying herbicides at an early timing. Late herbicide application resulted in lentil yields similar to the weed free control suggesting that early weed growth did not affect yield. The duration of the weed free period was also researched. The longer the crop remained free of weeds, the higher the lentil yield. However, results indicate that the crop should remain free of weeds until the 10 node stage to avoid yield loss.

Introduction

Lentil (*Lens culinaris* Medik.) is an important pulse crop in Canada. Canada is one of the major producers and is the world's largest exporter of lentil in the world (AAFC 2005). In 2004, Canada produced 680,000 tonnes with over 98% grown in Saskatchewan. In Saskatchewan, lentil is largely grown in the dark brown and brown soil zones (McVicar et al. 2005). Lentil has been difficult to grow because of its poor competition with weeds and limited broadleaf control options. Previously Sencor (metribuzin) was the only herbicide registered for post-emergent broadleaf control in lentil. However, Sencor has been observed to cause phytotoxic effects to lentil resulting in leaf drop, reduced yield and plant death. It also has variable control of broadleaf weeds (Malik and Townley-Smith 1990). Therefore, improved broadleaf herbicide options that have increased efficacy and less phytotoxicity are important for lentil production.

Lentil varieties tolerant to imidazolinone (IMI) herbicides have been developed by the Crop Development Center of the University of Saskatchewan (Holm and Vandenberg 1998). IMI lentils are tolerant to applications of Solo (imazamox) and Odyssey (imazamox/imazethapyr) (Chant 2004). Odyssey controls grassy and broadleaf weeds and has residual soil activity (SAF 2006, Shaner and Hornford 2005). The soils of the brown and dark brown soil zones are characterized by low organic matter and low soil moisture (Rostad et al. 1993). Therefore, in these conditions Odyssey may slowly dissipate and can have detrimental effects to follow crops (Malik and Townley-Smith 1990, Shaner and Hornford 2005). Solo also controls grassy and broadleaf weeds and has residual soil activity. However, the active ingredient of Solo (imazamox) is dissipated in soil at a much faster rate than Odyssey (imazethapyr/imazamox) and therefore can be safely used in regions with low soil moisture. The recommended herbicide timing is from the one to six node stage in lentil. However, the optimal herbicide application timing is not well understood in IMI lentil and different agronomic weed control recommendations may be required to optimize weed control.

Optimal herbicide application will be determined by investigating the optimal timing of weed removal, weed control of lentil herbicides at different application timings and by using a component of the critical period of weed control (CPWC), the weed free period. The CPWC is a period in a crops lifecycle in which weeds must be controlled to avoid yield loss (Knezevic et al. 2002). The weed free period is a certain length in the crops life cycle that must remain free of weeds in order to prevent yield loss. Optimizing weed control in lentil is important in developing successful integrated weed management programs.

Materials and Methods

The experiments were conducted in 2006 at two locations in Saskatchewan: the University of Saskatchewan, Kernen Crop Research Farm located near Saskatoon and at Vanscoy. The experimental design was a randomized complete block with four replications for each experiment. The IMI lentil variety used was CDC Impact, a small red lentil. The experiments were seeded in mid May at a seeding rate of 49.3 kg ha^{-1}. Weed species were seeded perpendicular to the crop seed rows. The weed species included: *Avena fatua* L.*,* *Setaria viridis* (L). Beauv.*,* *Sinapsis arvensis* (L.), *Polygonum convolvulus* L.*,* *Kochia scoparia* (L.) Schrad.*,* and *Amaranthus retroflexus* L. The weeds were seeded at 50 seeds m^{-2}. Herbicides were applied using a two meter wide, four nozzle, handheld sprayer. The sprayer was calibrated to deliver a volume of 100 L ha^{-1} at 40 psi for Solo (20.23 g ai ha^{-1} imazamox), Odyssey (29.4 g ai ha^{-1} imazethapyr/imazamox) and Poast (1.11 L ha^{-1} sethoxydim) and 173 L ha^{-1} at 40 psi for Sencor (205.63 g ai ha^{-1} metribuzin).

To determine the optimal weed removal timing the weeds were removed at the 1, 3, 5, 7, 9 and 11 lentil node stage. To establish the duration of the weed free period the crop remained free of weeds until the 1, 3, 5, 7, 9 and 11 node stages. Weeds were removed by hand weeding, Solo and Poast application. Measurements taken throughout the growing season included plant populations, crop and weed biomass and seed yield.

The herbicide timing experiment researched the weed control of Solo, Odyssey and Sencor+Poast at early and late applications. The herbicides were applied at the 2 and 6 lentil node stage, respectively. Poast was applied 5 to 7 days after Sencor application. The weed free control was hand weeded and sprayed with Poast for grassy weed control. The residual control was quantified by using plant population measurements, crop and weed biomass and seed yield.

Analysis of variance was conducted using the mixed procedure of SAS. Data was transformed prior to analysis to meet the assumptions of ANOVA. Back transformed results are presented.

Results and Discussion

Weed Removal. The lentil yield of different weed removal timings was determined (Figure 1). The weeds were removed by Solo application between the 1 and 5 node stage, hand weeding and Poast application. The averaged yield of the weed free control was 1645 kg ha^{-1} (SE 4.55).The results indicate that the maximum yield was reached when weeds were removed between the 3 and 5 node stage. The yields were 1025 and 1082 kg ha^{-1} and there was not a significant difference (P=0.7323, SE=2.56). Weed removal before and after these stages resulted in greater yield loss. When weeds were removed at the 1 node stage, the weed biomass was similar to the weedy control (data not shown). This probably occurred because the weeds emerged after this weed removal timing. High weed biomass occurred when the weeds were removed at the 7 node stage. This may have resulted from the subsequent rains after weed removal that promoted weed seed germination. In contrast the weed biomass was relatively low when weeds were removed at the 9 and 11 node stage (data not shown). However the yield was also low, indicating that weed competition prior to weed removal caused yield loss. Therefore, herbicide application should take place before the 7 node stage to reduce weed competition with lentil. However, herbicide application between the 3 and 5 node stage was only a maximum of 74% of the weed free control. The results indicate that multiple applications of Solo or another herbicide may be necessary to control multiple cohorts of weeds when herbicide application is early and weed populations are dense. Furthermore, it may be beneficial to use an herbicide with residual control such as Odyssey to control the subsequent cohorts of weeds.

Figure 1. Lentil yield response to weed removal.

Herbicide and Application Timing. Odyssey, Sencor+Poast and Solo were applied at early and late timings to determine the level of weed control with these herbicides and timings. This experiment was conducted at Saskatoon and Vanscoy. The results from the herbicide application trial at Saskatoon conclude that the late herbicide applications had statistically higher lentil yield than the early herbicide applications (*P*= 0.0065). Results are shown in Figure 2. The mean of the early treatments were 797.24 kg ha^{-1} (SE= 1.73) while the late herbicide applications were 1068.69 kg ha^{-1} (SE= 1.73). The yield results of the herbicide and application timing are shown in Figure 3. Differences did occur between treatments and application timings however, these differences were not significant and there was no herbicide and timing interaction (*P*= 0.1768, SE=2.4921). There also was not a significant herbicide effect between herbicides (*P*= 0.6322) (data not shown).

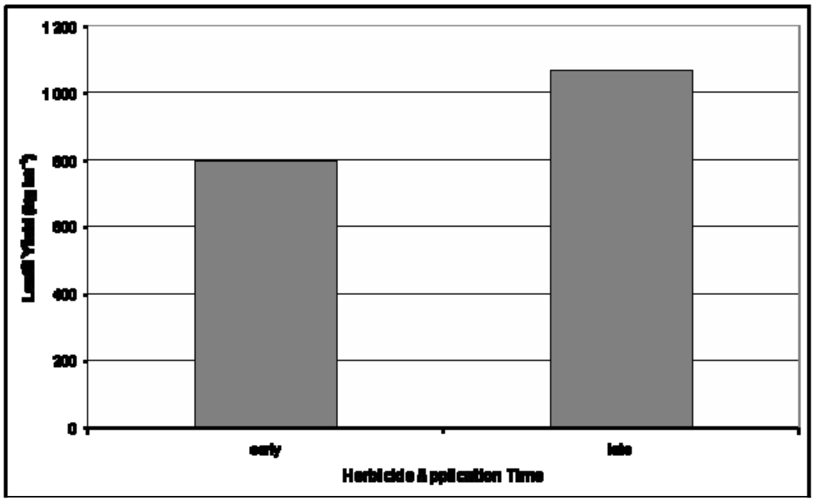

Figure 2. Lentil yield of early and late herbicide applications.

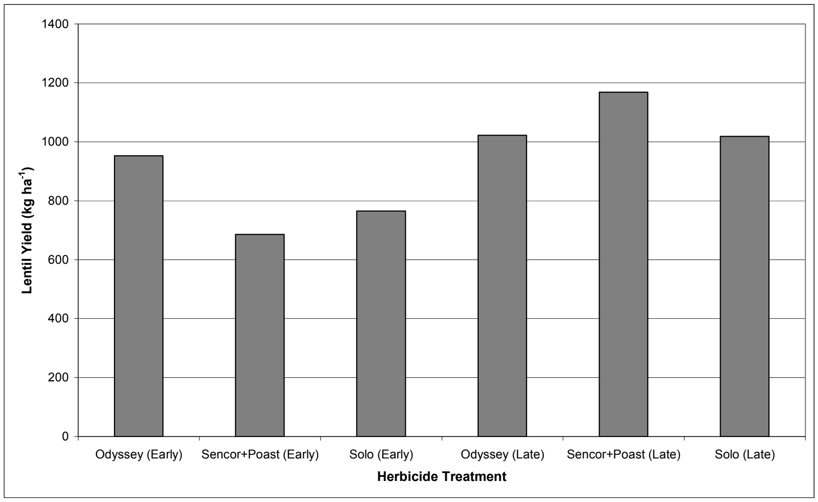

Figure 3. Lentil yield in response to different herbicides and herbicide application timings at the Saskatoon location.

The results from the Vanscoy site indicate that there was not a significant effect between early and late herbicide application timings (*P*=0.8892) (data not shown). However, the Odyssey and Solo treatments had statistically higher yields than the Sencor+Poast treatments (*P*=0.0002, SE= 3.09) (Figure 4). Similarly, there were differences between herbicides and herbicide timings (SE=3.7913) (Figure 5). However, these differences were not significant (*P*=0.8649) and there was not a statistical interaction between herbicide and herbicide timing.

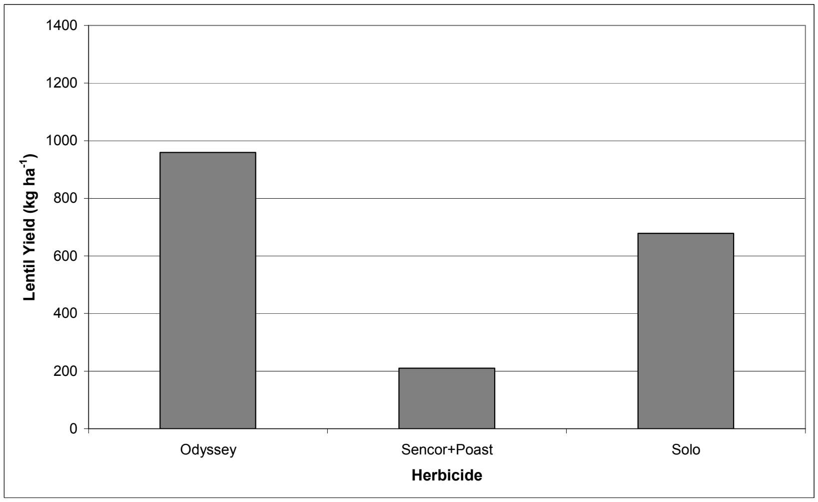

Figure 4. Lentil yield of herbicide application of Odyssey, Sencor+Poast and Solo.

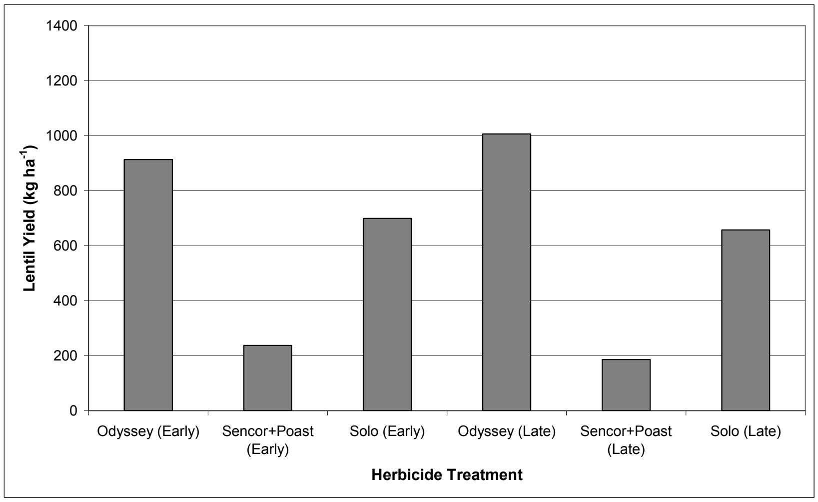

Figure 5. Lentil yield in response to different herbicides and herbicide application timings at the Vanscoy location.

The results from the weed control timings and herbicides differed between the Saskatoon and Vanscoy location. At Saskatoon there was a statistical relationship between early and late herbicide applications. The late herbicide applications resulted in higher lentil yield. In contrast, there was not a significant herbicide timing relationship at Vanscoy. Furthermore, there was a yield difference between herbicide treatments at Vanscoy. Sencor+Poast applications resulted in statistically lower yield than those treatments with Solo and Odyssey. There was not an herbicide application difference at Saskatoon. There also was not an herbicide timing and herbicide application interaction at either of the sites.

The predominant broadleaf weed species at the Saskatoon site included wild mustard (*Sinapsis arvensis*), wild buckwheat (*Polygonum convolvulus*) and red rooted pigweed (*Amaranthus retroflexus*). The results for broadleaf weed biomass for the early and late herbicide timings indicate that Solo and Odyssey had better broadleaf weed control than Sencor (*P*=<0.0001, SE=0.7899) (Figure 6). There was a significant relationship between herbicide type and timing at the Saskatoon location (*P*=0.1072). Solo and Odyssey had significantly lower broadleaf weed biomass than Sencor for both application timings (SE=0.9989). There was not a significant difference between Solo and Odyssey (*P*=0.2912). Solo applications resulted in 1.32 and 1.46 g m^{-2} at early and late applications respectively. The early Odyssey application resulted in 0 g m^{-2} broadleaf biomass while the late application resulted in 0.22 g m^{-2}. However, both Sencor application timings resulted in high broadleaf weed biomass. The early treatment had 62.15 g m^{-2} broadleaf biomass while the late treatment had 22.91 g m^{-2}.

According to many authors Sencor has a limited spectrum of weed control and has been found to cause phytotoxic effects to the crop that can cause unacceptable yield loss (Holm and Vandenberg 1998, Malik and Townley-Smith 1990). Therefore, this may explain the difference in weed control between the IMI herbicides and Sencor. The differences in weed control and application timing results from the differences of residual soil activity. Odyssey has soil activity that can control multiple cohorts of weeds throughout the season. Solo has some residual control, however dissipates much faster in the soil than Odyssey. Sencor also has some residual soil activity however did not sufficiently control the broadleaf weeds. Therefore, the high broadleaf weed biomass is a result of poor weed control. The results indicate that Odyssey can be applied at an early growth stage of lentil to control weed growth and prevent yield loss. However, early applications of Solo should also be followed by another herbicide application to control the late emerging weeds. Late applications of IMI herbicides resulted in high lentil yield and therefore suggests that early weed growth did not cause yield loss.

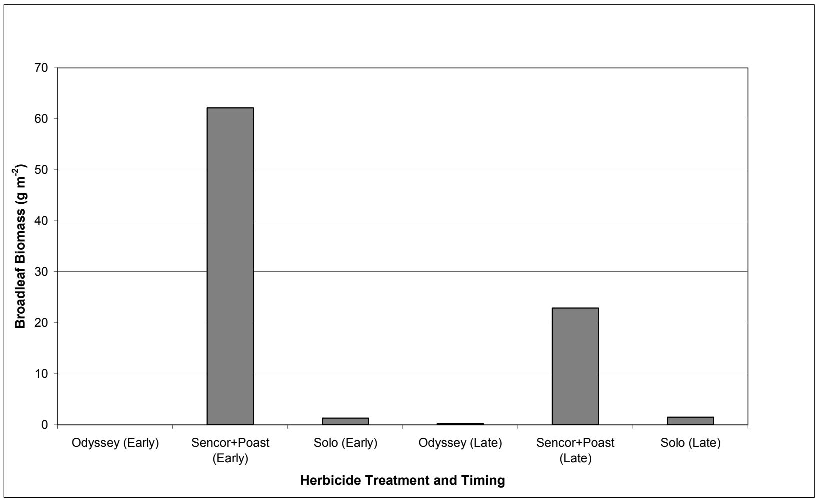

Figure 6. Broadleaf weed biomass at Saskatoon.

The results from Vanscoy indicate that Sencor treatments had significantly higher broadleaf biomass than Solo and Odyssey (*P*=<0.0001) (data not shown). For all treatments the broadleaf biomass was higher for the early herbicide application than the late herbicide application (*P*=0.0789). This is similar to the Saskatoon site and also suggests that early broadleaf weed growth did not cause yield loss. Late herbicide applications with sufficient weed control prevented yield loss.

The predominant grassy weeds at Saskatoon and Vanscoy included wild oats (*Avena fatua*) and green foxtail (*Setaria viridis*). At both the Saskatoon and Vanscoy location the late herbicide applications resulted in less grass biomass (*P*=0.0006 and *P*=0.0936, respectively) (data not shown). At Saskatoon, the herbicides differed in grassy weed control with Solo having the highest grass biomass (*P*=0.0142, SE=1.3946) (Figure 7). Therefore, Odyssey and Sencor+Poast had better grassy weed control than Solo. There was no herbicide effect at Vanscoy (*P*=0.6850) (data not shown).

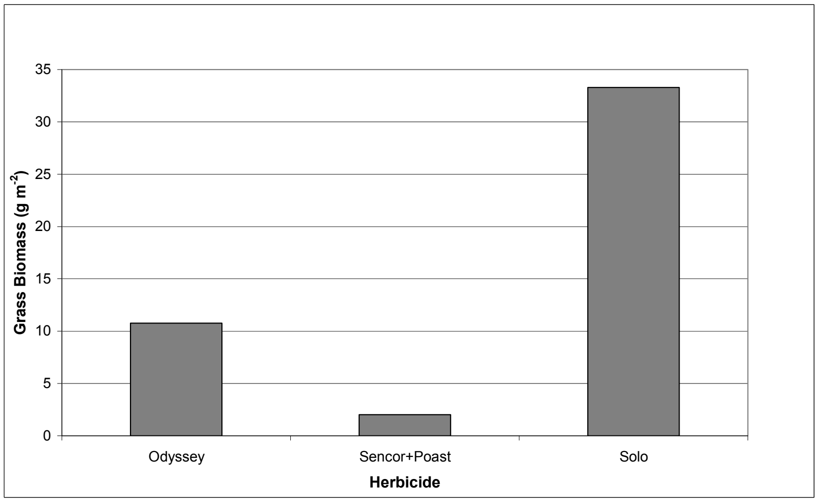

Figure 7. Total grass biomass for different herbicide treatments at Saskatoon.

Duration of Weed-Free Period. The results from the duration of the weed-free period are shown in Figure 8. The averaged yield of the weed free control was 1645 kg ha^{-1} (SE 5.70). The longer the crop remained free of weeds, the higher the lentil yield. The treatment that remained free of weeds until the 11 node stage yielded 1878 kg ha^{-1}, 114% of the weed free control. Figure 8 shows that yield loss occurred when weeds emerged before the 10 node stage. Therefore based on the results, the duration of the weed free period is until the 10 node stage in IMI lentil. Presumably, weed growth after this time will not affect lentil yield because either weed emergence has ceased or weeds that grow are too small to cause yield loss (Martin et al. 2001).

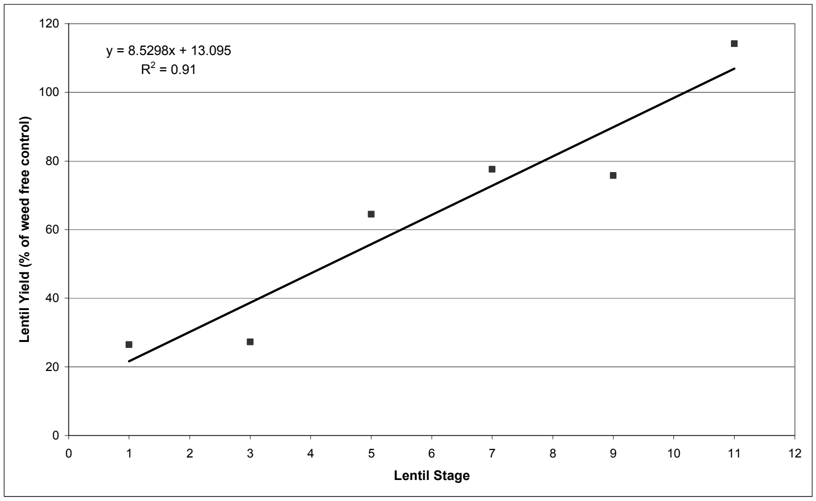

Figure 8. Relative lentil yield for the treatments determining the duration of the weed free period combined from the Saskatoon and Vanscoy locations.

Lentil is an important crop in western Canada; however, it is one of the least competitive. Therefore, it is important to optimize weed control to reduce yield losses. Detailed weed control timings were examined. The results indicate that weed control should take place between the 3 and 5 node stage. Furthermore, it is apparent that a single weed control event may not be sufficient to adequately control weeds and prevent yield loss when weed populations are high. Therefore, after an early Solo application, another weed control event may be necessary to reduce weed competition. Early weed competition presumably did not cause lentil yield loss when the weeds were controlled between the 3 and 5 node stage, yield loss occurred because weeds emerged before the duration of the weed free period was completed. To understand weed control with the different lentil broadleaf herbicides an early and late application of Solo, Odyssey and Sencor+Poast were used. The results from the different locations are contrasting. However the data indicates that Solo and Odyssey had better broadleaf control than Sencor+Poast and late herbicide applications produced higher lentil yield. These results can also be better understood when the duration of the weed free period is used. The duration of the weed free period had a significant effect on lentil yield. Lentil yield loss occurred when Solo and Sencor+Poast were applied early and when Sencor+Poast were applied late at Vanscoy. This yield loss resulted from weed emergence before the duration of the weed free period was completed. The treatments with early applications of Odyssey and the late applications of Solo, Odyssey and, at Saskatoon, Sencor+Poast resulted in yields similar to the weed free control. Presumably, weed growth occurred after the duration of the weed free period and therefore did not affect the lentil yield. The results show that weed growth causes yield loss and that optimal weed control is integral to successful and sustainable integrated weed management programs.

Acknowledgements

I would like to thank: NSERC and BASF Canada for their financial support. Shaun Campbell, Rachelle German and their crew. Glen Forster and the research staff at BASF.

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Dose-response of weeds to flame cultivation in vegetable crops

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Abstract

Flame weeding has been used to a greater degree in recent years, especially by organic producers. There has been minimal research in the use of flaming post-emergence in vegetable crops. Experiments were conducted to model the response of weeds to flame weeding in this context. A range of flaming intensities were applied to weeds in fields of Spanish onion (*Allium cepa* L.), broccoli (*Brassica oleracea* L. var. *italica*), spinach (*Spinacia oleracea* L.), and beet (*Beta vulgaris* L.). Dose-response curves were constructed for common lamb's quarters (*Chenopodium album*), redroot pigweed (*Amaranthus retroflexus*), and mixed grasses (*Echinochloa crus-galli* and *Setaria glauca*). Effective control was able to be achieved for *C. album* and *A. retroflexus*, with response dependent upon stage of maturity and dose applied. Monocot weeds were not effectively controlled at any rate tested. This study suggests that flame cultivation may be effective at controlling some, but not all annual weed species.

Introduction

Interest in flame weeding has increased in recent years, largely due to the surge in popularity in organic farming. Inter-row weeds can be effectively controlled through conventional mechanical methods (Melander, 1998). Intra-row weeds can pose a problem as mechanical methods are ineffective in controlling weeds or cause too much damage to the crop plants, especially early in the growing season. Flame cultivation is almost exclusively used to control weeds that occur within the crop row. Flaming is typically fuelled by liquefied petroleum gas (LPG), normally propane or propane/butane mixtures. Flaming is often used pre-emergence for slow-germinating crops such as onions and carrots (Ascard, 1995). This type of flaming is referred to as non-selective, as it takes place prior to crop emergence so no distinction is made between targeted and non-targeted plants. The alternative is selective flaming, where flame cultivation occurs after the crop has emerged, or after transplantation in the case of transplants. This method can be used if the crop is more tolerant to flaming than the surrounding weeds. Tolerance may be due to natural differences between the crop and the weed species, or by the crop being at a later stage of development such as in the case of transplants. A number of factors can affect a plant's tolerance to flaming including the presence of hair, wax, extent of lignification, and water status of the plant. Also, size has a large impact on a weed's susceptibility to flaming, with large weeds being much more resistant to flaming than smaller ones. Flaming efficacy is based on a number of factors, including temperature, exposure time, and energy input (Ascard, 1997). Exposure time is primarily controlled by driving speed in tractor mounted apparatuses.

Selective flaming depends on determining rates at which weeds can be effectively controlled without inducing unacceptable levels of damage on the crop species. These rates are therefore a compromise between high enough rates to kill weed species, and low enough rates for the crop to handle. Experiments were designed to evaluate the efficacy of different flaming intensities on weed populations as well as damage induced on crop species. In order to accomplish these goals, a range of flaming doses was applied over the course of the crops' growth cycles. At the same time, the weed population was exposed to the same flaming doses. This allowed construction of species and growth stage dependent dose response curves. These experiments were conducted over the course of two growing seasons. Here data is presented from the 2006 field season. Although crop data was recorded as well, this paper only presents data concerning the weed response.

Materials and Methods

Four experiments were conducted, one each with Spanish onion (*Allium cepa* L., cv. Vaquero), broccoli (*Brassica oleracea* L. var. *italica*), spinach (*Spinacia oleracea* L.), and beet (*Beta vulgaris* L.). Experiments were set up in randomized complete block design (RCBD) with 4 replications and distance of 0.9 meters between adjacent rows . Each experimental plot received a single flame treatment. Flame treatments consisted of all combinations of 3 fuel pressures (138, 241, 345 kPa) and 4 driving speeds (2, 3, 4, and 5 km h^{-1}), for twelve different flaming intensities. Each plot received a single flame treatment at a particular growth stage, depending on the crop: Spanish onion and broccoli were flamed at 5 growth stages after transplantation, while beet and spinach were flamed pre-emergence and at the 4 and 6 leaf stage. Experiments were seeded with 4 weed species common to horticultural fields in Eastern Canada. Each replication was seeded with one of the following weed species: *Chenopodium album*, *Amaranthus retroflexus*, *Setaria glauca*, and *Echinochloa crus-galli*. Weeds were tagged prior to treatment by placing a paper clip at a distance from and around the base of the plant. Treatment effect was determined between 1 and 3 days following flame treatment, depending upon the weed species and growth stage. Generally, a minimum of 50 weeds per species per growth stage were tagged for each treatment. Additionally, two controls were present in each replication. One control received no treatment and served as the weedy check, and the other was maintained weed free through hand weeding.

Flame treatments were performed using an unshielded Red Dragon (Flame Engineering Inc., LaCrosse, Kansas) two burner system with two LT 1 ½ x 6 burners, directed perpendicularly to the crop row. Burners were set at an angle of 30° with respect to the horizontal. Burners were 17.8 cm from the crop row when measured along the angle.

Regression analysis was performed using TableCurve 2D v. 4.0 (Systat Software Inc., Richmond, California). Graphs were constructed using SigmaPlot (Systat Software, Inc., Richmond, California).

Results and Discussion

The following four parameter logistic equation served as the core model for the response of weed species to the flame treatments:

$$y = C + \frac{(D - C)}{1 + \left(\frac{x}{a}\right)^{b}}$$

where *C* is the lower asymptote, *D* the upper asymptote, *a* the inflection point, which is also the point representing the mid-point between the upper and lower asymptotes, and *b* as the slope of the curve at *a* (Streibig et al., 1993). Since a percent scale was used, the upper asymptote, *D*, can be replaced by 100. Additionally, for weed species/growth stages where complete kill could be achieved at high flaming intensities, the lower asymptote, *C*, could be replaced with zero and thus removed from the equation

(Ascard, 1995). Though these models worked quite well for some species, they did not for all. Some species showed poor response and a realistic model was not found that could accurately represent the response. For these species a simple linear regression was included solely for reference. Graphs represent pooled data for each species from all four experiments. Doses in graphs are represented in a linear scale by converting them to kilograms of propane burned per hectare. The values are presented in Table 1.

Table 1. Flame treatments converted into kilograms burned per hectare.

Pressure kPa	Speed km/h	kg/ha
138	2	15.00
138	3	10.00
138	4	7.50
138	5	6.00
241	2	23.89
241	3	15.92
241	4	11.94
241	5	9.56
345	2	32.78
345	3	21.85
345	4	16.39
345	5	13.11

The logistic models described the effect of the flame treatments on *Chenopodium album* numbers quite well (Figure 1). The cotyledon stage had an LD_{50} of 4.67 kg ha^{-1}, and complete kill was observed by the third lowest dose tested (9.56 kg ha^{-1}). By the 2 leaf stage, the LD_{50} had increased to 6.48 kg ha^{-1}. With increasing maturity, the response of *C. album* shifts continually to the right, indicating a need for higher doses in order to achieve equivalent control. Beyond the 6 leaf stage, lower levels of control are seen and the slope flattens due to greater variability between individual plants.

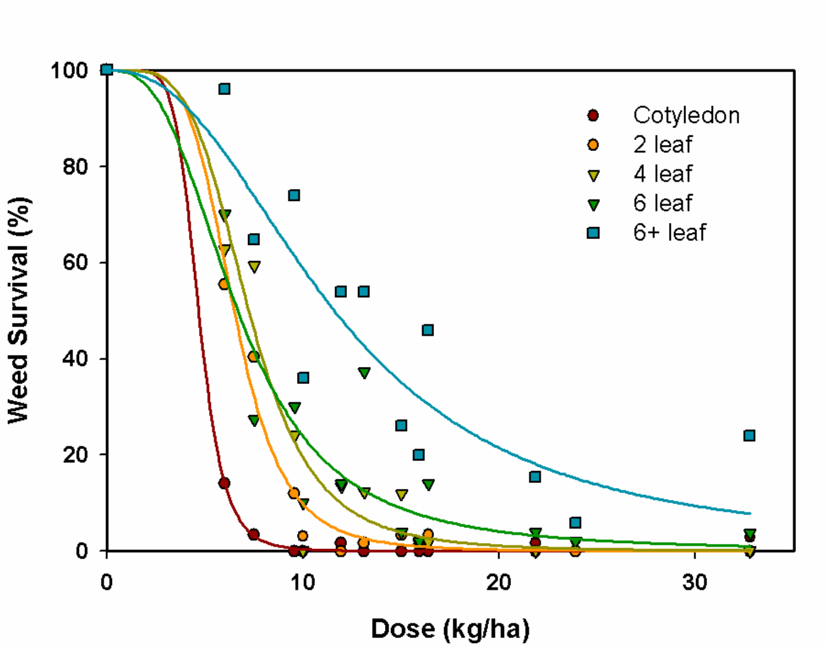

Figure 1. Response of *Chenopodium album* to flame treatment.

Though different methodologies and strategies were tested, the response of *C. album* reported here generally agrees with that reported in Ascard (1995). In both studies, *C. album* was found to follow the logistic model very well, with effective control achieved with moderate flaming doses in early maturity stages.

The response of *Amaranthus retroflexus* was generally similar to that of *C. album* (Figure 2). This is not surprising as both share overall similar growth habits and morphologies, though *A. retroflexus* has somewhat thicker leaves and greater pubescence, especially at later maturity stages. However, overall it took higher doses to achieve similar levels of control in *A. retroflexus* when compared to *C. album* at comparable maturity levels.

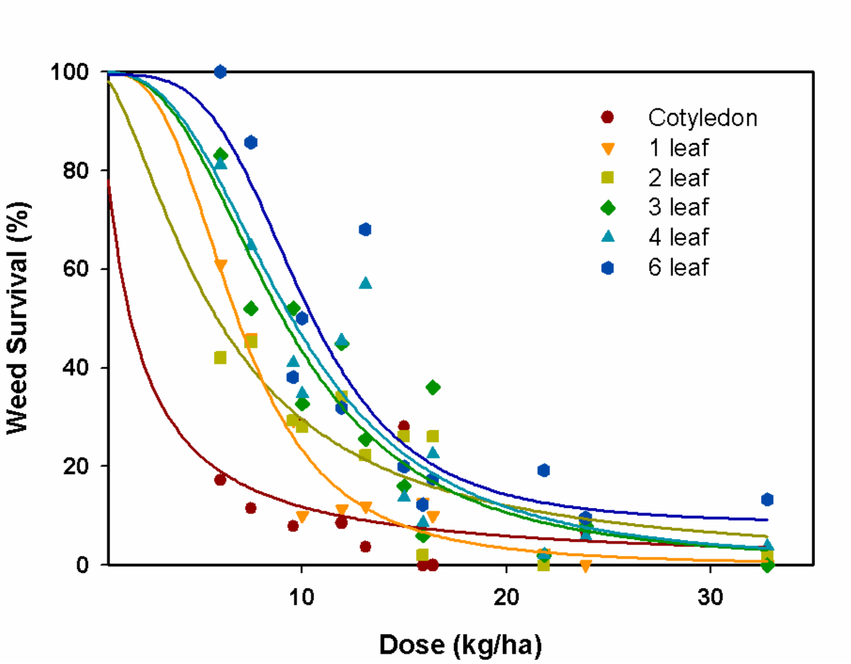

Figure 2. Response of *Amaranthus retroflexus* to flame treatment.

At the 1 leaf stage, the LD_{50} of *A. retroflexus* was 6.82 kg ha^{-1}, and increased to 9.04 kg ha^{-1} by the 3 leaf stage. Approximately 95% control was able to be realized in maturity stages up until the 4 leaf stage, thought at higher doses for more mature plants. Complete control was not achieved with *A. retroflexus* in the 6 leaf stage.

Adequate control of *C. album* and *A. retroflexus*, both dicotyledonous weeds with upright growth habits, was able to be achieved, with the doses required increasing with greater plant maturity. This stands in stark contrast to the response observed of the monocotyledonous weeds surveyed (Figure 3). Due to difficulties identifying *Echinochloa crus-galli* and *Setaria glauca* at the 1 and 2 leaf stages, along with the similarities of the data, it was chosen to pool the data for presentation in Figure 3.

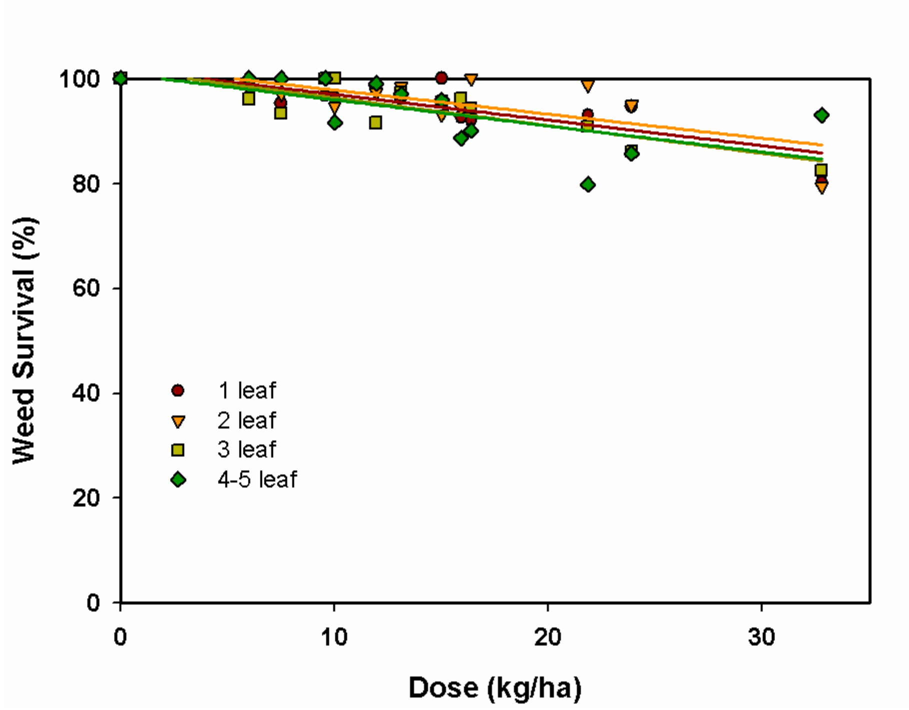

Figure 3. Response of mixed *Poaceae* to flame treatment.

As is observed in Figure 3, flame treatments were not able to effectively control grass weeds in this study. Even at the highest rate tested, approximately 33 kg ha^{-1}, greater than 80% of weeds survived flame treatment at all maturity stages evaluated. The logistic model was not able to adequately describe the response of grass weeds to flame application. Linear regressions, though not realistic, were included simply to show the overall trends. There were no discernible differences in response in monocot weeds as maturity progressed. There was a slight trend towards greater control as flaming intensity increased, though no doses tested resulted in adequate control.

Lack of control of grass species was not due to resistance to the flame treatment by the plants. Indeed, there was significant destruction of above ground biomass at most doses evaluated, especially in the earlier maturity stages. At the 1 and 2 leaf stages, near total destruction of biomass was observed at most doses. The plants were able to survive due to their ability for regrowth. This is due to the growing point being protected, being located near the soil surface and protected by surrounding leaves. Just after treatment, therefore, near complete control of grass species would be observed. After a few days, however, new growth could be seen on nearly all affected plants.

These results suggest that flame weeding can be used to effectively control some annual weed species. Weed species appear to be more likely to be effectively controlled using this method if they are dicots with upright growth forms and unprotected meristems. Monocot species were not able to be effectively controlled at any flaming rate tested in this study. These data seem to agree with previous reports in the literature regarding weed response to flame cultivation.

Acknowledgements

The authors would like to thank Germain Moreau for his excellent work as field technician, as well as all summer students who assisted in the gathering of data and implementation of this project. Their work is essential for the success of this project.

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Spectral analysis of UV induced fluorescence for the discrimination of grasses, dicot weeds and corn

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Abstract

Real-time spot spraying of weeds lies on the development of optical sensors. Plant UV-induced spectral signature of fluorescence offers potential for the discrimination between crop and weeds. Spectral signature of plant fluorescence may be influenced by "intra-specific" variability (leaf age and position on the leaf). This research aims to evaluate if this effect is important enough to thwart plant (4 corn hybrids, 4 grasses and 4 dicot weeds) classification and to measure the discrimination potential of spectral signature of fluorescence for three plant groups (corn, grasses and dicot weeds). Leaf readings were recorded at10 (on point on the leaf), 20 (two points) and 30 days (two points) after emergence. Mean spectra were analysed. Classification was done using linear discriminant analysis. Plant growth stage and recording position showed inferior effect on the spectral signature than plant group did. Linear discriminant analysis generated a prediction error of only 8,2 %. Moreover, most of the misclassification was generated by only one corn hybrid. It is concluded that spectral signature of UV induced fluorescence present a good potential for on the go plant discrimination.

Introduction

Weeds often occur in patches within field rather than regularly or randomly (Martinez, 2001; Perry et al., 2002). It was shown that compared to uniform application of herbicides, spot spraying resulted to an average saving of 54% could be achieved on herbicides (Timmermann et al., 2003). The challenge is to locate the weed patches. Scouting and mapping prior to treatment is labor intensive and often not feasible due to time constraints. Real-time treatments would be a much more promising approach but it requires the use of sensors that could discriminate crop from weeds in real-time. Spectral signatures from UV-induced fluorescence emitted from plant surfaces can be recorded as a plant fingerprint. This has the potential to be a basis for real-time sensor for plant identification.

Fluorescence is emitted by plants in response to excitation by UV or visible radiations (Buschman and Lichtenthaler 1998, Cerovic et al 1999). Strong transition in light intensity (low to high) will induce the Kautsky effect (Kautsky, 1931). In our case, we are interested in steady-state fluorescence observed using a low energy analytic light beam. Blue-green fluorescence (BGF) is emitted by the leaf epidermis and the leaf veins while red and far-red fluorescence is emitted by the leaf mesophyll (Cerovic et al., 1999). BGF is mainly emitted by ferulic acid bounded to cell walls but can also be emitted by other phenolics notably quercetins and coumarins (Lichtenthaler and Schweiger, 1998). Red and far-red fluorescences are often referred to as chlorophyll fluorescence (ChlF) as they are emitted from chlorophyll *a*. Chapelle et al. (1985) have demonstrated that BGF can be used to discriminate monocot (higher intensity) from dicot species. However, the capacity of UV-induced fluorescence to distinguish between monocot weeds and monocot crop, e.g. corn, remains to be demonstrated. The spectral signature of UV-induced fluorescence is a possible means for discriminating between weeds and crop seedlings (Chappelle et al., 1985; Hilton, 2000). We hypothesised that spectral signature is less affected by the seedling growth stages or the location of the recording point on the plant foliage than by the plant species and that UV-induced fluorescence makes possible the discrimination of three plant groups (corn, grasses end dicot weeds). The objective of this research is to study the feasibility of using spectral signature of plants resulting from induced fluorescence as a means to discriminate between corn, grasses and dicot weeds. The growth stage and the recording position on the leaf have to be proven not to influence the discrimination. If feasible, a real-time sensor can be developed to provide inputs for controlling a sprayer performing spot spraying of herbicides.

Materials and methods

The fluorimeter used in this studyis a custom assembly that includes a xenon flash lamp with a filter (327 ± 5 nm) for UV induction of fluorescence. Fiber optic bundles are used to carry light back and forth to the plant sample. Fibers were positioned at about 1 cm above the leaf surface. The fluorescence signal is filtered by a high pass filter (400 nm) before entering the spectrometer (400 to 760 nm) to remove second-order effects. The fluorescence spectrum was collected by an ICCD camera. Fluorescence was acquired under natural light in a greenhouse. To isolate the fluorescence signal, a reading was performed without the excitation light immediately followed by a second reading under UV excitation. Subtracting the first signal from the second yielded the net fluorescence spectrum. A sequence of 11 consecutive readings (10 Hz) was averaged to form a single measurement to smooth out noise.

Seedlings of four *Zea mays* L. hybrids (Elite 60T05, Monsanto DKC 26-78, Pioneer 39Y85 (RR), Syngenta N2555 (Bt, LL)), four annual grass species (*Digitaria ischaemum* (Schreb.), *Echinochloa crus-galli* (L.) Beauv., *Panicum capillare* (L.), *Setaria glauca* (L.) Beauv.) and four annual dicot weeds (*Ambrosia artemisiifolia* (L.), *Amaranthus retroflexus* (L.), *Capsella bursa-pastoris* (L.) Med., *Chenopodium album* (L.) were used. Five readings were taken on each seedling: one reading (randomly located on the tiny leaf) 10 days after emergence and two readings (base or tip for monocotyledons and leaf vein or leaf blade for dicots) at 20 days and at 30 days after emergence. The data set contains a total of 1440 spectra (3 experimental blocks, 3 plant groups, 4 plants per group, 8 replications of each plant species and 5 readings per plant).

Results and discussion

Mean spectra

To evaluate the potential of UV-induced spectral signature of fluorescence for the discrimination of plants groups, the mean spectra of corn, grasses and dicot weeds were compared. One can see that on average, corn, dicots and grasses have clearly distinct spectra (Fig. 1A). Corn has the highest BGF followed by grasses. The fact that these two last groups have higher BGF than dicots is consistent with the literature (Chapelle et al., 1985). Also, dicot weeds have a more pronounced shoulder at 530 nm than the two other plant groups. When the five different recordings (growth stage and recording position) are included in the display, it appears that these two parameters have less influence on the plant fluorescence spectrum than the plant group has (Fig. 1B).

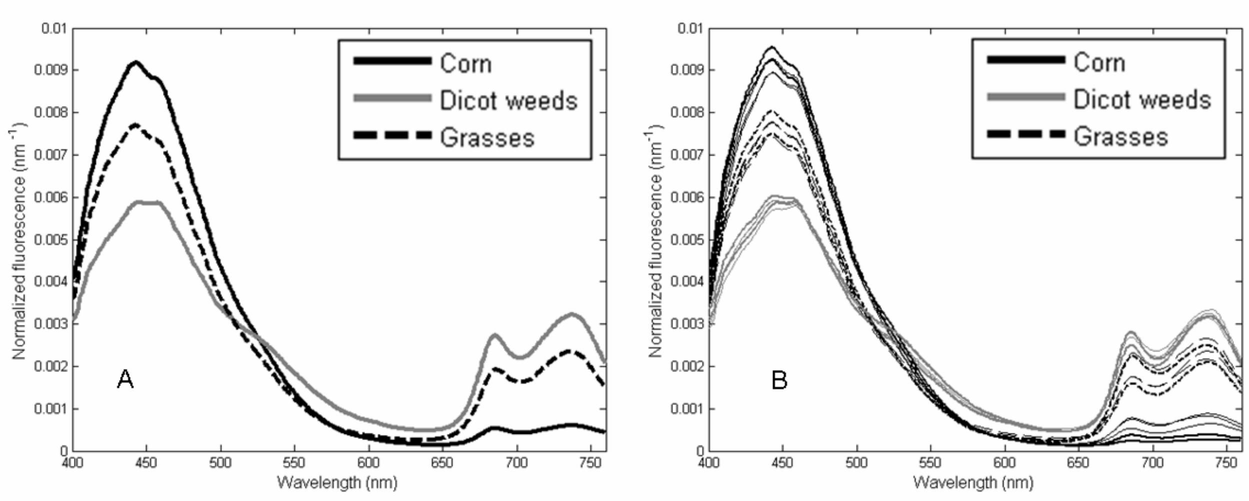

Figure 1 Mean spectrum of UV induced fluorescence displayed as A. the three plant groups and B. the five recordings (growth stage and recording position) for each plant group.

Linear discriminant analysis

A principal component analysis (PCA) was performed over the whole dataset. To determine the number of principal components (PCs) that would be kept for the analysis, the shape of the spectra of the loadings were interpreted. Five principal components were conserved for the analysis lowering the data set from 360 (1 data per wavelength) to 5 (number of PCs kept). A linear discriminant analysis (LDA) was performed on these five PCs (Venables and Ripley, 2002). Cross-validation using a leave-one-out procedure was used (Eriksson *et al.*, 2000). Note that the leave-one-out procedure did not include recomputing of the PCs. Classification was performed by applying the LDA model and computing the Mahalanobis distance (MASS package in R software) (Mahalanobis, 1936) to each of the classes. A sample was assigned to the class for which the Mahalnobis distance was minimal. The output of the linear discriminant analysis is a confusion matrix showing the predicted (columns) and the actual (rows) classifications (Kohavi and Provost, 1998). The whole data set was submitted to the LDA to classify between the twelve plant species or hybrids. Once the LDA done, the output was rearranged to show the classification of the three plant groups (grasses, dicot weeds and corn). In table 1, one can see that the prediction error (8,2 %) mainly comes from the misclassification of grasses as corn (44 % of the total error) and of corn as grasses (33 % of the total error). The rest (23 % of the total error) comes from the misclassification of weeds (monocots and dicots) between them. An interesting point is that dicots weeds never get confused with corn and corn never gets confused with dicots weeds.

Table 1 Confusion matrix of the LDA classification for the three plant groups. Summary of a 12 x 12 confusion matrix of the twelve plant species/hybrids (Table 2). The total prediction error is 8,2 %.

	Grasses	Dicot weeds	Corn
Grasses	**388 (87%)**[a]	9 (2 %)	49 (11 %)
Dicot weeds	17 (4 %)	**423 (96 %)**	0 (0 %)
Corn	36 (8 %)	0 (0 %)	**439 (92 %)**

a In parentheses are the percentages of the actual class attributed to the different predicted classes.

When looking further (plant by plant classification) in the data set, one can notice that 82 % of the misclassification of grasses as corn comes from one corn hybrid (Pioneer) and 44 % of the misclassification of corn as grasses comes from the same corn hybrid classified as one weed (*Setaria glauca*) (Table 2).

Table 2 Confusion matrix of the LDA classification for the twelve plant species/hybrids.

		Grasses				Dicot weeds				Corn			
		DI	EC	PC	SG	AA	AR	CA	CB	E	M	P	S
Grasses	DI[a]	74	3	18	0	0	0	0	8	1	3	**4**	0
	EC	4	83	7	8	0	0	0	0	2	0	**11**	0
	PC	12	15	59	2	0	0	0	0	0	1	**14**	0
	SG	4	4	1	94	0	0	1	0	0	2	**11**	0
Dicot weeds	AA	1	0	0	0	100	8	1	1	0	0	0	0
	AR	0	3	1	0	5	104	0	1	0	0	0	0
	CA	1	0	1	0	0	0	98	9	0	0	0	0
	CB	4	1	4	1	0	0	0	96	0	0	0	0
Corn	E	1	5	0	4	0	0	0	0	7	27	18	55
	M	0	3	0	3	0	0	0	0	6	36	21	50
	P	0	0	0	**16**	0	0	0	0	10	18	42	34
	S	0	3	0	1	0	0	0	0	5	31	15	64

a. E=Elite; M=Monsanto; P=Pioneer; S=Syngenta; DI=*Digitaria ischaemum*; EC=*Echinochloa crus-galli*; PC=*Panicum capillare*; SG=*Setaria glauca*; AA=*Ambrosia artemisiifolia*; AR=*Amaranthus retroflexus*; CB=*Capsella bursa-pastoris*; CA=*Chenopodium album*

In conclusion, both the growth stage and the position of the recording point on the plant leaf have a minor effect on the spectral signature of UV induced fluorescence. This result is important because the data acquisition is a lot simpler when not taking into account these two factors. With indoor grown seedlings, it is possible to classify three plant groups (corn, grasses and dicot weeds) generating a relatively low prediction error of 8,2 %. Moreover, most of this error can be linked to only one corn hybrid. Thus depending on the corn hybrid used, the classification could be improved. The discrimination capacity of the UV-induced spectral signature of fluorescence is established, opening the door to a new possibility for the real-time discrimination of plants. The next step will be to classify outdoor plants. This is a more challenging situation as outdoor grown plants may contain more flavonoids and cinnamic acid form a UV shield interfering with the UV-excitation and possibly introducing more variability.

Acknowledgement

Special thanks to Gilles St-Laurent and Marlène Piché for their technical support. Appreciation to Suzanne Buhler for her help. This research was financed by the Natural Sciences and Engineering Research Council of Canada.

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Outcrossing frequency for transgenic safflower (*Carthamus tinctorius* L.) intended for plant molecular farming

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Abstract

Safflower (*Carthamus tinctorius* L.) has been transformed for commercial field scale plant-molecular farming (PMF) with a constructs encoding a seed targeted high-value protein and constitutive expressed glufosinate resistance. One concern is intraspecific pollen mediated gene flow (outcrossing) from transgenic to commodity safflower. We quantified the frequency of outcrossing from PMF safflower to non-transgenic safflower under field conditions at three sites (Pirque Chile, Westwold BC, and Lethbridge AB). Transgenic 'Centennial' safflower was used as the pollen source and a non-transgenic line of the same variety was used as the pollen sink. Seeds from the pollen sink were grown in Edmonton in the following growing season, sprayed with a selective dose of glufosinate and surviving plants were counted and presence of the transgenic confirmed by endpoint PCR and immunochromatographic lateral flow cytometry. The results were subject to a regression analysis. Mean outcrossing frequency ranged from 0.002 to 0.056 in the first 10 m from the source and between zero and 0.011 from 10 to 20 m. Between 50 and 100 m from the source the mean frequency ranged from 0.00066 to 0.00004. Outcrossing rates were similar at the Chile and Lethbridge sites. The highest rates were found at the Westwold site where the mean at 20 m was similar to that of the other sites at 1 m. The results of this study will be useful to industry and regulators in development of best management practices and risk mitigation of pollen mediated gene flow between transgenic and conventional safflower.

Introduction

Safflower (*Carthamus tinctorius* L.) cv. 'Centennial' has been developed using modern biotechnology to produce high-value proteins (plant molecular farming – PMF) and resistance to the broad spectrum herbicide glufosinate. A biosafety concern with this new technology is intraspecific pollen mediated gene flow from this modified crop to commodity safflower. The consequence of commodity safflower containing genes for PMF could be food/feed safety, environmental impacts and market security. We conducted three trials at different locations to evaluate the frequency and direction of pollen movement from transgenic to non-transgenic safflower.

Crop species and varieties have different rates of outcrossing and autogamy ("selfing") that are controlled genetically but are also influenced by the environment (Eastham and Sweet, 2002). Pollen movement over distance for wind and insect pollinated species is dispersed leptokurtic and skewed with the nearest neighbors receiving most of the pollen. Major factors affecting outcrossing among populations include: the number of plant species attractive to pollinators in the area, isolation distance, form and density of donor and receptor plant populations, geographic and vegetative barriers, wind direction, speed and humidity, floral synchrony (sympatric), floral position on the plant, ploidy level of all populations, cross-compatibility, pollen longevity (Rognli et al. 2000; Luna et al. 2001). Complete containment of pollen and seed is not possible for any crops species to date (Eastham and Sweet, 2002). Management that incorporates spatial and temporal isolation could minimize gene flow between crops and volunteer populations. Vegetative barriers may reduce pollen movement but some long distance dispersal will occur. Genetic barriers or genetic use restriction technologies (GURTs), could be a means of reducing gene flow via pollen but the system needs to be stable across different environments and climatic conditions (Eastham and Sweet, 2002; National Research Council, 2004).

The consequences of contamination of commodity crops via pollen mediated gene flow can be serious. For example, pollen from a small plot experiment of transgenic corn intended for PMF of a pig vaccine cross pollinated a field of corn intended for food /feed in Iowa. The neighboring fields of 63 ha of corn growing near the site were ordered destroyed by US government regulators (Ellstrand, 2003).

Previous studies have shown safflower outcrossing to be primarily mediated by insects but wind did moved pollen among plants 1.22 m apart. Different cultivated varieties evaluated in the same field ranged in outcrossing rates from 0 to 100% suggesting that this characteristic is influenced by genotype (Claassen, 1950). The rate of outcrossing for transgenic ‘Centennial’ safflower intended for PMF was unknown. Here we present results from three trials designed to quantify pollen mediated gene flow from PMF safflower to its conventional counterpart.

Materials and Methods

Field design outcrossing

Seeding

To assess the frequency and distance of outcrossing from transgenic safflower to non-transgenic safflower we conducted outcrossing trials at Pirque Chile and Westwold BC in 2002 and Lethbridge AB in 2004. Each experiment included a pollen-source of transgenic safflower and a non-transgenic counterpart of the same cultivar as the pollen-sink (Fig. 1). The Westwold BC trial had a 30 x 30 m transgenic source plot. Four arms 1 x 107 m were planted parallel to one another and to the east of the transgenic plot (Fig. 1). The Pirque Chile trial had a 10 x 10 m transgenic plot of 16 rows in an E-W direction. The rows were 0.70 m apart giving a seeder swath of 2.8 m width. The central transgenic plot was surrounded by four rows of non-transgenic safflower of 2.8 m in width. Eight non-transgenic safflower plots with four rows of safflower 2.8 m wide were planted radially from the transgenic source plot. In addition, four rows of non-transgenic safflower were planted around the trial in rectangle of 115 x 85 m. The arms were not consistent in length (Fig. 1). The Lethbridge AB trial had a 10 x 10 m source plot and non-transgenic safflower planted in a solid square 50 m around the source plot. The outer portion of the non-transgenic plot was trimmed after the safflower bolted into a circle with a radius of *ca*. 50 m around the source plot (Fig. 1).

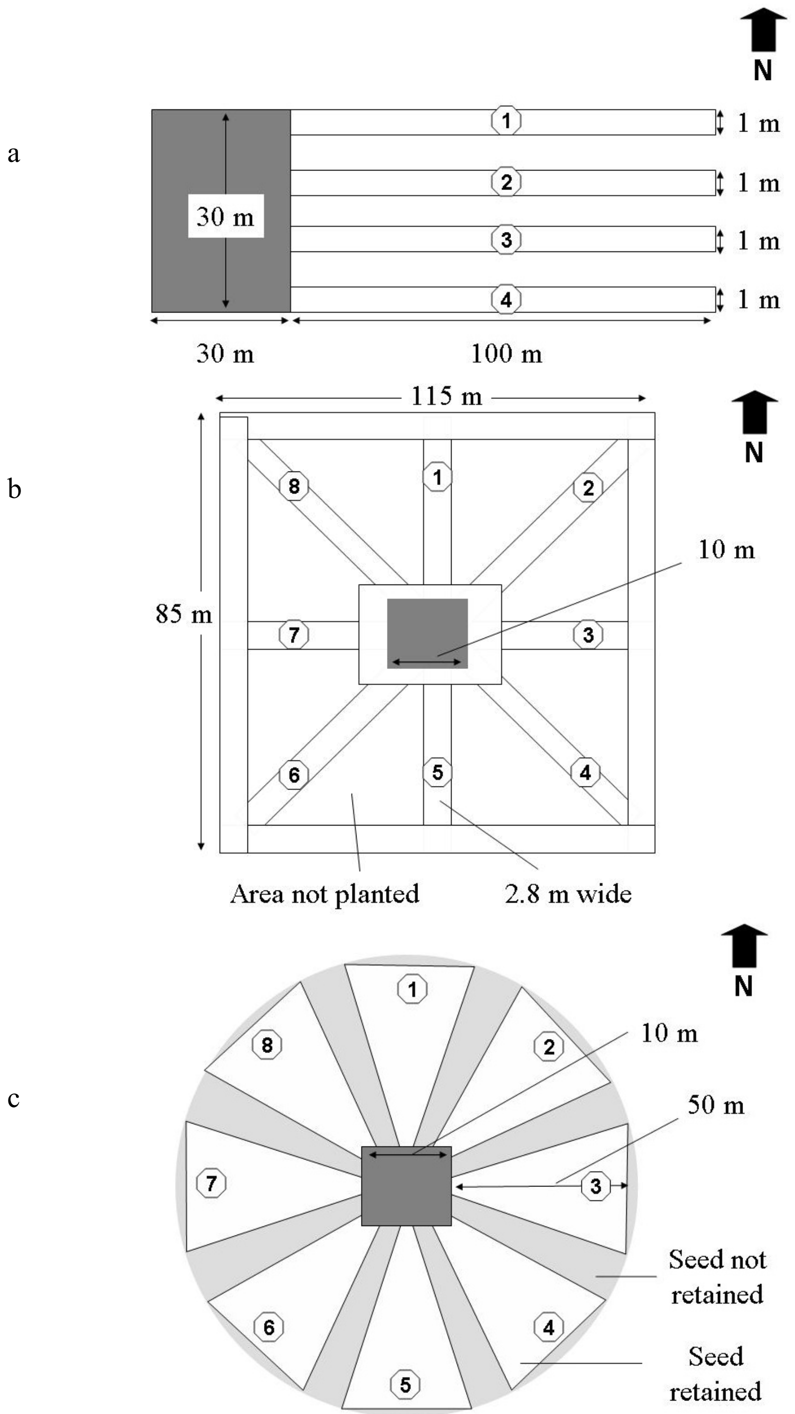

Figure 1. Outcrossing trial layout at a) Westwold, b) Chile and c) Lethbridge in 2002, 2002 and 2004, respectively. The white colour boxes are non-transgenic 'Centennial' safflower, the grey are are glufosinate resistant 'Centennial' safflower. Note at Westwold and Chile the area between the arms was not planted.

Harvesting

At all sites seed samples were harvested at different distances and directions from the transgenic source plot. Harvest at the Westwold BC and Lethbridge AB sites was conducted with a small plot combine. The plots were harvested from the outside to the inside contiguously to avoid contamination. The Westwold BC plots were harvested in a north/south direction with each plot 1.2 m wide. At Lethbridge each plot was 1.2 m wide and the harvest was in a circular fashion but wedges were removed from the circular non-transgenic plot prior to harvest to reduce the amount of seed retained. The seed at the Pirque Chile site were harvested by hand in eight directions (arms) from the non-transgenic safflower plots separately. The asymmetrical non-transgenic plots at this site necessitated the use of the transgenic plot as a reference to obtain samples with the same distance from the source. The first two plots were 1.4 m wide from the inner two rows of the border around the source plot and 1.4 m wide from the outer rows of the border around the source plot. Harvest continued in 1.2 m contiguous swaths going outward in sequence. Gaps not harvested between plots were used to reduce the amount of material to be processed by hand. The gaps were between the eighth and ninth plot of 1 m, between the tenth and eleventh plot of 2 m, between 12th and 13 plot of 3 m, between 14th and 15th plot of 4 m. A total of 16 samples per arm were harvested. In addition, four outer corners were collected at the distal diagonal of each arm, labeled as NE, SE, SW, and NW in Fig. 1. This gave 16 samples per arm from eight arms plus the four corners. Seeds from all three trials were cleaned and stored until the following field season at 10 ºC.

Field screening

The seeds harvested from the outcrossing trials were grown in subsequent years in separate plots on land never utilized for safflower cultivation. Plots of transgenic and non-transgenic safflower were grown with the samples from the outcrossing trials to ensure efficacy of the herbicide and consistency of the growing conditions. Seeds were treated with Helix Xtra ® (Thiamethoxam, Difenoconazole, Mefenoxam, and Fludioxonil) as recommended for canola to increase seedling emergence and survival. The Westwold BC plots closest to the source were screened but not reported as they were contaminated during harvest from the 30 x 30 m transgenic source plot. To reduce the land base needed every second plot from the Westwold BC trial was combined increasing the effective plot width from 1.2 to 2.4 m.

Safflower plants that emerged were counted and then glufosinate applied twice at 800 g ai - ha^{-1}; with a volume of 200 L - ha^{-1}. Preliminary studies in greenhouse had shown hemizygous (one copy of the transgenic construct) safflower plants could survive application of glufosinate at this high rate and frequency. Leaves from surviving plants in the field were sampled and confirmed as transgenic using commercially available immunochromatographic lateral flow test strips (Strategic Diagnostic Inc.®) and event-specific endpoint PCR. All surviving plants were confirmed to be transgenic.

Preliminary statistic analysis

The ratio of survivors and the initial population (emerged) were used to determine the outcross frequency. These data were then subject to a regression analysis (SAS 2006) using the NLIN procedure in SAS (SAS 2006). The data was treated as a binomial distribution and fitted to the equation $F = a * e^{[-b\,(D)]} + E$. Where F is the frequency of outcrossing, D is the distance from the source and a and b were estimated parameters.

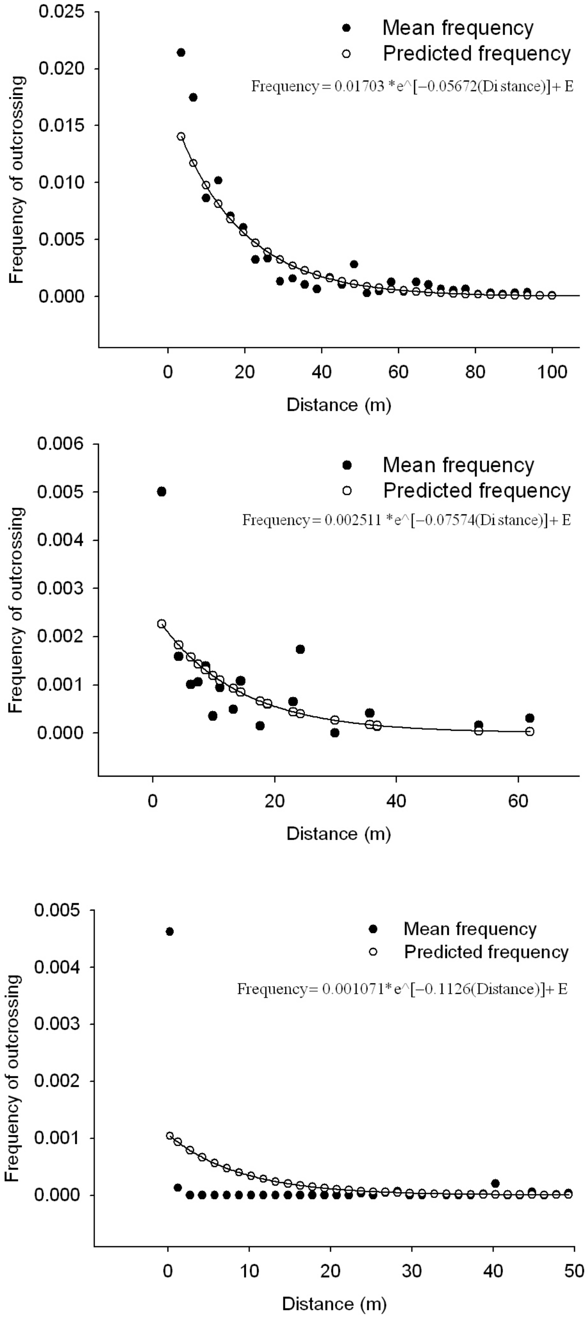

Figure 2. The results of the outcross screening at a) Westwold, b) Chile and c) Lethbridge. Solid circles are mean outcrossing frequency at each distance and the open circles are the estimates of outcrossing frequency based on the regression conducted in SAS.

Results

Total emerge plants screened in the field were: Westwold BC 392, 430 with a mean number per plot of 3090, Lethbridge AB 621, 419 with a mean number per plot of 2293, Pirque Chile 322, 800 with a mean number per plot of 1218 and the single non-trangenic plot 300 m from the Westwold BC experiment 85, 239. Outcrossing occurred at all distances except at the 300 m plot at Westwold where none of the seeds contain the transgene. Outcross frequency decreased with increasing distances from the pollen source in a left skew and leptokurtic pattern. These results show safflower mean outcross frequency ranged from 0.002 to 0.056 in the first 10m from the source and a mean frequency range of 0.000 and 0.011 at 10 to 20 meters. From 50 to 100 meters from the source the mean frequency ranged from 0.00066 to 0.00004.

Conclusions

Pollen mediated gene flow occurred at all sites but was the highest at the Westwold BC site. Pollen movement can be influenced by several biotic and abiotic factors. The difference in outcross frequency at the different locations presented here indicates that safflower outcrossing is influenced by environmental conditions. Outcrossing decreased dramatically after 20 m but some pollen movement was still detected after 50 and 100m.

Allowable thresholds of PMF seed in products for food/feed have not been set by the CFIA but proposed best management practices should be based on scientific field based experiments and designed to mitigate risk of outcrossing to commodity crops. It is likely that PMF will require confinement measures similar to those employed and enforced for confined research trials. The preliminary results presented here indicate that pollen mediated gene flow from PMF to commodity safflower can occur over short distances included in this study (0-100 m). These results should aid industry and regulators to designate an isolation distance to mitigate risk of outcrossing from PMF safflower production.

Acknowledgements

Funding from University of Alberta, NSERC, New Initiatives Fund AAFRD, SemBioSys Genetics Inc. Technical support from Lisa Raatz, Debby Topinka, and Greg Iwaasa. Technical, agronomic, and scientific inputs from Alberta Agriculture, Food and Rural Development. Brad D. Hanson and Carol A. Mallory-Smith providing initial SAS code for the data analysis.

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Branching in field pea

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Introduction

Field pea is an important crop in western Canada. Manipulation of plant populations through varied seeding rates is a critical management tool that can be used to modify crop productivity (Johnston et al. 2002). The current recommended seeding rate in field pea is 88 plants/m^2 (Saskatchewan Pulse Growers, 2000). Any yield advantage above that rate is unlikely to be economic, due to the additional seed costs (Moot and McNeil, 1995). With some of the newer pea varieties having increased branching ability, it is possible that a producer could plant at a lower rate and not notice a substantial decrease in yield. The objectives of this research are to determine if differences in the extent of basal branching in pea cultivars have an affect on productivity at different plant densities; and to determine if differences in the extent of basal branching have an affect on competitiveness of pea cultivars.

Materials and Methods

The first experiment involved examining the extent of basal branching of field pea cultivars with regards to seeding rates. In 2005, seven pea cultivars were seeded in the experiment; one green (CDC Striker), three yellow (Alfetta, CDC Bronco and Carrerra) two maple (CDC Acer and Courier) and one silage (CDC Sonata). Each of the seven cultivars were seeded at five different seeding rates (10, 30, 90, 120, and 150 plants/m^2). They were arranged in a Randomized Complete Block Design (RCBD) with four replicates. The plots were seeded May 9th, 2005 at Saskatoon and May 10th at Rosthern. They were harvested on Sept 1st at Saskatoon and on Sept 5th at Rosthern. Emergence counts, branching numbers, canopy light interception, plant height, plant biomass, lodging scores and blight ratings were taken throughout the year. The harvested samples were cleaned and weighted and seed weights were measured. The experiment was repeated for 2006 with the inclusion of 3 more cultivars (40-10, CDC Montero and Eclipse).

The second experiment involved examining the competitive ability of field pea cultivars with regards to basal branching. In 2005, eight cultivars were seeded in a Split Plot design with four replicates at both locations. The same seven cultivars were used as in the previous experiment as well as 40-10. They were seeded at 50 plants/m^2, one set with no weeds present and the other set with canola and wheat seeded as surrogate weeds to provide competition (at 25 plants/m^2 each) into the pea plots. The same measurements were taken throughout the year as in the previous experiment with the exception of canopy light measurements. This experiment was also repeated in 2006 with the inclusion of 2 more cultivars (CDC Montero and Eclipse).

Results and Discussion

The yield data for the seeding rate experiment was fitted to an asymptotic curve with the equation "**Yield = (Ymax * seeding rate) / (seeding rate + D_{50})**". The yield and seeding rate are inputted values and Ymax and D_{50} are fitted values. Ymax is the yield potential of the cultivar and D_{50} is the seeding rate at which 50% of maximum yield is achieved. The branching data for each cultivar was fitted to a linear regression with all of the slopes of the cultivars being the same and only the intercepts being different, depending on the amount of branching that occurred.

	Acer	**Alfetta**	**Bronco**	**Carrerra**	**Courier**	**Sonata**	**Striker**
Saskatoon							
Branches	2.45	1.93	2.15	1.86	1.02	2.09	2.00
D_{50}	8.6	10.9	7.1	12.2	11.2	4.4	8.4
Rosthern							
Branches	0.67	0.62	0.66	0.59	0.00	0.57	0.46
D_{50}	7.0	9.8	5.5	9.9	13.3	1.5	16.3

Table 1: Branching and D_{50} values at both locations for 2005.

The seeding rate results from the 2005 year are displayed in Table 1. At the Saskatoon location, the cultivars that exhibited less branching were Courier, Carrerra and Alfetta with Courier having the least amount of branching. When comparing these results to the D_{50} values, the cultivars with the highest D_{50} values were also Courier, Alfetta and Carrerra. The cultivars which branched more were CDC Acer, CDC Bronco and CDC Sonata with CDC Acer having the most branching occur. The cultivars with the lowest D_{50} values were the same cultivars that had the most branching (CDC Acer, CDC Bronco and CDC Sonata).

At the Rosthern location for 2005 (Table 1), the cultivars which had more branching were CDC Acer, CDC Bronco and Alfetta (Table 1). The cultivars with the lowest D_{50} values were CDC Sonata, CDC Bronco and CDC Acer. Two of the highest branching cultivars had the lowest D_{50} values. The cultivars with the lowest branching were CDC Striker, CDC Sonata and Courier. The highest D_{50} values were that of CDC Striker, Courier and Alfetta. Two of the lowest branching cultivars exhibited the highest D_{50} values.

At the Saskatoon location, the general trend was that the cultivars with the higher ability to branch exhibited the lower D50 values and the cultivars with the lower ability to branch exhibited the higher D50 values. At the Rosthern location, the same trend was not as clear as at Saskatoon. There were cultivars with high branching that did have low D50 values but there were also high branching cultivars with high D50 values. The opposite was also seen with the low branching cultivars and high D50 values.

	40-10	**Acer**	**Alfetta**	**Bronco**	**Carrerra**	**Courier**	**Sonata**	**Striker**
Saskatoon								
Branches	2.07	2.45	1.93	2.15	1.86	1.02	2.09	2.00
Yield Loss (%)	4	17	N/A	13	34	22	22	0
Rosthern								
Branches	0.55	0.67	0.62	0.66	0.59	0.00	0.57	0.46
Yield Loss (%)	6	12	39	24	47	18	0	22

Table 2: Branching and yield losses at both locations for 2005.

In the weed competition experiment (Table 2) for 2005, the Saskatoon location cultivars with the most yield loss were Carrerra, Courier and CDC Sonata. The cultivars with the least yield loss were CDC Striker and 40-10. The most branching occurred in CDC Acer and the least branching occurred in Courier. At the Rosthern location, the cultivars with the most yield loss were Carrerra and Alfetta and the least yield loss occurred in CDC Sonata and 40-10. The highest branching cultivar was CDC Acer and Courier was the lowest branching cultivar.

There does not appear to be any general trend with regards to branching and yield loss in the cultivars. Some of the higher branching cultivars had low yield losses and some had high yield losses. The same was true with the lower branching cultivars. When looking at the cultivars with respect to variety (green, yellow, maple and silage) as shown in Table 3, more of a trend shows through.

Cultivars	Saskatoon			Rosthern	
	Branching	Yield Loss (%)		Branching	Yield Loss (%)
Yellow					
CDC Bronco	2.15	13		0.66	24
Alfetta	1.93	N/A		0.62	39
Carrerra	1.86	34		0.59	47
Maple					
CDC Acer	2.46	17		0.67	12
Courier	1.02	22		0.00	18
Silage					
CDC Sonata	2.09	22		0.57	0
40-10	2.08	4		0.55	6
Green					
CDC Striker	2.00	0		0.46	22

Table 3: Branching and yield loss for 2005 divided into pea varieties.

Once the cultivars are separated into their groups, is appears that the higher the branching ability, the less yield loss that occurs. The highest branching cultivars for each variety are CDC Bronco, CDC Acer and CDC Sonata. The cultivars with the least yield loss in each variety are CDC Bronco, CDC Acer and CDC Sonata. The data exhibits a trend of high branching and low yield loss to be somewhat correlated from the data in Table 3.

These experiments showed that branching ability of field pea cultivars could be good indicators in the competition of the different cultivars. In the first experiment, branching ability of peas could indicate that higher branching cultivars achieve yields at lower seeding rates. In the second experiment, there were not high correlations between branching ability and yield loss of field peas in general. Once the field peas were separated into their groups, more of a trend could be seen with higher branching cultivars having less yield loss exhibited. Although correlations could be made in both experiments, it is only preliminary data with only one year of field experiments done. A better understanding will be achieved once the 2006 field data is analyzed.

Acknowledgments

I would like to acknowledge Sask. Pulse Growers for their financial assistance in this project. I would also like to thank the agronomy crew at Kernen for helping me with my plots during the summer collections.

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Intraspecific flowering synchrony and gene flow between volunteer and cropped wheat *(Triticum aestivum L.)*

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Introduction

Concerns over market acceptance of transgenic wheat and the importance of protecting patented plant cultivars has necessitated heightened attention around the issue of crop-crop and crop-volunteer gene flow (Conner et al., 2003; Kershen, 2004). The relatively high frequency of wheat in North American crop rotations is also concerning with respect to transgene movement and the potential for contamination (Leeson et al., 2002a,b, 2003; Van Acker et al., 2003) because it is likely that many GE wheat cultivars will be grown next to non-GE wheat cultivars. In addition, volunteer wheat plants also may serve to facilitate intraspecific transgene movement. Intraspecific trait movement is widespread and can occur via the movement of pollen and by seed or other propagules (Hall et al. 2000). Volunteer wheat is an abundant weed in western Canada, persisting on at least 18% of western Canadian fields (Leeson et al., 2005). In situations where GE wheat cultivars containing non-GE volunteers within or growing alongside non-GE cultivars with little to no separation between, the only effective barrier to gene flow will be flowering asynchrony between cropped and volunteer wheat. A thorough understanding of intraspecific gene flow and the factors that contribute to it are essential to ensure cultivar purity and keep adventitious presence below threshold levels. Because no information exists regarding the synchrony of flowering and gene flow between wheat crops and volunteers, the objectives of this research were to: 1) To examine flowering phenology and synchrony between volunteer and cropped wheat as a function of volunteer time of emergence and density 2) To determine the role of flowering phenology and synchrony in facilitating intraspecific gene flow as a function of volunteer time of emergence and density.

Materials and methods

The experiment was conducted at two locations in Manitoba over two years (2005 and 2006). The study sites were located at the University of Manitoba Crop Research Station at Carman and at the JRI Kelburn Research Farm at St. Adolphe, respectively. The experiment was designed as a four replicate split-plot with main plot treatments consisting of various target volunteer wheat densities (10, 20, 40, and 80 plants m^{-2}). Sub-plots treatments were comprised of various volunteer emergence times relative to the crop. Volunteer wheat was planted at 25 growing degree day (GDD) intervals resulting in two treatments emerging before the crop (50 and 25 GDD before), one treatment emerging with the crop (0 GDD) and two emerging after the crop (25 and 50 GDD after). Volunteer wheat served as the male pollinator source and was derived from CDC Imagine, a variety that expresses tolerance to the herbicide imazamox which was used in this study as a marker to detect outcrossing events. Cropped wheat served as the pollen receptor and consisted of the variety the AC Barrie (the most commonly grown wheat variety in Manitoba) seeded at a constant target density of 250 plants m^{-2}. Planting of the crop occurred once in each plot at the third volunteer planting date. Thus, the study employed a paired pollinator row methodology whereby each female receptor row (AC Barrie) was bordered on each side by a male pollinator (CDC Imagine) row (to differentiate between the two types). Fertilizer was broadcast and incorporated prior to seeding based on soil test recommendations. A subsample of AC Barrie was hand harvested in both years and the 2005 subsamples were screened for resistance by treating with 20 g ha^{-1} imazamox in field plots the following year (2006). Hybrids were identified by an injured (coleoptilar tillering) phenotype.

Data collection included emergence monitoring on both populations daily until each volunteer emergence treatment reached the two leaf stage. Flowering was rated daily based on the Zadok's Scale (Zadoks et al., 1973) to determine days to first flower, days to 5%, 50%, and 95% flowering, and days to final flower. Plant height, yield, spikes m^{-2}, and seeds spike were also recorded. Flowering percentage as a function of time was fit to a four parameter logistic equation (PROC NLIN, SAS Inst., 1996):

$$y = C + D / \left[1 + \left(\frac{x}{P_{50}} \right)^{b} \right]$$

where y is the percentage flowering at time x (days), D - C and C are the upper and lower asymptotes, respectively, b is the slope, and P_{50} is the time at which 50% flowering occurred. To rank flowering synchrony, a flowering synchrony index was calculated (Keatley et al., 2004):

$$Z = \frac{1}{n} \sum_{i=1}^{n} X_i \quad \text{where} \quad Xi = \left(\frac{1}{n-1} \right) \left(\frac{1}{f_i} \right) \sum_{j=i}^{n} ej \neq i$$

where Z is the index of flowering synchrony for the population, X_i is the index of flowering synchrony for the individuals (i), e_j is the number of days i and j flower synchronously, $j \neq$ i, f_i is the number of days individual i flowers for, and n is the number spikes sampled. Flowering indices were analyzed using the mixed models procedure of SAS (SAS Inst., 1996).

Results and discussion

Preliminary results from the first two years of the study indicate that flowering synchrony was highly dependent on volunteer wheat time of emergence relative to the crop. In all site years with the exception of Kelburn in 2006, volunteers emerging between 40 GDD before and 40 GDD after the crop exhibited the greatest degree of flowering synchrony with the crop (90-100% synchrony) (Figure 1). Alternatively, volunteers emerging more than 50 GDD after the crop generally exhibited little flowering overlap (0-10% synchrony). At Kelburn in 2006 the crop flowered earlier as a result of moisture stress and consequently, more synchrony was exhibited with volunteers emerging before the crop than with those following crop emergence. Likewise, flowering synchrony indices were also significantly ($P < 0.05$) higher when volunteers emerged just prior to or following crop emergence (data not shown). Synchrony indices averaged 0.81, 0.6 and 0.46 when the crop emerged at the same time, just prior to, and just following crop emergence, respectively (data not shown). Synchrony indices of 0.76 – 0.89 are considered high, 0.51 – 0.76 medium, and 0.22 – 0.50 low (Keatley et al., 2004). Synonymous with flowering synchronicity, unconfirmed gene flow was higher when volunteers emerged with the crop compared to emergence greater than 40 GDD before the crop or emergence greater than 40 GDD after the crop (data not shown).

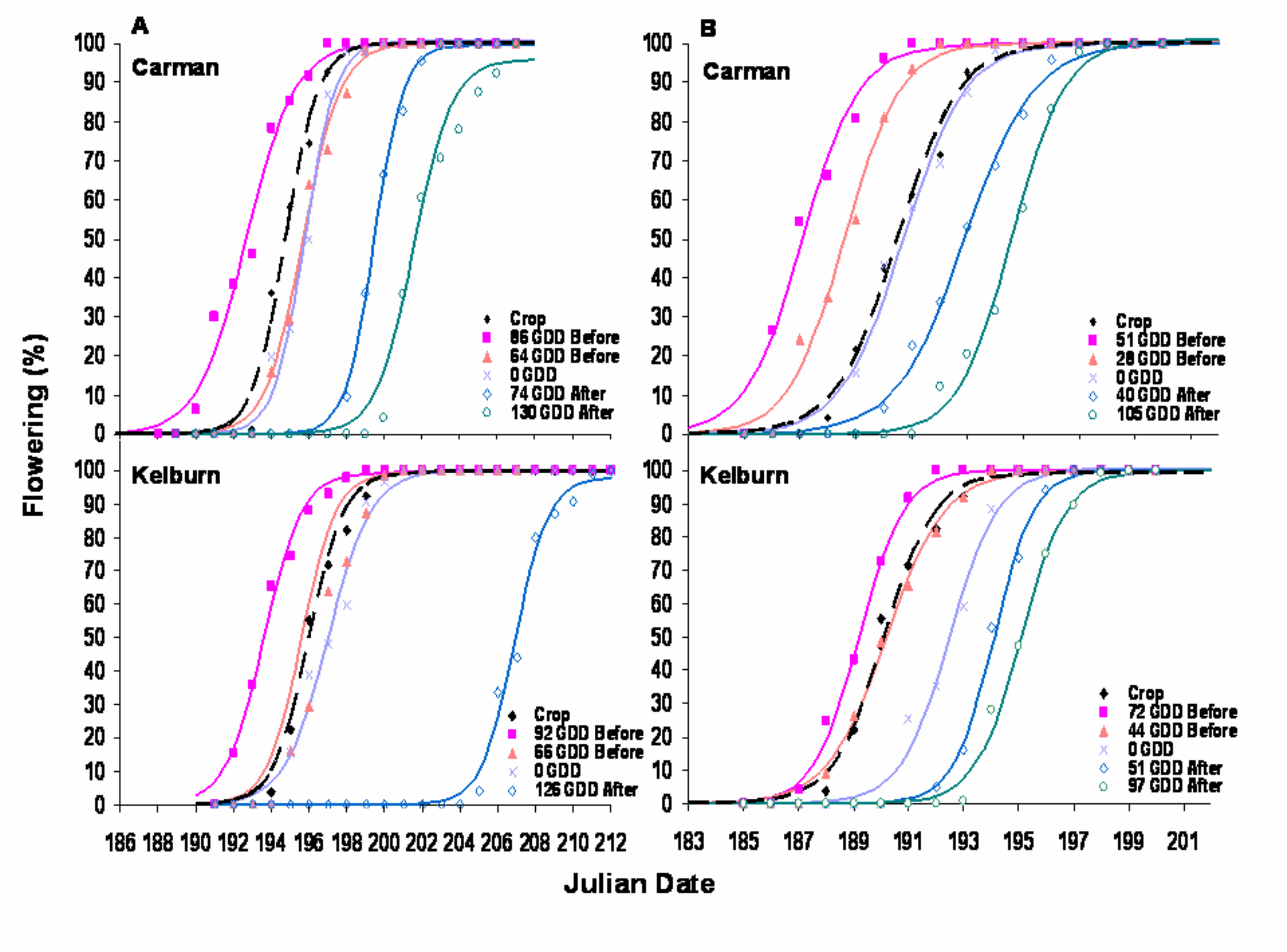

Figure 1. Percentage flowering of cropped and volunteer wheat in 2005 (A) and 2006 (B) as a function of volunteer relative time of emergence.

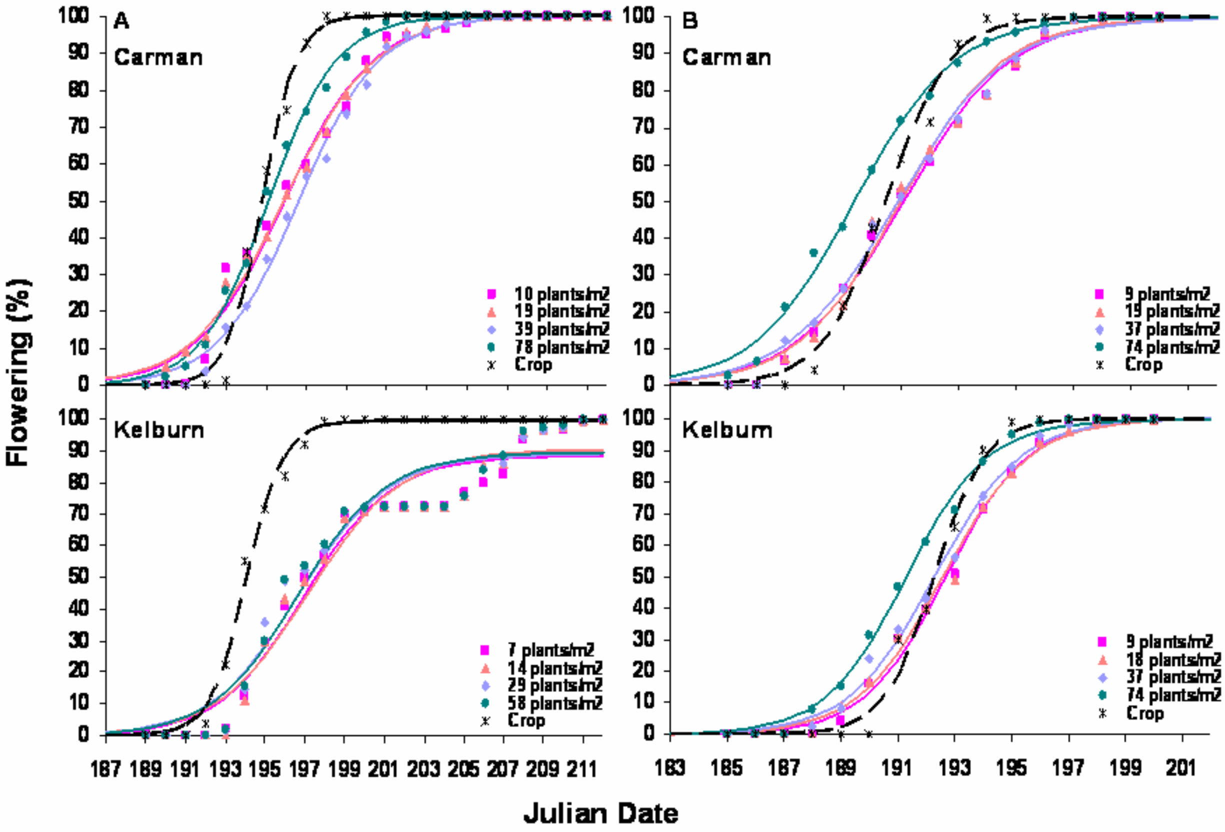

Figure 2. Percentage flowering of cropped and volunteer wheat in 2005 (A) and 2006 (B) as a function of volunteer density.

Volunteer density also influenced flowering synchrony, but to a lesser extent than time of emergence. In all site years, the earliest and greatest rate of flowering occurred in the highest volunteer densities (Figure

2). Volunteer density did not significantly ($P < 0.05$) affect flowering synchrony indices at Kelburn in 2005, but at Carman in 2005, flowering synchrony was significantly higher at 10 plants m^{-2} than at any other density (data not shown). Lower densities result in a prolonged tillering period and therefore, a prolonged flowering period as well. At both sites in 2005, flowering overlap was lower among all densities than at both sites in 2006 (Figure 2). Similar to the previous year, flowering synchrony indices were lowest at the highest volunteer densities (0.49, low) and increased with decreasing density (0.56, medium) (data not shown). Although flowering synchrony was lower at the higher volunteer wheat densities, unconfirmed gene flow was highest and decreased linearly with decreasing volunteer densities. This supports the idea that pollinator source size influences gene flow even at low densities (Willenborg and Van Acker 2006).

Conclusions

These studies provide the first evidence regarding the contribution of volunteers to intraspecific gene flow in wheat. Unconfirmed average gene flow among both site-years was low, suggesting that volunteer wheat may serve to facilitate a low of intraspecific gene movement. Although the level of outcrossing is low, high herbicide selection pressure (95%) could result in rapid evolution of a resistant volunteer wheat population (Brûlé-Babel et al, 2006). The densities used in these studies are representative of those observed in western Canadian fields and the results stress the importance of strict volunteer management to ensure flowering asynchrony results in low levels of gene flow. These are also the first studies to quantify flowering synchrony between wheat crops and volunteers and subsequently link this data to gene flow. Our results show that there appears to be a 40 GDD window on either side of crop emergence in which volunteer emergence results in synchronous flowering with the crop. This critical period for volunteer control is the period during which volunteers must be eliminated from the crop in order to limit gene flow. Taken together, these studies illustrate the potential level of movement of transgenes between cropped and volunteer wheat, vital information for the development of coexistence models based on population dynamics and gene flow. Moreover, the results indicate that time of volunteer emergence is a greater factor than crop and volunteer density in determining intraspecific gene flow mediated through synchronous flowering.

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Impact of In-crop and Soil Residual Herbicides on Effective Nitrogen Fixation in Field Pea (*Pisum sativum* L.) and Chickpea (*Cicer arietinum* L.)

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Key Words: herbicides, nitrogen, field peas, chickpea

Abstract

A three-year project was initiated in 2004 to examine the effects of residual herbicides and registered "in-crop" herbicides, both soil and foliar applied, on N fixation and consequent yield of field peas and chickpeas. Inoculation strategies were examined to determine if inoculant formulation (i.e., peat powder versus granular inoculant) influences the degree to which herbicides can affect N fixation. This research is on-going and thus all results are considered preliminary. Preliminary results in field pea, suggest that where herbicides had a negative effect on N fixation, the effects occurred at relatively early growth stages (i.e., soon after herbicide application) and were typically overcome at later growth stages. In addition, granular inoculants were associated with increased N fixation as compared to peat powder inoculants, and may have mitigated any negative herbicide effects. Chickpea incurred damage from the herbicides and all treatments had significantly less N fixation than the control. In general, results suggest that N fixation may be compromised if herbicides cause significant plant damage; however, improved weed control associated with herbicide application may counter the negative impact on early N fixation.

Introduction

The common use of herbicides in agriculture may negatively impact N fixation, by either directly affecting rhizobia (Mallik and Tesfai, 1985; Anderson et al., 2004) or indirectly by reducing photosynthate allocation to N_2 fixation (Sprout et al., 1992; Eberbach, 1993; Koopman et al., 1995) or by restricting root growth and hence, the number of root sites available for infection (Eberbach and Douglas, 1991). As well, there is the possibility that herbicides that are persistent in the soil may have a longer lasting impact on rhizobial survival and function (Eberbach and Douglas, 1989; Mårtensson and Nilsson, 1989; Koopman et al., 1995; Eliason et al., 2004).

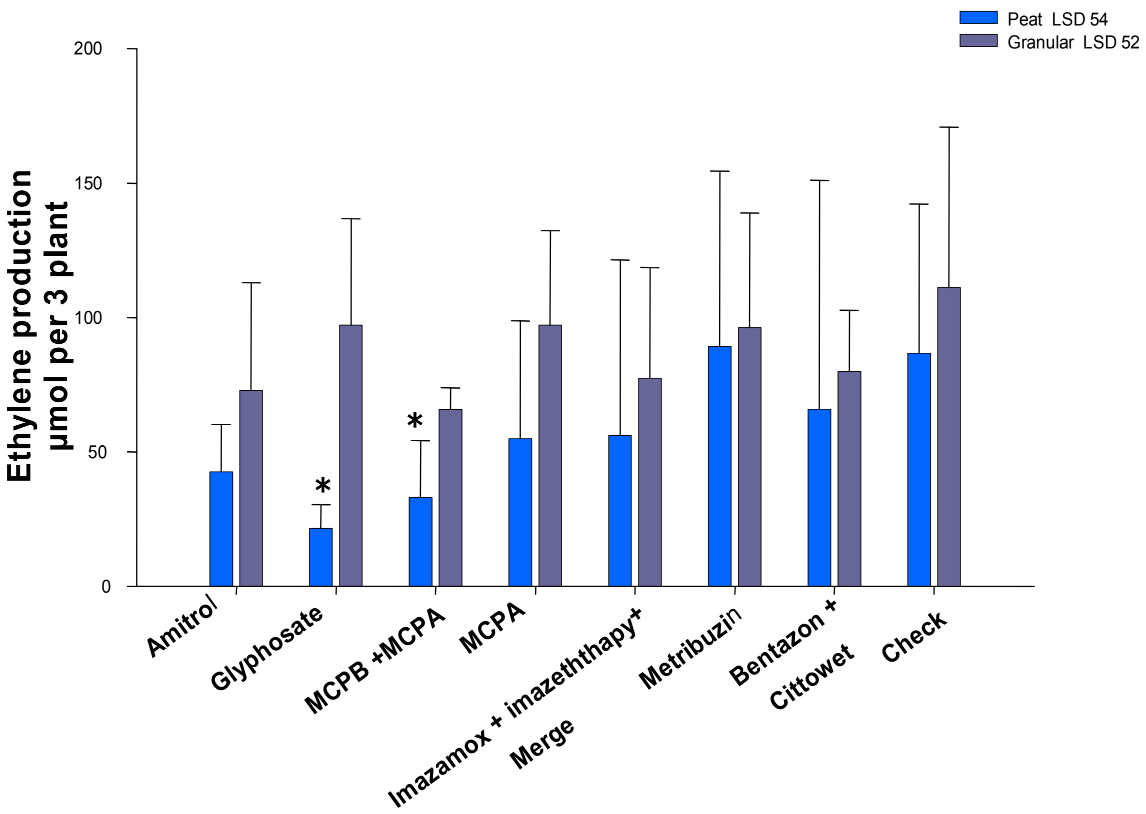
By scrutinizing the impact of herbicides on N_2 fixation, the consequent yield, and the mechanisms by which herbicides may impact nodulation and subsequent nodule occupancy, we can begin to develop effective strategies to minimize the impact of herbicides on the N_2-fixing association.

Materials and Methods

In order to measure the efficacy of the nodules, an acetylene reduction assay (ARA) was conducted (Hardy et al., 1973). For the ARA, three plant samples were removed from the soil and shaken gently. Shoots were cut off and the exposed roots were placed in a 1 L mason jar. One hundred mL of air was removed with a 24 cc syringe and replaced with 100 mL of acetylene (C_2H_2). Jars were buried in the soil and intermittently shaken to maximize nodule exposure to acetylene. Before sampling, the air in the jars was mixed by pumping the syringe 4-5 times to endure a homogeneous mixture of the gases. Ten mL was removed and placed into 12 mL evacuated x-tainers for gas chromatography (GC) analysis. The acetylene reduced to ethylene via the nitrogenase activity was measured using a GC (Hewlett-Packard 5890A). The “in-crop” experiments near Saskatoon were sampled two times throughout the season. The first sampling was done 10 d after herbicide application and the second was taken 20 d after herbicide application. The second sampling coincided with the flowering. In Beaverlodge, roots were sampled once near the end of July, during flowering and pod-filling.

Preliminary Results for Nitrogenase Activity

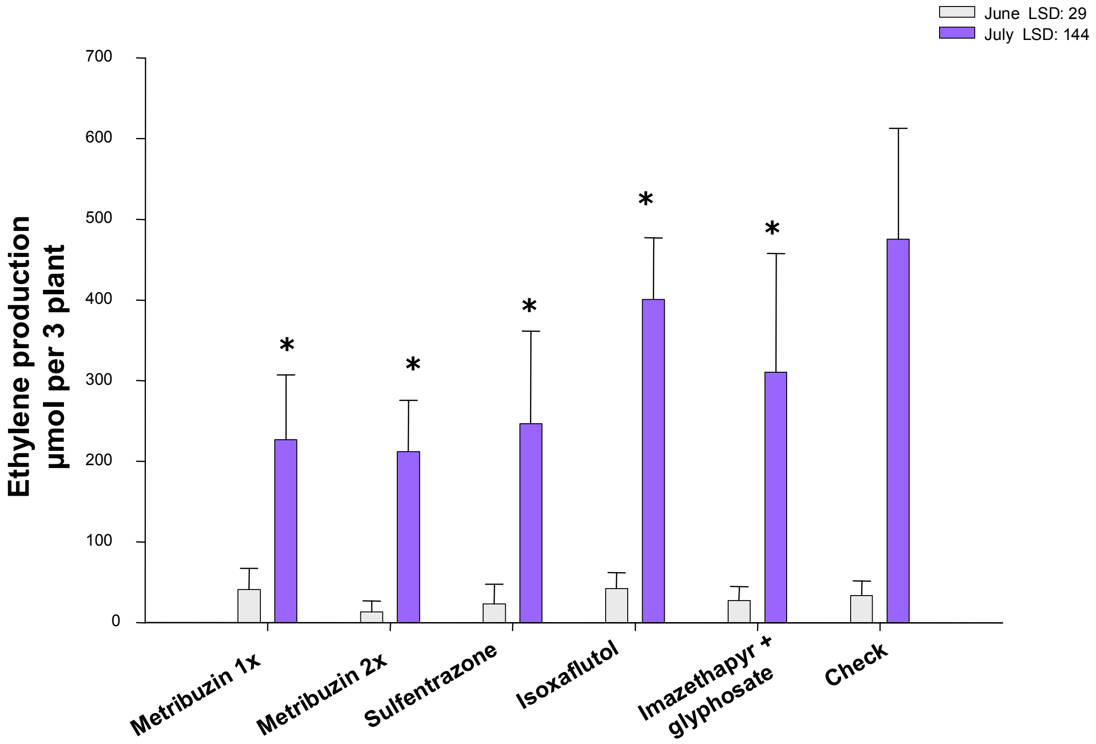
For all “in-crop” field pea trials, any differences in ARA activity that were detected in June were overcome by the July sampling period. Apparently, any damage that the herbicides may have had on the plants, had since been remedied. Typically, the granular treatment was associated with higher nitrogenase activity (Fig 1).



*denotes a significant difference

Figure 1. Nitrogen fixation activity at Beaverlodge for the “in-crop” herbicide treatments

For chickpea, only the metribuzin 1x treatment was a registered treatment. The 2x treatment was a “worse case scenario”, while the others were being evaluated for minor use registration. After the initial herbicide treatments, significant herbicide injury was detected (data not shown) at early growth stages which were exacerbated for the metribuzin at later growth stages (Fig 2). However the amount ethylene produced per nodule weight was the same (Fig 3) and the enzyme was unaffected. Nitrogenase activity, assessed using the ARA, typically reflected overall plant herbicide injury and not the nitrogenase enzyme nor the rhizobia producing it.



*denotes a significant difference

Figure 2. Chickpea ARA assessments

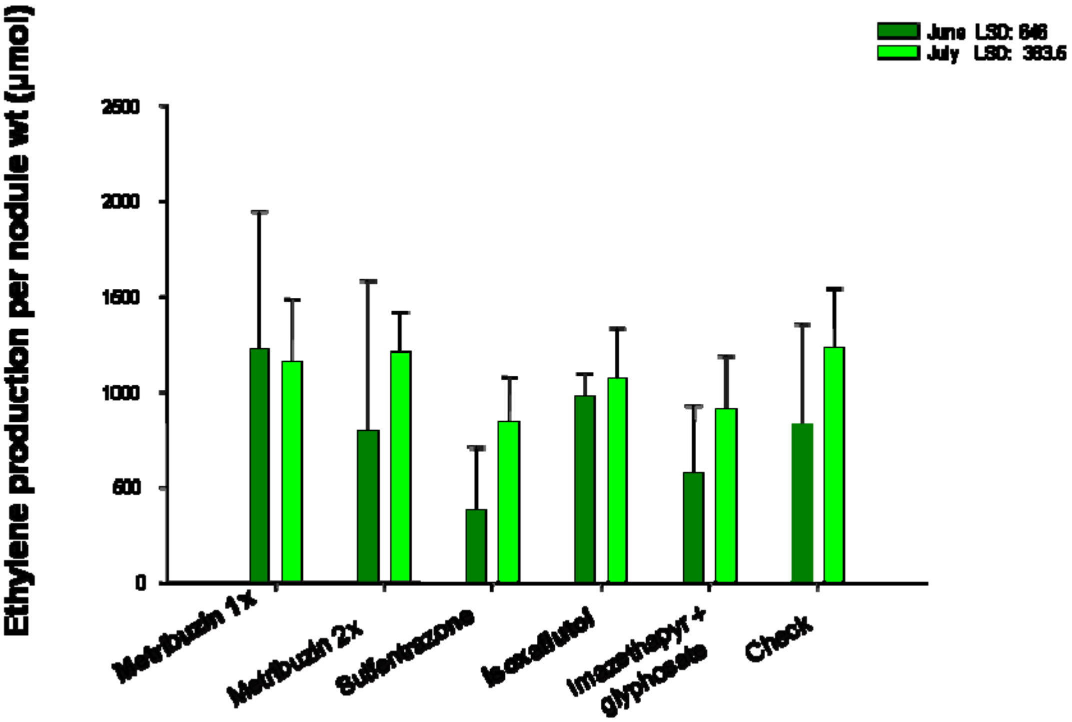


Figure 3. Ethylene production in chickpea per nodule weight

Summary

In field peas, ARA suggest that although there may have been several negative effects on N fixation 10 days after herbicide application, 20 days later, these inhibitions largely were overcome. However, in chickpea, herbicide damage was so severe that by the second sampling period, the plants had not fully recovered and N fixation was significantly less than the check, yet the nitrogenase enzyme was unaffected.

Acknowledgments

I would like to acknowledge the Alberta Pulse Growers and the Saskatchewan Pulse Growers for funding. I am grateful to Dr. Fran Walley for her guidance and assistance and I would like to recognize the Center for Crop Development in Saskatoon (Rick Holm and Ken Sapsford), Agriculture and Agri-Food Canada in Beaverlodge, AB (Newton Lupawi) and Philom Bios for all the assistance they have provided.

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Development of weeding strategies in grain pearl millet and forage pearl millet (*Pennisetum glaucum* [L.] R. Br.)

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Abstract

Pearl millet (*Pennisetum glaucum* [L.] R. Br.) is an interesting crop as it tolerates heat and drought extremes, performs well on poor and acidic soils and has the ability to reduce populations of root-lesion nematode (*Pratylenchus penetrans* [Cobb] Filipjev & Schuur. Stekh.) when included in rotations with susceptible crops. In addition, grain pearl millet stands out by its high nutritional value. However, lack of grass control has so far impeded progress of this crop. The objective of this project is to develop chemical and mechanical weeding strategies leading to the effective control of annual weeds without affecting the yield of grain and forage pearl millet. Treatments consist of s-metolachlor/benoxacor (Dual II Magnum) and pendimethalin (Prowl) applied in early post-emergence of the crop. Harrowing is also considered at the 3 and the 5 leaf stage of the crop. No phytotoxic effect or reduction of plant stand has been noticed in the crop after treatment. In both types of pearl millet, chemical weeding led to yields similar to the hand-weeded control's yield. S-metolachlor/benoxacor controlled annual grasses more efficiently than pendimethalin. In forage pearl millet, use of a half-rate application of s-metolachlor/benoxacor (0,57 kg a.i./ha) led to greater annual grass biomass compared to the use of the full rate recommended for corn. Finally, mechanical weeding did not control annual weeds in an effective way, resulting in grain and forage yield losses.

Développement de stratégies de désherbage dans les cultures de millet perlé grain et de millet perlé fourrager (*Pennisetum glaucum* [L.] R. Br.)

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Résumé

Le millet perlé (*Pennisetum glaucum* [L.] R. Br.) est une culture intéressante pour sa résistance à la sécheresse, son adaptation aux sols sableux et sa capacité à réduire les populations du nématode des lésions (*Pratylenchus penetrans* [Cobb] Filipjev & Schuur. Stekh.) lorsque cultivée en rotation avec des cultures sensibles. Le millet perlé grain se distingue également par sa haute valeur nutritionnelle. Toutefois, l'absence de moyens de répression des monocotylédones annuelles freine la progression de cette culture. L'objectif de ce projet consiste à vérifier l'efficacité de différentes stratégies de désherbage chimique et mécanique afin d'obtenir une répression efficace des mauvaises herbes sans nuire au rendement du millet perlé grain et fourrager. Les traitements consistent en l'application de deux herbicides en postlevée hâtive de la culture, soit le s-métolachlore/benoxacor (Dual II Magnum) et la pendiméthaline (Prowl), et le passage de la herse-étrille aux stades trois et cinq feuilles de la culture. Suite aux traitements, aucun symptôme apparent de phytotoxicité ou de dommage physique n'a été observé sur la culture. Dans les deux types de millet, le désherbage chimique a procuré des rendements équivalents au rendement obtenu dans le témoin désherbé à la main. Le s-métolachlore/benoxacor a réprimé plus efficacement les monocotylédones annuelles que la pendiméthaline. Dans le millet perlé

fourrager, la demi-dose de s-métolachlore/benoxacor (0,57 kg m.a./ha) a entraîné des biomasses plus importantes de monocotylédones annuelles que l'utilisation de la pleine dose. Enfin, le désherbage mécanique n'a pas permis de réprimer efficacement les mauvaises herbes annuelles, ce qui s'est traduit par une baisse de rendement importante.

Introduction

Le millet perlé est cultivé sur 26 millions d'hectares et constitue la céréale de base de 90 millions de personnes vivant en Afrique et sur le subcontinent indien (Andrews et Kumar, 1992). Cette graminée annuelle présente de nombreux avantages agronomiques tels que sa résistance à la sécheresse, son adaptation aux sols sableux à faible fertilité (Andrews et coll., 1996) ainsi que sa capacité à réduire les populations du nématode des lésions lorsque cultivée en rotation avec des cultures de pomme de terre (Bélair et coll., 2005). Le millet perlé grain se distingue par sa haute valeur nutritionnelle. En comparaison avec le maïs, il présente un contenu équivalent en énergie métabolisable pour les non ruminants, une teneur en protéines plus élevée et un excellent profil en acides aminés (Amato et Forrester, 1995). Ce grain de haute qualité peut donc être valorisé dans l'alimentation animale et humaine, notamment pour la production d'œufs riches en oméga-3 (Collins et coll., 1997). D'autre part, le millet perlé fourrager constitue un excellent fourrage annuel, exempt d'acide prussique et peut être utilisé pour le foin sec, l'ensilage ou comme engrais vert.

Il est reconnu que la répression des mauvaises herbes constitue une préoccupation majeure en agriculture puisque d'importantes pertes de rendement et de qualité à la récolte peuvent être observées sans un désherbage efficace. Cette suppression est d'autant plus nécessaire pour les cultures qui s'établissent lentement et qui demeurent peu compétitives face aux mauvaises herbes durant les premiers stades de leur développement, comme c'est le cas pour le millet perlé grain et le millet perlé fourrager. En soumettant le millet perlé grain à une forte pression de mauvaises herbes, Limon-Ortega et coll. (1995) ont observé une baisse du rendement en grain de 25 %. Au Québec, la répression des dicotylédones annuelles dans la culture de millet perlé fourrager peut être assurée par quatre produits herbicides (MAAO, 2004). Quant aux monocotylédones annuelles, des travaux de recherche additionnels s'avèrent nécessaires afin de trouver un herbicide qui soit à la fois efficace contre ce type de mauvaises herbes et surtout sans effet sur le millet. Étant donné que les publications scientifiques à ce sujet sont peu nombreuses et que le peu de moyens de désherbage dans le millet perlé grain et fourrager constitue un facteur limitant pour ces cultures, des efforts doivent être mis de l'avant pour développer des méthodes de désherbage, particulièrement contre les monocotylédones annuelles.

Méthodologie

L'objectif de ce projet consiste à vérifier l'efficacité de différentes stratégies de désherbage chimique et mécanique afin d'obtenir une répression efficace des mauvaises herbes sans nuire au rendement du millet perlé grain et fourrager. Les traitements consistent en l'application de deux herbicides en postlevée hâtive de la culture, soit le s-métolachlore/benoxacor (Dual II Magnum) et la pendiméthaline (Prowl), et le passage de la herse-étrille aux stades trois et cinq feuilles de la culture. Pour les deux matières actives herbicides, la pleine dose et la moitié de la dose recommandée dans le maïs grain sont considérées. Les parcelles ont été mises en place en 2005 et en 2006 à la station agronomique de l'Université Laval à St-Augustin (Québec) sur un loam sableux (59,5 % de sable, 33,6 % de limon, 6,9 % d'argile) comportant 3,6 % de matière organique. Un labour d'automne, suivi d'un faux-semis à la mi-mai et de deux passages de vibroculteur ont été effectués avant le semis. Le millet perlé grain et le millet perlé fourrager ont été ensemencés au début de juin en rangs espacés de 18 cm à raison de 14 grains et de 27 grains par mètre linéaire respectivement. Les traitements chimiques, soit les traitements 3 à 6 (tableaux 1 et 2), ont reçu une application de bentazone (Basagran Forte) à raison de 1,08 kg m.a./ha au stade trois feuilles du millet pour réprimer les dicotylédones annuelles. Diverses variables ont été évaluées soit le peuplement du millet, le pourcentage de recouvrement et de répression des mauvaises herbes, la densité et la biomasse aérienne sèche des mauvaises herbes par classe (dicotylédones annuelles (DA) et monocotylédones annuelles (MA)) et le rendement en grain ou en fourrage de la culture. Chacun des traitements a été répété quatre fois selon un dispositif en blocs complets aléatoires. Les données ont été soumises à l'analyse de la variance. Les traitements ont été comparés entre eux selon des contrastes établis à priori. Seules les données de 2005 sont présentées.

Résultats

Millet perlé grain

Suite aux traitements, aucun symptôme apparent de phytotoxicité ou de dommage physique n'a été observé sur la culture. Le peuplement du millet n'était pas significativement différent selon les traitements (valeurs non présentées). Le désherbage chimique a permis de diminuer de façon importante la pression des mauvaises herbes, ce qui a résulté en des rendements équivalents au rendement obtenu dans le témoin désherbé à la main (tableau 1). Le s-métolachlore/benoxacor tend à réprimer plus efficacement ($\alpha = 0{,}0817$) les monocotylédones annuelles que la pendiméthaline. Enfin, le désherbage mécanique n'a pas permis de réprimer efficacement les mauvaises herbes, ce qui s'est traduit par une baisse de rendement importante.

Tableau 1. Moyennes des traitements et valeurs de *p* des contrastes établis à priori pour la culture de millet perlé grain (2005).

No.	**Traitements**	**Stade[a]**	**Dose (kg m.a./ha)**	**Recouvrement des mauvaises herbes (%)**	**Biomasse des MH[bc] (g/m^2)**		**Rendement en grain (kg m.s./ha)**
					DA	**MA**	
				25-juil	**28-juil**		**12-oct**
1	**Témoin enherbé**			36	128.3	53.8	517
2	**Témoin désherbé à la main**			0	0	0	2 575
3	**S-métolachlore/benoxacor**	Post 1	0.57	3	9.6	2.8	2 447
4	**S-métolachlore/benoxacor**	Post 1	1.14	2	3.4	0.8	2 124
5	**Pendiméthaline**	Post 1	0.84	4	2.5	29.4	2 439
6	**Pendiméthaline**	Post 1	1.68	2	2.4	12.5	2 310
7	**Herse-étrille**	3 F		30	110.5	35.8	664
8	**Herse-étrille**	5 F		43	183.9	35.2	441
9	**Herse-étrille**	3 F et 5 F		34	111.7	21.9	876

Contrastes établis à priori	**Valeur *p***			
Témoin désherbé à la main vs. Traitements chimiques	N.S.	**0.0002**	**0.0243**	N.S.
Témoin désherbé à la main vs. Traitements mécaniques	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Témoin enherbé vs. Traitements chimiques	**<0.0001**	**<0.0001**	**0.0022**	**<0.0001**
Témoin enherbé vs. Traitements mécaniques	N.S.	N.S.	N.S.	N.S.
S-métolachlore/benoxacor vs. Pendiméthaline	N.S.	N.S.	*0.0817*	N.S.
0,57 kg m.a./ha vs. 1.14 kg m.a./ha S-métolachlore/benoxacor	N.S.	N.S.	N.S.	N.S.
0.84 kg m.a./ha vs. 1.68 kg m.a./ha Pendiméthaline	N.S.	N.S.	N.S.	N.S.
Herse-étrille stade 3 feuilles vs. Herse-étrille stades 3 et 5 feuilles	N.S.	N.S.	N.S.	N.S.
R^2	0.97	0.95	0.71	0.91

[a] Post 1: 2 feuilles de la culture, 3 F: 3 feuilles de la culture, 5 F: 5 feuilles de la culture.

[b] MH: mauvaises herbes, DA: dicotylédones annuelles, MA: monocotylédones annuelles.

[c] Les données de biomasses de mauvaises herbes ont subi une transformation logarithmique, [log (x + 1)], pour l'analyse statistique.

Millet perlé fourrager

Aucun symptôme apparent de phytotoxicité ou de dommage physique n'a été observé sur la culture suivant les traitements. Le peuplement du millet est le même quel que soit le traitement considéré (valeurs non présentées). Le désherbage chimique a assuré une bonne répression des mauvaises herbes conduisant ainsi à des rendements équivalents à celui obtenu dans le témoin désherbé à la main (tableau 2). Le s-métolachlore/benoxacor a réprimé plus efficacement les monocotylédones annuelles que la pendiméthaline. La demi-dose de s-métolachlore/benoxacor (0,57 kg m.a./ha) a entraîné des biomasses plus importantes de monocotylédones annuelles que l'utilisation de la pleine dose. La pleine dose (1,68 kg m.a./ha) de pendiméthaline a procuré des rendements significativement inférieurs à la demi-dose de pendiméthaline. Par contre, cette différence n'est pas attribuable à la phytotoxicité du produit sur la culture puisque aucun symptôme n'a été noté à cet effet. Les traitements de herse-étrille n'ont pas permis de réprimer efficacement les mauvaises herbes, ce qui s'est traduit par une baisse de rendement importante.

Tableau 2. Moyennes des traitements et valeurs de *p* des contrastes établis à priori pour la culture de millet perlé fourrager (2005).

				Recouvrement des mauvaises herbes	**Biomasse des MH[bc] (g/m^2)**		**Rendement cumulatif en fourrage**
			Dose	**(%)**	**DA**	**MA**	**(kg m.s./ha)**
No.	**Traitements**	**Stade[a]**	**(kg m.a./ha)**	**25-juil**	**26-juil**		**09-sept**
1	**Témoin enherbé**			45	139.4	187.0	4 962
2	**Témoin désherbé à la main**			0	0	0	8 273
3	**S-métolachlore/benoxacor**	Post 1	0.57	6	5.3	43.7	8 118
4	**S-métolachlore/benoxacor**	Post 1	1.14	5	5.7	5.0	7 643
5	**Pendiméthaline**	Post 1	0.84	8	4.8	82.5	8 758
6	**Pendiméthaline**	Post 1	1.68	5	0.2	63.3	6 937
7	**Herse-étrille**	3 F		39	97.5	146.3	4 991
8	**Herse-étrille**	5 F		43	115.9	204.4	4 747
9	**Herse-étrille**	3 F et 5 F		41	99.1	177.6	5 823

Contrastes établis à priori	**Valeur *p***			
Témoin désherbé à la main vs. Traitements chimiques	**0.0410**	**0.0133**	**<0.0001**	N.S.
Témoin désherbé à la main vs. Traitements mécaniques	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
Témoin enherbé vs. Traitements chimiques	**<0.0001**	**<0.0001**	**0.0006**	**0.0002**
Témoin enherbé vs. Traitements mécaniques	N.S.	N.S.	N.S.	N.S.
S-métolachlore/benoxacor vs. Pendiméthaline	N.S.	N.S.	**0.0030**	N.S.
0,57 kg m.a./ha vs. 1.14 kg m.a./ha S-métolachlore/benoxacor	N.S.	N.S.	**0.0020**	N.S.
0.84 kg m.a./ha vs. 1.68 kg m.a./ha Pendiméthaline	N.S.	N.S.	N.S.	**0.0357**
Herse-étrille stade 3 feuilles vs. Herse-étrille stades 3 et 5 feuilles	N.S.	N.S.	N.S.	N.S.
R^2	0.95	0.91	0.87	0.74

[a] Post 1: 2 feuilles de la culture, 3 F: 3 feuilles de la culture, 5 F: 5 feuilles de la culture.

[b] MH: mauvaises herbes, DA: dicotylédones annuelles, MA: monocotylédones annuelles.

[c] Les données de biomasses de mauvaises herbes ont subi une transformation logarithmique, [log (x + 1)], pour l'analyse statistique.

Discussion

Les essais effectués en 2005 démontrent que l'application en postlevée hâtive de la culture de s-métolachlore/benoxacor et de pendiméthaline pourrait être envisagée pour réprimer les monocotylédones annuelles dans les cultures de millet perlé. Par contre, les traitements de herse-étrille n'ont pas permis de réprimer efficacement les mauvaises herbes annuelles, ce qui a résulté en des baisses de rendement significatives. L'efficacité du désherbage mécanique contre les mauvaises herbes annuelles est reconnue dans les céréales à paille à condition que les instruments de désherbage tels que la herse-étrille soient passés au bon moment, idéalement au stade cotylédons pour les dicotylédones annuelles et au stade première feuille pour les monocotylédones annuelles (Douville et Coulombe, 2002). En 2005, des précipitations abondantes ont suivi le semis, ce qui a retardé l'exécution des traitements de désherbage mécanique. Au moment des passages de la herse-étrille, les mauvaises herbes étaient à des stades de croissance bien au-delà des stades recommandés. Ceci peut donc expliquer en partie l'inefficacité de ces traitements. En 2006, bien que les passages de herse-étrille aient été effectués lorsque les mauvaises herbes étaient au stade approprié, les parcelles sont demeurées très enherbées (données non présentées). D'autres facteurs peuvent expliquer l'inefficacité de la herse-étrille dans la culture du millet perlé. Contrairement aux céréales à paille, le millet perlé s'établit très lentement et la densité de semis est très faible, ce qui rend cette culture peu compétitive face aux mauvaises herbes en début de saison. De plus, bien que le but premier de la herse-étrille soit la destruction des mauvaises herbes, le bouleversement du sol provoqué par son passage pourrait stimuler la germination de nouvelles semences de mauvaises herbes. Par conséquent, il importe de bien connaître l'historique d'un champ en terme de pression de mauvaises herbes afin de prendre une décision éclairée quant à la stratégie à emprunter pour obtenir un bon désherbage. Le désherbage mécanique pourrait possiblement convenir à des champs dont la pression de mauvaises herbes est peu importante.

Une combinaison de plusieurs techniques de désherbage pourrait être une solution au présent problème de désherbage dans la culture de millet perlé. Compte tenu que le millet se sème plus tardivement vu sa sensibilité aux températures froides, il est possible de miser sur la technique du faux semis pour parvenir à réprimer la première cohorte de mauvaises herbes. On peut faire suivre le faux-semis d'une application d'un herbicide non sélectif, s'il y a présence de vivaces, ou retravailler le sol avant le semis. D'après les résultats obtenus dans ces essais, le s-métolachlore/benoxacor et la pendiméthaline pourraient être des herbicides envisageables pour réprimer les monocotylédones annuelles en postlevée hâtive dans cette culture. Les résultats de 2006 permettront de confirmer cette éventuelle possibilité.

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Posters

As in the past, some abstracts only were submitted while exceptionally,
some complete posters were also submitted.

The following posters were presented but their abstracts were lost in a hard disk crash.

P. Forsythe. Sulfonylurea usage for control of white cockle.
E.N. Johnson and D.J. Ulrich. Optimizing sulfentrazone rate in chickpea.
E.N. Johnson, D.J. Ulrich, R.E. Blackshaw, K.L. Sapsford, and F.A. Holm. Effect of isoxaflutole application timing on weed control in chickpea.
C. Lindgren. A Canadian Invasive Plant Strategy.
C. Lindgren. Jointed Goat Grass Invasive Plant Alert.
M. Entz and H. Flood. Weed suppressing effects of fall rye (Secale) cover crops in edible bean production
S.J. Shirtliffe, E.J. Johnson. The tolerance of cereal crops to in-crop harrowing.

Inhibitory effect of tall hedge mustard (*Sisymbrium loeselii* L.) allelopathic secondary metabolites on arbuscular mycorrhizal fungi.

Bainard, L.D.[1], Brown, P.D.[2], Upadhyaya, M.K.[1] [1]University of British Columbia, Vancouver, BC; [2]Trinity Western University, Langley, BC

Tall hedge mustard (*Sisymbrium loeselii* L.) is a common weed of southern British Columbia where it can form dense stands when well established. Similar to most plants in the mustard (Brassicaceae) family, tall hedge mustard contains glucosinolates (GSLs). The breakdown products of GSLs are associated with the phytotoxic, anti-microbial and anti-fungal properties of mustard plants and include isothiocyanates (ITCs), organic cyanides, oxazolidinethiones, and ionic thiocyanate. The objectives for this study were to identify the GSLs and their subsequent degradation products in tall hedge mustard, investigate their effect on arbuscular mycorrhizal (AM) fungal spore germination and hyphal growth, and determine the effect of tall hedge mustard infestations on AM inoculum potential. The two major GSLs identified in the root and shoot tissues of tall hedge mustard were isopropyl GSL and *sec*-butyl GSL. The shoots contained significantly higher concentrations of both GSLs. The degradation products of both these GSLs (isopropyl ITC and *sec*-butyl ITC) were identified in the root and shoot extracts. Tall hedge mustard aqueous root and shoot extracts and whole plant leachate inhibited spore germination and hyphal growth of *Glomus intraradices* Shenck & Smith. Isopropyl ITC and *sec*-butyl ITC inhibited spore germination, causing complete inhibition at 1.0 mM concentration; isopropyl ITC had a significantly stronger effect on spore germination at 0.5 and 0.1 mM concentrations. Hyphal growth was significantly inhibited by both ITCs at 0.5 and 1.0 mM concentrations, with isopropyl ITC causing greater inhibition. AM inoculum potential of tall hedge mustard infested soils was significantly lower compared to noninfested soils. The results of this study indicate that tall hedge mustard produces allelochemicals that inhibit AM fungi spore germination and hyphal growth, and tall hedge mustard infestations decrease the AM inoculum potential of soil.

Acetolactate synthase inhibitor-resistant stinkweed (*Thlaspi arvense* L.) in Alberta.

Beckie, H.J.[1], Hall, L.M.[2], Tardif, F.J.[3], and Séguin-Swartz, G[1]. [1]Agriculture and Agri-Food Canada, Saskatoon, SK; [2]Alberta Agriculture, Food and Rural Development/University of Alberta, Edmonton, AB; [3]Department of Plant Agriculture, University of Guelph, Guelph, ON

Two stinkweed populations from southern and central Alberta were not controlled by acetolactate synthase (ALS)-inhibiting herbicides in 2000. This study reports on their cross-resistance to ALS-inhibiting herbicides, molecular basis of resistance, and inheritance of resistance. Both putative herbicide-resistant biotypes responded similarly to increasing doses of the herbicides. The biotypes were highly resistant to ethametsulfuron and exhibited a low level of resistance to metsulfuron and imazethapyr. However, both biotypes were not resistant to florasulam, a triazolopyrimidine ALS inhibitor, or sulfometuron, a non-selective sulfonylurea ALS inhibitor. The cross-resistance pattern was consistent with the confirmed target-site mutation. Sequence analysis of the *ALS* gene detected a Pro_{197}Leu mutation in both biotypes. Similar to many other ALS inhibitor-resistant weed biotypes, resistance was conferred by a single dominant gene. This study confirms the first global occurrence of herbicide resistance in this species.

Does soil nitrogen level affect herbicide efficacy? Blackshaw, R.E. and Brandt, R.N. Agriculture and Agri-Food Canada, Lethbridge, AB

Field experiments were conducted at the Lethbridge Research Centre in 2004 and 2005 to determine if soil fertility affects herbicide activity on weeds. The factorial set of treatments in experiment 1 consisted of a) soil N level (30 or 110 kg ha^{-1}) and b) flucarbazone dose (0, 3.75, 7.5, 15, or 30 g ai ha^{-1}). Experiment 2 treatments consisted of a) soil N level (30 or 110 kg ha^{-1}) and b) sulfosulfuron dose (0, 2.5, 5, 10 or 20 g ai ha^{-1}). Herbicides were applied at a spray volume of 100 L ha^{-1} with a bicycle sprayer to wild oat at the 3 to 4 leaf stage growing in AC Barrie spring wheat. Herbicide efficacy was determined three weeks after herbicide application by taking aboveground wild oat dry weight biomass. Flucarbazone at lower than recommended doses was often more efficacious (17 to 28% greater) on wild oat at high compared with low soil N levels. However, flucarbazone efficacy at the recommended dose of 30 g ha^{-1} was not affected by soil N fertility. Wild oat control was greater with high than with low soil N at all sulfosulfuron doses in 2004 and with the three lower than recommended doses in 2005. Wild oat control with sulfosulfuron ranged from 7 to 38% higher with high compared with low soil N levels. The question remains as to how transferable are these results to other herbicides or other weed species. Additional research is clearly warranted.

Optimization of water activity and placement of "Pesta-*Pseudomonas fluorescens* BRG100" - biocontrol of green foxtail. Boyetchko S.M.,[1*] Hynes, R.K., Sawchyn, K., Hupka, D., and Geissler, J. [1]Agriculture & Agri-Food Canada, 107 Science Place, Saskatoon, SK. S7N 0X2

Pseudomonas fluorescens BRG100 was selected from earlier screening studies for pre-emergent bioherbicidal activity to green foxtail and wild oat. A granular formulation, Pesta, has been developed to deliver *P. fluorescens* BRG100. Delivery and placement of sufficient numbers of BRG100 to inhibit or suppress germination of the weed is one of the key challenges in bioherbicide product development. However, optimization of BRG100 survival, placement and dispersion from the Pesta granule in the target zone has not been fully established. Increased shelf-life of BRG100 in Pesta may be acquired by increasing BRG100 cell membrane integrity, optimizing the water activity of the granules (a_w), a useful measure of the free (unbound) water that is available for use by microorganisms. Addition of maltose, 3% w/w, reduced survival of BRG100 in peat culture and in Pesta granules prepared from peat powder cultures as compared to peat powder culture and resulting Pesta without maltose. Survival of BRG100 in Pesta was greatest with the water activity (a_w) adjusted to 0.2 as compared to 0.5 a_w and 0.8 a_w. Placement of Pesta in-row and side-banded with green foxtail was examined in a greenhouse study. Evidence of phytotoxin damage to green foxtail by Pseudophomins A and B was observed.

Investigation of allelopathic phenolics exuded from roots of *Verbesina encelioides*. Campbell, K.R., and Clements, D.R. Biology and Environmental Studies, Trinity Western University, Langley, BC

Verbesina encelioides (Cav.) Benth. & Hook. f. ex A. Gray, golden crownbeard (Asteraceae), has been reported to contain allelopathic phenolic chemicals. We used High Performance Liquid Chromatography (HPLC) to monitor exudation of phenolic chemicals over time in rhizosphere solution of *V. encelioides* plants in soil and soil-less solution. Phenolics were not found in the rhizosphere solution or in the soil surrounding the roots of the plant. Bioassays were preformed by germinating cultivated radish seeds (*Raphanus sativus)* with the root exudate of *V. encelioides*. Average radish wet weight was 0.085 g for seeds germinated in exudate and 0.071 g for seeds germinated in deionized water. The increased wet weight in the bioassay group may have been due to low concentrations of allelopathic phenolics or to fertilizer present in the hydroponic solution. Chemoassays were conducted on radish plants using 13 different phenolics. Individual phenolics decreased radish wet weight while a mixture of all 13 phenolics increased radish wet weight particularly at 250 and 500µm. Further investigation is required to assess allelopathic potential; the release of the phenolics may occur only at low concentrations and at a specific points in the life cycle of *V. encelioides*, and may depend on plant size (the plants tested were not as vigorous as those observed in the field).

Formulation of *Colletotrichum truncatum* into complex coacervate - biocontrol of scentless chamomile, *Matricaria perforate.* Chumala, P., Hynes, R.K., Hupka, D., Peng, G. Agriculture & Agri-Food Canada, 107 Science Place, Saskatoon, SK. S7N 0X2, Canada hynesr@agr.gc.ca, chumalap@agr.gc.ca

Colletotrichum truncatum (schwein.) Andrus and W. D. Moore is a phytopathogenic fungus to scentless chamomile, *Matricaria perforate* Mérat, a noxious weed in western Canada. High virulence and host specificity of the fungus toward scentless chamomile allowed considering it as a potential candidate for weed biocontrol. Microencapsulation of *C. truncatum* conidia in a complex coacervate has been investigated. Complex coacervates have been widely used as a microencapsulation technique for oil-dispersible active ingredients in the pharmaceutical and food industries. Conidia of *C. truncatum* are hydrophilic and oil-indispersible, therefore, an initial formulation step of suspending them in a water/oil invert emulsion was required before encapsulating in a complex coacervate. To maximize % conidial encapsulation, parameters such as wall materials i.e. protein-polysaccharide, stirring speed, surfactants, and conidial suspension to oil ratios were optimized. Weed control efficacy of the formulations was determined on scentless chamomile at the 6-8 leaf stage both under greenhouse and field conditions. In addition, the synergistic effect between the *C. truncatum* formulation and the herbicide Sencor® was evaluated. Here, our new approach to formulate *C. truncatum* in a complex coacervate and the efficacy assay results are presented and implications for controlling scentless chemomile are discussed.

Weed Alert: *Bromus secalinus* L. in Ontario. Stephen Darbyshire, Agriculture and Agri-Food Canada, Eastern Cereal and Oilseed Research Centre, Ottawa, Ontario, K1A 0C6 and Michael Cowbrough, Ontario Ministry of Agriculture, Food, and Rural Affairs, Field Crops, Crop Science Bldg., University of Guelph, Dept of Plant Agriculture, Guelph, Ontario, N1G 2W1

Cheat is an annual or winter annual weed of cereals reproducing entirely through seeds. Originating in the Mediterranean region, it has been introduced to many areas of the World. In arable fields it is most frequently associated with winter wheat. Throughout most of its range in Canada it is sporadic, but sometimes occurs in high densities. In southern Ontario it is usually considered rare or ephemeral, but large outbreaks can occur locally causing considerable production and market losses. The cause of local infestations is unknown, but may be due to, or exacerbated by, cultural practices, seed source, climate and/or historical factors. Seeds of are restricted in 13 US States and prohibited in India and The Republic of China. Although a few herbicide options exist in western Canada none are currently registered in Ontario.

Characteristics useful in the identification of *Bromus secalinus* include: stems 30 - 90 cm tall, finely hairy only on the nodes; the leaf sheaths are smooth or the lower ones hairy, with small, claw-like auricles; the inflorescence is a panicle with rather stiff, nearly erect branches; the florets are 6.5-8.5 mm long, hairless and awnless or with short, more or less straight awns; the seeds are strongly U-shaped in cross-section.

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Ontario

Weed Alert: *Bromus secalinus* L. in Ontario

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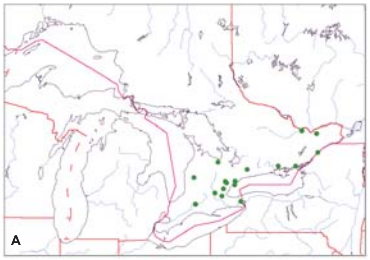
English names:	**cheat, cheatgrass, cheat chess, chess, chess brome, rye brome**
French names:	**brome des seigles, brome sécalin, coquiole noire, séglin, seigle bâtard, brome faux seigle, brome faux-seigle, seiglin**
BAYER code:	**BROSE**

Cheat is an annual or winter annual weed of cereals reproducing entirely through seeds. Originating in the Mediterranean region, it has been introduced to many areas of the World including Australia, central Asia (including Russia), Japan, northern Europe, South America and North America.

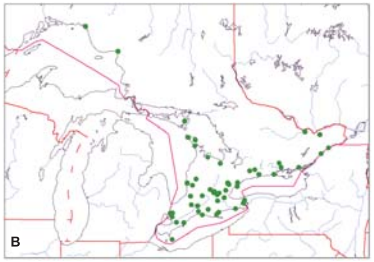
In Canada it is known from the Yukon, Newfoundland (but not Labrador), Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Manitoba (uncertain), Alberta and British Columbia (Darbyshire 2003). Throughout most of its range in Canada it is sporadic in occurrence, but sometimes occurs in high densities.

Although not considered a common weed in Ontario today, it was more prevalent 50-100 years ago prior to modern seed cleaning techniques. Dore & McNeill (1980) state, "Formerly a serious weed in the wheat-growing areas of the southwestern counties, *Bromus secalinus* occurs elsewhere only temporarily along roadways and in waste ground." The first documented record in the province is at Prescott in 1860, but it is likely to have been present earlier since records do not go much before this time. Over the years it has been detected over much of southern Ontario (Map C), but is usually considered rare or ephemeral in its occurrence. In arable fields it is most frequently associated with winter wheat, but it also occurs in other rotational crops, especially cereals (e.g., rye, oats, etc.).

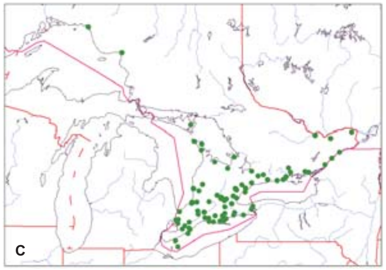
Herbarium records are limited in their utility to assess the prevalence of agricultural weeds, but indicate a scattered occurrence in low numbers along roads and at the edges of fields throughout much of southern Ontario. Large outbreaks can occur locally causing considerable losses, as indicated in the label comments on some herbarium specimens such as, "a large infestation" in a field at Galt (1951) and "20% cover in grain field" at Trenton (1951). Whether the occurrence of large infestations is due to, or exacerbated by, cultural practices, seed source, climate and/or historical factors is unknown.



Occurrences of *Bromus secalinus* in Ontario prior to 1900



Occurrences of *Bromus secalinus* in Ontario prior to 1950



All known occurrences of *Bromus secalinus* in Ontario

Agricultural Significance: Field studies in Oklahoma have shown 28-48% yield loss when winter wheat was competing with an average density of 25 plants per m^2 (Medlin et al. 2003) and that there is a direct 1:1 ratio between cheat production and wheat reduction (Anderson and Medlin 2005). Seeds of *Bromus secalinus* are restricted in several US States and prohibited in India and The Republic of China. Therefore any amount of *Bromus secalinus* found in grain commodities could have trade implications.

Noxious Weed Designation: Bromus secalinus is recognized as a noxious weed seed under the U.S. Federal Seed Act which sets a tolerance of up to 300 seeds per pound of certified seed in the following American States (United States Department of Agriculture 2002): Alabama, Arkansas. Delaware, Florida, Georgia, Kansas, Louisiana, Mississippi, New Jersey, Oklahoma, South Carolina, Tennessee, and Texas.

Chemical Control: Although a few herbicide options exist in western Canada and the United States, none are currently registered in Ontario. The following herbicides have proven to be effective on *Bromus secalinus* in Oklahoma (Medlin et al. 2003): metribuzin (Trade Name: Sencor); flucarbazone (Trade Name: Everest); sulfosulfuron (Trade Name: Sundance, Maverick)

Figure 1
Bromus secalinus L. Cheat. **A**, habit-x0.5; **B**, spikelet- x2.5 **C**, ligule-x1.5, **D**, floret, 3 views-x3; **E**, caryopsis-x3

Identification:
Stems: 30 - 90 cm tall, smooth but finely hairy on the nodes. Node hairiness is only visible with magnification (Fig. 2).
Leaves: 3 - 9 mm wide, either smooth or softly hairy on either or both surfaces (Fig. 1C, 2). The leaf sheaths smooth or lower ones hairy; leaf sheaths usually closed (margins united) nearly to the top (Fig. 1C).
Auricles: Usually present, small and claw-like (Fig. 2).
Ligule: Membranous, 1 - 2 mm long (Fig. 1C, 2).
Inflorescence: A panicle with rather stiff, nearly erect branches (Fig. 1A, 3)
Spikelets: Have a firm, plump appearance, 1 - 3 cm long, 6 - 10 mm wide, each spikelet having 5 to 15 seeds (Fig. 1B, 3).
Florets: 6.5-8.5 mm long, hairless and awnless or with short, more or less straight awns 3-8 mm long (Fig. 1D).
Grain: As long as and adhering to the lemma and palea, with a brush of hairs at the apex (Fig. 1E) and strongly in-rolled with a deep longitudinal grove on the adaxial surface, i.e., U-shaped in cross-section (Fig. 4)


Figure 2
Stem showing finely hairy node (above) and claw-like auricle (below)


Figure 3
Portion of the inflorescence


Figure 4
Cross sections through a grain (scale in millimetres)

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Canada

The Biology of Invasive Alien Plants in Canada: ***A New Series of Review Papers.*** Stephen Darbyshire and Suzanne I. Warwick. Agriculture and Agri-Food Canada, Eastern Cereal and Oilseed Research Centre, Ottawa, Ontario

A new series, *The Biology of Invasive Alien Plants in Canada*, was initiated in 2003 in the Canadian Journal of Plant Science. It is intended as a companion series to the long-running *Biology of Canadian Weeds* which appears in the same journal. Five species accounts have been published and nine more are in preparation. The series of peer-review contributions is designed to review the biology of recently introduced plant species that pose a demonstrable economic or environmental risk in Canada. Presently an estimated 1-2 new alien plant species are becoming established in Canada each year and this rate is expected to increase. These new pests are generally poorly known and their weedy potential unrecognized. As well as summarizing current knowledge, contributions to the series will serve as alerts of emerging problems, emphasizing aspects of identification, occurrence, impact, effective control methods and future prognosis. The series will also engender research to fill important gaps in our knowledge. Plant species covered in the series must occur in Canada, but contributing authors need not. For more information on the series, submission process and instructions to authors, see the Canadian Weed Science Society web site (http://www.cwss-scm.ca/Biology_of_weeds/invasive.htm) or contact the associate editor at warwicks@agr.gc.ca for a pdf file.

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The Biology of Invasive Alien Plants in Canada: *A New Series of Review Papers*

Stephen Darbyshire and Suzanne I. Warwick

Agriculture and Agri-Food Canada, Eastern Cereal and Oilseed Research Centre, Ottawa, Ontario

ABSTRACT:

A new peer-review series: *The Biology of Invasive Alien Plants in Canada* was initiated in 2003 in the Canadian Journal of Plant Science. To date, four species accounts have been published and eleven additional species have been assigned.

BACKGROUND:

The Series is designed to review various aspects of the biology of recently introduced or adventive 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, but the rate of introduction and establishment is expected to increase (Darbyshire 2002). Many of these new allen plants are likely to become widespread problematic weeds in the future. These new plants 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 impacts. 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.

OFFERS OF CONTRIBUTION:

Species covered in the series must be established in Canada, although account authors need not be. Offers of contribution to the series should be made to the associate editors, presently Suzanne Warwick and Stephen Darbyshire. For more information on the submission process and instructions to authors, see the Canadian Weed Science Society web site, Warwick et al. (2003) or contact warwicks@agr.gc.ca for a pdf file.

ACCOUNTS TO DATE:

PUBLISHED:	**Common name**
#1 *Eriochloa villosa* (Thunb.) Kunth	wooly cup grass
#2 *Cynanchum louiseae* (L.) Kartesz & Gandhi	black dog-strangling vine
Cynanchum rossicum (Klepow) Borhidi	dog-strangling vine
#3 *Amaranthus tuberculatus* (Moq.) Sauer var. *rudis* (Sauer) Costea & Tardif	water hemp
#4 *Heracleum mantegazzianum* Sommier & Levier	giant hogweed
#5 *Polygonum cuspidatum* Sieb. & Zucc.	Japanese knotweed
IN PRESS:	
Berteroa incana (L.) DC.	hoary alyssum
SPECIES ASSIGNED:	
Ailanthus altissima (Mill.) Swingle	tree-of-heaven
Cabomba caroliniana A. Gray	fanwort
Daphne laureola L.	spurge laurel
Glyceria maxima O.R. Holmberg	rough manna grass
Impatiens glandulifera Royle	Himalayan balsam
Lepidium latifolium L.	Perennial pepper-grass
Lonicera maackii (Rupr.) Herder	Amur honeysuckle
Rosa multiflora Thunb. ex Murray	multiflora rose
Trapa natans L.	water chestnut

Polygonum cuspidatum

Rosa multiflora

FORMAT:

1. **Species Name and Taxonomic Relationships**
2. **Description and Account of Variation**
3. **Economic Importance and Environmental Impact**
4. **Geographical Distribution**
5. **Habitat**
6. **History**
7. **Growth and Development**
8. **Reproduction**
9. **Hybrids**
10. **Population Dynamics**
11. **Response to Herbicides and Other Chemicals**
12. **Response to Other Human Manipulations**
13. **Response to Herbivory, Disease and Higher Plant Parasites**
14. **Prognosis**

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Heracleum mantegazzianum

Cabomba caroliniana

Trapa natans

Berteroa incana

Cynanchum rossicum

Effects of timing and rate of perennial ryegrass (*Lolium perenne* L.) on weed suppression in established turfgrass. Evan M. A. Elford, Darren E. Robinson, François J. Tardif, and Eric M. Lyons. Department of Plant Agriculture, University of Guelph, Guelph, Ontario N1G 2W1

Over 115 municipalities in Canada have restricted or introduced legislation banning the use of herbicides. Optimising cultural management practices, such as overseeding, could provide an extra weed control option for turfgrass managers. Perennial ryegrass (*Lolium perenne* L.) is typically used in overseeding programs with established Kentucky bluegrass (*Poa pratensis* L.) as it is quick to germinate and establish and blends well in colour and growth habit. There are concerns, however, about perennial ryegrass winter hardiness and the possibility of it becoming a weedy species on athletic fields.
Trials were conducted between spring 2005 and fall 2006 at the Guelph Turfgrass Institute to assess establishment of perennial ryegrass and overseeding efficacy for weed control.
Twenty one irrigated and non-irrigated overseeding treatments were applied during each growing season combining rates (2, 4, and 8 kg $100m^{-2}$) and timings (May, June, and September) of perennial ryegrass into established Kentucky bluegrass athletic turf. Weed and turf cover was assessed four times each year using a randomised point quadrat. Plant species was recorded at each point.
Preliminary results show that perennial ryegrass populations significantly increased in all overseeding treatments. Timing of overseeding was found to be most effective for weed control when treatments were applied in May and September. These results will help facilitate turf managers in maintaining field in integrity through competition by preventing encroachment and degradation by weedy species. Concerns regarding perennial ryegrass becoming the dominant species on athletic turf are still valid.

Control of the invasive perennial weed *Galium Mollugo* in pastures with selective herbicides. Ivany, J.A.[1], and Rodd, V.[2] [1]Agriculture and Agri-Food Canada (AAFC), Crops and Livestock Research Centre, Charlottetown, PE. [2]Agriculture and Agri-Food Canada (AAFC), Nappan Research Farm, Nappan, NS.

The invasive perennial weed smooth bedstraw (*Galium mollugo* L.) over the past 30 years has spread throughout the Maritime provinces and is commonly seen along roadsides from where it spreads into pastures making them useless for grazing. The plant is toxic to cattle and if consumed affects weight gain and in dairy cattle milk production. Non-selective herbicides will kill it down and reseeding is possible, but with the large seed bank, re-infestation occurs quickly. Growers do not want to lose pasture for several months so effective selective herbicides are needed for use in early summer to give control without loss of pasture usage. We evaluated the selective herbicides MCPA, mecoprop and dicamba alone and in mixtures, clopyralid, and triclopyr for control of smooth bedstraw. Herbicides were applied in early June to bedstraw 15 – 30 cm tall applying 200 L/ha at 207 kPa. Control was evaluated monthly after application and in June of following year. Biomass of bedstraw and grass spp was obtained late August of the application year. In 2002-2003 and 2004-2005 mecoprop (2.0 kg/ha) and dicamba + mecoprop (1.0 + 0.75 kg/ha) controlled smooth bedstraw for the growing season but neither controlled it into the second season. The other herbicide mixtures did not give control. Triclopyr (0.48, 0.96, or 1.92 kg/ha) provided 90% or greater control which carried into the second season and reduced smooth bedstraw biomass by 95% resulting in grass yields significantly higher than the untreated control. Additional research is needed to determine level of control with triclopyr at lower rates of application.

Lemnatec image analysis to assess tuber skinning after desiccant application at different times of potato maturity. Ivany, Jerry A. Agriculture and Agri-Food Canada, Crops and Livestock Research Centre, Charlottetown, PE.

Desiccants are used to remove potato tops, help set the tuber skin before harvest, and prevent entry of rot organisms and weight loss in storage, but skin set takes time dictating when harvest can begin. We evaluated the skin set after desiccation with diquat (0.84 kg ai/ha) applied on September 1, 8, 15 and 22 and visually rated at 3, 7, 14 and 21 days after treatment (DAT). Tubers were hand harvested at 7, 14 or 21 DAT, washed, tumbled within 2 hrs in a cage to simulated mechanical harvest, and skinning assessed by skin index and by image analysis. Thirty tubers (3 lots x 10) were tumbled for 10 revolutions at 40rpm. Skinning was visually assessed into four categories (0%, 1-33%, 34-66%, 67-100%) and skin index calculated. Each tuber surface was scanned and % skinning calculated using the pre-calibrated program. Tubers from the second row were weighed, stored 4 months at 95% RH and 4 C and every 30 days weighed. Diquat gave complete vine desiccation at 21 DAT and at 14 DAT when applied to more mature vines. Tuber yield and specific gravity was lower when desiccated early. Tubers desiccated with diquat lost less weight in storage (120 d) than fresh tubers or tubers desiccated later. Tubers from the control had greater skinning than tubers desiccated with diquat but with later desiccation skinning was less. The skin index was high and more subjective compared to the LemnaTec % skinning. The LemnaTec scanner is an excellent tool to evaluate tuber skinning and other treatment effects that cause colour differentials when detection of small difference in response are needed.

Flaming in beets. Maryse L. Leblanc[1], Daniel C. Cloutier[2], Evan Sivesind[3], Katrine Stewart[4], and Philippe Séguin[4]. [1]Researcher, Institut de recherche et de développement en agroenvironnement, Saint-Hyacinthe, QC, Canada J2S 7B8 E-mail : maryse.leblanc@irda.qc.ca [2]Researcher, Institut de malherbologie, Ste-Anne-de-Bellevue, QC, Canada H9X 3R9 [3]Graduate student, McGill University, Ste-Anne-de-Bellevue, QC, Canada H9X 3R9 [4]Researcher and professor, McGill University, Ste-Anne-de-Bellevue, QC, Canada H9X 3R9

A field experiment was conducted at the IRDA research station, St-Hyacinthe, QC to determine beet and weeds sensitivity to different thermal treatments under Québec field conditions, The experiment involved 4 tractor speeds with three different rates (kg h^{-1}), enabling us to develop a dose response curve with weed control and propane quantity in g m^{-1}. The quantity of propane used varied between 0,54 and 2,95 g m^{-1} (depending on speed and rate). For beet response, thermal treatments were done in a weed free situation by hand weeding the plots as needed. For weeds, at least 20 seedlings per developmental stages per species per dose were tagged to determine their response to flaming. The plant response to the various propane doses were described by a logistic model. In general the model gives a good description of % of weed control and % of yield. Plant age at treatment time had a major influence on the dose required. The LD50 increased as the plant aged. The LD50 of lamb's-quarters for the cotyledon, 2-leaf, 4-leaf, 6-leaf and greater than 6-leaf stages were 0,35, 0,53, 0,68, 0,80 and 0,86 g m^{-1}, respectively. No relation could be established in preemergence flaming for beets. In post-emergence, beets were more thermosensitive at 4-leaf than 6-leaf stage with a LD50 of 1,0 and 2,36 g m^{-1}, respectively.

Economic Impact of Alien Weeds on Wheat, Barley and Canola Production. Leeson, J.Y. [1], Thomas, A.G. [1], and O'Donovan, J.[2] [1]Agriculture and Agri-Food Canada (AAFC), Saskatoon, SK; [2]AAFC, Lacombe, AB

One of the primary characteristics of invasive alien species is the potential to cause economic losses. This poster illustrates the economic impact of alien and native weeds on spring wheat (including durum), barley and canola production in the Prairie Provinces based on Prairie Weed Survey data. Economic impact is summarized in terms of herbicide product costs, application costs and yield loss. Detailed information on herbicide products, application rates, treated acreage, application methods and target weeds are from questionnaires distributed in conjunction with weed surveys in 2001 in Alberta, 2002 in Manitoba, and 2003 in Saskatchewan. Residual weed density data from provincial weed surveys conducted in 2000s are used with yield loss models to determine the impact of the top 28 species on crop production. Yield loss was calculated at the quadrat level to account for variable densities within fields. Ninety-nine percent of all herbicide expenditures (product and application costs) were directly incurred controlling alien species. Relatively few herbicide applications targeted native species. Similarly 99% of the yield losses are attributable to alien species, with field horsetail (*Equisetum arvense* L.) as the only native ranking in the top 28 most abundant species. Based on recent weed survey data, similar results would be expected for other annual crops grown on the Canadian Prairies. In total, the economic impact of alien invasive species in spring wheat, barley, and canola in the Canadian Prairie Provinces was estimated to be over one billion dollars annually . It is clear that weeds of annual crops should be considered in any management plan for invasive alien species. While native species represent a small portion of the total economic impact of weeds in wheat, barley and canola, their impact is significant and these species should also be recognized for their invasive characteristics.

Managing wild oat in tame oat through the seeding date and seeding rate of tame oat. May, W.E., Shirtliffe, S.J. Lafond, G.P and McAndrew, D. 2006. AAFC, Indian Head Research Farm, Box 760, Indian Head, SK, S0G 2K0

Traditionally farmers have managed their wild oat by using tillage and delayed seeding to control wild oat populations. However, yield and quality decline as planting is delayed especially after the middle of May (May et al. 2004). Many producers have now moved towards reduced- or no-till management strategies, reducing the effectiveness of delayed seeding. To make these decisions farmers need agronomic and economic information that is not currently available. Therefore a study was initiated to investigate the ability of early seeded oat to compete with wild oat using high seeding rates. Four seeding dates, early May, mid-May early June and mid-June and four tame oat seeding rates, 150, 250, 350 and 450 viable seeds m^{-2} were used in the presence and absence of wild oats. The study was conducted in 2002, 2003 and 2004 at the Indian Head and Saskatoon, SK, and at Winnipeg in 2002 and Morden in 2003 and 2004. Wild oat panicle density decreased as the seeding rate increased at all locations except Saskatoon in 2003. The seed date with the highest wild oat panicle density was early or mid-May depending on the site and year. The grain yield increased as the seeding rate increased except at Saskatoon in 2003. Seed yield tended to decrease as seeding was delayed. The results from this study indicate that high seeding rates of tame oat are required to manage wild oats when seeding tame oat early in order to maximize yield and quality.

Altering the competitiveness of tame oat verses wild oat with phosphorous and seeding rate. May, W.E., and Lafond, G.P.. Address of Authors: AAFC, Indian Head Research Farm, Box 760, Indian Head, SK, S0G 2K0

Traditionally, tillage in combination with delayed seeding has been used to control wild oat in tame oat. Recent research in oat has shown the importance of early seeding to optimise yield and quality (May et al. 2004). However, early seeding requires that any flush of wild oat emerging as the tame oat emerge must be controlled using agronomic practices since no incrop herbicide is registered to control wild oat in tame oat. High seeding rates are important for controlling wild oat in tame oat (May 2001). Phosphorous banded near the seed has promoted the early season growth in cereals (Grant 2001). The yield response of oat to phosphorous has always been tested in a weed free environment. Therefore, phosphorous fertilizer by increasing early season growth may make the oat crop more competitive resulting in higher yield and quality. Since seeding rates increase the competitiveness of oat, the effect of phosphorous needs to be measure across a range of seeding rates. The objective of this research was to determine if phosphorous place near the seed would increase the competitive ability, quality and yield of tame oat in the presence of wild oat in the field. Three rates of phosphorous 0, 15, and 30 kg ha^{-1} and four tame oat seeding rates , 150, 250, 350 and 450 viable seeds m^{-2} were used in the presence and absence of wild oats. The study was conducted in 2003, 2004 and 2005 at the Indian Head, SK on plot land that had low levels of available phosphorous in the soil. Wild oat panicles m^{-2} averaged 59 in 2003, 53 in 2004 and 74 in 2005. In all three years the rate of phosphorous did not change the density of wild oat panicles. In 2004 and 2005, increasing the tame oat seeding rate decreased the density of wild oat panicles. In 2003 very little moisture was received during the growing season. In 2003, when little precipitation occurred during the growing season, the addition of phosphorous increased the grain yield of tame oat, however, there was no yield response to phosphorous in 2004 and 2005. Increasing the seeding rate of tame oat increased grain yield of the tame oat in all three years. These results indicate that seeding rate is more important than the addition of phosphorous when using agronomic practices to control wild oats in a crop of tame oat.

Effect of sweetclover cultivars and management practices on weed infestations and wheat yield. J. R. Moyer and R. E. Blackshaw, Agriculture and Agri-Food Canada, Lethbridge, AB.

Five sweetclover cultivars were established with wheat as a companion crop in four replicate experiments in1999 (Exp.1), 2000 (Exp. 2), and 2002 (Exp. 3). Sweetclover was killed in the second year with a wide blade cultivator at the early bud stage and at 70% bloom. Sweetclover on half of each kill treatment was removed to simulate a hay harvest. Wheat was seeded following cultivation in the third year. Competition from sweetclover in the spring of year 2 greatly reduced weed biomass with all cultivars compared to the no clover plots. In August and October of year 2, weed densities were greatly reduced by sweetclover residues when it was killed at 70% bloom and the residues were left on the soil surface. For example, with this residue management method, densities of common lambsquarters (*Chenopodium album* L.) (August) and flixweed (*Descurainia sophia* (L.) Webb. ex Prantl) (October) were reduced by >80% by all sweetclover cultivars compared to the no clover check. Wild oat (*Avena fatua* L.) was present in Exp. 3 and was suppressed throughout the duration of the experiment by Yukon (yellow) and Artic (white) sweetclover cultivars which have high coumarin content. Cultivars with low coumarin content did not prevent the development of a competitive wild oat population. Grain yield increases for varieties with high coumarin content compared to low coumarin content were >50%. Our research suggests that good weed management and wheat yield can be obtained, especially with Yukon yellow sweetclover, when sweetclover is killed at 70% bloom and left on the soil surface.

Foxtail Barley (*Hordeum jubatum*) Control in Wheat and Flax. K.L Sapsford, F.A. Holm - University of Saskatchewan

Foxtail barley (*Hordeum jubatum)* is a perennial grass native to western North America. Previous studies have shown that fall applications of glyphosate resulted in the best control of foxtail barley. However, if glyphosate is not applied in the fall, the question becomes, "is early or late spring application of glyphosate the best alternative?" Trials were conducted at the near Saskatoon to evaluate glyphosate application and seeding dates and in-crop herbicides for control of foxtail barley in wheat (2005) and flax (2006). In 2005 early glyphosate treatments were applied May 9th, wheat was seeded on May 11th and sulfosulfuron was applied June 9th. The late glyphosate treatments were applied May 30th, wheat was seeded on June 3rd and sulfosulfuron was applied June 21st. In 2006 early glyphosate treatments were applied May 5th, flax was seeded on May 11th and quizalofop was applied June 13th. The late glyphosate treatments were applied May 31st, flax was seeded on June 2nd and quizalofop was applied June 22nd. In 2005, late application of glyphosate at 450 g ai ha-1 provided excellent foxtail barley control at all growth stages and was superior to 1800 g ai ha-1 applied in early spring. In 2006, 450 g ai ha-1 glyphosate applied late again provided excellent control and was slightly better than 900 g ai ha-1 applied early. In 2006, post-emergent quizalofop improved seedling foxtail barley control in plots receiving early glyphosate application but did not improve seedling control in plots receiving late glyphosate treatment. Quizalofop did not improve the control of established foxtail barley at either glyphosate application time. Late May glyphosate applications appear to be the best time to control foxtail barley in the spring but crop yield reduction will likely occur in some years. Early May glyphosate applications should be followed with a post-emergent application of quizalofop in flax to improve seedling foxtail barley control.

Efficacy of corn herbicides when applied with flat-fan and air-induction nozzles. Peter H. Sikkema, Lynette Brown, Christy Shropshire, Helmut Spieser and Nader Soltani. University of Guelph Ridgetown Campus, Ridgetown, ON, N0P 2C0.

Twelve field experiments were conducted over a four-year (2002 to 2005) period to determine the influence of herbicide dose, nozzle type, spray volume and spray pressure on herbicide efficacy in field corn. Control of *Abutilon theophrasti* (velvetleaf), *Ambrosia artemisiifolia* (common ragweed), *Chenopodium album* (common lambsquarters), *Amaranthus powellii* (green pigweed) and *Echinochloa crus-galli* (barnyard grass) was improved with the use of full herbicide doses compared to half doses. The application of the full compared to the half herbicide dose resulted in an increase in control of 11 to 27% of *A. theophrasti*, *A. artemisiifolia* and *C. album* with bromoxynil (140 vs 280 g ha^{-1}), an increase in control of 20 to 28% of *A. powellii* and *C. album,* with glufosinate (200 vs 400 g ha^{-1}), an increase in the control of *A. theophrasti*, *A. artemisiifolia* and *C. album* of 11 to 19% with dicamba (150 vs 300 g ha^{-1}) and an increase in the control of *E. crus-galli* of 8 to 11% with nicosulfuron (12.5 vs 25 g ha^{-1}). Yield was increased by 9 to 15% for bromoxynil, 16 to 19% for glufosinate and 8% for nicosulfuron when the full herbicide dose was used. When applied at the manufacturer's recommended dose, flat fan (FF) nozzles compared to the air induction (AI) nozzles provided better control of *A. theophrasti*, *A. artemisiifolia* and *C. album* with bromoxynil, *A. artemisiifolia* and *C. album* with dicamba and *E. crus-galli* with nicosulfuron. Weed control with bromoxynil was the only herbicide that was affected by water carrier volume. By increasing spray pressure with an AI nozzle from 280 to 490 kPa, there was an improvement in the control of *A. theophrasti*, *A. artemisiifolia*, *C. album* with the application of bromoxynil and *E. crus-galli* with the application and nicosulfuron, and a 16% yield increase with bromoxynil. Overall, this study concludes that the optimum nozzle type, water carrier volume and spray pressure is herbicide and weed species specific.

Environmental impact and economics of dry bean weed management with reduced rates of imazethapyr plus dimethenamid applied pre-emergence. Nader Soltani, Laura L. Van Eerd, Richard Vyn, Christy Shropshire and Peter H. Sikkema. University of Guelph Ridgetown Campus, Ridgetown, ON, N0P 2C0.

Field experiments were conducted in 2003, 2004 and 2005 at the Huron Research Station, Exeter, Ontario to determine if reduced rates of imazathapyr tank-mixed with dimethenamid applied pre-emergence (PRE) can be used as an efficacious, environmentally acceptable, and economically feasible weed management strategy for broad spectrum weed control in white and kidney beans. There was no injury in white or kidney beans with the imazethapyr plus dimethenamid tank-mix treatments evaluated. The rate of imazethapyr required to provide a minimum of 80 and 95% control of green foxtail, common lambsquarters, common ragweed, wild mustard and redroot pigweed was generally reduced when tank-mixed with dimethenamid (1000 g ha^{-1}). There was no adverse effect on the yield of white and kidney beans with the highest rates (75 g ai ha^{-1}) of imazethapyr evaluated. The low application rate of imazethapyr compared to dimethenamid (75 vs. 1000 g ai ha^{-1}, respectively) resulted in an environmental impact (EI) of imazethapyr that was seven-times less than dimethenamid. Other than the weedy check, the lowest profit margins occurred in dimethenamid (1000 g ai ha^{-1}) and imazethapyr alone (15 g ai ha^{-1}) treatments. Higher rates of imazethapyr alone and tank-mixes of dimethenamid with imazethapyr increased the profit margins for both white and kidney beans. Profitability generally increased as the rate was increased. Tank-mixes of imazethapyr with dimethenamid will provide growers with a weed management strategy that causes only a minor increase in environmental impact, acceptable weed control and increased net returns.

Transgenic canola along transportation routes and port of Vancouver in western Canada.
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The occurrence of transgenic-herbicide-resistant canola (*Brassica napus* L.) in ruderal (non-crop disturbed) areas has not been investigated previously in Canada. The primary objective of this study was to document their occurrence in two main ruderal areas (along railways and roads) in Saskatchewan, where half of all canola is grown, and at the port of Vancouver where most canola destined for export is transported by rail. During the 2005 growing season, leaf samples of canola plants were collected at randomly-selected sites along railways and roads across Saskatchewan ecoregions and at Vancouver; infestation area, density, and plant height of canola were measured at each site. The presence of the glyphosate and glufosinate resistance traits was determined using test strips. The infestation area of canola, averaged across 155 sampled sites in the Saskatchewan survey, was markedly smaller in populations along railways than roads; in contrast, infestation area averaged across 54 sites in the Vancouver survey was greater for populations along railways than roads. In both surveys, mean plant density was greater for populations found along railways than roads. Two-thirds of canola plants sampled across Saskatchewan ecoregions and at Vancouver were transgenic, although the relative proportion of plants with the glyphosate or glufosinate resistance trait varied between surveys. Frequency of occurrence of transgenic plants in ruderal areas was similar to the proportion of the canola area planted with transgenic cultivars in the recent preceding years. A single transgenic *B. rapa* x *B. napus* hybrid was found along a road in Vancouver, confirming the relatively high probability of hybridization between these two *Brassica* species. With current control measures, transgenic canola populations may persist and spread in these ruderal areas.

TOLERANCE OF VARIOUS MARKET CLASSES OF DRY BEANS TO CLOMAZONE

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INTRODUCTION

Weed control is one of the major production problems of Ontario dry bean growers. With recent withdrawal of monolinuron and metobromuron from the market, there are a few herbicides available for broadleaf weed control in dry beans. Imazethapyr is the only soil applied broadleaf herbicide registered for use in some market classes of dry beans. However, imazethapyr provides marginal control of common ragweed and common lambsquarters and has a narrow margin of crop safety in some market classes of dry beans (OMAFRA 2006). More research is needed to identify herbicides that provide consistent control of annual grass and broadleaf weeds in dry beans with an adequate margin of crop safety (Urwin et al. 1996; Wilson and Miller 1991).

Clomazone inhibits the biosynthesis of carotenoids and causes loss of photosynthetic pigmentation in sensitive species. Clomazone can effectively control broadleaf weeds such as common lambsquarters (including triazine-resistant biotypes) and velvetleaf. Clomazone also can effectively control many annual grasses including barnyardgrass, crabgrass and foxtails (Vencill 2002).

The objective of this study was to determine the tolerance of eight cultivars of dry beans, representing eight market classes (black, brown, cranberry, kidney, otebo, pinto, white and yellow eye beans) to clomazone applied pre-emergence (PRE).

MATERIALS AND METHODS

Study establishment: Field studies were conducted in 2004 and 2005 at Exeter and Ridgetown, Ontario. The experiments were established in a split plot design with four replications. Main plots were herbicide treatments which consisted of a non-treated check and clomazone applied pre-emergence at 1116 and 2232 g/ha, representing once and twice the maximum proposed use dose in dry beans in Ontario. Sub-plots were eight cultivars of dry beans which consisted of one row of black ('AC Harblack'), otebo ('Hime'), pinto ('GTS 900'), white ('OAC Thunder'), brown ('Berna'), cranberry ('Hooter'), kidney ('Montcalm'), and yellow eye ('GTS 1701') beans. The plots were 6 m wide (8 rows spaced 0.75 m apart) at all sites and 10 m long at Exeter and 8 m long at Ridgetown. Beans were planted in early June at a rate of 400,000 seeds/ha for black, otebo, pinto and white beans and 200,000 seeds/ha for brown, cranberry, kidney and yellow eye beans. PRE herbicide applications were made 1-2 days after planting to the soil surface with a CO2 pressurized backpack sprayer calibrated to deliver 200 L/ha of spray solution at a pressure of 200 kPa using Teejet 8002 flat-fan nozzle tip. Plots were maintained weed free during the growing season.

Data collection: Visual crop injury was rated on a scale of 0 to 100% (0=no visible injury, and 100=plant death) at 14 days after emergence (DAE). Ten plants were randomly selected per plot and the height from the soil surface to the highest growing point of each plant was measured 28 DAE. A 1 m section of row was hand harvested from each plot and dry weight was determined at 42 DAE. Yields were measured at crop maturity by hand harvesting the remaining 9 m from each plot at Exeter and 7 m from each plot at Ridgetown. Yields were adjusted to 18% moisture.

Statistical analysis: All data were subjected to analysis of variance. Tests were combined over locations and years and analyzed using the PROC MIXED procedure of SAS (Ver 8e, SAS Institute Inc., Cary, NC). Treatment means were separated using Fisher's protected LSD (P<0.05).

Figure 1. Visual injury symptoms of dry beans treated with clomazone.

Table 1. Mean percent injury 14 days after emergence (DAE) and yield of eight market classes of dry beans at Exeter and Ridgetown, ON, in 2004 and 2005 (averaged) in response to clomazone applied pre-emergence. Means followed by the same letter within a column (visual injury) or row (yield) are not significantly different according to Fisher's Protected LSD test (P<0.05).

	Visual injury 14 DAE		Yield (t/ha)		
	Clomazone rate g ai/ha		Clomazone rate g ai/ha		
Market Class	**1116**	**2232**	**0**	**1116**	**2232**
Black bean	**3 ab**	**13 b**	**3.6 a**	**3.3 a**	**3.3 a**
Brown bean	**3 abc**	**8 ab**	**2.5 a**	**2.6 a**	**2.7 a**
Cranberry bean	**6 c**	**14 b**	**3.1 a**	**3.2 a**	**3.0 a**
Kidney bean	**5 bc**	**10 ab**	**2.3 a**	**2.3 a**	**2.3 a**
Otebo bean	**3 ab**	**11 ab**	**3.4 a**	**3.4 a**	**3.2 a**
Pinto bean	**4 abc**	**11b**	**3.1 a**	**3.1 a**	**3.0 a**
White bean	**2 a**	**6 a**	**3.0 a**	**3.1 a**	**3.2 a**
Yellow eye bean	**6 c**	**10 ab**	**2.3 a**	**2.6 a**	**2.5 a**

RESULTS AND DISCUSSION

Visual crop injury symptoms included leaf bleaching (whitening), chlorosis, necrosis, and growth reduction.

Clomazone applied pre-emergence caused up to 6% visual injury at 1116 g/ha and 14% visual injury at 2232 g/ha in dry beans at 14 DAE (Table 1).

White bean exhibited the least visual injury followed by brown, kidney, yellow eye, otebo, pinto, and then black and cranberry beans at 14 DAE in clomazone treated plots (Table 1).

Clomazone applied pre-emergence at 1116 and 2232 g/ha did not have any effect on the height and shoot dry weight of black, brown, cranberry, kidney, otebo, pinto, white and yellow eye beans (data not shown).

Seed moisture content of the various market classes of dry beans at harvest ranged from 17 to 24% and was not affected by the pre-emergence application of clomazone, indicating no delay in maturity (data not shown).

Clomazone applied pre-emergence at 1116 and 2232 g/ha did not have any effect on the yield of dry beans.

CONCLUSIONS

Based on these results, clomazone applied pre-emergence at 1116 g/ha has an adequate margin of crop safety for use in black, brown, cranberry, kidney, otebo, pinto, white and yellow eye beans. Availability of clomazone for weed management in dry beans would provide growers with a viable option to manage troublesome weeds such as common lambsquarters, velvetleaf, nightshade spp., barnyardgrass and foxtails.

ACKNOWLEDGEMENTS

We would like to acknowledge T. Cowan for his expertise and technical assistance in these studies. Funding for this project was provided by the Ontario White Bean Producers, Ontario Coloured Bean Growers, and the Agricultural Adaptation Council.

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CONTROL OF COCKLEBUR IN SOYBEAN

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INTRODUCTION

Common cocklebur (*Xanthium strumarium*) is a short-day annual plant that is native to Asia and the Americas. It is a member of the Asteraceae family, the largest with approximately 24,000 species. Cocklebur grows to about 1.5 m tall, with thick, rough leaves from 10-12 cm long. Seeds are enclosed inside a bur measuring 2 to 4 cm long, with many hooked prickles, which may attach to clothing or animals, aiding their dispersion.

Cocklebur has become a pest throughout the world, invading agricultural land, most commonly in low, moist areas with fine-textured soil. It is an aggressive weed, capable of growing 1-2 cm in one day. It is among the most problematic weeds in soybean. It competes for moisture, nutrients and light, and can drastically reduce yield, harvesting efficiency, and grain quality due to seed contamination.

The objective of this study was to determine the effectiveness of various PRE- and POST-emergence herbicides for the control of cocklebur in soybean.

MATERIALS AND METHODS

Study establishment: In 2006, three field experiments were established on Ontario farms with heavy infestations of cocklebur; two experiments were located near Windsor and the third near Ridgetown. The experiments were arranged in a randomized block design with four replications. Treatments are listed in Table 1. Plots consisted of four rows of glyphosate-tolerant soybean planted 0.53 m apart at Ridgetown and 0.38 m apart at Windsor in rows that were 8 m long. Soybean was planted in May 8 at Ridgetown and June 5 in both locations at Windsor. PRE herbicides were applied May 10 at Ridgetown and June 6 (both locations) at Windsor. POST herbicides were applied on June 12 at Ridgetown, and June 26 (1st location) and July 3 (2nd location) at Windsor. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 200 L ha^{-1} of spray solution at 200 kPa pressure using Hypro ULD120-02 nozzle tips.

Data collection: Visual injury in soybean at 7, 14, and 28 days after emergence (DAE) and cocklebur control at 28 and 56 days after treatment (DAT) were rated on a scale of 0 to 100% (0=no injury/control, and 100=plant death/total control). At 56 DAT, cocklebur density and dry weight in each plot were determined by counting and harvesting cocklebur plants in a 1 m^2 quadrat.

Statistical analysis: All data were subjected to analysis of variance. Tests were combined over locations and analyzed using the PROC MIXED procedure of SAS (Ver 8e, SAS Institute Inc., Cary, NC). To meet assumptions of the variance analysis, percent visual injury/control, density, and dry weight were transformed. These means were compared on the transformed scale and were converted back to original scale for presentation of results. Treatment means were separated using Fisher's protected LSD (P<0.05).

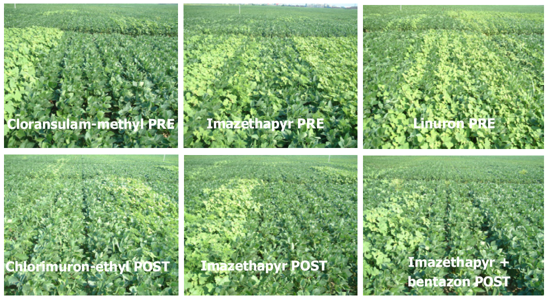

Fig. 1. Control of cocklebur in soybean with various PRE/POST-emergence herbicides.

Table 1. Mean visual control, density, and dry weight of cocklebur treated with various PRE/POST-emergence herbicides from three trials conducted in Ontario, Canada in 2006.

Treatments	Rate	Control	Density	Dry wt.
PRE-emergence	(g ai ha^{-1})	(%)	(#/m^{-2})	(g)
Weedy Check		0 e	23 a	254 a
Weed Free Check		100 a	0 d	0 c
Cloransulam-methyl	35	96 a	3 c	4 c
Linuron	2250	32 d	20 ab	218 a
Metribuzin	1120	30 d	21 a	217 a
Flumetsulam	70	71 b	10 b	48 c
Imazethapyr	100	49 c	14 ab	128 b
Clomazone	846	15 e	28 d	280 a
POST-emergence				
Weedy Check		0 f	30 ab	215 a
Weed Free Check		100 a	0 g	0 h
Acifluorfen	600	21 de	32 a	97 ab
Fomesafen	240	33 d	19 bc	57 bc
Bentazon Forte	1080	34 d	16 cd	31 cd
Thifensulruon-methyl	6	14 e	30 ab	166 a
Chlorimuron-ethyl	9	79 bc	12 cde	10 def
Cloransulam-methyl	17.5	89 b	5 f	3 gh
Imazethapyr	100	72 c	9 def	10 efg
Imazethapyr + Bentazon	75+840	73 c	7 ef	5 fg
Glyphosate (WM)	900	75 bc	9 def	21 cde

RESULTS AND DISCUSSION

There was no injury to soybean at 7, 14, and 28 DAE from any of the PRE-emergence and POST-emergence herbicides evaluated (data not shown).

Cloransulam-methyl applied PRE provided 96% visual control, reduced density 87%, and reduced dry weight of cocklebur 98% (Table 1).

Flumetsulam applied PRE provided 71% visual control, reduced density 56%, and reduced dry weight of cocklebur 81%.

Linuron, metribuzin, imazethapyr, and clomazone applied PRE provided little (15-49%) visual control and reduced density and dry weight of cocklebur minimally (50% or less) compared to the weedy check.

Cloransulam-methyl applied POST provided 89% visual control, reduced density 83%, and reduced dry weight of cocklebur 99% (Table 1).

Chlorimuron-ethyl, imazethapyr, imazethapyr plus bentazon, and glyphosate applied POST provided 72-79% visual control, reduced density 60-77%, and reduced dry weight of cocklebur 90-98%.

Acifluorfen, fomesafen, bentazon, and thifensulfuron-methyl applied POST provided 14-34% visual control, reduced density 0-47%, and reduced dry weight 0-86% compared to the weedy check.

CONCLUSIONS

Cloransulam-methyl applied PRE or POST-emergence provides excellent control of cocklebur in soybean.

Flumetsulam applied PRE and chlorimuron-ethyl, imazethapyr, imazethapyr plus bentazon, and glyphosate applied POST have some potential for cocklebur control in soybean.

Linuron, metribuzin, imazethapyr, and clomazone applied PRE and acifluorfen, fomesafen, bentazon, and thifensulfuron-methyl applied POST do not provide adequate control of cocklebur in soybean at the rates evaluated.

ACKNOWLEDGEMENTS

Funding for this project was provided by the Ontario Soybean Growers and the Agricultural Adaptation Council.

Influence de l'engrais vert et la technique des faux semis sur la levée des mauvaises herbes dans les cultures maraîchères en régie biologique: Résultats 2004-2005. D.L. Benoit [1], È. Abel [2], M.Leblanc [3], G.Leroux [2], A. Hammermeister [4] et É. Jobin [5]. [1] Agriculture et agroalimentaire Canada, Centre de recherche et développement en horticulture (CRDH), Saint-Jean-sur-Richelieu (Québec) [2] Département de phytotechnie, Université Laval, Québec (Québec) [3] Institut de recherche et de développement en agroenvironnement (IRDA), Saint-Hyacinthe (Québec) [4] Centre d'agriculture biologique du Canada (CABC), Truro (Nouvelle-Écosse) [5] Centre de recherche agroalimentaire de Mirabel (CRAM), Sainte-Scholastique (Québec)

Le but de cette étude est de mieux comprendre l'interaction entre l'utilisation d'un engrais vert et l'usage des faux-semis sur la levée des mauvaises herbes. Un essai était établi à Mirabel et à Saint-Bruno sur un emplacement qui n'avait reçu aucun intrant au cours des trois années précédentes. Le dispositif en tiroir avec trois répétitions avait les engrais verts (trèfle rouge, sarrasin, témoin non ensemencé) en parcelles principales en 2004 et les semis différés de maïs sucré var. Luscious en sous parcelles en 2005. Les engrais verts étaient semés à la fin août. La biomasse des engrais verts a été estimée avant leur incorporation, le sarrasin et le témoin étant fauchés, disqués et labourés en octobre et le trèfle après la repousse printanière (25 mai). Le maïs sucré a été semé sans ajout d'engrais (Saint Bruno- FS0 3 juin; semis différé 7 et 21 jours plus tard (FS7 et FS21)). La densité des mauvaises herbes a été suivie hebdomadairement dans des quadrats et la libération de l'azote dans le sol en 2005 a été mesurée par membrane ionique (NO_3 et N total) (PRS™ probes, Western Ag Innovation Inc., Saskatoon, SK, Canada). À Saint-Bruno, la densité des mauvaises herbes était plus importante dans le trèfle, suivie par le témoin et le sarrasin. La biomasse totale incorporée au sol était significativement plus importante dans le sarrasin que dans le trèfle mais leur contenu en azote ne différait pas. Au printemps suivant, le nombre total de mauvaises herbes émergées ne différait pas entre les engrais verts mais était différent entre les faux-semis en étant moindre dans FS21 par rapport à FS7. Même si l'engrais vert de trèfle n'a pas apporté plus de nitrate disponible que le témoin ou le sarrasin, la disponibilité des nitrates différait dans le trèfle en cours de saison et était associée à la levée du chénopode blanc, de l'amarante à racine rouge et du panic capillaire. À Mirabel, les patrons d'émergence des mauvaises herbes suite au semis très tardif (24 juin) semblent être fonction des fluctuations de températures du sol à 2 cm de profondeur plutôt que la disponibilité de l'azote dans le sol. Ces résultats justifient que l'expérience soit reconduite sur 3 nouveaux emplacements (Mirabel, Saint-Bruno et L'Acadie) afin de confirmer les phénomènes observés et mieux cerner les variations reliées aux différences géographiques, édaphiques et climatiques.

How flowering synchrony affects canola outcrossing. Simard M.-J.[1], and Légère, A.[2], Agriculture and Agri-Food Canada (AAFC), Québec, QC; [2]AAFC-Saskatoon, SK.

The recent introduction of herbicide resistant canola crops exposed otherwise inconsequential gene flow patterns. Gene flow can be limited by isolation in space. Isolation in time, by reducing flowering synchrony, has received less attention. Our goal was to determine if outcrossing rates can be managed by seeding adjacent canola (*Brassica napus*) plots at varying seeding intervals (up to 28 days). Canola plots (separated by at least 7 m) were seeded in a honeycomb display and divided in two sections (subplots). Subplots were seeded with glyphosate (cv. 375 RR) or glufosinate (cv. 5090 LL) resistant canola. The experiment included five seeding intervals (0, 7, 14, 21 and 28 days) between adjacent subplots and four blocs. Half the plots (bloc 1 & 2) were seeded with one cultivar on the windward side of the field and vice-versa. The seeding sequence (what cultivar is seeded first) was also taken into account by seeding either glyphosate (bloc 2 & 3) or glufosinate (bloc 1 & 4) resistant subplots first. Seeds were carefully collected from the first five rows (1 m wide, in the center) of the common border and tested for double resistance. Analysis of variance was used to compare mean outcrossing rates. De-synchronising flowering periods by seeding at an interval of 21 days or more reduced total outcrossing ($p < 0.05$). However, cultivar ($p < 0.001$) and flowering sequence (order) ($p < 0.001$) had the most effect on outcrossing rates. The 375 RR plots had higher contamination from 5020 LL gene flow than the opposite. Plots seeded second had higher contamination rates than plots seeded early. Results have implications on gene flow between crops and between crops and weeds.