Expert Committee on Weeds
Comité d'experts en malherbologie

Proceedings of the 2000 National Meeting

November 26 - 30, 2000
Rimrock Resort Hotel
Banff, Alberta, Canada

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Expert Committee on Weeds
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Introduction

Expert Committee on Weeds 2000 National Meeting
Banff, Alberta

The 2000 annual meeting was held in Banff, Alberta, from November 26 to November 29 and was attended by over 200 people. The plenary session theme was "Herbicides and the Environment" and Neil Harker (Agriculture and Agri-Food Canada) acted as moderator.

Bob Blackshaw (Agriculture and Agri-Food Canada), Linda Hall (Alberta Agriculture), Scott Meers (Alberta Agriculture) and Wendy Schatz (Alberta Agriculture) organised a symposium titled Integrated Weed Management – Explore the Potential. Over 260 persons attended that one day event and a book containing the presentations has been printed.

There were 16 graduate students oral presentations and 25 posters were displayed during the meeting. The poster titled "Herbicide detections in Alberta rainfall 1999-2000", by B.D. Hill, K.N. Harker, P. Hasselback, J.R. Moyer, D.J. Inaba, and S.D. Byers won first place. The poster titled "Biological control of scentless chamomile using plant pathogens" by Gary Peng, Karen Bailey, and Kelly Byer won second place. The poster titled "The role of spray pressure and nozzle choice in grassy weed control with low-drift nozzles" by Tom Wolf, Eric Johnson, and Brian Caldwell won the third place.

Several awards and scholarships were awarded at the Banff meeting. The Monsanto Canada Scholarship Awards were awarded to Laura Van Eerd, University of Guelph, and to Kris McNaughton, also from the University of Guelph. The Dow AgroSciences Canada Travel Awards were awarded to Robert Gulden, University of Saskatchewan and to Peter Burgess, Nova Scotia Agricultural College. The Zeneca (Syngenta) Canada Travel Awards were awarded to Ty Faechner, University of Alberta, and to Mike Cowbrough, University of Guelph. The Bayer Inc. Best Student Presentation Award was awarded to Mike Cowbrought, University of Guelph. The Excellence in Weed Science Award, Sponsored by Dow AgroSciences was awarded to Dr. Neil Harker, Agriculture and Agri-Food Canada, Lacombe, Alberta. Dr. Bill Hamman, Monsanto Canada, Lethbridge, Alberta, received The Outstanding Industry Member Award. This award was conferred for the first time. Honourary Life Membership was conferred upon Judy Hume in recognition of valuable service to the Committee and to Weed Science in Canada.

The committee members and their responsibilities were:

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Agenda
2000 Meeting

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Agenda

Sunday / dimanche, 26 Nov. / nov.

10:00 – 15:00	Executive Meeting / *Réunion du conseil exécutif*
12:00 – 19:00	Registration / *Inscription*
12:00 – 19:00	Poster/Commercial Display Set-up / *Montage des affiches de recherches et affiches commerciaux*
20:00 – 21:00	Computer Committee / *Comité informatique*

Monday / lundi, 27 Nov. / nov.

07:00 – 12:00	Registration/ *Inscription*

Herbicides and the Environment
***Moderator: Neil Harker**, Agriculture and Agri-Food Canada, Lacombe, AB*

08:15 – 08:30	ECW Welcome
08:30 – 09:15	Herbicide Use in World Food Production *Dr. Gerald Stephenson, University of Guelph, Guelph, ON*
09:15 – 10:00	Pesticide Use Intensities Across Different Pesticide Use Sectors *Janet McLean, Alberta Environmental Protection, Edmonton, AB*
10:00 – 10:15	Break and Poster Viewing
10:15 – 11:00	Herbicide Residues in the Air and Groundwater – Mitigation and Education Must Replace Negation *Dr. Bernard Hill, Agriculture and Agri-Food Canada, Lethbridge, AB*
11:00 – 11:30	Persistence and Detection of the Low-Use Rate Herbicides *Dr. Chris Hall, University of Guelph, Guelph, ON*

11:30 – 13:15	Awards Banquet

Graduate Student paper presentation
Moderator: Anne Légère, *Agriculture and Agri-Food Canada, Ste-Foy, PQ*

13:15 – 15:15	Graduate Student Awards Paper Presentations (15 minute intervals)
15:15 – 15:30	Break and Poster Viewing
15:30 – 17:15	Graduate Student Awards Paper Presentations (continued)
17:15 – 17:40	ECW Computer Program Introduction *Dr. Chris Hall, ECW Chair*
17:40 – 18:00	ECW Computer Program Demonstration *Dr. Daniel Cloutier, ECW Executive Assistant*
18:30 – 23:00	CPI Reception

Tuesday / mardi, 28 Nov. / nov.

08:00 – 09:00	Poster Viewing and Registration

Integrated Weed Management – Explore the Potential
Moderator: Bob Blackshaw, *Agriculture and Agri-Food Canada, Lethbridge, AB*

09:00 – 09:15	Introduction *Denise Maurice, Westco, Calgary, AB*
09:15 – 10:00	Herbicide Resistance – Where Are We at Today? *Dr. Hugh Beckie, Agriculture and Agri-Food Canada*
10:00 – 10:45	Expanding the Context of Weed Management *Dr. Doug Buhler, MSU, East Lansing, MI*
10:45 – 11:00	Break and Poster Viewing
11:00 – 12:00	Integrated Weed Management – Making It Work *Steve Sutherland, NSW Agriculture, Wagga Wagga, Australia*
12:00 – 13:00	LUNCH

Integrated Weed Management – Explore the Potential *(continued)*
Moderator: Scott Meers, *Alberta Agriculture, Food and Rural Development, Strathmore, AB*

13:00 – 13:45	Weed-Crop Interaction *Dr. Rene Van Acker, University of Manitoba, Winnipeg, MB*
13:45 – 14:30	How to Implement IWM in Barley *Dr. John O'Donovan, Agriculture and Agri-Food Canada, Beaverlodge, AB*
14:30 – 15:15	How to Implement IWM in Canola *Dr. Neil Harker, Agriculture and Agri-Food Canada, Lacombe, AB*
15:15 – 15:30	Break and Poster Viewing
15:30 – 16:15	The Challenges of Implementing IWM: A Pesticide Manufacturer's Perspective *Dr. Len Juras, Dow AgroSciences Canada, Saskatoon, SK*
16:15 – 17:00	Making it Work on the Farm – A Producer's Perspective *John Benett, Producer, Biggar, SK*
17:00 – 17:30	Integrated Weed Management – An Agronomist's Perspective *David Kelner, Westco, Rosser, MB*

Wednesday / mercredi, 29 Nov. / nov.

08:00 – 08:30	Coffee and Poster Viewing

Concurrent Working Groups

08:30 – 10:00	Application Technology *Dr. Tom Wolf, Agriculture and Agri-Food Canada, Saskatoon, SK*
	Herbicide Resistance *Dr. François Tardif, Guelph University, Guelph, ON*
10:00 – 10:30	Break
10:30 – 12:00	Pesticide Product and Herbicide Characterization Dr. *Marvin Faber, Dow AgroSciences Canada Inc., London, ON*
	Site Specific Weed Management *Dr. Linda Hall, Alberta Agriculture, Food & Rural Development, Edmonton, AB*

12:00 – 13:00	Lunch
13:00 – 14:30	Biological Control *Brian Ure*
	Extension and Teaching *Dr. Carol Bubar, Olds College, Olds, AB*
14:30 – 15:00	Break
15:00 – 16:30	Integrated Weed Management *Dr. Anne Légère, Agriculture and Agri-Food Canada, Ste-Foy, PQ*
	Noxious Weeds *Roy Cranston, BC Ministry of Agriculture and Food, Abbotsford, BC*
16:30 – 18:00	Business Meeting

Thursday / jeudi 30 Nov. / nov.

08:00 – 12:00	Executive Meeting / *Réunion du conseil exécutif*

Herbicides and the environment

Pesticide use and world food production: risks and benefits

Gerald R. Stephenson
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Abstract

For most of the next century, we will need to produce enough food for nine billion people instead of the six billion we are trying to feed today. If we try to improve the average diet as well, we may need to double annual world food production for most years of the next century. There is not much more land that can be devoted to agriculture without having an enormous environmental impact on forested of wilderness areas. Furthermore, a higher proportion of agricultural land may be used industrially to produce fuel or fibre instead of food. Thus, we may need to grow twice as much food on even less land than we are using today. We are currently using $35 billion worth of pesticides each year in agriculture, world wide. What will the benefits and risks be if this level of pesticide use is continued or increased? What will they be if pesticide use is discontinued? Several years ago, farmers in highly developed, industrialized countries could expect a three or four fold return on money spent on pesticides. Is this still true? Can we meet world food demands if producers stop using pesticides because of reduced economic benefits? Can better IPM preserve the economic benefits of pesticide use? Although crop losses are currently greatest in less industrialized countries, can we meet the educational and training requirements to safely increase pesticide use in these areas? These are just some of the questions facing scientists and pest management experts as agriculture faces its greatest challenge in history between now and the year 2100.

Introduction

The pesticide industry is a very big. World-wide pesticide sales now exceed $35 billion per year. However, sales have exceeded $20 billion per year since the 1980's and herbicides account for at least half of the business. More than half of the world's pesticides are used is in Europe and North America., 25% are used in the far east and approximately 25% in the rest of the world combined. Latin America, particularly Brazil, is an area where there is perhaps the greatest potential for the pesticide market to expand. Developing countries in warmer climates use half of the insecticides whereas industrialized countries in more temperate climates use most of the herbicides. For example, herbicide use accounts for 70% and 80% of total pesticide use in the USA and Canada, respectively.

Health risks associated with pesticide use

Unfortunately, pesticide misuse can be a human health risk. In his recent book, Don Echobichon estimates that there are numerous accidental deaths and thousands of accidental pesticide poisonings in North America each year. In developing countries, there are millions of reported poisonings and hundreds of thousands of pesticide related deaths each year. How many incidents go unreported? What about the chronic health effects of pesticide use in developing countries? Fortunately, the health risks associated with pesticide use are largely a preventable problem. In fact it is accurate to say that 'proper' pesticide use rarely results in a human health problem. The industry has a major role in preventing human health effects with their continuing efforts to develop even safer pesticides. However, safe pesticide use requires safe equipment and good systems for training and educating pesticide applicators and farm workers. Good regulations of pesticide sale and use that are regularly enforced are also essential. With so many cuts in government spending it is hard enough to maintain these systems in industrialized countries. It is even more difficult to get these systems established in developing countries.

Environmental risks associated with pesticide use

Pesticide use can also present risks to the environment. To visualize the factors that contribute to this risk, it may be helpful to think of the following equation or model,

$$\mathbf{ER = V \times P \times M \times T}$$

Quite simply, the environmental risk (ER) of any chemical depends on the volume used (V), the persistence of the chemical (P), its mobility in the environment (M) and its potential toxicity (T) to non-target organisms. We have regulatory systems to prevent the introduction of persistent, bioaccumulating pesticides like DDT for use in agricultural environments. Our early experience in managing spray drift and vapor drift with 2,4-D is helping us prevent similar problems with newer herbicides like glyphosate and clomazone. Likewise, our earlier experience with triazine carry-over, soil residue problems are a guide in managing similar problems with the newer sulfonyl urea, imidazolinone and other soil active herbicides.

With few exceptions, our experience with older pesticides has been quite good. For example, in a study conducted at Rothemsted in England (cited by Evans, 1998), research plots were treated with at least five pesticides each year for 20 years. Seventeen months after pesticide use was discontinued, there were no detectable pesticide residues in the plots. Furthermore, there were no differences between treated and control plots with respect to either soil microbial processes or the yield of barley used as an indicator crop. The increasing use of the new "low-rate" pesticides is certainly reducing the risks for non-target organisms in the environment as a whole. However, our farmers are struggling with the management of "on farm risks" associated with the "carry-over" residues of the new "low-rate" herbicides in soil and their potential for injury to subsequent crops grown in rotation. In Canada, the labels for many of these products require farmers to conduct their own field bioassays to assess the safety for candidate rotation crops. I am sure that it is difficult for farmers to conduct these bioassays with proper controls etc. Quite frankly, I think that such requirements are unfair and unmanageable.

Evaluating the benefits of pesticide use

For our consideration of pesticide benefits, we should ask, benefits to whom? At the 1998 IUPAC meetings in London, England, Sir Colin Spedding encouraged us to consider benefits to manufacturers, growers, processors, and consumers or citizens. Of course there are large differences in the numbers of people in these various groups. For example, there are relatively few people associated with the manufacture of pesticides, while the number of consumers or citizens impacted by pesticide use is enormous. Furthermore, in industrialized countries, there is a low percentage of people who would be involved with pesticide application whereas in developing countries, the application of pesticides with hand operated equipment may involve a larger number of people.

Manufacturers. In the development of a new pesticides, the financial benefits and risks to the manufacturer are huge. At 8 or 10 years after discovery, when the first product is sold, investments in research and development may total nearly $100 million (Klassen, 1995). Companies need to know that a candidate chemical far exceeds current government requirements for health and environmental safety, very early in development, to be sure that the chemical will have a sustainable life on the market. The current trend toward fewer but larger companies simply reflects the reality, that only a very large company can manage the risks associated with the huge investments required to develop new pesticide products.

Growers. What about benefits to the grower? For many years, we have commonly assumed that there is about a $4 return to the grower for every dollar spent on pesticides. Is this still true? Most studies indicate (e.g. Fernandez-Cornejo et.al., 1998) about a 30% yield benefit when pesticides are used. For the USA in 1997, when a 30% increase in crop value was compared to total expenditures on pesticides, the return was approximately $3-$4 for every dollar spent on pesticides.

Several industrialized countries are in the midst of programs to reduce the use of pesticides in agriculture. Canada is one of the leading countries in this endeavor. In the Province of Ontario, we have program called Food Systems 2002 which was initiated as a political campaign promise during the 1980's (Surgeoner and Roberts, 1993) The goals of this program are two-fold, (1) To reduce pesticide use in agriculture by 50% by the year, 2002 and (2)To accomplish this without reducing agricultural productivity. In a sense, the goal was to increase grower education and to develop better pest monitoring and effective alternatives to chemical pesticides so that there could be nearly a 100% reduction in the use of pesticides when they were not needed. I wondered how this program was impacting the economic returns to growers on dollars spent for pesticide use.Fortunately, we have data going back to 1973 to help answer this question. Our last pesticide use survey was in 1998, and with four years to go, we had already reduced the total kilograms of pesticides used in Ontario agriculture by nearly 40% compared to 1983. In fact, the reduction was nearly 50% in maize (corn) where herbicides are the predominant pesticides used (Hunter and McGee, 1999). Of course this is largely due to a shift to new low-rate herbicides in corn. Environmental critics complain that the shift is simply to lower rate, more powerful pesticides that may not be reducing environmental risks. However, our researcher have gone further. Kovach et.al.(1992), at Cornell University have developed a model to calculate the environmental impact quotient (EIQ) for each pesticide or each crop as well as for total pesticide use for different years. The model includes estimates for farm worker risk, consumer risk and ecological risk. When pesticide use in Ontario was examined with this model, it was apparent that the overall EIQ per hectare in 1998 was only 34% of what it was in 1983. Furthermore, because of higher crop yields, the EIQ per tonne of crop produced in 1998 was 58% of what it was in 1983, a 42% reduction. This is a definite benefit to the citizens of Ontario and to their environment. However, what about economic returns on pesticide use to the growers. A recent study by Teague and Brorsen (1995) indicated that for the ten major agricultural states in the USA, returns to the grower on pesticide use declined from $8 per dollar in 1949 to approximately $4 per dollar in 1991. I wondered whether the success of the Food Systems 2002 program in Ontario, with respect to preventing un-needed pesticide, was slowing this trend. This proved not to be true. When we assumed the commonly accepted, 30% yield benefit with pesticide use and compared increased crop values with total expenditures for pesticides, Ontario growers had a return of $3.22 per dollar spent on pesticides compared to $8.42 per dollar in 1983. The main reason for this was that pesticide expenditures had increased 8-fold since 1973 with only a 3-fold increase in crop value-despite dramatic increases in crop yields. In Canada's Province of Saskatchewan, herbicides represent more than 90% of the pesticides used. With the help of F.A. Holm at the University of Saskatchewan, I was able to get similar data to examine the economic returns to growers for pesticide use in that province where Canola (oilseed rape) and cereals are the major crops. Again, assuming a 30% yield benefit, the economic returns to the growers have declined from $16.45 per dollar spent on pesticides in 1973 to $2.22 per dollar in 1998. The conclusions are obvious. It probably costs manufacturers at least six times as much to develop a new pesticide today as it did in the early 1970's, $90 to $100 million in stead of $15 million. Higher pesticide prices today reflect this. However, there has not been a parallel increase in the value of agricultural commodities. Thus, in industrialized countries, programs to eliminate pesticide use when and where there is little chance for a yield benefit not only reduce potential risks to the environment, they are absolutely essential to preserve economic benefits of pesticide use for the growers.

Society. What about the economic benefits of pesticide use to society as a whole? Pimentel and Greiner (1997), at Cornell University, estimate that the $6.5 billion spent on pesticides by farmers in the USA prevented about $26 billion in crop losses due to pests, again about a $4 return to the growers for each dollar spent on pesticides. However, they pointed out that we should also consider the $8 billion in indirect costs to society for regulating, preventing and correcting environmental and health problems associated with pesticide use. With this approach, the net economic benefit to society in general was closer to $2 per dollar spent on pesticides.

Pesticides save human labour. Pesticide use, particularly herbicide use for weed control, reduces hand labour requirements for agriculture. Ontario agriculture probably reflects the norm in industrialized countries and only 2% of our population is involved in production agriculture. In other words, one person can produce enough food for 50
other people. In developing countries, this is far from true. World-wide, 46% of the population is involved in field work for agriculture. In Brazil it is 20%; Mexico, 25%; and in Kenya it is 70% or two people in every three (Akobundu, 2000). In too many parts of the world, too many people, especially women and children, are deprived of an education and chances for a better standard of living because their labour is needed to weed and to harvest crops.

Pesticide use saves energy. It is often assumed , that as agriculture has become more intensive and more dependent on technology - energy requirements have increased. In fact, energy requirements for crop production in Ontario did increase between the 1940's and the 1970's, largely due to a 1000 % increase in energy requirements for producing nitrogen fertilizer (Commoner, 1972). However, these trends are now reversed. More efficient methods have reduced energy requirements in fertilizer production by at least 40%. Swanton et.al.(1996) have shown that herbicide use increases the energy efficiency in both corn and soybean production. This is largely due to eliminating the need for primary tillage (plowing). Furthermore, in crops like soybeans, energy efficiency is even greater if at least one secondary tillage operation (rotary hoeing) can be eliminated. The trend toward the new, low-rate herbicides is also decreasing the energy investment in each herbicide application. As fuel costs continue to increase, the energy benefits of pesticide use should continue to increase as well.

World Food Production. Oerke et.al. (1994), have estimated that the use of crop protection chemicals doubled the yields of the world's eight principal cash crops between 1965 and 1990. For the agricultural land involved in 1990, there was a potential to produce $579 billion in food, world-wide. They estimated that pesticide use in agriculture doubled yields from 30% of the potential without pesticides to 60% of the theoretical potential. However, pests were still causing an approximate 40% loss in total food production. Successes with pest control in agriculture, varied with the crop and the regions in the world where the crop was grown. Losses due to pests in maize (corn) were less than 30% in Europe but greater than 50% in Africa. Losses in wheat production were less than 30% in Europe but greater than 40% in what was the former USSR. Losses in rice production were less than 30% in Oceania but greater than 50% in Africa and the Americas. Overall, crop losses due to pests in Africa were double what they were in Europe. However, even in most developing countries, food production is increasing faster than the increase in population. Thus, food production per capita is increasing. Despite an increasing world population, the actual number of malnourished people is decreasing (Klassen, 1995). That is good news. However, the bad news is that there are still more than one half billion undernourished people in the world and in Sub-subsaharan Africa, the number is still increasing (Klassen, 1995).

World Land Use. The potential impact of pesticide use on the environment is discussed throughout the world. However, what about the impact of 'agriculture' on the environment? If we were still producing crops with the yields of 1960, we would need nearly three times as much land for agriculture - an area equal to all of the land currently used for agriculture in Brazil, Europe and the USA, combined (Avery, 1997). If herbicides and other pesticides had not been available since 1950, how much pasture land or wilderness land would already be lost. If this technology and other technology is not available in the future, how much more land will be consumed by agriculture and lost for other uses for our children and grandchildren?

World Population Trends and Needs for the Next Century. As recently as the 1960's, Paul Ehrlich was warning us with his book, "The Population Bomb", that we would already be experiencing a world-wide catastrophe because of over population. Fortunately, this has not happened. The rate of population increase has already peaked and is beginning to decline. In every part of the world except Africa, populations are aging. Current, conservative estimates (UN and others) are that our present population of 6 billion will continue to increase for only another 50 years and will peak at close to 9 billion in about 2050. Beyond 2050, world population should begin to decline. Keep in mind, that these are the best possible predictions. However,it is only recently that we could begin think in such positive terms about world population trends. What this means for most of the 21st century is the following:

- 50% more people will need food, 9 billion instead of 6 billion
- a higher standard of living for people in developing countries could mean 50% more buying power for food
- this could mean that people in developing countries will consume less rice and sorghum, more wheat and maize, more potatoes and vegetables, more fruits, more dairy products, more animal protein. (Thompson, 1999)

This would mean that although food production has already been doubled or tripled in the last 50 years, we need to double it again. However, there is hardly 10% more rain-fed, arable land that would be sustainable for use in agriculture. In addition, more land may be diverted from food production to the production of fuel or fibre. We may decrease world food losses 30 to 40% by further preventing losses due to pests in the field and in storage (Oerke, et.al., 1994). However, we need to double world food production again by about the year, 2025, on about the same land that we are using now (Thompson, 1999). This will require advances not only in pest management and pesticide technology but in other technology such as crop genetics..

"The Mental Affluence Trap." Can we meet these challenges, as we have met the earlier challenges for world agriculture? Technologically, it is quite possible. Psychologically and culturally, it is much less certain. Particularly worrying, are the changing attitudes among the more affluent people of the world. It is what Hans Mohr (1991) of the Universitat, Freiburg calls the "The Mental Affluence Trap". According to him, the willingness of people to accept change (new technology) is inversely proportional to their affluence. This attitude eventually leads to a mental immobility among the more affluent members of society, who become more and more critical of the advances and technology that were originally responsible for their prosperity. Conversely, less affluent people will more readily accept the potential risks of change in attempts to improve their prosperity. Therefore, people in developing countries will likely favour increased pesticide use to improve their health, whereas the more affluent people in industrialized countries will want to decrease pesticide use and more organic food in an attempt to preserve the good health that they already enjoy.

Summary and conclusions

- Pesticide use has had a major role in tripling world food production during the last 50 years.
- Pesticide use benefits humans and their environment by reducing world hunger and by saving human labour, fossil fuels, and land
- However, world food production must again be doubled for most years of the next century.
- Pesticide use as well as other technology will be essential to prevent the encroachment of agriculture onto unsuitable land, even wilderness land, that would not be sustainable for agricultural use.
- Efforts to reduce the use of agricultural pesticides where and when there is little chance to improve food production should continue. Such efforts minimize environmental risks and maximize economic benefits associated with pesticide use.
- A wide-scale reduction in "needed" pesticide use for agriculture in industrialized countries is morally incorrect, in view of world food needs.
- There will be pressures to increase pesticide use in developing countries. However, we must be sure that educational and regulatory needs are met to prevent adverse health and environmental effects.
- Our goal for the next 100 years should be to prevent human hunger without irreversible harm to the world environment. We have a greater chance to achieve this goal with integrated pest management, including the use of pesticides and other technology than with a major shift to organic farming.
- If the world population peaks at 9 billion in 2050 and declines to about 5 billion in 2125, future generations may have the choice between wide scale dependence on organic farming or reducing the amount of land devoted to agriculture. It would be selfish, narrow minded and short sighted to think that we have those choices today.

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Pesticide Use Across Different Sectors

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This presentation was originally in Microsoft Powerpoint.
It has been converted in Adobe Acrobat and is available separately in the file named McLean.pdf

Herbicide residues in the air and groundwater: Mitigation and education must replace negation

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Mitigation and Education must replace Negation: I think many proponents of herbicide use are still in denial mode (negation) about environmental problems. On the other hand, environmentalists certainly can distort issues and exaggerate their points of view. However, I think it's time that we move onto solutions (mitigation). We also need to educate the public about what good science is and about risk/benefit decisions. With this theme in mind, I will discuss two recent projects from our environmental research.

1. Protect Alberta Groundwater by Selecting Herbicides with Lower Leaching Potential

This one-year (1998-99) AESA-funded study, was conducted by Bernie Hill, Jim Miller, Neil Harker, S. Byers, D. Inaba and C-Y. Zhang. It has now been peer-reviewed and published (Hill et al. 2000). The idea of this project, to determine and publish relative leaching potential (LP) rankings for Alberta herbicides, has received support from Alberta Environment, criticism and opposition from The Crop Protection Institute of Canada (CPIC), and cautious observation from Alberta Agriculture, Food and Rural Development (AAFRD).

Background: Over the period 1991-97, we conducted several field studies to monitor for herbicides in Alberta groundwater. We found that certain herbicides do leach into Alberta groundwater. In fact, we found widespread low levels of herbicides in the groundwater (Hill et al. 1996). On occasion, herbicide levels exceeded the Canadian Drinking Water Guidelines or the Aquatic Life Guidelines. We think these herbicide detections occurred because of the shallow (perched) water tables (0.5-6 m depth) and the macropores in the soil structure. It appeared that when the first moisture event after a recent herbicide application was a large rainfall, or an irrigation, the 'fresh' residues were flushed down the macropores into the groundwater in large amounts.

Need for a Screening Model: One can't conduct field studies *ad infinitum*; they are expensive and it's impossible to test or control all the field variables. What's needed is a reliable, comparative indicator of LP. What's needed is a screening model. Screening models can usually be applied to all herbicides, are not necessarily site specific, and some give numerical rankings. There is also a need to convey LP information to producers via Crop Protection Guides. Then, if a producer is environmentally concerned, he can make an informed product choice.

Crowe and Mutch (1993) from the CCIW, Burlington, ON reviewed several screening models, namely the DRASTIC, AF and Jury models which all require site information, as well as the CDFA, Cohen, GUS, and Laskowski models. They chose the Laskowski et al. (1982) models: $LP = S / (Vp \times K_{oc})$ and $LI = (S \times T_{1/2}) / (Vp \times K_{oc})$ to include in their EXPRES system because these models calculated numerical rankings. We chose to use the Laskowski LP model in this project.

Our Objectives in this study were to:

1. use the LP model to determine the relative leaching potential for the 139 herbicides used in Alberta
2. investigate the leaching rates of 9 herbicides on 5 Alberta soils using lab soil columns
3. use the lab soil column results and previous field results to validate the LP rankings for the 9 herbicides
4. transfer LP information to producers.

Results: We calculated the LP = S / (Vp x K_{oc}) for 80 herbicide a.i. listed in the 1998 Alberta Crop Protection guide ('BlueBook'). Some K_{oc} values had to be estimated. We then converted the LP to Leaching Potential Rankings (LPR), based on an arbitrary 1-9 scale where 9 = the highest potential to leach. We determined the LPR for 138 different herbicide products (weighted means were used for mixtures).

The results of the lab soil columns indicated some differences among soil types related to organic matter (% OM), however, the relative rates of leaching among herbicides were quite consistent: dicamba, 2,4-D, MCPA and quinclorac leached very rapidly, bromoxynil leached rapidly, diclofop and fenoxaprop leached an intermediate rates; triallate leached slowly; and trifluralin did not leach.

Overall, our LPR were partially validated by the soil column leaching results. There was agreement for 5 of the 9 herbicides, partial agreement for diclofop and bromoxynil, but the LPR for MCPA and quinclorac underestimated the leaching of these compounds on the soil columns.

Compared with previous field results, our LPR agreed with the number of field detections for 6 of the 8 herbicides. The LPR underestimated the number of bromoxynil detections and overestimated dicamba detections. For dicamba, it appeared that lower application rates may have reduced the number of field detections in the groundwater.

LPR as an Extension Tool: The LP model provided a viable method of estimating the relative LP for 80 a.i. used in Alberta. LPR are convenient way to transfer relative leaching information to producers. Our LPR were partially validated, but most notably the leaching of bromoxynil and quinclorac were underestimated. The LPR could be used in Producer guides with certain provisos: some LP will be inaccurate because of inaccurate or estimated S, Vp and K_{oc} values; the LPR are affected somewhat by soil type, and low application rates may reduce leaching in the field.

LPR vs AAFRD (1998) section 12 'Movement in Soil' statements: Of 139 total products, our LPR agreed with the 'BlueBook' section 12 statements 101 times (73%) and disagreed 38 times (27%). Of the 38 disagreements, we feel there is a problem with the LPR values in 19 cases, and a problem with the section 12 statements in 19 cases. Examples of some section 12 anomalies are: Amitrol-T (LPR=8) at recommended rates, persists in soil 2-6 wk; 2,4-D (LPR=7) leaching does not pose a problem. Minimal soil movement. 30 d half-life; Banvel (LPR=7) more subject to leaching in sandy soils than in clay, half-life < 30d; Pursuit (LPR=6) not leached appreciably.

CPIC Objections and (our Replies):

1. Can't use a simple screening model to predict herbicide leaching in the field (but one has to use a simple model to include all herbicides; has been done in Florida).
2. Leaching is a complicated process, depends on specific site factors, should not be generalized (complicated yes, but we have to start somewhere, so use generalized rankings, then refine for anomalies).

3. Low annual rainfall on Prairies greatly reduces potential for all compounds to leach (leaching does not depend on annual rainfall, per se. It is affected more by rainfall timing and patterns).
4. If certain compounds really had a high potential to leach, they would not have been registered (registered herbicides do leach, our field studies prove it).
5. No information is better than poor information (rather self-serving? …. denial mode).

2. Herbicide Detections in Alberta Rainfall

This two-year (1999-00) AESA-funded study was conducted by Bernie Hill, Neil Harker, P. Hasselback, Jim Moyer, D. Inaba and S. Byers. Please see our poster abstract for further information on this study.

Background: Allan Cessna (Agriculture & Agri-Food Canada, Saskatoon) detected herbicides in virtually every dugout tested in Saskatchewan and postulated that the mode of herbicide entry, especially for remote locations, was via rainfall. Cessna's flux measurements and calculations indicated there could be as much as 18% of applied herbicides in the air. This compares with about 1-2% of applied herbicides detected in surface water and groundwater. Thus, we may have been 'ignoring' one of the largest sinks of herbicide residues in the environment?

In 1998, we conducted an initial survey for herbicides in the Lethbridge area rainfall, then in 1999 and 2000, we expanded our monitoring to province-wide. We sampled rainfall because, from an agricultural perspective, rainfall would be the mode of exposure to sensitive crops and the mode of entry into dugouts and ponds.

The rainfall from 18 Alberta locations (Lundbreck to Seven Persons; Warner to Vegreville) was sampled at 3-14 day intervals over April-September and analyzed (MSD-GC with ion-ratio confirmation) for the following 19 'herbicides': 2,4-D, 2,4-DB, atrazine, bromacil, bromoxynil, clopyralid, dicamba, diclofop, dichlorprop, ethalfluralin, fenoxaprop, imazethapyr, lindane, MCPA, mecoprop, picloram, quinclorac, triallate and trifluralin. The minimum quantifiable limit was 0.02-0.1 ppb depending on amount of rainfall.

Results: We detected herbicides at most sample dates at all locations. The herbicides detected most often (in order), and in the highest amounts, were: 2,4-D, dicamba, bromoxynil, MCPA, and mecoprop. The highest herbicide levels occurred in June/early July and were spread out in southern Alberta, but were concentrated into a two to three week period in central Alberta. Herbicide levels were lowest in the remote locations (2,4-D 1-14 ug/m^2, 0.1-2 ppb), intermediate in the City of Lethbridge (2,4-D 1-36 ug/m^2, 0.1-10 ppb), and highest in the farming areas (southern AB, 2,4-D 1-149 ug/m^2, 0.1-53 ppb; central AB, 2,4-D 1-89 ug/m^2, 0.1-3 ppb).

Questions and concerns:

1. Are the occasional high (>2 ppb) herbicide levels detected in Alberta rainfall unique? We hope to address this in 2001 by sampling rainfall in AB and BC, SK, MB.
2. Are the high herbicide detections caused by local spray activity? We hope to intensively monitor spray activities at some local Lethbridge sites in 2001.
3. Could maximum herbicide levels in southern Alberta rainfall cause sub-lethal effects on sugar beets and potatoes? Kudsk et al. (1998) from Denmark estimated 23-82 ug/m^2 of mecoprop over 14 days would injure sensitive plants. We detected 20-120 ug/m^2 2,4-D in 1999, and 25-93 ug/m^2 2,4-D in 2000, over different 14 day periods. We also conducted

indoor bioassays using simulated rain containing 2,4-D (1g/ha), MCPA (0.5 g/ha), bromoxynil (0.5 g/ha) and dicamba (0.25 g/ha) to yield a herbicide mixture at the highest rates detected in rainfall. We observed transient, sub-lethal effects (*P*=0.05) in tomatoes and sunflowers, but not in sugar beets and potatoes.

4. Could herbicide amounts in rainfall negatively impact surface water quality in dugouts and ponds? The 2,4-D amounts entering surface water would be 0.2-1.2 g/ha over 14 days.
5. Could herbicides in Alberta air have chronic effects on public health? We can not speculate on this. We sampled rainfall (agricultural perspective), not air.

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Persistence and detection of the low-use rate herbicides

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Introduction

There is a major need to define the safe re-cropping intervals for highly sensitive crops that may be planted during the seasons following use of a number of the new "low-use rate" herbicides that have been recently registered for use in corn or soybeans in Canada. Many of these low-use rate herbicides belong to the imidazolinone (e.g. imazethapyr), sulfonylurea (e.g. chloroimuron), and triazolylpyrimidine (e.g. flumetsulam) families of herbicides. These herbicides typically have low octanol/water coefficients (low potential to accumulate in non-target organisms). They are also non-volatile, have moderate water solubilities and low mammalian toxicity. Many of these herbicides are known to have undefined residual activity and are biologically active in grams of active ingredient per hectare. They are difficult to detect using existing analytical methods. Toxicological concerns, environmental fate, and impact on soil, potable waters, and foodstuffs determine their registration and continued use.

Sulfonylurea herbicides tend to persist at high soil pHs. Soil adsorption of the sulfonylurea herbicides increases as soil organic matter and clay content increase and decreases as soil pH increases. Half-lives of most sulfonylureas, including chlorimuron-ethyl, tend to be one to eight weeks in most soil types. Soil degradation of the sulfonylureas is primarily by hydrolysis both chemical and microbial. Hydrolysis is accelerated in warm, moist, low pH, and high organic matter soils. As these herbicides are anionic in most soils, they have a potential to leach.

Triazolylpyrimidine and imidazolinone herbicides persist at low soil pH. Unacceptable injury to many subsequent crops may occur in these situations. Imazethapyr, an imidazolinone herbicide, is weakly adsorbed to most soils. Adsorption of herbicides in this group also increases as soil organic matter and clay content increase but increases below pH 6.5. There is little soil adsorption in soils with pH values ranging from of 6.5 to 8. Degradation of imazethapyr is primarily by microbes. Half-lives of 60 - 90 days are typical in most agricultural soils. Herbicides in this group have the potential to leach as they are anionic at pH values above their pka. Flumetosulam, a member of the triazolylpyrimidine group of herbicides, is more tightly adsorbed to organic matter than clay. As with the imidazolinones, flumetosulam adsorption to soil increases as soil pH decreases. Degradation of flumetosulam is also primarily by microbes and is faster in high pH, low organic matter soils. The average half-life of flumetosulam in most agricultural soils is 60 - 90 days.

Industry has conducted re-cropping trials with these herbicides for replanting to major rotation crops grown in Ontario following soybeans. Limited resources and time on the part of industry are available for studies on limited acreage crops and especially those of high value per acre. Industry's solution to this dilemma is to place statements on product labels that suggest growers conduct a bioassay using the intended rotational crop that is either not indicated on the label as being acceptable for use following the original herbicide treatment or whose interval between treatment and planting is shorter than that indicated on the product label. These statements are of limited value since growers either do not know how to conduct a bioassay and interpret the results or cannot wait for the bioassay results.

Based on the above information, there is a need for data from objective sources to document the required number of seasons after which it is safe to plant sensitive crops. Innovative, ultra-sensitive chromatographic, immunoassay, and bioassay methods must be developed to determine the interval after which it is safe to plant sensitive rotational crops. In this paper we describe research to determine the "safe" interval for two sensitive crops, sugar beet and spring canola, grown in three soil types with different chemical and physical properties that were previously treated with imazethapyr, flumetsulam, or chlorimuron-ethyl.

Material and methods

Bioassay of Growth-Room Spiked Soils

In order to make standard growth curves to determine the response of sugar beet and spring canola grown in soils from Huron, Thorndale, and Simcoe, Ontario, each soil was treated in the growth room with either chlorimuron-ethyl (Classic, 250 g a.i./kg, DuPont Canada Inc.) or imazethypyr (Pursuit, 240 g a.i./L, Cyanamid), at 0, 0.05, 0.1, 0.5, 1.0, 2.5 µg/kg (Table 1). Each treatment was replicated five times. Untreated soil from the three study sites was air dried and placed in a foil lined bag, labeled, wetted (to 80% FC) with herbicide solutions and mixed for 8 minutes. The bags were then tightly wrapped and left for 24 h. Labeled styrofoam cups were filled with 205 g of treated soil. Each 237-ml cup received 180 g of soil, either 15 seeds of sugar beet (Michigan Sugar Company) or 10 seeds of spring canola and another 25 g of soil to cover the seeds.

Table 1. Soil Characteristics

Site	pH	OM	Sand	Silt	Clay	Soil Type
Huron	8.0	3.0	33.2	45.8	21.0	Loam
Thorndale	7.0	3.9	44.8	39.6	15.6	Loam
Simcoe	7.1	0.8	76.0	19.1	4.9	Loamy Sand

Plants were top-watered daily to maintain 80% field capacity. A double-cup system allowed any leachate to be collected and returned to the soil. The cups were placed in flat, plastic trays. The trays were randomly placed in the growth chamber and moved each day. Immediately after planting, the cups were covered with plastic and placed in the dark. Once germination began, the plastic was removed and the growth-room lights turned on. Light intensity in the growth chamber was 500 $\mu mol/m^2/s$. Relative humidity averaged 55%, temperature 24/16 ^{0}C day/night with a 16-hour photoperiod. The plants in each cup were reduced to five about 10-12 days after planting. Plants were fertilized weekly with 20:20:20 N:P:K containing micro-nutrients (Plant Products Inc).

Plants were harvested approximately 33 days after planting. The plant shoots were rated visually after comparison to untreated control. The plants from each cup were separated, removed from the soil and washed to remove soil from the roots. Dry weights were measured and recorded. The data was analyzed using GLM-General Factorial and Compare Means using SPSS 7.5 for Windows.

Growth-Room Bioassay of Field-Spiked Soils
Applications of chlorimuron-ethyl (9 g a.i./ha), imazethypyr, (75 g a.i./ha) and flumetsulam (70 g a.i./ha) were made postemergent to an established soybean crop at Huron, Thorndale, and Simcoe, Ontario, Canada (Table 1). Applications of the test substances were made with a CO_2 powered back pack sprayer equipped with a stainless steel canister for holding the test solution and a 3-m boom with six 8003 nozzles. The solution for each replicate within a treatment was separately mixed and a sample of the mix solution was retained for chemical analysis. Following application, chemical phytotoxicity to the soybean crop was evaluated. Very little injury was observed as expected. Prior to and following application at 0 day, and then at approximately monthly intervals up to the end of November, soil samples were taken at each location. A sample consisted of 6 sub-samples; each sub-sample being 15-cm deep by approximately 10-cm in diameter. The sub-samples were bulked by treatment for each replicate and kept frozen. The indicator species were planted in the soil sampled monthly and the growth room bioassay was conducted as described above. The indicator species were compared to the standard curve for each chemical and an estimate of the herbicide residue was made.

In Situ (Field) Bioassay
The soybean crop was harvested from the field sites in preparation for planting the indicator species (sugar beet), which was planted during the 2nd year, rated, harvested and yields recorded. The percentage reduction in field growth of the indicator species when compared to an untreated control was used to interpolate from a standard dose-response curve, prepared by spiking the respective soil type with known concentrations of the herbicide, the herbicide residue remaining in the soil.

Enzyme-Linked Immunosorbent Assay
Synthesis of immunogen. Chlorimuron-ethyl was conjugated to keyhole limpet hemocyamin KLH using the method of Fleeker. Chlorimuron (73.49 mg) and N-hydroxyl succinimide (NHS, 21.87 mg) were dissolved in 2 ml dioxane. N,N'-dicyclohexyl carbodiimide (DCC) 39 mg was dissolved in 0.5 ml dioxane. This solution was added to the chlorimuron/NHS solution, gently swirled and left standing for 12 hours. It was then centrifuged at 14,000 rpm for 20 minutes, the liquid phase discarded and the supernatant dried under N_2 at room temperature after which 6.2 ml of the KLH solution was added. Chlorimuron-KLH solution was dialyzed three times against 1 liter of distilled water. The immunogen was stored in a -20^{o}C freezer for future use.

Polyclonal antisera production. Two New Zealand white rabbits were injected intramuscularly with chlorimuron-ethyl immunogen. Blood was collected after four weeks of the injection. A checkerboard test showed good binding activity between polyclonal antiserum and coating conjugate.

Analysis of Soils Using ELISA. Soils from the three test sites were incubated overnight with 10 mM phosphate buffer, shaken, centrifuged and the supernatant collected and basified with 1M NH_4OH. The supernatant was then filtered, acidified with acetic acid and passed through a C18 column. Herbicide was eluted with ethyl ether, volume reduced and reconstituted in phosphate buffered saline (PBS). Radiolabelled chlorimuron-ethyl was used to determine the extraction efficiency, which averaged 82%. The samples were then analyzed by ELISA.

Results

Bioassay of Growth-Room Spiked Soils

When the herbicides were applied to the soil in the growth room, both root and shoot growth of sugar beet and spring canola was severely inhibited at levels of 0.5 µg/kg and 0.1 µg/kg of imazethypyr (Figure 1) and chlorimuron-ethyl (Figure 2), respectively.

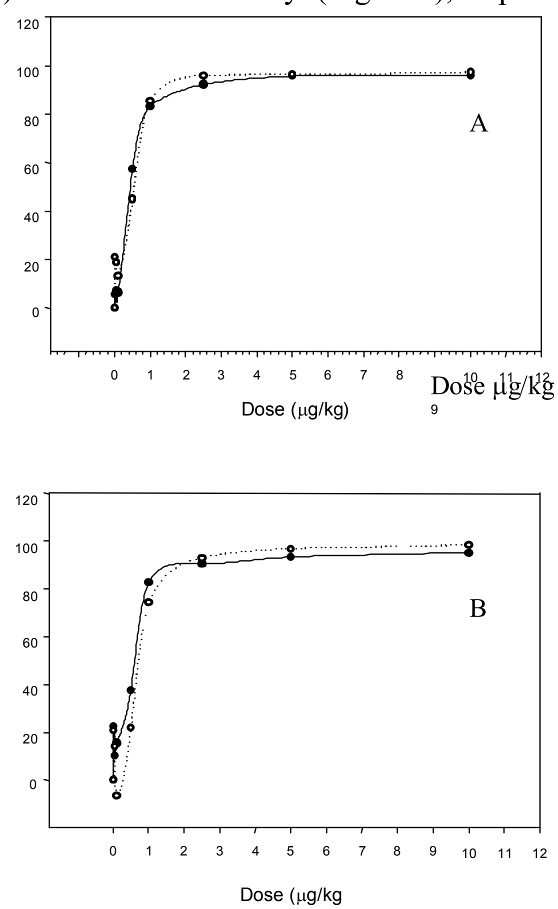

Figure 1. Bioassay of growth-room soils spiked with imazethapyr. Indicator species were A: sugar beet B: spring canola; root ❍ shoot ●.

Growth-Room Bioassay of Field-Spiked Soils

In these experiments herbicides were applied to the soil in the field. One year after their application soil samples were taken and sugar beets were grown in the soil maintained under growth room conditions. Imazethapyr caused injury symptoms that correlated with doses of 0.07, 0.75, and 2.2 µg/kg, respectively, in soils from Huron, Thorndale, and Simcoe, respectively when values were interopolated from the standard curve generated from growth-room spiked soils (Figure 3).

Similarly, sugar beet injury symptoms correlated with doses of 0.13, 0.19, and 0.07 µg/kg in Huron, Thorndale, and Simcoe soils treated with imazethapyr (Figure 4).

In Situ (Field) Bioassay

Generally, growth reduction of the indicator species was comparable between plants grown in the growth-room in soil from the field and plants grown in situ in the field (Table 2).

Enzyme-Linked Immunosorbent Assay (ELISA)

Immunoassays for residue analysis of trace organic contaminants in the environment offer the advantages of sensitivity, specificity, speed of analysis, low cost, ease of automation, and general applicability. Immunoassays can be used as a tier 1 screen to quickly and efficiently eliminate samples containing no contaminants (negatives) prior to analysis of positive samples by more costly and complicated GC and/or HPLC methods thereby saving money and time while improving overall efficiency. Correlation of conventional methods with bioassay, and immunoassays can determine if, for example, a bioassay or immunoassay can be used, in what situations it can be used for analysis, and whether these assays are more time and cost effective.

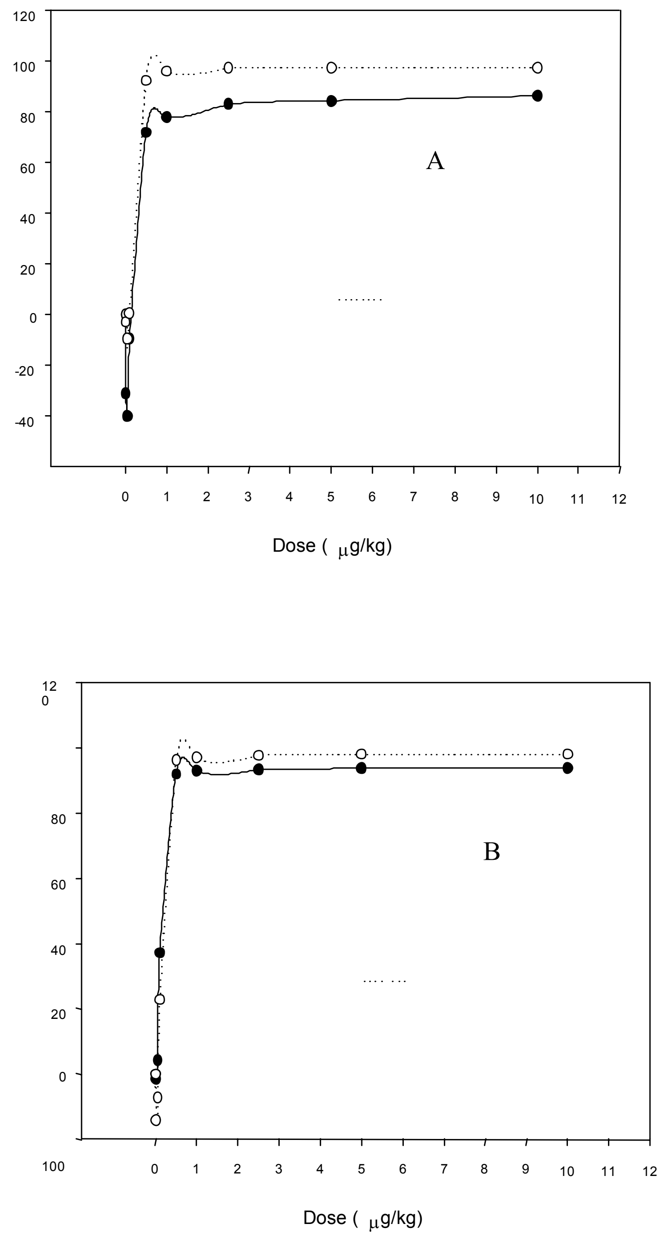

Figure 2. Bioassay of growth-room soils spiked with chlorimuron-ethyl. Indicator species were A: sugar beet B: spring canola; root ❍ shoot ●.

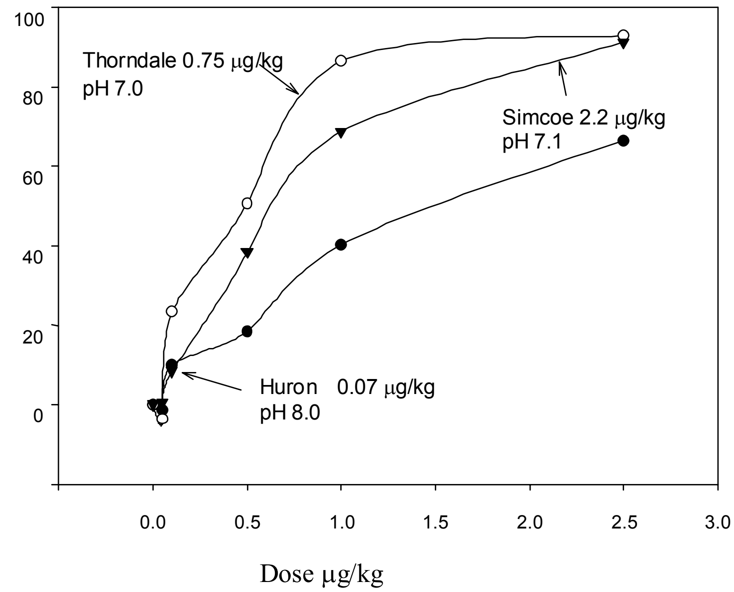

Figure 3. Growth-room bioassay of soils spiked with imazethapyr in the field. Soils samples were taken from the field one year after treatment. Imazethapyr was estimated by interpolating growth reduction from the standard curve shown in Figure 1B; Thorndale ❍, Huron ●, and Simcoe ▼.

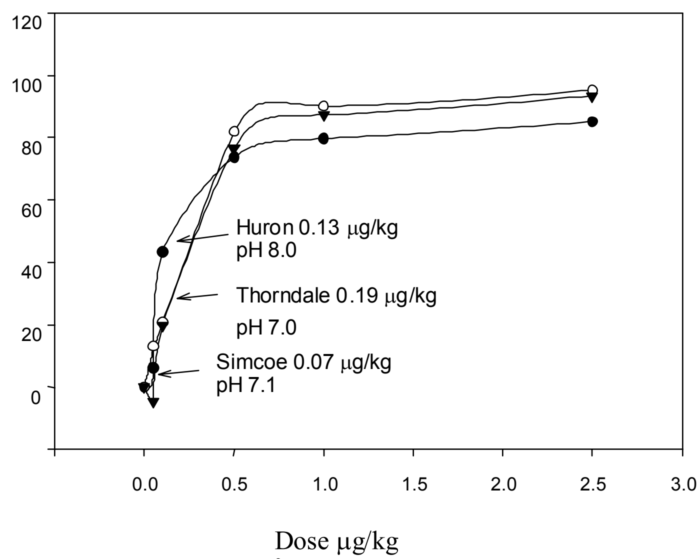

Figure 4. Growth-room bioassay of soils spiked with chlorimuron-ethyl in the field. Soils samples were taken from the field one year after treatment. Chlorimuron-ethyl was estimated by interpolating growth reduction from the standard curve shown in Figure 2B; Thorndale ❍, Huron ●, and Simcoe ▼..

Table 2. Comparison of herbicide residues from field spiked soils measured by bioassay conducted in the growth-room versus the field (in situ). Numbers are expressed as % growth reduction of sugar beet.

	Growthroom	Field
	-----% growth reduction-----	
Flumetosulam		
Huron	-16.6	22.9
Thorndale	55.0	53.9
Simcoe	42.0	40.3
Chlorimuron-ethyl		
Huron	45.8	14.3
Thorndale	35.3	-11.3
Simcoe	6.1	59.6
Imazethapyr		
Huron	6.1	3.8
Thorndale	77.7	58.6
Simcoe	88.0	94.5

The linear working range of the ELISA assay ranged from 1 to 1000 ng·mL^{-1} (Figure 5). The assay has an IC_{50} value of 54 ng·mL^{-1}, with a limit of detection (LOD) of 2 ng·mL^{-1} and a limit of quantification (LOQ) of 27 ng·mL^{-1}. There was good correlation between chlorimuron-ethyl in PBS standards and in soil extract (Figure 6). Currently, we are screening soils from the field bioassay to determine the quantity of chlorimuron-ethyl and compare these results to the growth-room and filed bioassays.

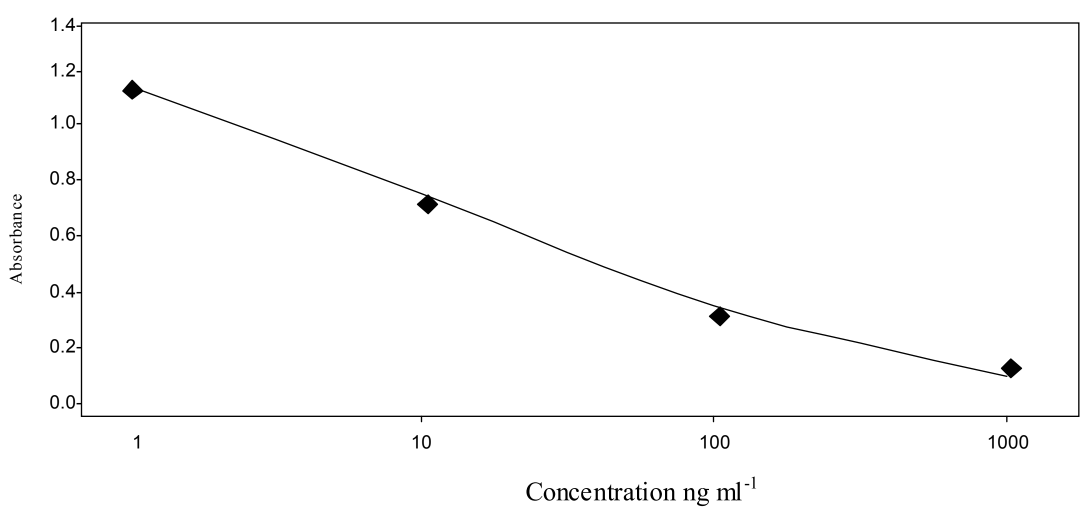

Figure 5. Chlorimuron-ethyl ELISA standard curve.

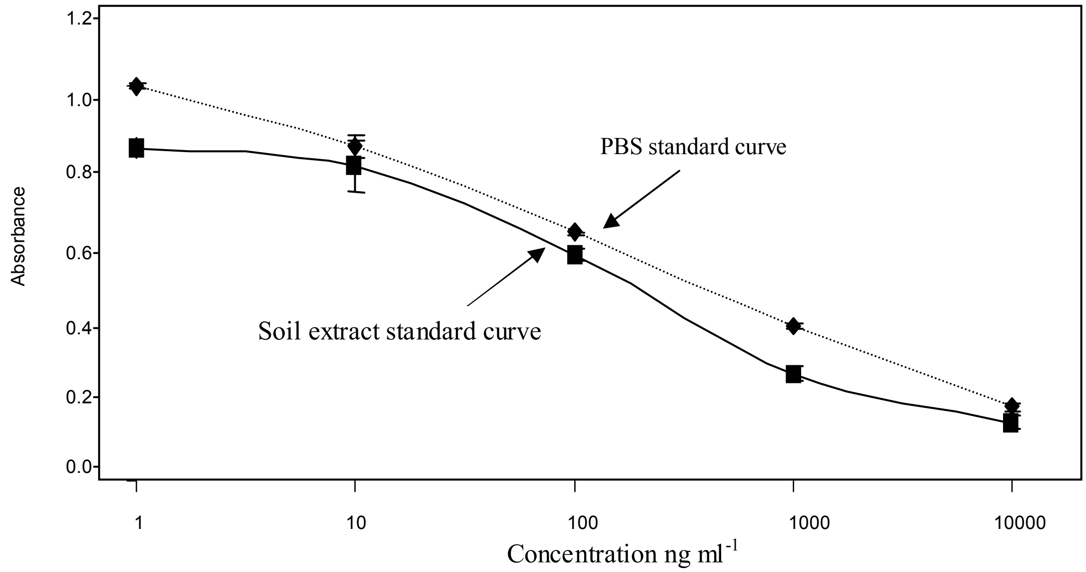

Figure 6. Comparison by ELISA of chlorimuron-ethyl in phosphate buffered saline and soil extract.

Conclusions

These new "low-rate" herbicides are effective and usually selective for control of weeds in corn and/or soybeans at application rates that are 1% or less of the application rates for the herbicides they replace (i.e. atrazine, metolachlor). Because they have low toxicity to organisms other than plants, their use could significantly reduce the overall environmental impact of weed control in corn and soybeans, two of Ontario's largest acreage field crops. However, more information is needed to define the time intervals and the risks to sensitive rotational crops in subsequent seasons following their use. We doubt that growers can conduct effective field bioassays with adequate controls on the same soil types to predict which crops can be safely grown. Unacceptable levels of follow-crop injury could be a result but because of label instructions the companies may not be liable. Such an unacceptable situation could limit the acceptance or result in removal of some of these herbicides from the market.

In order to register and maintain registrations for the low-use rate pesticides, innovative, ultra-sensitive chromatographic, immunoassay, and bioassay methods must be developed and evaluated to determine the fate and persistence of these molecules in the environment. In many cases these new chemistries, such as the imidazolinone and sulfonylurea herbicides, are biologically active at levels that cannot be detected by existing analytical methods. In these cases, bioassay or immunoassay techniques may provide the only method with suitable detection limits. Therefore, it is essential we develop new ultra-sensitive chromatographic and immunochemical methods. These methods will be used to monitor new pesticides and to correlate the limits of detection with the thresholds of biological activity in target and non-target organisms. Canadian agriculturists will then be prepared to meet the technological changes associated with the development of new and innovative pesticides in the next century.

These methods can be used to monitor residues and conduct fate and persistence studies in important Ontario agricultural environments including corn, soybean, and wheat crops. In addition, the following studies can be conducted using these assays (bioassays and ELISA):

- correlation of residue levels with biological injury symptoms on sensitive crop species as well as non-target organisms
- assessment of new sprayer technologies
- worker exposure studies
- monitoring of lateral and vertical movement of pesticides in soil with lysimeters and surface water collectors
- development of dissipation models for new pesticides under Ontario conditions to predict residues at harvest, carry over of residues to subsequent seasons, and to facilitate diagnoses in pesticide damage claims
- monitoring for pest resistance to new pesticides

Acknowledgements
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Graduate Students Papers

Wild oat (*Avena fatua*) emergence as affected by tillage and ecodistrict

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DA. Derksen, M.H. Entz, T. Andrews

Introduction

Characteristic seasonal patterns for individual weed species emergence has been observed and recorded by a number of authors in the past. The findings were that emergence of an individual species begins and ends in a set pattern, dependent on temperature and moisture levels in the microsite (Egley 1991, Ogg and Dawson 1984, Stoller and Wax 1973).

The intent of a number of studies is to build predictive emergence models (Forcella 1993). Datasets used to build these models, in general, have either come from controlled environmental experiments or limited field studies. The intentions of this study to examine the emergence period of weed species under unmanipulated field conditions across a broad ecodistrict area in Manitoba. From the dataset we were interested in discovering if any statistical empirical difference in emergence period between conventional and zero-tillage fields and between fields in different ecodistricts was present.

The uniqueness of this project is the fact that emergence data was collected from so many fields and so the dataset not only represents differences in tillage and ecodistrict, but also a broad range of agronomy. In this respect we are able to test whether tillage or ecodistrict are robustly significant factors to consider in empirical emergence models because we are testing these factors on a background of no control of other factors which may interact to affect emergence, such as fertilizer rate and placement, soil type, and history of tillage practice.

The goals of this study were to gain a robust dataset from a variety of fields under different tillage systems and within different areas of southern Manitoba. From the dataset, we wanted to determine if there were significant differences in the emergence pattern of wild oat (Avena fatua) between tillage systems and regions. The differences would be examined both post-seeding and within the early growing season (early April to mid June). This work is a vital part in the further efforts to produce accurate emergence models for producers in Manitoba.

Materials and Methods

Field Selection

Fields were initially selected on the basis of tillage system, i.e. zero- or conventional-tillage and weed spectrum. Medium infestations of at least three of the following weeds (wild oat (*Avena fatua*), green foxtail (*Setaria viridis*), wild buckwheat (*Polygonum convolvulus*), wild mustard (*Sinapsis arvensis*), stinkweed (*Thlapsi arvense*), redroot pigweed (*Amaranthus retroflexus*)) must have been previously observed within the field to be selected. All fields were seeded to canola, and had a spring cereal crop (excluding rye) as the previous crop.

Classification of Tillage System and Ecoregion

Over the early growing seasons of 1999 and 2000, a total of thirty-six fields representing one million hectares of land in southern Manitoba were sampled for weed emergence. Both zero- and conventionally-tilled fields were examined (eighteen fields under each tillage system) over four ecodistricts. Ecodistrict separation (Table 1) was based on soil type (Agriculture Canada 1989), accumulated growing degree days, precipitation, and soil moisture deficit (Smith et al. 1998).

Table 1: Soil and environmental characteristics of ecodistricts included in study.

Ecodistrict	Soil Type	Soil Moisture Deficit (mm)	(April to June) GDD>5	Rainfall
Gladstone/Winnipeg	Clay	190	1675	340
Pembina Hills	Clay Loam	150	1645	340
Stockton/Shilo	Sandy Loam	230	1625	340
St.Lazare/Hamiota	Clay Loam	200	1550	305

In Field Sampling

Sampling occurred ever two to four days within each field. In 1999, sampling occurred from seeding to canola bolting stage, and in 2000 sampling occurred from the first week of April until canola bolting stage.

Within each field, four ¼ m^2 permanent quadrats were placed in representative field areas. Emerging plants (crop or weed) were marked with colored chicken rings with each color being representative of a particular sampling date. The numbers and identities of the emerging plants were also recorded at each visit. Gravimetric soil moisture samples were taken on each sampling date to a one inch depth. Rainfall was also recorded at each sampling date. Soil temperature was recorded continuously throughout the sampling period with Stow Away® TidbiT™ temperature recorders[1] (TidbiTs™ were removed during seeding and tillage events). The quadrats were covered with a white, non-permeable plastic barrier sheet at the time of in-crop herbicide applications.

At weed harvest (canola bolting stage) all plants were removed from the quadrats, and individual plants were sorted by date of emergence, species and staging. Species dry biomass was determined and recorded for each quadrat.

Air temperature and precipitation data was obtained from Environmental Canada weather stations located closest to the fields where sampling was occurring.

Statistical Analysis

Combination of 1999 and 2000 data for post crop seeding analysis

PROC GLM (SAS[2]) function was used to obtain GLM data for the post-seeding wild oat emergence within 1999 and 2000 for comparison with Barlett's test for homogeneity. From the results of the Barlett's test for homogeneity, it was determined that emergence data for wild oat post-seeding in 1999 and 2000 could be combined.

Nonlinear Regression Analysis

Seedling emergence for each observation date at each site was expressed as a cumulative percentage of total emergence for the site. Time was measured in growing degree days (GDD) and was calculated using 0C as the base temperature, and the equation,

$$GDD = \frac{\text{Maximum + Minimum Daily Temperature} - \text{BASE}}{2}.$$

PROC NLIN (SAS) was used to obtain the parameters for the post-seeding wild oat emergence curves between tillage systems and regions. A logistic model was fitted to the data from the wild oat emergence monitoring. The logistic function chosen was used because of its straightforwardness and accuracy. It serves as a biological model of wild oat emergence with parameters assigned having biological meaning (Friesen et al.1999). The model fitted was,

$$y = a/(1 + be^{-cx})$$

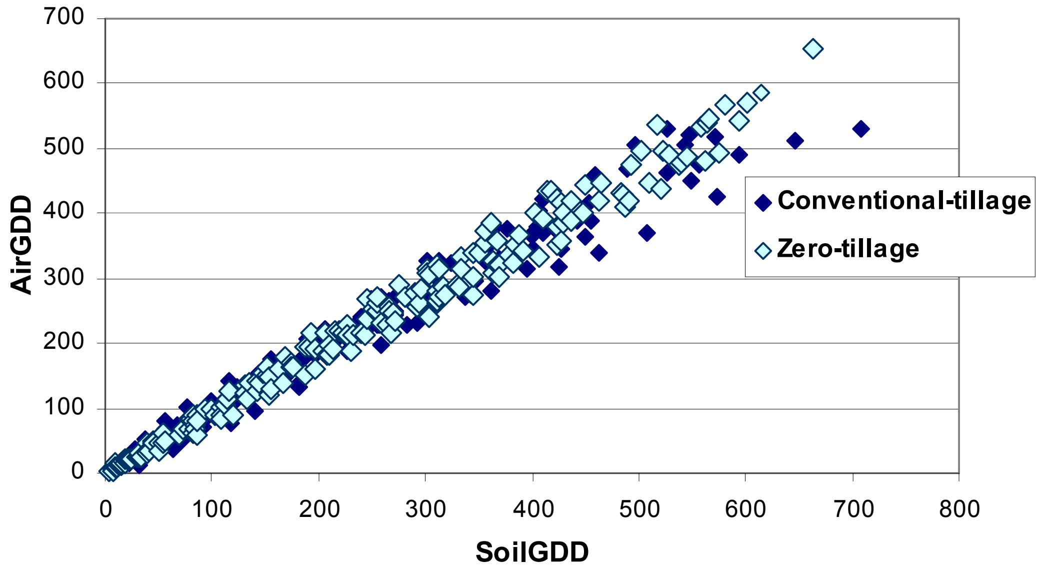
where y is the dependent variable (post seeding wild oat emergence) , x is the emergence percentage expressed in soil growing degree days, e is the base of the natural logarithm, and a, b, and c are the nonlinear parameter estimates. Specifically for the logistic function, a is the estimated value of the upper asymptote, and b, c are used to calculate the shape of the emergence curve.

After the A, B, and C parameters were obtained, F-tests were used to test significance between parameters. Nonlinear regressions were run on a dataset where included sites must have greater than five wild oats emerged within the post-seeding sampling period (i.e. analysis run on the 27 remaining sites). Analysis was completed using both air and soil GDD data.

Correlation of Accumulated Soil and Air GDD

Air and soil temperatures were both collected for each site and the accumulated GDDs calculated. Therefore the dilemma of which measurement(s) of time to use when analyzing the wild oat emergence data was present. The PROC CORR (SAS) function was used to find the correlation coefficient between soil and air GDD and potentially help with the decision of which time measurement to use. The results from PROC CORR found soil and air GDD measurements had a correlation of .99 (Figure 1). Therefore, the data analysis shown after this point was run on soil GDD.

Figure 1: Correlation between soil and air GDD post-seed in 1999 and 2000.



Because the correlation between soil and air GDD was high, it is assumed that either measurement of GDD could be used to look at the relationship between accumulated temperature and wild oat emergence. We will be presenting the results on the basis of accumulated soil GDD, because it represents the temperature where emergence is occurring, and the measurements were unique for each field. Soil temperature also reflects the greater extent of moisture by temperature interactions, as well as the influences of tillage and soil type on individual field temperature.

Results

Post-seeding, wild oat populations begin emerging earlier in zero-till systems, but as time progresses, emergence rate under conventional-tillage increases, and the wild oats conclude their emergence earlier under conventional-tillage versus zero-tillage (Figure 2).

The nonlinear analysis of the post-seeding wild oat emergence patterns (Figure 3) showed that initially among the ecodistricts wild oats emerged first in ecodistrict 4. As time progressed, the percentage emergence rate in ecodistricts 2 and 3 surpassed the emergence in ecodistrict 4. 80% wild oat emergence (E_{80}) was obtained by the ecodistricts in the following order ecodistrict 2>ecodistrict 3[1]>ecodistrict 4[1]>ecodistrict 1. The rate of wild oat emergence was slowest, in general, in ecodistrict 1 (Gladstone/Winnipeg).

[1] Ecodistricts 3 and 4, belong to the same region (Aspen Parkland), but differ on the basis of soil type.

Figure 2: Nonlinear regression analysis of tillage effects on wild oat emergence

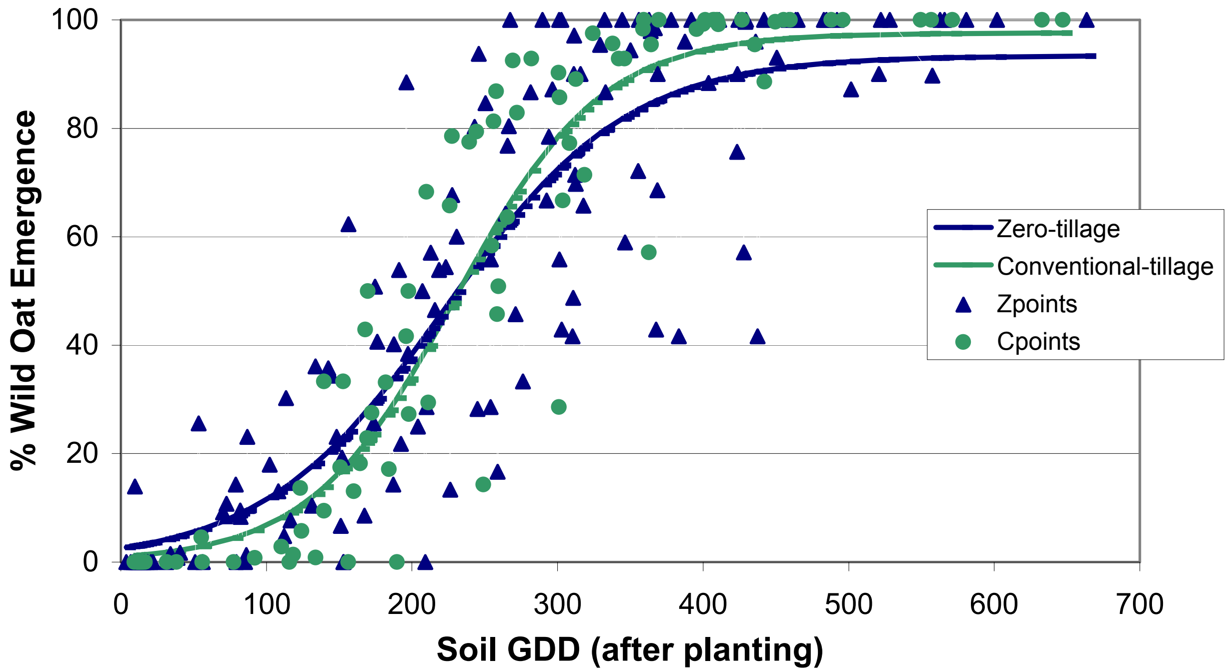
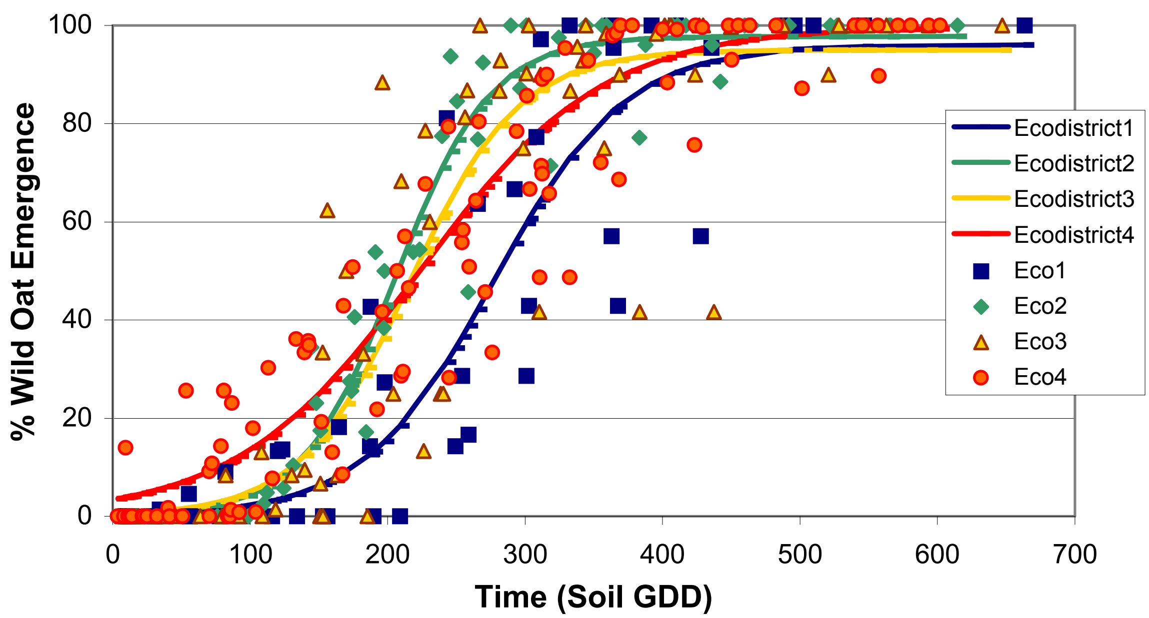


Figure 3: Nonlinear results of ecodistrict effects of post-seed wild oat emergence.



Actual E80 determine from the curves in Figure 3, are as follows in table 2. Differences in E_{80} between tillage systems were only thirty GDD post-seeding. The differences in E_{80} between the ecodistricts were much higher. The smallest spread of E_{80} values was between ecodistricts 2 and 3, equaling 24 GDD. The largest spread was between ecodistricts 1 and 2, equaling 104 GDD.

Table 2: Time to reach E_{80} between different tillage systems and ecodistricts.

Nonlinear Regression Curve	E_{80} (soil GDD)
Tillage	
Conventional	305
Zero	335
Ecodistrict	
1	362
2	258
3	282
4	316

Significance test between tillage systems and ecodistricts are found in table 3. Both the B and C parameters determine the shape of the post-seeding wild oat emergence curve, therefore if either parameter is shows significance when tested against the same parameter for another curve, the results is that the curves would be significantly different. Post-seeding wild oat emergence curves were found to be significant when different tillage systems were compared. The ecodistricts combined, as well as comparisons between ecodistricts 1 and 2; 1 and 3; 1 and 4; 2 and 4, were found to be a significant. The post-seeding emergence curves of ecodistricts 2 and 3, and 3 and 4, were found to be non-significant.

Table 3: F-Test results on the parameters received from the nonlinear regression analysis for different tillage and ecodistricts

Interactions	A	B	C
Tillage	NS	*	*
Ecodistrict 1+2+3+4	NS	NS	*
Ecodistrict 1+2	NS	NS	*
Ecodistrict 1+3	NS	NS	*
Ecodistrict 1+4	NS	*	NS
Ecodistrict 2+3	NS	NS	NS
Ecodistrict 2+4	NS	*	*
Ecodistrict 3+4	NS	NS	NS

Explanations to why significance was found in post-seeding wild oat emergence patterns between ecodistricts can be formulated by examining the environmental differences in temperature and gravimetric soil moisture collected found between the four ecodistricts (Table 4).

Table 4: Average accumulated temperatures and soil moisture from different sampling regions, based on 2000 data from April 5 to June 5

	From 2000 sites April 5 to June 5		
Ecodistrict	Accumulated Air GDD	Accumulated Soil GDD	Total Gravimetric Soil Moisture (g)
1	580	585	175
2	620	630	165
3	670	665	155
4	575	565	190

From table 4, the ecodistricts could be categorized into two simplistic classes, warm and dry (ecodistricts 2 and 3) or cool and wet (ecodistricts 1 and 4).

Discussion

F-test results found tillage system to be a significant factor in determining post-seeding wild oat emergence. When examining the two curves (figure 2) and looking at the E_{80} values, the curves appear to be almost identical. That raises the question are the two curves biologically different?

Thirty soil GDD is a very small difference to have between the E_{80} in two curves, it would equal about two days within that period in the growing season. Reasons for such a small difference in the E_{80} values could be because mergence data was gathered in years where adequate to above-adequate moisture was available in the fields. Therefore the characteristic drier conventional-tillage soil versus zero-tillage soil did not apply in these years. In years when moisture is lacking, post-seeding wild oat emergence differences between tillage systems may be much more significant, due to the increased differences in soil moisture between the different tillage system soils (Spandl et al. 1998).

Significant differences in post-seeding wild oat emergence were found between certain ecodistricts. Ecodistricts comparisons showing the greatest significance, tended to have both different environmental conditions occurring in the areas, and different soil types. Comparisons of significance from F-test results and similarities between soil type, environmental conditions (table 5) indicate both factors need consideration.

Table 5: Comparisons of F-test results and Soil Type, Environmental Conditions for ecodistricts.

	Similarities		
Ecodistrict	**Soil Type**	**Environment***	**Significance**
1+2+3+4	N	N	Y
1+2	Y	N	Y
1+3	N	N	Y
1+4	Y	Y	N
2+3	N	Y	N
2+4	Y	N	Y
3+4	N	Y	N

*Refer to tables 1 and 4 for environmental condition classification that distinguished the different ecodistricts (table 1) and the environmental conditions occurring within the ecodistricts from April 5 to June 5, 2000.

When table 5 is examined, ecodistrict environment shows definite importance into whether the post-seeding wild oat emergence between ecodistricts would be similar. Again, the years in which the data was collected may have influenced the results obtained. In comparison of tables 1 and 4, substantial differences are noticed between what the accumulated GDD and moisture for and areas should be, and what it actually was in 2000.

Results obtained were expected with regards to what was being observed in the field. Ecodistricts 3 and 4 belong to the same ecoregion (but have different soil types), therefore it was expected the emergence periodicities would be similar. Ecodistricts 2 and 3, being in different ecoregions, but very close in proximity, were also expected to have similar emergence patterns. Ecodistricts 1 and 4 were also expected to have similar emergence patterns since both experienced high levels of precipitation in both 1999 and 2000, and were cooler in temperature than the other ecodistricts. Significance was found in ecodistrict 1 and 4 at the 0.05 level (just barely), but no significance was found at 0.025 level. Again, as with tillage, statistical significance was found, but is there biological significance between the two ecodistricts? The significance found in the comparisons of the other ecodistricts made sense as well, since other comparisons had soil type differences and usually environmental differences as well.

Conclusions

A robust dataset in unmanipulated fields is possible. All that is needed is the ambition to collect such a dataset. Within the robust dataset, tillage was found to be a statistically significant factor effecting post-seeding wild oat emergence, but the observed curves are very similar and leads to the question are the results really biologically significant? Ecodistrict was also found to be statistically significant in eco districts where both soil type and environment are dissimilar from each other. This indicates that if modeling is going to be done for a large area, simple empirical ecodistrict models are needed to account for the physical and environmental variation between areas.

Further Directions

The second part of the exploration into if tillage and ecodistrict affect wild oat emergence patterns is looking at the data obtained from very early in the growing season (close to 0 soil GDD). From this data and analysis it can be determined optimal planting dates for delayed planting wild oat control benefits between tillage systems and ecodistricts.

Sources of Materials

[1] Stow Away® TidbiT™ , Onset Computer Corporation, Box 3450, 536 MacArthur Blvd., Pocasset, MA 02559-3450.
[2] SAS version 8, SAS Institute Inc., Box 8000, Cary, NC 27511-8000.

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The effect of low-temperature and moisture stress on the rate of germination of oat (*Avena sativa* L.) and wild oat (*Avena fatua* L.)

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Abstract

Rapid emergence is one of the traits that influence the competitive ability of cereals with wild oat. Differences in low-temperature germination rate amongst oat varieties may be exploited in order to obtain high levels of competition with wild oat. The objective of this research was to determine if varietal differences in germination rate exist under low-temperature and moisture stress. There are differences in the germination rates of the oat varieties OT 288 and Triple Crown as well as between the same varieties and the wild oat population tested. In a range of water potentials from 0.0 to –0.8 MPa , Triple Crown germinated faster than OT 288. Both tame oat genotypes had germination rates higher than wild oat. Differences amongst germination rates suggest that the rate of germination at low temperature may be related to the time of emergence of the crop and thus competitive ability.

Introduction

The control of wild oat in tame oat is particularly daunting due to the lack of herbicides and the sole reliance on cultural control methods. One possible control measure may be the selection of oat genotypes that are more competitive. It has been suggested that accelerated rates of germination and emergence may be traits that confer competitiveness (Froud-Williams, R.J., 1997). These characteristics may reduce the time period between crop and weed emergence, subsequently decreasing the effects of weed competition on oat.

Due to the lack of herbicides for wild oat control, oat producers have used tillage and delayed seeding as means to eliminate wild oat. However, early seeding is beneficial in the production of oats, further limiting producers choice in terms of control methods. Humphreys et al. (1994) found that early seeding leads to an increase in both the yield and test weight of oat. Kiesselbach and Lyness (1924) (as cited by Kiesselbach, 1925) found that the time of planting had dramatic effects of both the yield and quality of oat. With just a 12-day difference in seeding, yield was reduced by 15%. Test weight was also found to decline with later seeding. Similar work conducted by Ciha (1983) indicates that delayed seeding significantly reduces yield. These findings show that characterization of varietal traits such as germination and emergence rate could be used to maximize yields and reduce losses to weeds.

Wild oat has a greater effect on crop yield when it emerges prior to the crop. O'Donovan et al. (1985) found that early emergence leads to increased competitive ability in wheat and barley. Yield loss increases with increasing time between wild oat and crop emergence.

Christensen (1995) found that differences in weed dry matter could be related to time of crop emergence. Early crop emergence was found to favor the growth of the crop over the weed population. By determining if differences in germination rate do exist amongst oat varieties at low-temperature, there is the potential to exploit this characteristic in IWM strategies.

Yield loss due to the presence of wild oat may be reduced by ensuring that the crop gains a competitive advantage over wild oat (Bubar, 1983). Therefore by planting a variety that possesses those traits which confer competitive ability, yield losses to wild oat may be reduced. Differences in competitive ability among varieties have been associated with early emergence and seedling vigor. Lopez-Castaneda et al. (1995) found that the greater early vigor of barley as compared to wheat is due to the differences in relative growth rate between the time of germination and the appearance of the second leaf. Differential seedling emergence rate amongst crop varieties is due to differential coleoptile growth rate (Allan et al., 1962) as well as seed coat thickness and permeability (Swanson and Hunter, 1936). It was shown that semidwarf varieties in general have a slower rate of coleoptile growth and in turn emergence compared to standard height varieties (Allan et al., 1962). The objective of this research was to determine the effects of low-temperature and osmotic stress on the germination rate of wild oat and tame oat genotypes.

Materials and Methods

Tame oat genotypes, Triple Crown and OT 288 were obtained from seed grown in 1999 at the University of Saskatchewan's Kernen Research Farm. The wild oat seed was taken from a population harvested several years earlier, to ensure low dormancy. OT 288, a semi-dwarf variety, and Triple Crown were selected based on differences in competitive ability and differential emergence rate as observed in a previous field experiment. Preliminary germination tests at 25°C under total darkness indicated 98% germination for Triple Crown, 96% germination for OT 288 and 87% germination for wild oat. The seed was surface-sterilized by immersion in a 1% sodium hypochlorite solution for 1 min. The seed was then triple rinsed with distilled water and placed on two pieces of filter paper and immersed in 8 ml of water.

A three-factor randomized design was used to test the effects of two temperatures (5 and 10°C) and seven initial osmotic potentials (0.0, -0.2, -0.4, -0.6, -0.8, -1.0, -1.3 MPa) on the germination of three seed lots (OT 288, Triple Crown and wild oat). Seeds were subjected to a photoperiod of 14:10h (light:dark) while temperatures remained constant at 5 and 10°C. Each treatment was replicated 4 times.

For each treatment, 40 seeds were placed into 10-cm petri dishes. Each dish was lined with 2 pieces of Whatman no.3 filter paper and then one of the seven PEG (polyethylene glycol) stock solutions was added. PEG solution was added at a volume of 8ml per dish. The osmotic potential of the solutions was measured using a vapor pressure osmometer (model 5100C, Wescor Inc.). PEG was used to alter osmotic potential, as it has no effect on seed germination (Hardegree and Emmerich, 1994). Due to low temperatures and prolonged germination period, seed-borne diseases were a concern. To minimize the effect of disease, Captan (N-trichlorolmethylthio-4-cyclohexene-1, 2dicarboximide) was added to all of the stock PEG solutions (Dahal and Bradford, 1994) at a rate of 270µl per 100g of seed (0.37g ai/ml).

Petri dishes were placed in the 168 cells of the thermal gradient plate. Each cell was individually equiped with a separate electronic temperature controller (McLaughlin et al., 1985). Germinated seeds were counted every 12-h for 20d and once every 24-h for the following 11 days. Seeds were removed when the length of the radicle exceeded 2mm. The volume of PEG solution contained in each petri dish was periodically adjusted with the addition of distilled water to correct the effects of evaporative losses. After 30d the seeds which had failed to germinate were tested for viability by applying pressure to the seed. If the seed remained firm under pressure it was considered to be viable (Baskin and Baskin, 1998). However, if the seed collapsed it was considered non-viable. To calculate final percent germination, the total number of germinated seeds was expressed as a percentage of the total number of viable seeds following the 30d test period (Thomas et al., 1994). Germination rate was calculated as one over the time to 50% germination of viable seeds**.** The data from the above experiment was analyzed using a three-way analysis of variance and orthaganol contrast (SAS, 1990).

Results and Discussion

There was significant variation ($P < 0.001$) amongst germination rates of the three varieties tested (Fig. 1). Triple Crown had the highest germination rate followed by OT 288 and then wild oats over all osmotic stress levels. At 0.0 MPa (10°C) all three oat samples approached 100% germination after 720h. With an increase in osmotic stress level to –0.2 MPa the two tame oat varieties maintain high levels of germination. However, the germination of wild oat declined (Fig. 1-C). At 5°C results were similar, but the time required for initial germination to occur was greater (Fig. 1-D).

The two tame varieties differed significantly in germination rate compared to the wild oat ($P < 0.05$) and highly significant differences were also found between the two tame varieties ($P < 0.001$) (Table 1). Triple Crown had the highest average germination rate of the three oat genotypes tested. The germination rate of OT 288 and wild oats were 87% and 86% respectively that of Triple Crown.

Germination rates were higher at 10°C than at 5°C ($P < 0.0001$). No significant variety X temperature interactions were observed. The germination rate of both oat varieties and wild oat averaged over all osmotic stress levels at 5°C was 50.3% of the germination rate at 10°C.

Highly significant differences ($P < 0.0001$) were found amongst germination rates over the tested osmotic stress levels. As expected, increasing osmotic stress led to decreased germination rates amongst all varieties. No interactions were found to exist between osmotic stress and varieties indicating that the two tame varieties and wild oat all respond similarly to moisture stress conditions during germination.

The interactions between osmotic stress and temperature for germination rate were significant ($P < 0.0001$). Increasing osmotic stress led to a greater decline in germination rate over all varieties at 10°C then it did at 5°C. The interaction occurs when osmotic potential is decreased from 0.0 MPa to –0.2 Mpa (Fig. 2). At 10°C the germination rate decreased by 32% when the osmotic potential decreased to –0.2 MPa while at 5°C the germination rate falls by only 25%.

Previous research has found differences in germination rate amongst wheat genotypes (Lafond and Baker, 1986). In our study varietal differences were found to exist among the tame oat varieties Triple Crown and OT 288. The slower rate of germination in OT 288 (semidwarf) may relate to reduced rates of emergence in the field. In their examination of over 100 wheat genotypes, Allan et al. (1962) found that semidwarf varieties have a slower rate of coleoptile growth and hence emergence compared to varieties of standard height. Differences were also found between the tame varieties and the wild oat population examined. The germination rate of Triple Crown was greater than that of OT 288 which was greater than wild oat.

Crop emergence prior to wild oat emergence increases yield and improves crop quality (O'Donovan et al. 1985, Anderson and Henning, 1964, Kiesselbach 1925). Seeding prior to significant wild oat emergence will reduce the number of wild oat killed by pre-seeding tillage. However, early seeding and rapid germination may reduce the amount of time lapsed between crop and weed emergence. As low soil temperatures during the early spring may reduce germination rate, quantifying low temperature germination amongst oat varieties may allow the identification of varieties that have the ability to maintain high rates of germination under adverse conditions. This maintenance of germination rate under low temperatures may allow the crop to establish rapidly and therefore increase competitiveness. However, preliminary results from the 2000 field season do not appear to indicate dramatic differences in emergence rates among oat genotypes. This may be due to a combination of environmental factors or perhaps rate of germination does not correlate well with rate of emergence.

Due to the preliminary nature of the above study, investigation has been expanded to include other genotypes as well as an examination of the effects of seed size on germination. Other studies include an examination of the effects of seed size on rate of emergence and early morphological traits. Field studies currently under way include the determination morphological traits that confer competitiveness with wild oats, focusing on the importance of light interception and plant density on crop competition.

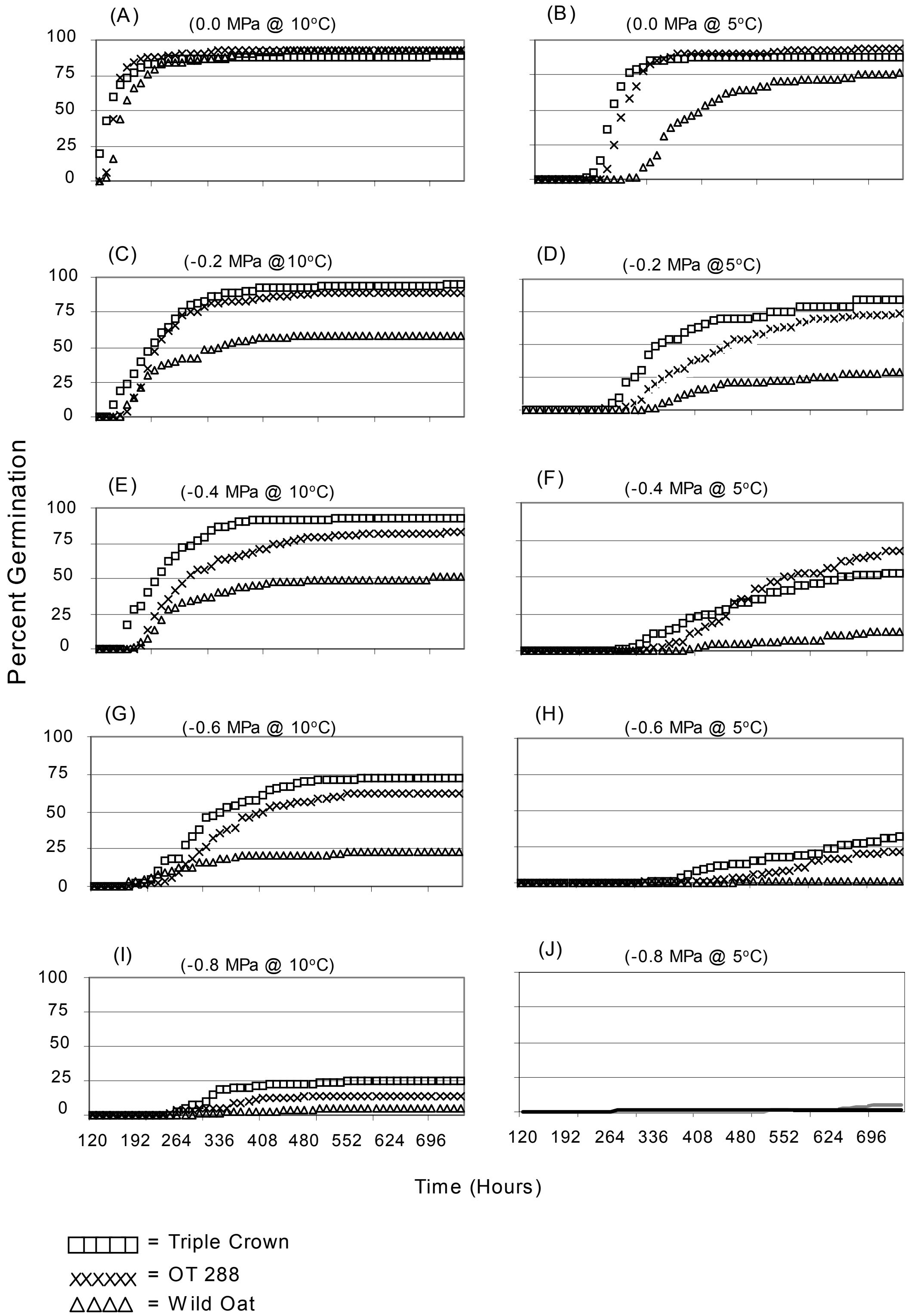

Figure 1.(A – J) Cumulative cereal germination curves averaged over temperature and osmotic potentials of 0.0, -0.2, -0.4, -0.6, and –0.8 MPa.

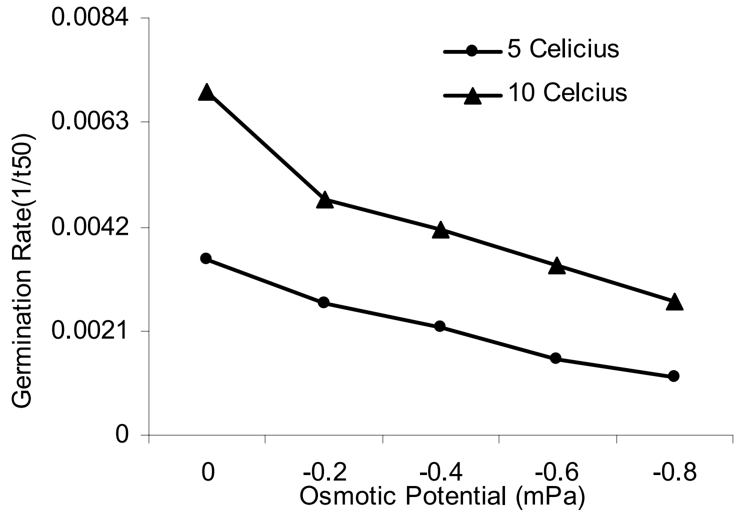

Figure 2. Averaged germination rate of all genotypes at 5°C and 10°C over 5 osmotic stress levels.

Table 1. Germination rates averaged over 5 and 10°C and 0.0, -0.2, -0.4, -0.6, -0.8 MPa

	Avg. Germ. Rate	**P – value**
Tame oat	0.00249	0.029
Wild oat	0.00231	
Triple Crown	0.00268	0.0011
OT 288	0.00232	

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Modelling germination of wild mustard (*Sinapis arvensis* L)

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Abstract

Laboratory studies were conducted to determine the interaction of temperature and water potenial on the germination of wild mustard seed. Eight thermoperiods and seven water potentials were tested, ranging from means of 3.5 to 42.5 C and 0 to -1 MPa respectively. Cumulative germination was modeled by a logistic function. Cardinal temperatures of 2.8, 22.1 and 42.6 C and a base water potential of –0.80 MPa were estimated respectively by probit anaylsis. Germination of wild mustard was mathematically described using hydrothermal time ($\square_{HT}$). This model described germination using a single curve generated from the relationship of temperature, water potential and time. The parameters derived from this study can be used in future weed emergence modelling.

Introduction

Predictability of weed emergence, relative to the crop, is very important in determining the outcome of weed and crop competition (Swanton and Murphy 1996). For example Knezevic et al. (1994) showed that, while an early emerging weed flushes can cause a 34% yield losses in corn, a late flush causes negligible yield loss. Hydrothermal time ($\square_{\square\square}$) was originally proposed as an approach to modelling seedling emergence (Gummerson 1986) which uses a single function to describe the interaction of osmotic potential and temperature above their respective base values. The concept of $\square_{\square\square}$ was expanded to include a maximum temeprature for emergence (Bradford 1990; Dahal and Bradford 1994) and described emergence over a specific range of temperatures and osmotic potentials. Oryokot et al. (1997) decribed germination and found that osmotic potential had an increasing effect as mean temperture moved away from the optimum. Roman et al. (2000) developed a mechanistic model which described the emergence of lambsquarters in $\square_{\square\square}$. This model defined germination ($\square_{\square\square}$) and elongation (thermal time) as two separate processes. This approach was also used by Shrestha et al. (1999) to describe ragweed emergence. The use of $\square_{\square\square}$ in weed emergence models has shown to be effective in predicting weed emergence when compared to other emergence models (Forcella 2000). It is very important however to combine both laboratory based research with field condition observations in order to provide an accurate model for weed seedling emergence (Grundy and Mead (2000). The objective of this study is to describe wild mustard, a very early emerging cold tolerant weed, germination in hydothermal time for later incorporation into an ecophysiological model for emergence prediction.

Materials and Methods

Temperature and Water Potential Effects of Seed Germination

A completely randomized design (CRD) with three replicates, repeated once, was used to test the effects of eight thermoperiods and seven water potentials on seed germination ranging from means of 3.5 to 42.5 C and 0 to -1 MPa respectively. Polyethylene glycol (PEG)[1] was used to create the different osmotic potential solutions.

For each treatment, 100 seeds were placed in a 10-cm petri dish lined with Whatman No. 3 filter paper. Five milliliters of PEG solution were added to each petri dish such that each osmotic potential occurred in combination with each of the 8 thermoperiods. The petri dishes were placed in a seed germinator consisting of 168 individual temperature controlled cells. Germinated seeds, determined by the presence of a 1mm root radical, were counted and removed every 12 h until all germination ceased. The cumulative numbers of germinated seeds were expressed as percentages of the treatment with the highest observed total germination (Thomas et al. 1994).

Modeling Seed Germination

To calculate the rates for germination, cumulative germination curves for each treatment were modeled by a logistic function. The slope of the curve at 50% germination was calculated using the first derivative of the logistic function. The rates in the sub- and supra-optimal ranges were regressed against temperature for each osmotic potential. The base temperature (T_b) and maximum temperature (T_{max}) were estimated from the interception of the sub- and supra-optimal regression line with the abscissa respectively (Dumur et al. 1990). The optimal temperature (T_{opt}) was calculated as the point estimate from the interception of these two regression lines. The rate to 50% germination was regressed against ψ for each thermoperiod to determine base osmotic potential (ψ_b). The intersection of the regression line with the abscissa was defined as the ψ_b (Fyfield and Gregory 1989). The procedure was done to determine the interaction of osmotic potential with temperature.

For modelling purposes, estimates of T_b, T_{opt}, T_{max} and ψ_b, representative of the population, were calculated by probit analysis using models of thermal- and hydro-time against percent germination. These values were then used to calculate hydrothermal time for the population of wild mustard for each temperature-osmotic potential combination. Hydrothermal time was calculated using a broken linear function adapted from Hammer et al (1993). Subsequently, percentage germination from each treatment was plotted against hydrothermal time and modeled by the Weibull function in which hydrothermal time (θ_{HT}) was inserted as the independent variable (Roman et al. 1999).

Results and Discussion

Temperature and Water Potential Effects on Germination

Germination of wild mustard seed varied with the interaction of temperature and water potential. Seed germination decreased with decreasing water potential for all temperatures tested with the exception of 42.5 C, at which no germination occurred. As well, no germination was observed in treatments containing a water potential of –1.0 MPa.

Both cardinal temperatures and ψ_b did not vary with changing conditions. The 95% confidence intervals (Sokal and Rohlf 1981) were considered wide for the purposes of modelling (Roman et al. 1999). These large confidence intervals resulted from a relatively small number of observations determining the sub- and supra-optimal ranges used in the regression analyses. High variability inherent within estimates of cardinal temperatures and base water potentials have been reported for mungbean (*Vigna Radiata* L.) (Fyfield and Gregory 1989), faba bean (*Vicia faba* L) (Dumer et al 1990), Lamb's-quarters (*Chenopodium album* L) (Roman et al 1999) and ragweed (*Ambrosia artemisiifolia* L) (Shresthra et al. 1999).

Estimates for cardinal temperatures and base water potential from probit analysis were 2.8, 22.1 and 42.6 C for T_b, T_{opt} and T_{max} respectively and –0.94 MPa for ψ_b. These values were used to calculate hydrothermal time.

Hydrothermal Time

The germination time course curve, predicted by hydrothermal time, adequately described the seed germination phenology for wild mustard. The predicted curve, generated by the Weibull function, agreed closely with the observed germination sequence. The model was deemed appropriate based upon normally distributed residuals. This hydrothermal time model was similar to that of Roman et al. (1999), which was the first model to describe the germination sequence of a weed population with a single curve generated from the relationship of temperature and water potential.

The model had a lag period of 10.1 C MPa days prior to the initiation of germination, followed by a rapid linear phase until approximately 80% germination, after which it plateaued. The inclusion of the data from the extreme temperatures decreased the goodness of fit of the model. Ellis et al. (1986), Roman et al (1999) and Oryokot et al (1997) noted that extreme temperature values tended to worsen the goodness of fit of their models as well.

The description of germination as a function of the combined effects of temperature and water potential avoided the need for describing germination as separate functions for different conditions. Some models describing cumulative germination based on thermal time have limitations in modeling germination under limiting moisture (Oryokot et al, 1997). Extension of the thermal time concept to include responses to water potential through explicit incorporation of an interaction term for water potential resulted in a model that described germination across a range of temperatures and water potentials (Roman et al. 1999).

The simplicity and goodness of fit provided by this model offers considerable potential for predicting germination and seedling emergence in field situations where water potential and temperature vary unpredictably. The model must, however, be tested in the field. This model represents an important advancement toward the development of an ecophysiological model of weed seed germination and seedling emergence.

Sources of Materials

[1] Carbowax PEG 8000, Fisher Scientific Ltd., 112 Colonnade Road, Nepean, ON, Canada K2E 7L6.
[2] Controlled environment cabinets, Conviron Model E8H, Controlled Environments Limited, Winnipeg, MB, Canada R3H 0S1.

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Weed seedling emergence in three integrated pest management systems

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Introduction

Each type of management system affects the dynamics of weed populations. Zero, minimum, and conventional systems differ in the number and type of tillage operations and these operations have an impact on weed populations since tillage is an important method of weed management. Reducing tillage within management systems increases the amount of surface crop residue (Buhler *et al.*, 1994; Koskinen and McWhorter, 1986). This alters the soil microclimate and creates a variety of conditions that affects germination of weed species and results in long-term changes to the weed flora (Dorado *et al.*, 1999; Felix and Owen, 1999; Mulugeta and Stoltenberg, 1997; Stahl *et al.*, 1999; Swanton *et al.*, 1999). Perennial weeds may become a major problem after a few years of reduced tillage. Large-seeded broadleaf weeds become less of a problem in reduced tillage systems whereas small-seeded annuals either remain constant or become more important weeds.

Crop residues have a far greater suppressive effect on large-seeded broadleaf weed species than on grasses because of different seedling morphology (Bergelson, 1996; Schumann *et al.*, 1995). Under normal circumstances, seedling shoot growth occurs in a gaseous medium, so shoots are generally not designed to force their way through particularly resistant physical barriers. The presence of crop residues in conservation tillage systems would thus affect weed community structure not only by modifying environmental conditions but also by screening weed species according to their capacity to emerge through a physical barrier.

The main objective of this study was to determine the pattern of weed seedling emergence in three integrated pest management systems. Specifically, we wanted to answer three questions. Is weed emergence affected by the presence of a crop residue barrier in reduced tillage management systems? Are some weed species affected more than others? Can differences in emergence be explained by weed seedling morphology?

Materials and Methods

A field experiment was established in the fall of 1996 on the Kernen farm of the University of Saskatchewan at Saskatoon, Saskatchewan. The experiment included six crop management systems, applied to a four-year crop rotation (hard red spring wheat, canola, malt barley, pea). The six management systems were: High Herbicide - Zero Tillage (HH/ZT); Medium Herbicide - Zero Tillage (MH/ZT); Low Herbicide - Zero Tillage (LH/ZT); Low Herbicide - Low Tillage

(LH/LT); Medium Herbicide - Medium Tillage (MH/MT); No Herbicide - High Tillage (NH/HT). Systems were replicated four times and each phase of the rotation was present each year. Data collection that related to our research objective was restricted to canola plots in systems HH/ZT, LH/LT, and NH/HT. To differentiate between management systems, percent surface residue coverage was measured, using the line-transect method, pre- and post-plant for the three tillage systems in 1999 and 2000 (Morrison *et al.*, 1993). For example, in 1999 the percent residue cover prior to spring operations was 97%, 97%, and 74% in HH/ZT, LH/LT, and NH/HT respectively and after seeding was 65%, 45%, and 28%.

In mid-April of 1999 and 2000, two permanent quadrats, 50 cm by 25 cm, were placed in each plot. Weed seedling emergence was monitored weekly until mid-August by counting and tagging new cohorts of weed species with colored markers. To reduce the impact of monitoring on the plots, a platform (10' x 2' x 2') was built to hold two people who could then position themselves on the table and reach down and tag the weeds in the plots.

Weed emergence data were analyzed using Freidman's non-parametric two-way ANOVA based on system ranks. Multiple comparisons between management systems were performed on the significant weed species. Emergence data were grouped according to management operations; before seeding, before spraying, and after spraying. Separate analyses were carried out for each year at each time for each weed species. Actual emergence data collected are represented in the following graphs.

Results and Discussion

In total, 26 weed species were found in the permanent quadrats, but only 6 weed species showed significance differences among management systems (Table 1).

Table 1. Summary of six weed species that responded significantly to management system at three times[1] within the 1999 and 2000 field season.

	Bseed '99	Bspray '99	Aspray '99	Bseed '00	Bspray '00	Aspray '00
Cleavers				*	*	
Volunteer Wheat	**			*		**
Redroot Pigweed		**	**			**
Wild Buckwheat	*			**		
Stinkweed	**		**	**	**	**
Wild Mustard	**		*	**	**	**

** = 0.01 significance, * = 0.05 significance
[1] Bseed = before seeding, Bspray = before in-crop herbicide application, Aspray = after in-crop herbicide application

Cleavers (*Galium aparine* L.) was associated with HH/ZT and LH/LT before spraying in 2000 (data not shown). Emergence of cleavers was similar in the two systems because LH/LT did not have a spring tillage operation in 2000. Therefore, cleavers establishes in management systems without fall or spring tillage.

Volunteer wheat (*Triticum aestivum* L.) emerged in HH/ZT and LH/LT before seeding in 1999 and 2000 and in HH/ZT after spraying in 2000 (Figure 1). One exception was high emergence of volunteer wheat in NH/HT before seeding in 2000. High crop yields in 1999 may have caused volunteer wheat to be a problem in the spring of 2000.

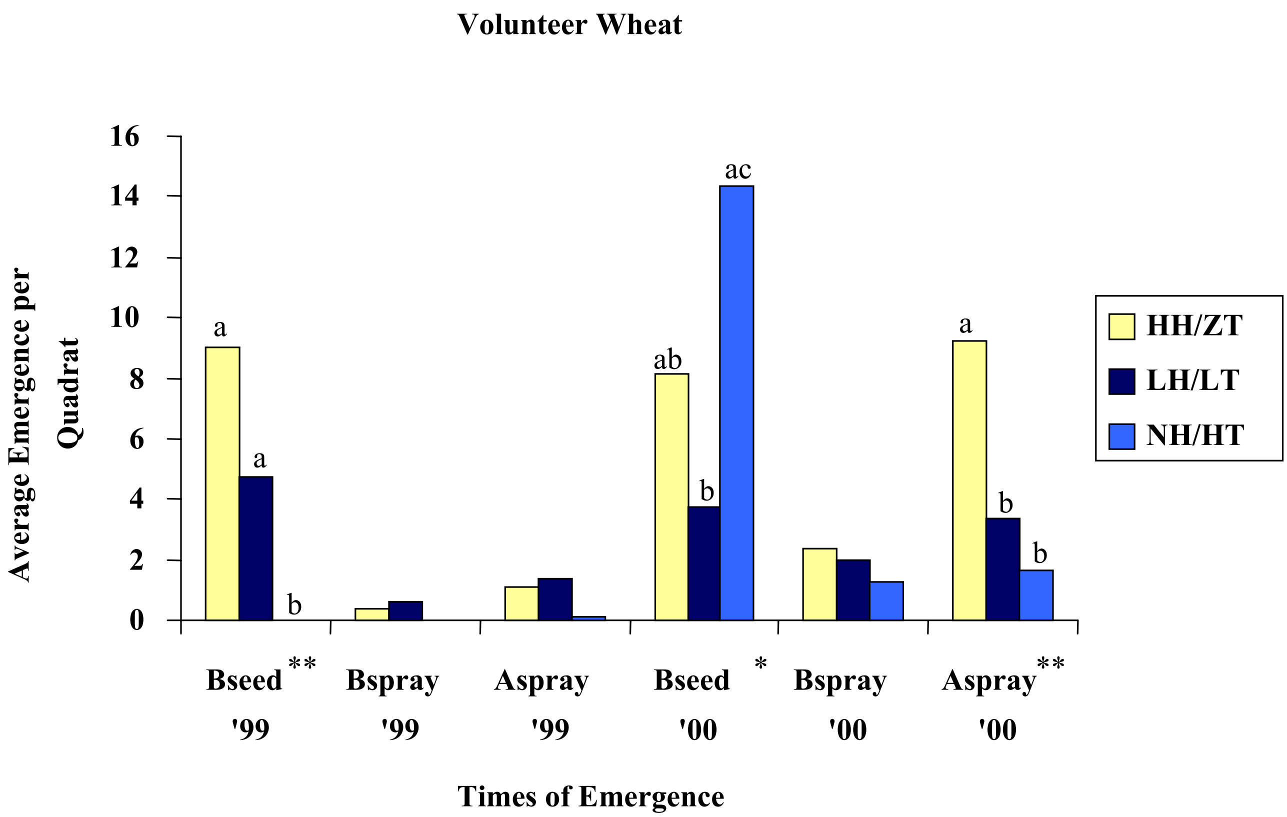


Figure 1. Emergence of volunteer wheat at three times within the 1999 and 2000 field seasons.

Redroot pigweed (*Amaranthus retroflexus* L.) did not emerge before seeding. Emergence was significantly higher in LH/LT and NH/ZT before spraying and after spraying in 1999 and after spraying in NH/HT in 2000 (Figure 2). In 1999, redroot pigweed escaped in-crop weed control in LH/LT, likely because the surface residues modified the seedbed environment in some way to delay germination of redroot pigweed.

Redroot Pigweed

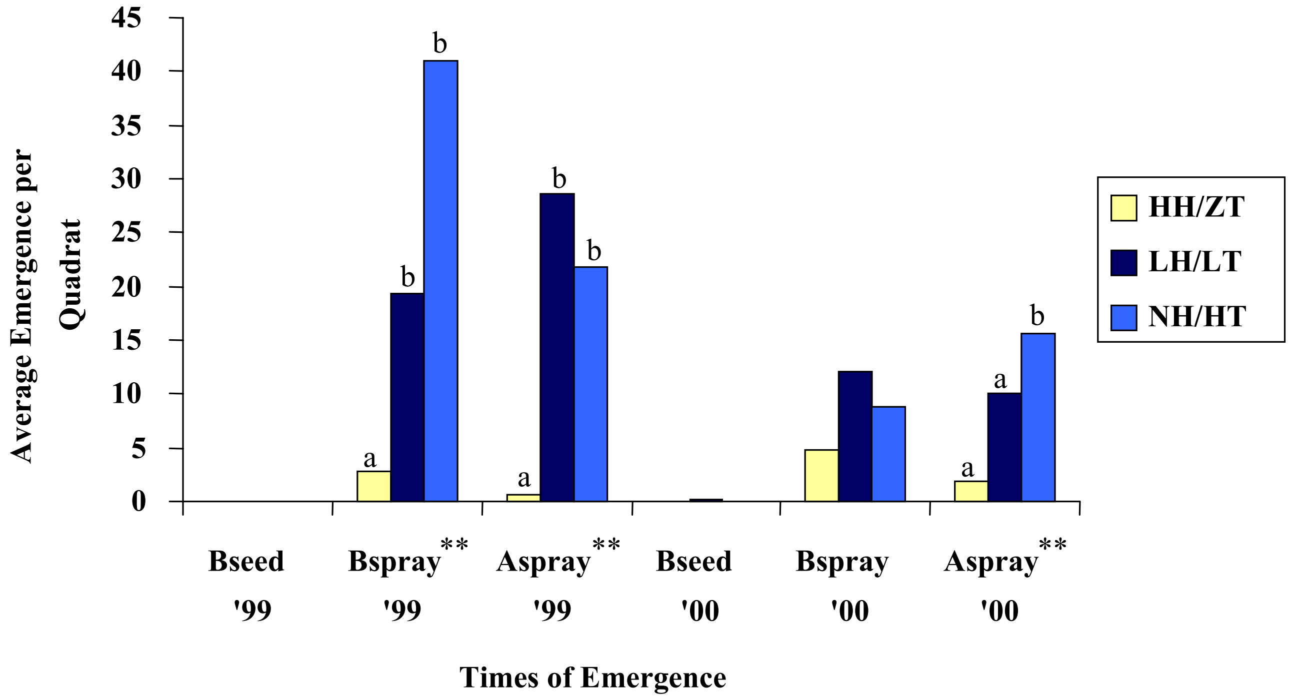
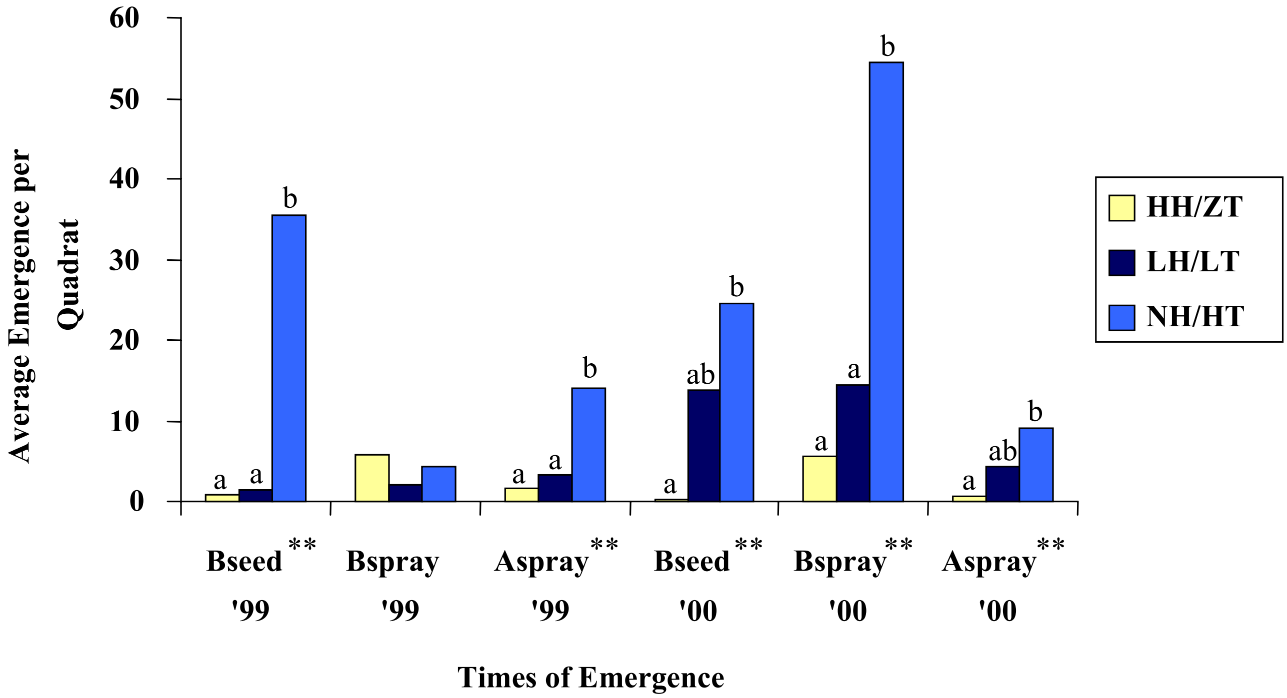


Figure 2. Emergence of redroot pigweed at three times within the 1999 and 2000 field seasons.

Emergence of wild buckwheat (*Polygonum convolvulus* L.) was significantly higher in NH/HT before seeding in both years, 1999 and 2000 (data not shown). The specific time of wild buckwheat emergence suggests that the cool spring temperatures or large fluctuation of temperatures enhance wild buckwheat germination in NH/HT. The crop residues in HH/ZT and LH/LT dampen temperature fluctuation.

Stinkweed (*Thlaspi arvense* L.) and wild mustard (*Brassica kaber* (DC.) L.C.Wheeler) emerged throughout the monitoring period. Emergence was significantly higher in NH/HT before seeding and after spraying in 1999 and all times in 2000. Stinkweed data are represented in Figure 3 (wild mustard data not shown). Frequent tillage operations of NH/HT create a favorable environment for stinkweed and wild mustard germination. The disturbance may expose seed to light, aerate the soil, replace non-dormant seeds near the surface or displace seed from the moisture limited soil surface to greater depths in the profile, where most seeds germinate (Mulugeta and Stoltenberg, 1997). Tillage, rather than lack of residue, is important for stinkweed and wild mustard germination and emergence.

Stinkweed



Conclusions

The three integrated pest management systems affect emergence of particular weed species. In the HH/ZT and the LH/LT systems, cleavers and volunteer wheat have significantly higher emergence. In the LH/LT and NH/HT systems, redroot pigweed showed significantly higher germination. Wild buckwheat, stinkweed, and wild mustard are associated with the NH/HT system. Crop residues, tillage and environmental factors interact to regulate weed species emergence. Further analysis will be done to relate weed emergence to environmental data (soil temperature and moisture) to better understand weed emergence patterns within a weed community. This knowledge will help improve both short- and long-term weed-management strategies (Mulugeta and Stoltenberg, 1997).

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Impact of common ragweed (*Ambrosia artemisiifolia*) aggregation on threshold value in soybean (*Glycine max.*)

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Introduction

It has been well documented that certain weed species occur in patches throughout agricultural fields (Gerhards et al. 1997; Goudy et al. 1999; Stafford and Miller, 1996; Williams et al. 1999). The development of sensor technology, variable rate applicators, software tools, global positioning systems (GPS), and geographic information systems (GIS) have made site-specific herbicide applications onto patchy weed populations feasible (Brown and Steckler, 1995). One approach to site-specific weed control is to map weeds within a field and then divide the field into smaller grid units. The decision to apply a herbicide treatment to the individual grid units is made by employing economic threshold and yield loss models. However, grid units often contain weed populations with aggregated distributions, and many yield loss models have not considered the spatial distribution of weeds within an area, since many experiments dealing with weed-crop competition have assumed weeds to be uniformly distributed. Therefore, these models may be overestimating yield loss. Similarly, economic threshold models do not consider how certain crop quality parameters, such as seed moisture content and crop dockage, are affected by weed competition.

The objective of the study was to compare the impact of competition from uniform and aggregated distributions of common ragweed at increasing densities on soybean seed yield loss, moisture content, and dockage.

Materials and method

Field studies were conducted in 1999 and 2000 at the Woodstock Research Station (Woodstock, Ontario). The experimental design was a randomized complete block with four replications. In 1999, treatments consisted of a weed free control and six average ragweed densities (1, 2, 4, 8, 12, and 16 plants/m^2), and two distribution patterns (uniform and aggregated). In 2000, treatments consisted of a weed free control and nine average ragweed densities (0.4, 1, 1.6, 2, 2.4, 3.6, 4, 8, and 12 plants/m^2), and two distributions (uniform and aggregated). The purpose of the additional treatments was to give greater insight into the weed-crop interference dynamics at sub-threshold density levels.

Field trials were fall moldboard ploughed, and cultivated in the spring prior to planting. Fertilizer was not amended as soil tests indicated adequate nutrient levels. The glyphosate tolerant cultivar 'First Line 2801R' was inoculated with *rhizobia* - 532C (Hi-Stick) at a rate of 1kg ha^{-1}. The seed was planted at a depth of 4 cm., and a seeding rate of 500 000 seeds per hectare in rows spaced 18.75 cm apart.

After soybean emergence, 300 ml cardboard cups were placed over top of ragweed seedlings needed to establish each density and distribution. Following this, a single application of glyphosate was made at a rate of 890 g ai^{-1}. which killed all other non-target weeds that were not protected by the 300 ml cup. The placement of cups within the plots depended on the desired ragweed distribution. If experimental units were to contain a uniform distribution of ragweed, then cups were spaced evenly apart and placed over ragweed to obtain an average density of "x". If experimental units were to contain an aggregated distribution of ragweed, cups were placed so that one third of the experimental unit was at a density of "*2x",* one third of the experimental unit was at a density of "*x*", and the rest of the experimental unit remained weed-free. The soybean crop was harvested using a Massey Ferguson XR8 plot combine. Soybean seed moisture content was taken using a standard moisture reader, and dockage was evaluated as per guidelines set by the Canadian Grain Commission.

Statistical analysis

Seed dockage and moisture content were each fit separately to the following linear model (PROC GLM; SAS Version 6.12, Cary, N.C.):

$$Y_{ijk} = \mu\rho_i\, \alpha_j + \beta_k + \alpha\beta_{jk} + \varepsilon$$

where μ is the mean, ρ_i is the block effect, α_j is the effect of weed density, β_k is the effect of aggregation, $\alpha\beta_{jk}$ is the interaction between both density and aggregation, and ε is the experimental error. The relationship between soybean seed yield and ragweed densities with aggregated and uniform distributions were analyzed by fitting the data sets separately for each year to a modified version of Cousens (1985) hyperbolic yield curve (PROC NLIN; SAS Version 6.12, Cary, N.C.):

$$Y = YWF\left(1 - \frac{I_c D}{100\,(1 + I_c D / A_c)}\right)$$

$$\text{* } where\ c = 1 \ \ if\ weeds\ are\ aggregated$$
$$c = 0 \ \ if\ weeds\ are\ uniform$$

Where Y is the observed yield (kg/ha), D is the weed density (plants/m^2), and YWF is the estimated weed-free yield. Parameters I_1 and I_0 are the percent yield loss per weed density as $D \rightarrow 0$, and A_1 and A_0 are the asymptotic percent yield loss as $D \rightarrow \infty$ for an aggregated and uniform weed distribution respectively.

Results and discussion

Yield Loss

Observed weed-free yield was 3050 and 4170 kg ha^{-1} in 1999 and 2000 respectively. The YWF parameter in 1999 (3298 kg ha^{-1}) was lower ($p<0.05$) than the YWF parameter in 2000

(4247 kg ha^{-1}). The *I* parameter for the uniform distribution was greater than the *I* parameter for the aggregated distribution in 1999 but did not significantly differ ($p<0.05$). In 2000, I parameters for both distributions were the same and did not significantly differ ($p<0.05$). The A parameters for uniform distributions was greater than the A parameters for aggregated distributions and were significantly different ($p<0.05$) in both 1999 and 2000. Differences in parameter estimates between years may be the result of differing soil types, and environmental conditions (Weaver, 1991).

Seed Moisture Content

In 1999, significant differences in seed moisture content occurred between the two distributions at ≥ 5.8 plants m^{-2} ($\alpha<0.05$). In the aggregated distribution at ≥ 9.4 plants m^{-2}, there was a significantly higher seed moisture content level compared to the weed-free control ($\alpha<0.05$). In the uniform distribution at ≥ 4.8 plants m^{-2} there was a significantly higher seed moisture content level than in the weed-free soybean control ($\alpha<0.05$).

In 2000, significant differences in seed moisture content occurred between the two distributions at ≥ 7.2 plants m^{-2} ($\alpha<0.05$). In the aggregated distribution at ≥ 6.8 plants m^{-2}, there was a significantly higher seed moisture content level compared to the weed-free control ($\alpha<0.05$). In the uniform distribution at ≥ 4.1 plants m^{-2}, there was a significantly higher seed moisture content level than in the weed-free soybean control ($\alpha<0.05$).

Dockage

In 1999, significant differences in dockage occurred between the two distributions at 2 plants m^{-2} and greater ($\alpha<0.05$). In the aggregated distribution at ≥ 2.5 plants m^{-2}, there was significantly higher dockage compared to the weed-free control ($\alpha<0.05$). In the uniform distribution at ≥ 0.8 plants m^{-2} there was significantly higher dockage than in the weed-free soybean control ($\alpha<0.05$).

In 2000, significant differences in dockage occurred between the two distributions at ≥ 11 plants m^{-2} ($\alpha<0.05$). In the aggregated distribution at ≥ 2 plants m^{-2}, there was significantly higher dockage compared to the weed-free control ($\alpha<0.05$). In the uniform distribution at ≥ 2.2 plants m^{-2}, there was significantly higher dockage than in the weed-free soybean control ($\alpha<0.05$).

Influence of weed aggregation on spray decision

Yield loss at low weed densities (parameter *I*) did not differ between distributions, therefore weed distributions of common ragweed would not greatly affect threshold level and thus spray decision. Soybean seed moisture content and dockage increased with increasing weed densities. At low weed densities, soybean seed moisture content and dockage did not greatly differ from the weed-free control. Therefore, the impact of dockage and drying costs from increased soybean seed moisture content are minimal, and would not impact spray decision.

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Secondary dormancy in volunteer canola (*Brassica napus* L.)

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Abstract

A series of lab experiments investigating the influence of genotype and location as well as temperature, osmotic potential, and induction period on the development of secondary dormancy in *Brassica napus* were initiated. Among the sixteen cultivars obtained from two locations in Saskatchewan, a few consistently showed high potential for induction into secondary dormancy while several others consistently showed low levels of secondary dormancy. A small location effect was observed. In another experiment, higher temperature during the induction period proved to be the most influential factor on the quantity of seeds induced into secondary dormancy in one *B. napus* genotype.

Introduction

The annual acreage seeded to canola (*Brassica napus* and *B. rapa*) in western Canada has increased approximately 3.1 fold over the last 25 years (Statistics Canada, 1999). Based on relative abundance, an all encompassing measure calculated from the frequency, occurrence, and density of a weed species, volunteer canola has moved from ranking below 30th in the mid 1970's (Thomas, 1991; Thomas and Donaghy, 1991) to a rank of 12th during a 1995 summer survey conducted in Saskatchewan (Thomas et al., 1996), surpassing traditionally more important weeds such as kochia (*Kochia scoparia* [L.] Schrad.) and quack grass (*Agropyron repens* [L.] Beauv.). Recent survey (Thomas et al., 1999) and research plot (Derksen et al., 1999) data has shown that volunteer canola may persist for at least four years in rotation. Presently, it is not known whether long term persistence is the result of seed losses at the time of canola harvest or is primarily due to re-seeding by subsequent volunteers.

Recent research conducted in Europe has shown that *B. napus* can readily be induced into secondary dormancy by a combination of moisture stress and darkness (Pekrun, 1994). In conjunction, field experiments have confirmed that long term volunteer canola persistence is linked to a cultivar's potential for induction into secondary dormancy as well as burial depth (Pekrun et al., 1998).

The objectives of these experiments were to determine the effects of genotype and location of growth as well as the relative importance of induction period, osmotic stress and temperature on the development of secondary dormancy in *B. napus*.

Materials and methods

Seed source

All *B. napus* cultivars were obtained from two Canola Production Centre locations in Saskatchewan (Delmas, Grenfell). These genotypes used in this study included 9 herbicide tolerant and 7 conventional type cultivars. Both groups contained genotypes of various quality characteristics.

Genetic and environmental differences in secondary dormancy

Four replicates of 100 seeds per petri dish were incubated at 20 °C in polyethylene glycol (PEG-8000) solution with an initial osmotic potential of -1.5 MPa in the dark for 4 weeks (Pekrun et al., 1997). A two week dark germination test in distilled H_2O followed, after which the remaining hard, non-germinated seeds were enumerated. Seeds were stored at –15°C and the experiment was repeated four times with the following start dates Oct 26, 1999, Nov 5,1999, Jan 28, 2000, and Feb 29, 2000. To confirm secondary dormancy as the cause for failure to germinate, the induced condition was relieved using a stratification treatment of 5 days at 2-4 °C. Analysis of variance was conducted within and between locations.

Hydrothermal time requirements for the development of secondary dormancy

An assay examining the relative importance of the effects of temperature, osmotic stress and time of exposure on the development of secondary dormancy in the canola cultivar that consistently exhibited the highest levels of secondary dormancy was conducted. Four replicates of 100 seeds were dark incubated using all combinations of the following factors and levels - time (1,2,3,4 weeks), initial osmotic solution potential (-0.5, -1.0, -1.5, -2.0 MPa) and temperature (5, 10, 15, 20 °C). A control treatment using distilled H_2O (0.0 MPa) at each temperature was also included which served as the reference point. Seeds exposed to negative osmotic potentials were subject to the two week dark germination test at 15 °C similar to that described above.

To standardize treatment differences, accumulated hydrothermal time was calculated using the following formula:

Hydrothermal Time = (initial MPa of osmotic solution) * (trt. temp.) * (# weeks in induction)
= MPa degree weeks

Treatments of identical hydrothermal time with representation of 5, 10, and 20 °C induction temperatures were chosen and analysed using ANOVA within a hydrothermal time.

Results and discussion

A combined analysis of all four repetitions of the petri-dish assay was conducted. All parameters of the model showed high. Significant differences among cultivars were noted at all times (table 1), although the absolute proportion of a seed lot induced into secondary dormancy decreased substantially over time (October - March). Variations of similar magnitude have also been observed in European cultivars (Pekrun et al., 1997), however the clear reduction in secondary dormancy over time observed here has not yet been reported. Induction into secondary dormancy of the genotypes ranged from 16.3 to 95.0% in experiment 1 and decreased to 1.7 to 53.0% by experiment 4 with seeds stored at -15 °C between experiments. Results from other experiments on one of these genotypes have indicated that the level of secondary dormancy increased again over the spring and summer month while still in storage at -15 °C (data not shown), suggesting an annual dormancy cycle observed in many weed species (Baskin and Baskin, 1985). More experiments are underway to verify these observations. In the genotype comparison experiment, cultivars with high potential for induction into secondary dormancy exhibited high secondary dormancy in all experiments while cultivars showing low induction into secondary dormancy remained low in all experiments. Such clear trends were not observed among the bulk of cultivars that exhibited intermediate induction into secondary dormancy which exhibited very similar levels of dormancy. These observations indicate a clear genetic component to the induction of *B. napus* into secondary dormancy and similar observations have been reported in European cultivars (Pekrun et al., 1997). To date, little evidence indicating the effect of the environment on the development of secondary dormancy in *B napus* has been established. Our results combined over all four runs of the experiment indicate that the location effect (environment) in the induction of secondary dormancy in canola was limited between these two locations in 1999. *B. napus* genotypes from Delmas tended to show 12.7 % higher levels of secondary dormancy than cultivars from Grenfell on average which considering the significant changes in secondary dormancy related to experimental run seems of limited significance. In addition, only 4.3% of the available SS were partitioned towards the location effect whereas 25.7% of the SS were allocated towards genotype in the analysis.

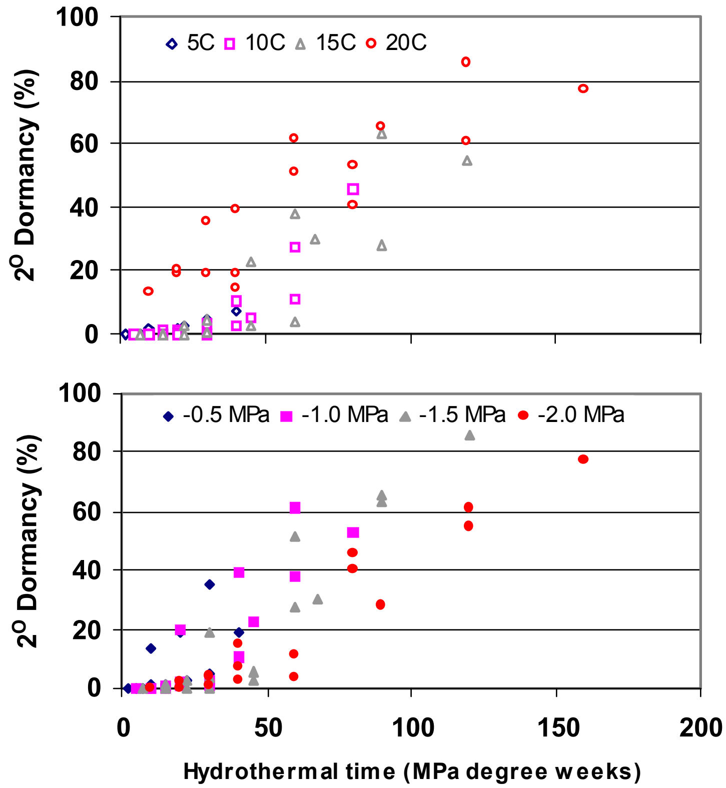
The hydrothermal time experiment showed that the induction period temperature was the most important factor affecting overall induction into secondary dormancy (table 2, figure 1). When comparing equal hydrothermal induction time, the proportion of seeds induced into secondary dormancy was significantly higher at 20 ºC than at 10 and 5 ºC, respectively (table 1). This can also be observed in figure 1, where all treatment means have been grouped according to imbibition temperature (top) compared to initial osmotic potential (bottom). These findings in conjunction with the removal of secondary dormancy at low temperatures (2-4 ºC) suggest that the seed ecology of *B. napus* is that typically observed in weeds with a summer annual growth habit where high temperatures induce secondary dormancy while low temperatures readily remove secondary dormancy (Baskin and Baskin, 1988). In the field, *B. napus* seed dormancy in spring would be low while during the warmer summer months, seeds may become dormant. This behaviour was observed in the field experiment, where no further germination could be detected after June 30, 2000 (data not shown) from a one time addition to the seed bank in the fall of 1999. However, it is not yet clear whether this is the result of increased dormancy due to high temperatures in conjunction with moisture stress or simply the result of a lack of moisture for germination. More detailed studies investigating these hypotheses are currently underway.

Table 1. Genetic differences in the proportion of induction into secondary dormancy in 16 *B. napus* genotypes grouped into conventional (top) and herbicide-tolerant (bottom) genotypes. Fisher's protected LSD within location is indicated.

Location	Delmas	Grenfell
Cultivar	Secondary dormancy (%)	Secondary dormancy (%)
AC Excel	72.9	43.8
Magnum	67.7	53.0
Millenium 01	48.2	39.4
Nexera 500	56.6	42.8
Option 501	9.8	19.9
Quantum	27.2	26.3
Sentry	63.2	46.6
Exceed	54.0	39.9
IMC 107	36.8	29.3
InVigor 2273	64.8	48.3
InVigor 2463	64.2	44.9
InVigor 2473	70.8	54.1
LG 3235	54.5	38.4
LG3295	76.5	66.2
LG Dawn	20.6	17.3
SW Rider	68.9	43.9
LSD	5.1	4.7

Table 2. Proportion of *B. napus* induced into secondary dormancy in relation to temperature at different hydrothermal times. Means were separated using Fisher's protected LSD $\alpha = 0.05$.

	Hydrothermal time (MPa degree weeks)		
Temp / MPa	20	30	40
+20/-0.5	19.0 a	35.3 a	18.8 b
+20/-1	20.0 a		39.5 a
+20/-1.5		19.0 b	
+20/-2			14.5 bc
+10/-0.5	1.5 b		
+10/-1	0.8 b	3.0 cd	10.8 bc
+10/-1.5		0.3 d	
+10/-2			2.8 c
+5/-1	2.3 b		
+5/-1.5	2.0 b	3.8 cd	
+5/-2		4.5 c	7.0 bc
LSD	7.1	3.7	12.2



Secondary dormancy in *B. napus* grouped by temperature (top) and initial osmotic potential (bottom) at various hydrothermal times where hydrothermal time is the product of initial solution osmotic potential, temperature and induction period.

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Interaction between leaf and background reflectance: implications for spectral measurements of young canopies

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Introduction

The optical properties of leaves have been studied for some time, with varied motivations. The most common aims have been to use optical properties to distinguish plants from each other or to measure various plant properties or conditions, such as nitrogen content, moisture content or water stress. Studies conducted in the first half of the twentieth century were limited to the visible and a very small part of the near infrared (NIR) bands (Myers et al. 1966). As NIR instrumentation improved with extended spectral range, it was found that leaves were very translucent at some wavelengths, particularly in parts of the NIR spectrum (Myers et al. 1966). Thus, incident light is able to pass through the leaf, reflect off the underlying material and pass back through the leaf. In the context of using spectral techniques in the field, the consequence of this behaviour is significant. Canopy reflectance is affected not only by its own composition, but also by the soil and groundcover underneath. For a sparse or undeveloped canopy, this effect could be a large contributor to the measured reflectance. The side effect of the background, which will vary between locations, complicates the comparison of reflectance measures.

The objective of this study was to investigate leaf spectra collected against contrasting backgrounds.

Materials and Methods

An UV-Vis-NIR spectrophotometer (Cary 5G, Varian Inc., Mississauga, Ontario) equipped with an integrating sphere was used for data collection. The background materials used were white and black Spectralon (Labsphere Inc., North Sutton, New Hampshire). Other apparatus used and procedures followed were developed and described by Noble (2000).

Four plant species were examined: Wheat (*Triticum aestivum*, 'Katepwa'), wild oat (*Avena fatua* L. # AVAFA), wild buckwheat (*Polygonum convolvulus* L. # POLCO) and Canada thistle (*Cirsium arvense* (L.) Scop. # CIRAR). Plants were grown in the College of Agriculture Phytotron at the University of Saskatchewan under controlled conditions (18-hour day, 21°C day/16°C night). The wheat, wild oat and wild buckwheat plants were grown from seed, and measurements were taken at the four to five leaf stage. The Canada thistle plants were grown from transplanted shoots, and measurements were taken when the plants were approximately 125 mm high.

Results and Discussion

Figures 1 through 4 show the five-sample reflectance averages of leaves from the species studied. Data shown are leaf reflectance against the white background and leaf reflectance against a black background. The value of infinite reflectance (R_∞) was calculated based on these reflectances (Major et al. 1993). Reflectance of translucent materials is typically a function of the material thickness. R_∞ is a measure of material reflectance at the thickness beyond which any increase in thickness would not result in any reflectance changes. The white background was used as the 100% reflectance reference in this case. All reflectance spectra followed the same basic patterns. The visible range was characterised by the green reflectance peak (555 nm) followed by the red trough (675 nm), corresponding to absorption of red light by chlorophyll. Moving towards the UV range, there was a drop in reflectance. Moving toward the NIR spectrum, there was a dramatic increase in reflectance leading up to the NIR plateau. A small step was visible in some traces on this plateau. This was related to changes in scanning parameters at this point (870 nm). The two major troughs in the NIR region (1455 nm and 1900 nm) were water absorption bands.

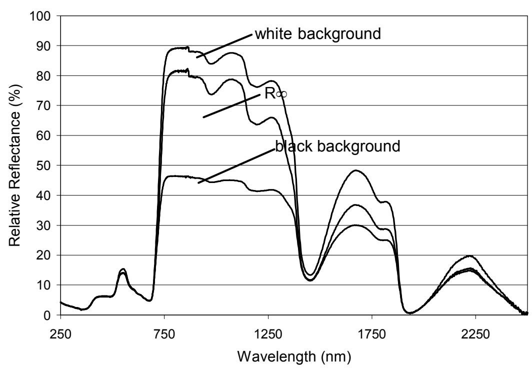

Figure 1: Wheat leaf reflectance – white background, black background and R_∞.

Figure 2: Wild oat leaf reflectance – white background, black background and R_∞.

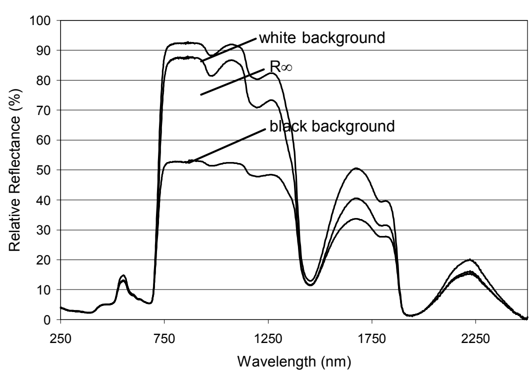

Figure 3: Wild buckwheat leaf reflectance – white background, black background and R_∞.

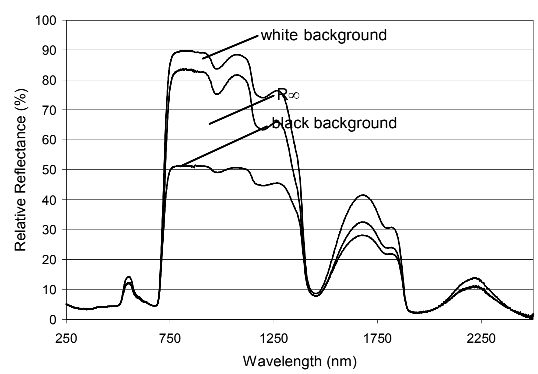

Figure 4: Canada thistle leaf reflectance – white background, black background and R_∞

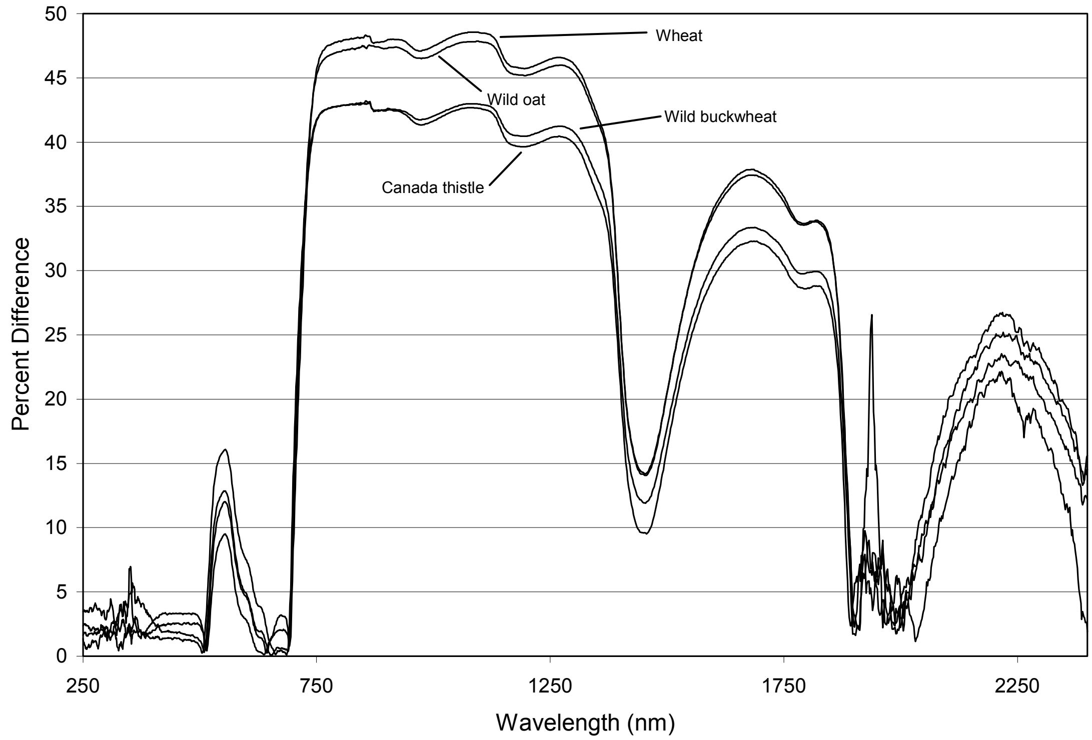

Figure 5: Percent difference in reflectance of single leaf with white and black backgrounds (smoothed using five-sample moving average)

It was in the NIR region that the most dramatic background effects were seen. Figure 5 shows the percent difference between leaf reflectance with white and black backgrounds with respect to wavelength. The differences corresponding to the NIR plateau were between 40 and 50% of the leaf reflectance with the white background.

Conclusions

From figure 5 it was clear that the NIR region was most sensitive to the effects of background reflectance. While there were some significant differences at the green portion of the spectrum, most of the visible range had very small differences, supporting the presumption of leaf opacity in the visible spectrum.

At first examination, it would appear prudent to avoid using the sensitive NIR wavelengths in favour of the less background-sensitive UV and visible wavelengths. However, many studies have indicated that certain NIR wavelengths are best suited for modelling chemical and cellular constituents, such as nitrogen, chlorophyll (e.g. Yoder and Pettigrew-Crosby 1995) and water, and show promise for discriminating between species (e.g. Vrindts et al. 1999). As completely avoiding these wavebands may not be an option, work needs to be done on how to account for the effect of background on the reflectance of sparse and developing canopies. In the context of weed science, such work would be relevant to the development of technologies such as rapid machine-vision based weed surveying and classification, and real-time, site-specific weed control early in the growing season.

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Suppression of living mulches in lowbush blueberry

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Abstract

Living mulches are being examined as a mechanism to stabilize the soil in bare areas and minimize soil erosion in lowbush blueberry (*Vaccinium angustifolium* Ait.). Living mulches can cause competitive pressures on the crop and decrease the harvest efficiency and yield. The study site, in Oxford, Nova Scotia, had a dense infestation of Poverty oat-grass (*Danthonia spicatum* L. Beauv.), where five herbicides were tested for suppression of this living mulch. Visual and quantitative ratings were taken on the living mulch and the blueberry plants to assess suppression and damage. Initial results indicate there were significant differences between herbicide treatments and herbicide rates at $\alpha = 0.05$. All of the herbicides, except for primisulfuron, showed an increasing phytotoxic effect on the poverty oat grass with increasing herbicide rates. Fluazifop-p-butyl showed only suppression effects on the living mulch, thus maintaining a vegetative cover with negligible blueberry damage. Nicosulfuron/rimsulfuron showed significantly higher levels of lowbush blueberry and living mulch phytotoxicity but showed an increase in floral bud numbers with increasing rates.

Introduction

Wild lowbush blueberries, in commercial production, have a relatively low rate of biomass production and vegetative expansion. Lowbush blueberry fields are thus, very susceptible to invasion by weeds; one of the major limiting factors in production (M^{c}Cully *et al.*, 1991). As a result, chemical weed control can be a useful method to limit competition. In the early 1980's, the development of hexazinone helped eliminate many prominent weeds that were previously uncontrolled, and thus helped create a boom in both yields and ease of harvest (Yarborough and Ismail, 1985, Hanchar *et al.*, 1985). With the elimination of competing vegetation, there became a high susceptibility to soil erosion with the exposure and destabilisation of the top soil.

Living mulches are being used to stabilize the soil in bare areas and minimize soil erosion in many cropping situations. The use of mulches has drastically reduced erosion problems in many horticultural crops (Bruce *et al.* 1995 and Abdual *et al.* 1996). Mulches in general reduce frost heaving, provide winter protection, moderate soil temperatures, benefit soil fertility and increase soil moisture (Sanderson and Cutcliffe 1991). Living mulches can also increase harvest efficiency in lowbush blueberry by supporting the crop, resulting in a lower rate of unharvested and damaged crop.

Materials and Methods

The trial site for the first year of the study was done on a commercially managed lowbush blueberry field in Oxford, Nova Scotia. This site contained a dense infestation of poverty oat grass.

The treatment area was designed as a strip-split plot design; where the strip plot factor was 0 and ½ recommended rates hexazinone, the whole plot treatments were five selected herbicides (nicosulfuron/rimsulfuron, primisulfuron, clethodim, sethoxydim and fluazifop-p-butyl) and the subplot treatments were four rates of these herbicides (0, 1/3, 2/3 and full recommended rates). Visual and quantitative ratings for phytotoxicity were taken throughout the summer months, as well stem lengths and floral and vegetative bud numbers were measured in the fall of the sprouting year.

The objectives of the proposed research are to (1) compare and contrast the effects of sub-lethal doses of several herbicides on living mulches; (2) determine if suppressed living mulches and are at sufficient levels to provide erosion control; (3) analyse the effects of different herbicides used with in combination with hexazinone**;** and (4) develop a management plan that allows for a suppression of the living mulch while maintaining an effective vegetative cover.

Preliminary Results

Initial results indicate there are significant differences between whole plot treatments as well as within the subplot treatments at $\alpha = 0.05$. Four of the five herbicides showed an increasing phytotoxic effect on the poverty oat grass with increasing rates (fig.1). However, herbicides like fluazifop-p-butyl showed definite suppression of the living mulch without eliminating it, even at high rates. Nicosulfuron/rimsulfuron showed living mulch mortality and in fact elimination of all competing vegetation at the highest recommended rate.

Primisulfuron and nicosulfuron/rimsulfuron showed high levels of lowbush blueberry phytotoxicity up to two months after application (fig.2). It remains to be seen if this will effect yields, as the crop will not be harvested until August 2001. Initial results indicate that floral bud numbers per plant are lowered due to the sulfonylurea herbicide applications. The graminicides used in this trial did not show significant levels of phytotoxicity on the lowbush blueberry (fig.2).

Conclusions

Fluazifop-p-butyl may minimize significant poverty oat grass competition pressures in lowbush blueberry, while maintaining a living and adequate ground cover to control erosion in bare areas. Nicosulfuron/rimsulfuron showed good poverty oat grass control, however the crop phytotoxicty may outweigh the competitive pressure release. Final conclusions on yield and harvesting efficiency cannot be made until next summer as the lowbush blueberry is produced on a two year cycle. A study will be conducted next year looking at crop year applications of some of these herbicides.

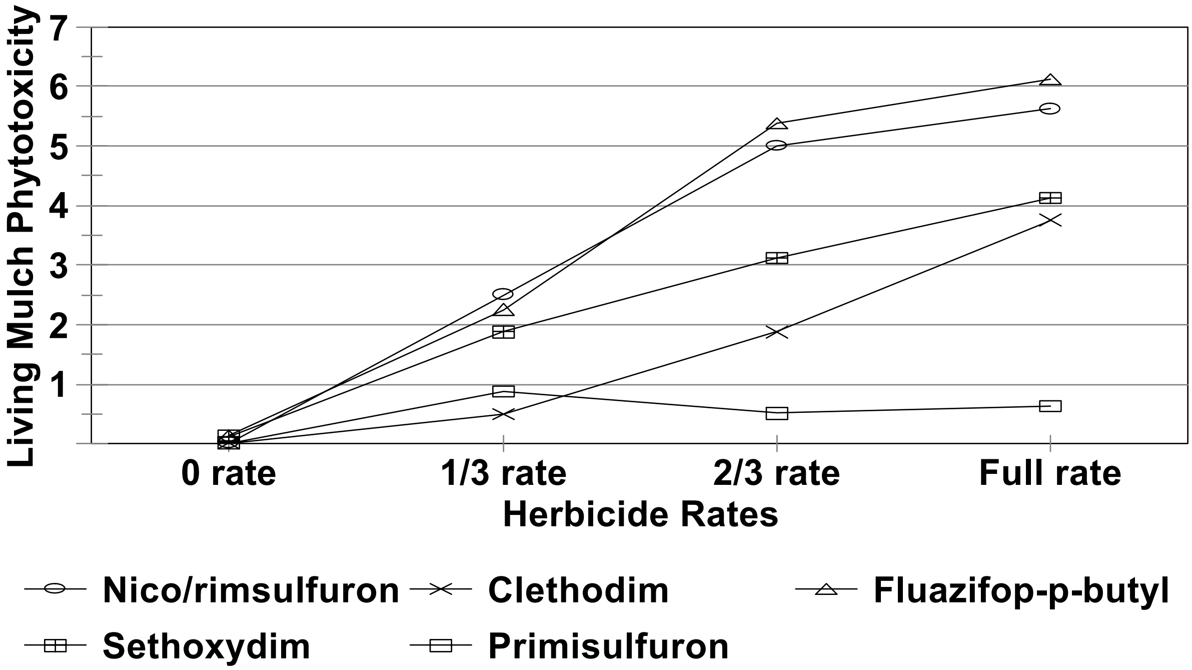

Figure 1. Living mulch phytotoxicity with increasing rates of several different herbicides

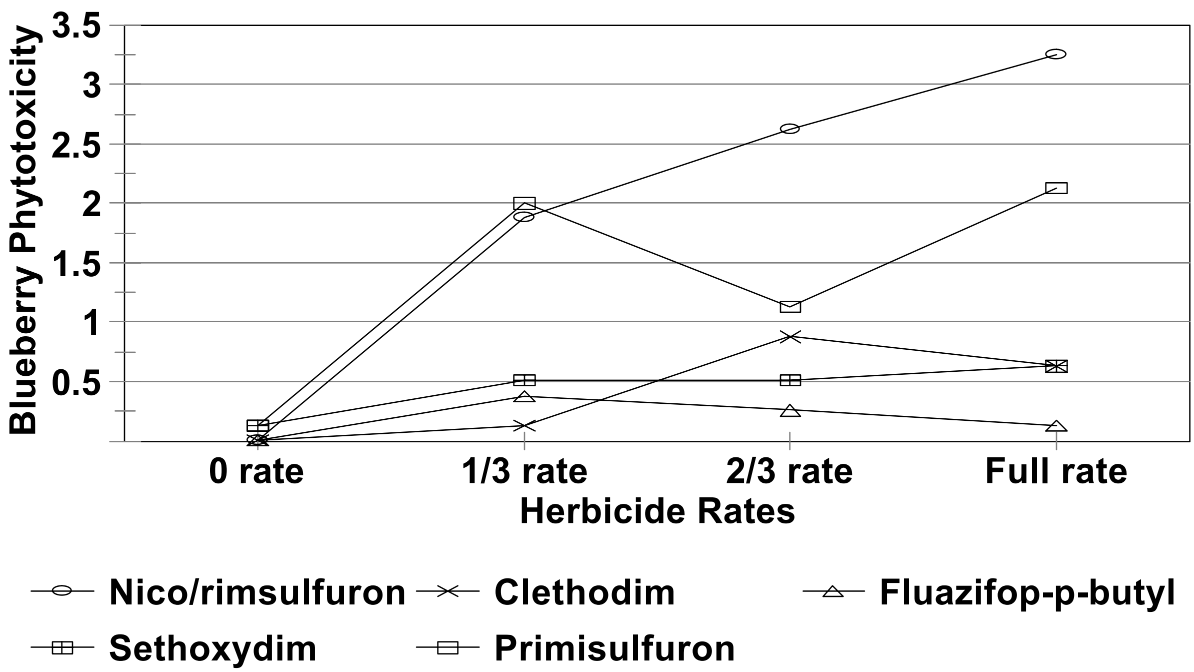

Figure 2. Lowbush blueberry phytotoxicity at increasing rates of various herbicides

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Dandelion's (*Taraxacum officinale*) distribution, interference, and control in Roundup-Ready™ canola (*Brassica napus*)

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Abstract

Dandelion populations appear to be increasing in Western Canada. This research aims to 1) improve our understanding of dandelion's distribution in fields, 2) determine dandelion's ability to interfere with canola productivity, and 3) provide efficient methods of controlling dandelion in an annual cropping system. Measures of dandelion infestation were not found to be significantly correlated with reduction in canola yield in conventionally tilled fields. In zero tillage fields, reduction in canola yield was correlated with dandelion cover, density, root diameter, biomass, and leaf area. It appears that glyphosate applications before crop emergence and after harvest provide the greatest control of dandelion. Increasing glyphosate rate does not significantly improve dandelion control. Sequential applications of glyphosate provide near-complete eradication of dandelion when post-harvest applications are used. Dandelion can be an effective competitor with canola, however management techniques are available to reduce dandelion's impact on crop productivity.

Introduction

In Western Canada, dandelion (*Taraxacum officinale*) has long been considered a noxious weed. The majority of attention paid to dandelion, however has been from those concerned about it's role in reducing the feed value and productivity of forages. Surveys of Western Canadian fields, which were conducted in 1986-9 and 1995-7, show an alarming increase in dandelion frequency in Western Canada (Thomas et al., 1998). In 1986-9 dandelion was present in 6 percent of wheat fields and 13 percent of canola fields in the Prairie Provinces. In 1995-7 however, dandelion presence increased to 20 percent of wheat fields and 23 percent of canola fields. Based on a relative abundance index, there was an increase in rank of 17 in wheat fields and an increase in rank of 7 in canola fields. Dandelion appears to be developing into a significant weed of annual cropping systems.

The primary objective of this research is to improve our understanding of dandelion's role as a crop pest in annual cropping systems. We have broken our research into two components: Dandelion competition (distribution and interference) and control.

The objectives of our dandelion competition research are three-fold. First, we intend to determine an effective measure of dandelion infestation. Secondly, we intend to determine the effect of dandelion interference on canola yield. Finally, we expect to provide an estimate of canola yield loss on a whole-field basis.

The dandelion control component considers the impact of three factors on dandelion control: 1) glyphosate rate, 2) time of glyphosate application, and 3) spring tillage intensity.

Our goal was to determine the most efficient use of glyphosate for dandelion control in an annual cropping system.

Materials and Methods:

Dandelion competition studies were completed in the summer of 2000. We surveyed 8 dandelion-infested fields across Southern Manitoba that were being planted to canola. At 50-meter intervals we made passes across a field with an ATV and stopped every 50 meters to record dandelion density. We selected 6 of these fields for our interference studies. Four were conventional till and two were zero till. Anywhere from 15 to 35 one-m2 quadrats were established on dandelion patches of varying intensity in each field. These quadrats were maintained free of all weeds except dandelion. Weed-free quadrats were established to correspond with each dandelion quadrat in a paired fashion. Several measurements were made of the dandelion and canola in each quadrat during the growing season. In crop (2-4 leaf stage of canola) we measured dandelion and canola density, dandelion and canola ground cover, and total dandelion leaf diameter. At harvest we measured dandelion density, leaf area, biomass, root diameter, and canola grain yield.

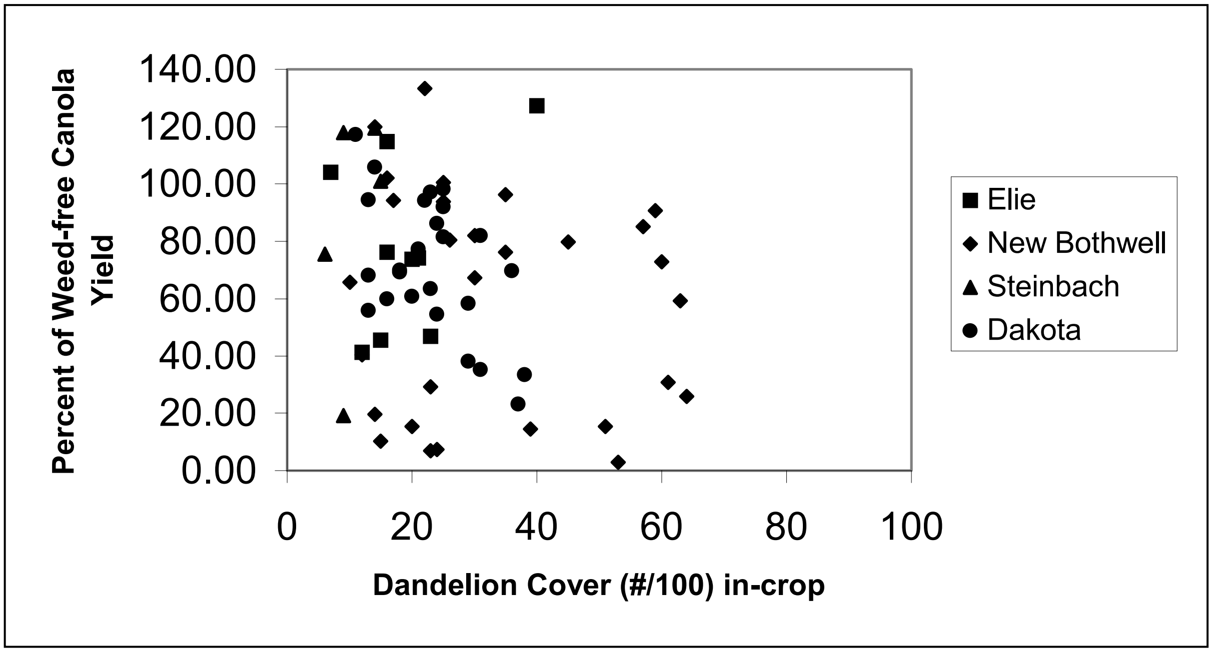
In the summer of 1999, the first two control trials were established, at Oakville and Carman. Trials were set up as a split-plot, randomized complete block design. The split-plot treatment was spring tillage intensity (low/high disturbance) and main-plot treatments were comprised of varying rates and timings of glyphosate (Roundup Transorb™) application. Before spray treatments began, dandelion density was measured in all plots to determine the consistency of the dandelion populations in each plot. Dandelion control was measured in the spring, one year after treatment. Measures of dandelion control were dandelion density, biomass, leaf area, and root diameter. To date, we have two site-years of data. Three more site-years will be completed in the spring of 2001.

Results:

I. Dandelion Competition

The field surveys demonstrate that dandelion has a patchy distribution in fields. Combining all sites for determining relationships between reduction in canola yield and dandelion infestation was not possible as there was no significant correlation between reduction in canola yield and any measure of dandelion infestation used. When the data was separated into conventional and zero till fields, it became clear that conventionally tilled fields were the reason for a lack of correlation. There was no significant relationship between reduction in canola yield and any measure of dandelion infestation for any conventionally tilled field (Figure 1).

Figure 1: Reduction of canola yield by dandelion in conventional till fields



The relationship of canola yield loss to measures of dandelion infestation was similarly poor for all measures in conventionally-tilled fields.

Both sites (Carman and Brandon) exhibited some significant correlations between reduction in canola yield and some measures of dandelion infestation, however these relationships were much more significant at the Carman site. When both sites had significant relationships, the models best used to describe them were very different between sites (Figure 2).

In summary, absolutely no correlation was found between any measure of dandelion infestation and reduction in canola yield for the conventionally-tilled fields. Several measures of dandelion infestation level provided significant correlation with reduction in canola yield in zero till fields. In-crop, the best relationships were found with measures of 1) dandelion and canola cover, and 2) dandelion density. At the time of crop harvest, the best relationships were found with measures of 1) total dandelion root diameter, 2) dandelion density, 3) dandelion biomass, and 4) dandelion leaf area.

II. Dandelion Control

Time of glyphosate application had a significant impact on dandelion control. Dandelion control in untreated plots was not significantly different from plots receiving 1 liter per acre of Roundup Transorb™ at the 0-3 leaf stage of canola (or pre-harvest in the low disturbance treatments). In the high disturbance plots, the split application treatment of ½ liter/acre early and late in crop was also not significantly different from the control. The best treatments were the pre-seed and post-harvest plots, however they were not significantly different from the split treatment in low disturbance plots and the split and pre-harvest treatments in the high disturbance plots.

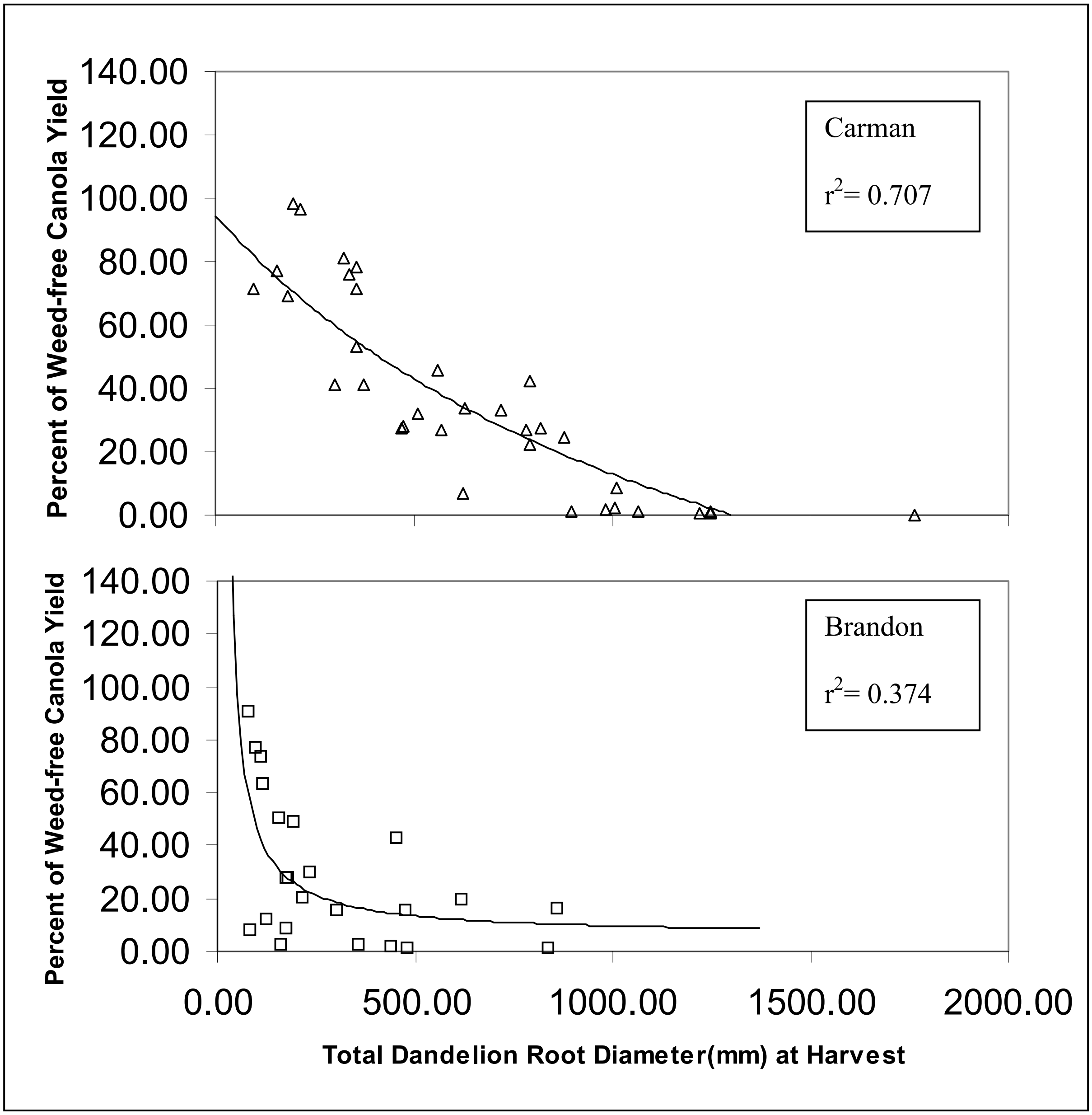


Figure 2: Reduction in canola yield by dandelion in zero till fields

Table 1: Dandelion biomass after application of 1 L/acre of Roundup Transorb™ at various timings

Treatment	Low Disturbance				High Disturbance			
	Mean	+/-	Standard Deviation		Mean	+/-	Standard Deviation	
Control	50.86	**+/-**	30.1	A	9.36	**+/-**	6.73	A
Pre-harvest	33.07	**+/-**	28.19	A B	4.55	**+/-**	7.51	A B C
0-3 Leaf	26.99	**+/-**	27.4	A B	4.77	**+/-**	4.86	A B
0-3 Leaf (½) 4-6 Leaf (½)	12.28	**+/-**	6.98	B C	2.99	**+/-**	3.54	A B C
Pre-seed	6.55	**+/-**	7.37	C	1.27	**+/-**	1.2	B C
Post-harvest	4.04	**+/-**	2.57	C	0.77	**+/-**	1.39	C

Tillage did have a significant influence on dandelion biomass. In control plots, dandelion biomass was reduced almost 82 percent in high disturbance plots relative to low disturbance plots. Data is presented for the first two site years, which received extreme disturbance treatments. The three additional sites, which will be completed in the summer of 2001, will be compared to these results, as they were not subjected to a much less intense tillage treatment.

For the most part, glyphosate rate did not have a significant influence on dandelion control. Table 2 outlines dandelion control under 1 (900 g ai/ha), 2 (1800 g ai/ha) and 3 (2700 g ai/ha) of Roundup Transorb™ at the post-harvest timing. All treatments were significantly different from the untreated check (control) however the treatments were also not significantly different from one another. The only time dandelion biomass was significantly influenced by glyphosate rate was at the pre-harvest timing in low disturbance plots.

The greatest control of dandelion was achieved using sequential applications of glyphosate (Table 3). Treatments involving post-harvest applications of glyphosate in combination with applications earlier in the season provided almost complete control.

Table 2: Dandelion biomass after application of various rates of Roundup Transorb™ at the post-harvest timing

Glyphosate g ai/ha	Low Disturbance					High Disturbance				
	Mean	+/-	Standard Deviation			Mean	+/-	Standard Deviation		
Control	50.86	**+/-**	30.1	A		9.36	**+/-**	6.73	A	
900	4.04	**+/-**	2.57		B	0.77	**+/-**	1.39		B
1800	2.44	**+/-**	2.3		B	1.6	**+/-**	3.45		B
2700	4.16	**+/-**	7.74		B	0.18	**+/-**	0.39		B

Table 3: Dandelion Biomass after Sequential applications of Roundup Transorb™

Glyphosate	Low Disturbance						High Disturbance					
Trt. (Rate)	Mean	+/-	Standard Deviation				Mean	+/-	Standard Deviation			
Control	50.86	**+/-**	30.1	A			9.36	**+/-**	6.73	A		
0-3 Leaf (½) **4-6 Leaf (½)**	12.28	**+/-**	6.98		B		2.99	**+/-**	3.54		B	
Pre-seed (1) **Post-harvest (1)**	0.25	**+/-**	0.35			C	0.08	**+/-**	0.13			C
0-3 Leaf (½) **4-6 Leaf (½)** **Post-harvest (1)**	0.06	**+/-**	0.11			C	0.21	**+/-**	0.34			C

Conclusion

Dandelion appears to be developing into an important pest of annual cropping systems. Producers need more information regarding the influence of dandelion on crops, as well as efficient control methods. Dandelion is an effective competitor with canola, however there is no significant relationship between dandelion infestation and reduction in canola yield in conventionally tilled fields. A significant relationship exists in zero tillage fields, which can be used to effectively predict the influence of dandelion infestation on canola yield. Dandelion root diameter, cover, density, biomass, and leaf area are effective measures of dandelion infestation. The optimum timing of glyphosate application for dandelion control appears to be pre-seed and post-harvest. A minimum rate of 900 g ai/ha is recommended. Sequential applications within one growing season can provide almost complete control when post-harvest treatments are included. By providing better tools to understand and manage dandelion problems in Western Canada, producers will be able establish cropping systems that cope with dandelion in an efficient manner.

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Influence of crop row spacing and density on predispersal predation of weed seeds

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Abstract

A two-year field study was conducted at Woodstock, Ontario to determine if the spatial arrangement of corn affected predispersal seed predation of common lambsquarters and redroot pigweed. Corn was planted in 75cm or 37.5cm rows with plant densities ranging from 0 to 10 plants m^{-2}. The extent of seed predation occurring on terminal weed inflorescences in the treatments was evaluated. The spatial arrangement of corn did not affect levels of weed seed predation ($P>0.05$) for both years of the study. Predation of redroot pigweed seed was higher ($P\leq0.05$) in 2000 than 1999, averaging 11% and 3%, respectively. *Coleophora lineapulvella* were the dominant predator of redroot pigweed seed and were responsible for consuming up to 42% of seeds on some plants in 1999 and up to 93% of seeds in 2000. In 1999, average predation levels for common lambsquarters seed were negligible (0-1%).

Introduction

Each year some weeds die of natural causes with the greatest mortality occurring at the seed stage (Harper 1977). It is important to identify these sources of mortality and determine what influences their magnitude. Seed predation is one form of weed mortality that can affect the population dynamics of weeds. Recent studies of Cardina *et al*. (1996) and Cromar *et al*. (1999) have determined that postdispersal seed predation influence weed populations in agricultural systems. Until recently, predispersal predation studies primarily focused on biological control research with little interest in agricultural systems. Research by Griffiths (1999) and Nurse (2000) has confirmed that predispersal predation of weed seeds also occurs in corn and soybean systems. Therefore, it is imperative we understand how weed management practices affect weed seed predators in agricultural production systems.

As part of Integrated Weed Management (IWM), altering the spatial arrangement of the crop can naturally reduce weed populations. Murphy *et al*. (1996) found that increasing corn density and decreasing row spacing reduced incoming solar radiation. The narrow rows allowed the corn canopy to fill in earlier with the resulting shade reducing the biomass of weeds located under the canopy. Altering the spatial arrangement of the crop may also influence populations of indigenous weed seed predators feeding under these crop canopies. This leads us to the question: will altering the spatial arrangement of the crop actually encourage weed seed mortality?

Objective and methodology

Field studies were conducted from 1999-2000 at Woodstock, Ontario to determine if the spatial arrangement of corn affected levels of predispersal seed predation of common lambsquarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*). The experiments were designed as a 2x4 factorial randomised complete block (RCBD) with four replications. The two factors consisted of corn row spacing and corn density. Corn was planted in 75cm or 37.5cm rows with densities ranging from 0 to 10 plants m^{-2}. The extent of seed predation occurring on terminal weed inflorescences in the treatments was evaluated.

Preliminary results

Results from both years of the study showed that the spatial arrangement of corn did not affect levels of weed seed predation ($P>0.05$). Predation of redroot pigweed seed was higher ($P\leq0.05$) in 2000 than in 1999, averaging 11% and 3%, respectively. *Coleophora lineapulvella* (Lepidoptera: Coleophoridae) were the dominant predator of redroot pigweed seed and were responsible for consuming up to 42% of seeds on some plants in 1999 and up to 93% of seeds in 2000. In 1999, average predation levels for common lambsquarters seed was negligible (0-1%). Therefore, the evaluation of this weed species was discontinued in 2000.

Summary

This research suggests that weed seed predation is a biological process that can affect weed community dynamics. By influencing the density and distribution of seeds in the soil, seed predation may influence the outcome of weed competition through feeding preferences.

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Mutations in the ALS Gene Conferring Herbicide Resistance in Redroot Pigweed (*Amaranthus retroflexus*) and Green Pigweed (*A. powellii*)

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Abstract

Resistance to the acetolactate synthase (ALS)-inhibiting herbicides is becoming more common and is causing increased problems to agriculturalists. Populations of green pigweed and redroot pigweed have been found on many farms in southwestern Ontario. These populations showed various patterns of cross-resistance to thifensulfuron-methyl and imazethapyr, suggesting the presence of different mutations in the ALS gene. Primers were therefore designed to isolate the gene for twenty populations of redroot and green pigweed. The obtained wildtype sequence varied slightly between the two species however, both pigweed sequences were similar to an ALS sequence previously determined for *Amaranthus rudis*. The ALS gene from resistant populations was also amplified by PCR, sequenced, and compared to the susceptible for differences at the nucleotide level. Mutations were found within domains B, C and D of the ALS gene for redroot pigweed and within domains B and C for green pigweed. The pattern of resistance observed for populations with mutations in one of these domains is consistent with similar studies conducted on other weed species. In addition, a mutation located near the carboxy terminal of the gene was discovered for one of the redroot and two of the green pigweed populations studied.

Introduction

Acetolactate synthase (ALS)-inhibiting herbicides are among the most widely used herbicides today (Woodworth *et al*., 1996. The popularity of ALS-inhibiting herbicides has been attributed to their efficacy at low use rates, multi-crop selectivity, a broad spectrum of weed control season long and low mammalian toxicity (Bernasconi *et al*., 1995). Unfortunately resistance has quickly developed to the ALS-inhibiting herbicides. In 1999, the International Herbicide Resistance Survey reported the occurrence of 53 weed species resistant to the ALS-inhibitors (Heap, 2000).

Single nucleotide changes resulting in a different amino acid residue within the ALS gene are sufficient to confer resistance (Guttieri *et al*., 1995). Although an alteration in the ability of a weed to metabolize ALS-inhibiting herbicides may also confer resistance (Christopher *et al*., 1992) the majority of reported cases have been due to a target site mutation. Several past studies have been conducted on the ALS gene within plant species. It has been shown that the mutations which tend to confer resistance to ALS-inhibiting herbicides may be found within one of five highly conserved domains, A, B, C, D and E (Boutsalis *et al*., 1999). Of these, the most research has focused around domains A and B since they contain the majority of mutations causing resistance. Within domain A, a change from the wildtype Pro to Thr, Arg, Leu, Gln, Ala, Ser or His confers resistance. It is believed that the degree and type of cross-resistance exhibited is dependent on the specific amino acid the Pro has mutated to. An amino acid change of TrpàLeu in domain B has been shown to convey cross-resistance to all of the ALS-inhibiting herbicide classes (Woodworth *et al*., 1996) as has the amino acid change of AlaàVal in domain D. The substitution of AlaàThr in domain C results in resistance to only the imidazolinolines (IM) herbicides (Bernasconi *et al*., 1995).

In view of past research and the occurrence of resistance to ALS-inhibiting herbicides in *Amaranthus* species in Ontario (Ferguson *et al*., 2000), the mutations responsible for conferring resistance to ALS-inhibitors in 20 redroot pigweed (*Amaranthus retroflexus*) and green pigweed (*Amaranthus powellii*) populations from Southern Ontario were examined. These populations showed various patterns of cross-resistance to thifensulfuron-methyl and imazethapyr, suggesting the presence of different mutations in the ALS gene. PCR analysis and gene sequencing was used to examine this hypothesis.

Materials and Methods

Pigweed populations used in this study have been previously described (Ferguson *et al*., 2000). DNA was extracted from five plants for each of the susceptible redroot and green pigweed populations and from three plants for each of the resistant populations using the FastDNA kit from QBiogene. Pigweed plants were grown to the five leaf stage before DNA was extracted. Primers were constructed using an ABI 394 DNA synthesizer from Beckman. PCR amplification was completed using the Stratagene Robocycler 96 with the following program: 94ºC, 5 minutes, 1 cycle; 94ºC, 1 minute, 59ºC, 1.5 minutes and 72ºC, 2 minutes for 34 cycles; 72ºC, 7 minutes for 1 cycle. PCR reaction volume was 50 ml. Concentrations of reagents added were 35 ng genomic DNA, 0.4mM primer, 50mM $MgCl_2$, 200mM dNTP, 1X polymerase buffer and 0.5ml of Platinum Taq from Gibco Life Technologies. PCR reactions were loaded on 0.8% agarose gel, 0.5X TBE and run at approximately 94V. Desired bands were excised from the gel using the Gibco CONCERT Rapid Gel Extraction System. Bands were then sequenced directly using the ABI Prism 377 automated sequencer. Each PCR fragment was sequenced in both the forward and reverse direction to ensure a correct read. Sequencing results were aligned and nucleotide changes compared using ClustalW from EBI. The sequences of the two susceptible populations were sequenced first and compared to the resultant resistant population sequences to determine the presence of a nucleotide change.

Results and Discussion

Sequences from wildtype *A. retroflexus* and *A. powellii* were found to vary slightly between the two species, as there were just five nucleotide differences. Only one amino acid difference, which was not located within a recognized ALS domain, resulted from these changes. The two susceptible pigweed sequences were also very similar to an ALS sequence previously determined for *Amaranthus rudis* (Woodworth *et al*., 1996).

When the sequence of the susceptible green and redroot pigweed populations were compared to the known resistant populations, mutations within domains B, C and D were identified (Tables 1 and 2). Two redroot pigweed and two green pigweed populations were found to contain the TrpàLeu mutation associated with domain B. One redroot and four green pigweed populations contained the AlaàThr substitution in domain C. Only one redroot pigweed population was found to have the AlaàVal change within domain D (Table 1). It is interesting to note that the green pigweed populations from Brigden displayed two different mutations, both occurring in close proximity to each other (Table 2). This coupled to the fact that the populations were noted as being resistant in 1997, suggests the occurrence of independent mutational events.

All of the populations with a domain B mutation were resistant to imazethapyr and thifensulfuron-methyl (Ferguson *et al*., 2000). This finding is consistent with the findings of previous studies citing that a domain B mutation confers resistance to all ALS inhibiting chemistries (Bernasconi *et al*., 1995). All populations with a domain C mutation were found to be resistant to imazethapyr but not to thifensulfuron-methyl. This is in agreement with results previously published (Bernasconi *et al*., 1999). Although past research suggests that a domain D mutation should confer resistance to all ALS chemistries, the Woodstock 46 population was only resistant to imazethapyr (Ferguson *et al*., 2000). This finding could be explained by the possibility of a varying degree of resistance to ALS-inhibiting herbicides within a given chemistry. For example, recent examination of the Woodstock population has suggested that it is resistant to chlorimuron ethyl, a sulfonylurea (SU), but susceptible to thifensulfuron-methyl, another SU. Many past studies have only used one or two representative herbicides from each of the chemistries when listing patterns of resistance. Without testing a broader spectrum of herbicides within each of the chemistries an incomplete pattern of resistance may be reached.

In addition to mutations previously described in conserved domains, a SeràThr mutation, located near the carboxy terminal of the gene, was discovered for two of the green pigweed populations and one of the redroot populations studied. Past studies have indicated that a SeràAsp mutation, in the same location, is responsible for resistance to the IM's only (Sathasivan *et al*., 1991). This finding is consistent with the pattern of resistance results for all the pigweed populations with a mutation observed at the carboxy terminal. The pigweed populations were resistant to imazethapyr but not thifensulfuron-methyl.

Conclusion

The occurrence of various mutations within the ALS gene, all emerging within a similar timeframe, suggests independent mutational events. As well, the discrepancy between the cited pattern of resistance for domain D and the one observed for population 46 indicates the need for further extensive testing of multiple ALS-inhibiting herbicides, from the same chemistry to confidently state the pattern of resistance. It is important to examine the mechanisms of resistance in pigweed towards the ALS-inhibiting herbicides since a large percentage of crops are sprayed yearly with this type of herbicide. Resistant pigweed can cause significant yield loss to producers. Sequencing of the gene, and its possible mutations, is necessary since it functions as a potential starting block for discovering gene markers which could allow for rapid identification of the type of cross-resistance present in a pigweed population. This in turn would help the producer determine an alternative spray regime to control the pigweed and help maintain expected crop yields.

Table 1: Redroot Pigweed Mutations

Population	Mutation	Susceptible Amino Acid	Resistant Amino Acid
Parkhill 14	Domain B	Q**W**ED	Q**L**ED
Parkhill 15	Domain B	Q**W**ED	Q**L**ED
Caledonia 43	Domain C	AYPGG**A**SMEIHQALTRS	AYPGG**T**SMEIHQALTRS
Woodstock 46	Domain D	**A**FQETP	**V**FQETP
Southwold 27	Carboxy	VLPMIP**S**GAAFKD	VLPMIP**T**GAAFKD

Table 2: Green Pigweed Mutations

Population	Mutation	Susceptible Amino Acid	Resistant Amino Acid
Brigden 29	Domain B	Q**W**ED	Q**L**ED
Brigden 30	Domain B	Q**W**ED	Q**L**ED
McKillop 9	Domain C	AYPGG**A**SMEIHQALTRS	AYPGG**T**SMEIHQALTRS
Brigden 33	Domain C	AYPGG**A**SMEIHQALTRS	AYPGG**T**SMEIHQALTRS
Brigden 36	Domain C	AYPGG**A**SMEIHQALTRS	AYPGG**T**SMEIHQALTRS
Brigden 39	Domain C	AYPGG**A**SMEIHQALTRS	AYPGG**T**SMEIHQALTRS
Elma 4	Carboxy end	VLPMIP**S**GAAFKD	VLPMIP**T**GAAFKD
Iona 20	Carboxy end	VLPMIP**S**GAAFKD	VLPMIP**T**GAAFKD

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Multiple resistance to ALS-inhibiting and triazine herbicides in green pigweed (*Amaranthus powellii*)

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Introduction

Herbicide resistant weeds are becoming an increasingly problematic situation worldwide. Although most of the original reported cases involve resistance to only one herbicide, there is now an increasing concern of weeds with cross- and multiple-resistance. This new dilemma poses a problem to crop producers because it limits the number of effective herbicides that can be used for weed control.

For the past 20 years, Ontario growers have intensively relied on ALS-inhibiting and triazine herbicides for weed control in their corn / soybean rotation. Therefore, the potential for weeds in Ontario being resistant to both ALS inhibiting and triazine herbicides exists. Until recently, there were only two documented cases of weeds having resistance to ALS-inhibiting and triazine herbicides (i.e. multiple resistance) in all of North America. Both cases were discovered in Illinois, U.S.A., where biotypes of common waterhemp (*A. rudis*) and kochia (*Kochia scoparia*) were found to be resistant to atrazine and a number of different ALS-inhibiting herbicides (Foes *et al*., 1998; Foes *et al*., 1999).

In the fall of 1997, 39 populations of green and redroot pigweed (*A. retroflexus*), suspected to be resistant to ALS-inhibiting herbicides, were collected from various farms across Southwestern Ontario. The populations were screened with imazethapyr and thifensulfuron-methyl and many were found to be resistant to these herbicides (Ferguson *et al*., 2000). Because of the prevalence of triazine resistance in Ontario (Stevenson *et al*., 1990), it was suspected that some of these populations could also express triazine resistance.

In 1999, 26 of the original 39 pigweed populations were screened with atrazine. Two green pigweed populations survived a foliar application of atrazine at 1500 g ai ha^{-1}. One of these populations, originating from Perth County, Ontario, was also resistant to imazethapyr. Multiple resistance was confirmed when this population survived treatment with a mixture of atrazine (1500 g ai ha^{-1}) and imazethapyr (75 g ai ha^{-1}).

There were two objectives to this research. The first was to determine to what degree four different green pigweed biotypes are resistant to ALS-inhibiting and triazine herbicides by conducting a dose response analysis. The four biotypes included one that is triazine and imazethapyr susceptible (Harrow 41), one that is multiple resistant (Elma 4), one that is triazine resistant (Southwold 24), and one that is imazethapyr resistant (Brigden 29). Two analyses were performed, one using atrazine and another using imazethapyr.

The second objective was to determine the basis of triazine resistance in the Southwold 24 and Elma 4 pigweed biotypes. Sequencing of the psbA gene, which codes for the D1 protein in plant chloroplasts and is the primary site for atrazine binding, was performed to verify if the typical substitution of serine with glycine at residue 264 is responsible for resistance.

Materials and methods

Dose Response

Seed was planted in a soil mixture containing loam : coarse sand : peat (3:2:1 ; v/v/v). Upon emergence, plants were thinned to five plants per pot and sprayed when they reached the two to four leaf stage. Herbicide applications were made in a moving nozzle spray chamber calibrated to deliver 210 L ha^{-1} of spray solution at 40 PSI using compressed air and a Teejet SS8002E spray tip.

Plants were harvested 10 days after treatment, dried at 70C for 3 days, and then weighed. The dry weight biomass was converted to % of mean control and analyzed using a log-logistic statistical model. The resistance factors (RF) for each biotype were then calculated by dividing the dose required to reduce growth by 50% (GR_{50}) of the resistant biotype by the GR_{50} of the susceptible biotype.

Sequencing of psbA Gene

DNA was extracted from 5 plants of Harrow 41, 3 plants of Southwold 24, and 3 plants of Elma 4, and subjected to a polymerase chain reaction (PCR) to amplify the psbA gene. The PCR cycle used followed that of Foes *et al*. (1998), with the exception that the annealing temperature was reduced from 60 to 58C. After amplification, the PCR products were cleaned up using a Microcon® PCR Kit, which removes all small fragments (mainly primers) under 300 bp in size. The samples were then sequenced to determine the nucleotide sequence of the gene. Five plants of the Harrow 41 biotype were sequenced in order to ensure that the sequence of the susceptible biotype was correct.

Results

Dose Response

The atrazine dose response analysis indicates that Harrow 41 and Brigden 29 have a very similar response curve and GR_{50}. The atrazine doses that were found to reduce growth by 50% for Harrow 41 and Brigden 29 were 16.09 and 8.97 g ai ha^{-1}, respectively. Conversely, the response of Southwold 24 and Elma 4 to atrazine were similar to each other, but they could tolerate a much greater dose. Even at 30 kg ai ha^{-1} of atrazine, the GR_{50} could not be reached for either of the two biotypes.

The imazethapyr dose response analysis showed Harrow 41 and Southwold 24 to have similar response curves and GR_{50} values; the GR_{50} values for both biotypes were 0.28 and 0.46 g ai ha^{-1}, respectively. Elma 4 and Brigden 29 had a significantly higher tolerance to imazethapyr, with their GR_{50} values being calculated as 31.97 and 203.06 g ai ha^{-1}, respectively.

Table 1. GR_{50} and RF values for the four pigweed biotypes tested in response to atrazine and imazethapyr.

	atrazine		imazethapyr	
Pigweed Biotype	***GR_{50} (g ai ha^{-1})***	***RF***	***GR_{50} (g ai ha^{-1})***	***RF***
Harrow 41	16.09	1.00	0.28	1.00
Southwold 24	not reached	>1849*	0.46	1.67
Brigden 29	8.97	0.56	203.06	725.12*
Elam 4	not reached	>1849*	31.97	114.20*

* means that the RF is significantly higher than that of the susceptible

DNA Sequence Analysis

Results from sequencing the psbA gene indicate that the Southwold 24 and Elma 4 pigweed biotypes both have a mutation at residue 264. A change at the first nucleotide position of the codon results in a subsequent amino acid change, where serine is substituted for glycine (Table 2a). This indicates that the most probable basis for triazine resistance is due to an altered target site. In addition, a second mutation was found in Elma 4 at residue 108, where a nucleotide substitution was made at the third nucleotide position of the codon that codes for asparagine. However, this is a silent mutation since the codon still codes for the same amino acid (Table 2b).

Table 2a. A portion of the sequenced psbA gene depicting a substitution of serine for glycine at residue 264 in Southwold 24 and Elma 4.

					Ser							
Harrow 41	TTC	CAA	TAT	GCT	**AGT**	TTC	AAC	AAC	TCT	CGT	TCT	TTA
Southwold 24	TTC	CAA	TAT	GCT	**GGT**	TTC	AAC	AAC	TCT	CGT	TCT	TTA
Elma 4	TTC	CAA	TAT	GCT	**GGT**	TTC	AAC	AAC	TCT	CGT	TCT	TTA
Amino acid	Phe	Gln	Tyr	Ala	**Gly**	Phe	Asn	Asn	Ser	Arg	Ser	Leu
Position	260				**264**							271

Table 2b. A portion of the sequenced psbA gene depicting the second mutation found in Elma 4.

					Asn							
Harrow 41	GAG	TGG	TTA	TAC	**AAT**	GGT	GGT	CCT	TAT	GAA	CTA	ATC
Southwold 24	GAG	TGG	TTA	TAC	**AAT**	GGT	GGT	CCT	TAT	GAA	CTA	ATC
Elma 4	GAG	TGG	TTA	TAC		GGT	GGT	CCT	TAT	GAA	CTA	ATC
Amino acid	Glu	Trp	Leu	Tyr	**AAC**	Gly	Gly	Pro	Tyr	Glu	Leu	Ile
Position	104				**Asn 108**							115

Conclusions

The *A. powellii* biotype Elma 4 has a high degree of resistance to both atrazine and imazethapyr. The imazethapyr dose response analysis showed that Elma 4 had a significantly higher GR_{50} than the susceptible biotype, but it was not quite as high as the GR_{50} of Brigden 29. The atrazine dose response analysis found Elma 4 to respond very similarly to Southwold 24, both having an extremely high resistance compared to the susceptible. Analysis of the psbA gene indicate that atrazine resistance, for both Elma 4 and Southwold 24, is most likely due to a mutation at residue 264 where serine is substituted for glycine.

The significance of finding this multiple resistant green pigweed biotype in Ontario is three-fold. First, we now know that a multiple resistant weed biotype does exist here in this province, and there are probably more biotypes that have not been discovered yet. Second, this finding should reinforce the fact that herbicide choice, rotation, and mixtures are very important. It is easier to be proactive and try to prevent herbicide resistance from occurring than it is to fix the problem after resistance has appeared. Third, there is a continued need for grower education in order to try and prevent resistant weeds from being selected for. The fight against herbicide resistant weeds should start with the people that are trying to manage them.

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Determining the mechanism of quinclorac resistance in a false cleaver (*Galium spurium*) biotype

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Introduction

Galium spurium is an economically important weed species because it competes with the crop, contaminates harvested grain, and delays harvest (Malik and Vanden Born 1988). Due to the extreme competitiveness of *G. spurium* and prolific seed production, acceptable weed thresholds are not practical (Malik and Vanden Born 1988). In Canada, quinclorac is registered as Accord® at 135-165 g ha^{-1} for control of *G. spurium* (1-3 whorl) in wheat and other cereal crops.

Quinclorac and quimerac, members of the quinolinecarboxylic acid family of herbicides, are auxinic herbicides (Grossmann 1998, Lopez-Martinez *et al*. 1998). Although auxinic herbicides have been in use for over 50 years, progress in the elucidation of their mode of action and mechanism of auxinic herbicide resistance has been made only recently (Sterling and Hall 1997).

G. spurium seeds were collected in a field in Alberta, because the plants were suspected to be resistant to sulfonylurea herbicides. This field was sprayed 3 out of 6 years with ALS inhibitors, but, quinclorac had never been used (Hall *et al*. 1998). Greenhouse experiments confirmed that the *G. spurium* biotype was resistant to several ALS herbicides and quinclorac, but not to auxinic herbicides fluroxypyr or MCPA/mecroprop/dicamba (Hall *et al*. 1998). The mechanism of ALS resistance in the R biotype was due to an altered ALS target site (Hall *et al*. 1998). However, the mechanism of quinclorac resistance is not known.

Research Goals and Objectives

The primary research goal is to determine the mechanism of quinclorac resistance in this *G. spurium* biotype. Ultimately, this research may provide insight into the mode of action and target site of quinclorac in dicot plants. The initial research objectives were to determine: i) the level of quinclorac resistance in *G. spurium*, ii) quinclorac absorption, translocation, root exudation or metabolism are involved in resistance, and iii) ethylene biosynthesis.

Preliminary Results

LD_{50} values for R and S biotypes, determined by dose-response experiments, were >1500 and <20 g ai ha^{-1}, respectively (Figure 1). Symptoms of quinclorac phytotoxicity in the S biotype include leaf hyponasty, reduced leaf area, internode elongation, chlorosis, necrosis, and ultimately plant death. In contrast, quinclorac treated R plants displayed leaf tip chlorosis, but generally little or no phytotoxic symptoms were observed.

Generally, the pattern of [^{14}C]quinclorac absorption and translocation was similar in both biotypes (Table 1). More [^{14}C]quinclorac was absorbed in the R biotype and less radiolabelled herbicide was removed via root exudation in the R biotype compared to S. Less than 5% of quinclorac was metabolized in both R and S biotypes at all harvest times up to 96 HAT (Figure 2). Therefore, preliminary results indicate that the mechanism of resistance is not due to differences in quinclorac absorption, translocation, root exudation or metabolism between the R or S biotype. These results are similar to a quinclorac resistant *Echinochloa* biotype (Grossmann 1998, Lopez-Martinez *et al*. 1998). Based on aforementioned results, it is hypothesized that the mechanism of quinclorac resistance in *G. spurium* is potentially due to an altered target site.

Consequently, experiments were conducted to determine if ethylene, which is induced in auxin susceptible plants, is selectively induced in the *G. spurium* S biotype. Hydroponic treatment with quinclorac (10^{-4}M), resulted in a three-fold increase in ethylene biosynthesis in light grown S seedlings compared to untreated control, 72 HAT (Figure 3). Quinclorac did not induce ethylene in R seedling at any time sampled. Thus, it appears that quinclorac induces a biochemical cascade in the S and not the R. Similarly, quinclorac induced ethylene biosynthesis in quinclorac susceptible, but not resistant *Echinochloa* (Grossmann 1998, Lopez-Martinez *et al*. 1998).

Future Research

The pathway of auxin induction by quinclorac in dicots involves the stimulation of ACC synthase activity, and concomitantly, increases in ACC, ethylene, and ABA levels in susceptible species (Grossmann 1998). ACC synthase activity, and the levels of ACC and ABA will be analyzed in both biotypes. Determination of quinclorac phytotoxicity in R and S plants after application of i) aminoethoxyvinylglycine (AVG), a ACC synthase inhibitor, and ii) salicyclic acid, an ACC oxidase inhibitor, will elucidate the pathway of quinclorac induction in R and S biotypes.

Great potential for determining the mechanism of quinclorac resistance is through breeding and genetic analysis. From R and S breeding lines, F_1 and F_2 generations, as well as, F_1 back crosses (F_1BC_1) were established. F_1BC_1 and F_2 plants will be screened for herbicide resistance to determine the nature of the gene, such as dominance, and the number of genes controlling resistance. Random amplified polymorphic DNA (RAPD) or amplified fragment length polymorphisms (AFLP) analysis will be conducted on parental and F_2 individuals to locate closely-linked markers to the resistance locus. Ultimately, the resistance locus will be isolated and characterized.

Conclusions

Preliminary results indicate that the mechanism of quinclorac resistance in the *G. spurium* biotype is not due to differences in absorption, translocation, root exudation or metabolism. Selective ethylene biosynthesis induction indicates that a signal transduction pathway is induced in the S and not in R biotype. Biochemical analysis of the auxin induction pathway will be investigated to characterize resistance. In addition, future research to determine the mechanism of resistance will include breeding and genetic analysis.

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Table 1. Distribution of radioactivity in *Galium spurium* plant, expressed as percent of recovered [^{14}C]. Plants were treated at the 3-whorl stage of development and harvested 0, 24, 48, and 96 hours after treatment (HAT) of the second whorl with [^{14}C]quinclorac.

Plant part	Biotype	Distribution of [^{14}C] (% of recovered)			
		Harvest Time			
		0	24	48	96
Leaf rinse	R [a]	92.2 (1.1) [b,c]	56.3 (2.3)	34.2 (4.7)	28.4 (5.2)
	S	92.4 (1.9)	51.5 (5.5)	42.6 (4.8)	35.6 (3.5)
Root exudate	R	0.04 (0.002)	3.0 (0.4)	7.2 (1.2)	7.7 (1.5)
	S	0.04 (0.003)	2.3 (0.8)	4.3 (0.9)	14.6 (3.3)
Shoots above trt whorl	R	0.2 (0.05)	14.4 (0.4)	23.8 (1.9)	23.8 (1.9)
	S	0.1 (0.04)	19.2 (1.7)	27.2 (1.9)	25.8 (3.5)
Treated (trt) whorl	R	7.3 (1.1)	3.6 (0.5)	3.82 (0.8)	3.5 (0.6)
	S	7.2 (1.9)	7.2 (1.4)	4.05 (0.3)	2.3 (0.3)
Shoots below trt whorl	R	0.2 (0.04)	20.7 (1.5)	28.2 (1.6)	35.4 (3.4)
	S	0.2 (0.05)	18.6 (2.4)	20.3 (3.2)	18.5 (2.2)
Roots	R	0.07 (0.02)	2.1 (0.1)	2.9 (0.6)	1.2 (0.2)
	S	0.1 (0.05)	1.2 (0.2)	1.5 (0.4)	3.2 (1.0)
Percent recovered	R	85.6 (2.6)	92.4 (2.9)	94.5 (3.6)	97.0 (4.0)
	S	84.4 (3.1)	92.1 (2.1)	94.5 (1.2)	96.5 (0.8)

[a] Resistant (R) and susceptible (S) biotypes, [b] Sample size was 4, [c] Means followed by SEM in parenthesis

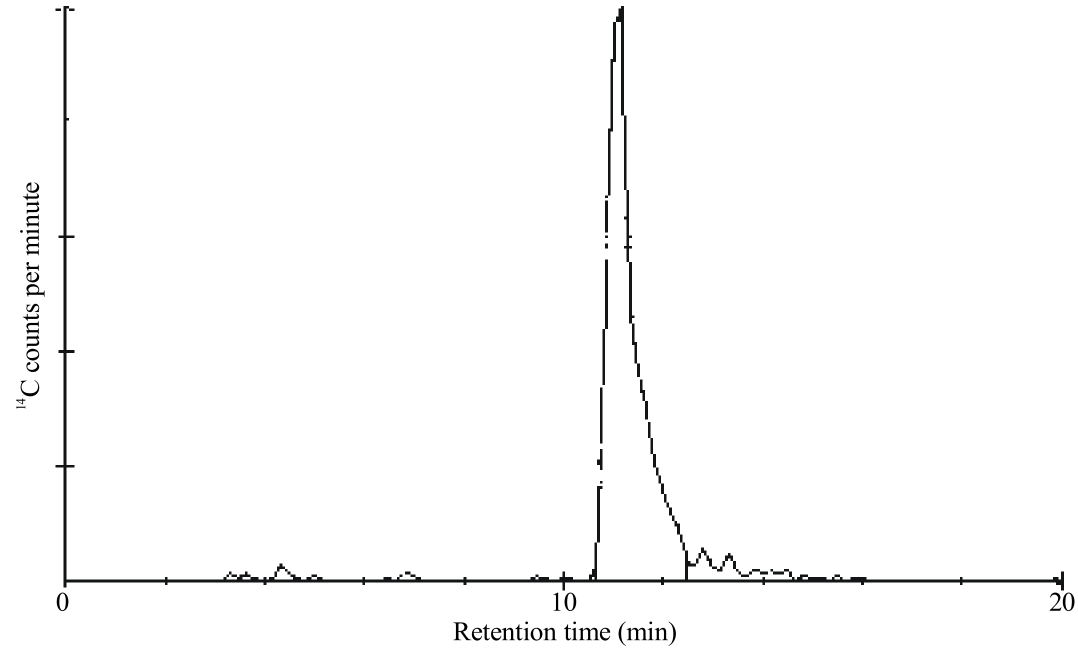

Figure 2. Typical high-performance liquid chromatograph of extracts obtained from quinclorac-resistant or susceptible *G. spurium* plants treated with [^{14}C]quinclorac at the 3-whorl stage of development and harvested 0, 24, 48, or 96 hours after application. Retention time for quinclorac was 11.17 min.

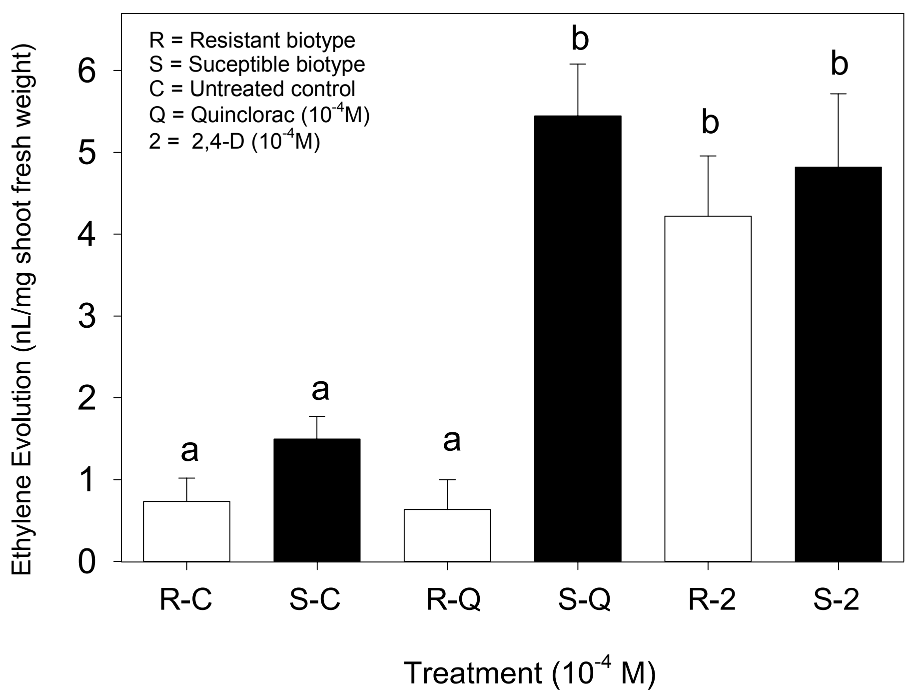

Figure 3. Ethylene evolution (nL/mg shoot fresh weight) from false cleavers **72 h** after root treatment of 10^{-4}M quinclorac or 2,4-D amide. Data are expressed as means with standard error. Different letters (a, b) indicate statistical difference based on Student-Newman-Keuls test.

Basis of resistance of wild oat (*avena fatua*) to several herbicides with different mechanisms of action

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Introduction

In the early 1990s, two resistant populations of wild oat were discovered on nearby farms in the Swan River Valley of Manitoba that were resistant to three herbicides, i.e., fenoxaprop-ethyl, imazamethabenz-methyl, and flamprop-methyl, each of which has a completely different mechanism of action. These two populations of wild oat were resistant to imazamethabenz-methyl and flamprop-methyl in spite of the fact that these herbicides had not been previously used for weed control (Morrison et al., 1995). Generally, resistance of this type can be caused by a genetic mutation(s) causing alterations in herbicide uptake, translocation, and/or metabolism, or by mutations at each target-site. However, it is unlikely that the three target-sites of these herbicides are mutated since resistance developed toward imazamethabenz-methyl and flamprop-methyl prior to their applications. Based on the field history, resistance in these populations is more probably caused by one genetic mutation such as altered metabolism. Furthermore, dose responses of the resistant populations were relatively low compared to the usually high resistance factors associated with target-site enzyme alterations inferring that metabolism is the basis of resistance.

Research objective

The objective of our research is to determine how these two populations of wild oat are concurrently resistant to fenoxaprop-ethyl, imazamethabenz-methyl, and flamprop-methyl. Resistance to herbicides in plants is usually due to alterations in (1) target-site enzymes, (2) uptake, (3) translocation, and/or (4) metabolism. We are investigating all four of these mechanisms as possible explanations for resistance.

Preliminary results and conclusions

The absorption and translocation of ^{14}C-fenoxaprop-ethyl in these populations is not significantly different from a susceptible population 72 hours after treatment (HAT). Typically less than 5% of the radiolabelled herbicide remained unabsorbed and less than 1% translocated to untreated shoots and roots. Herbicide metabolism studies indicated that the resistant populations have significantly less fenoxaprop-ethyl converted to biologically active fenoxaprop. For example, 72 HAT, 10% of the recovered radioactivity remained in the form of fenoxaprop-ethyl in the susceptible biotype compared to 30% in the resistant biotypes. Acetyl coenzyme-A carboxylase (ACCase) - the target-site enzyme for fenoxaprop – is currently being studied to determine whether any differences in herbicide affinity exist between the resistant and susceptible biotypes. Based on the data gathered thus far we hypothesize that the resistance expressed by these populations of wild oat is caused by a decreased rate of de-esterification of fenoxaprop-ethyl to phytotoxic fenoxaprop.

Significance to weed science and agriculture

Wild oat ranks second in relative weed abundance on the Canadian Prairies, occurring in 64% of surveyed fields; 27% of surveyed fields had resistant wild oat. The cost to growers managing herbicide-resistant wild oat in Saskatchewan and Manitoba was estimated at over $4 million annually (Beckie et al., 1999). Resistance that occurs in populations that have not been "pre-exposed" to the herbicide is especially serious since current management strategies for minimizing/rotating herbicide use may not be effective. This research, therefore, will contribute to studying the mechanism of resistance in these populations, and, in consequence, may lead to alternative management strategies to ameliorate the growing phenomenon of herbicide resistance.

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Weeds in Space

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Introduction

Site-specific weed control has become possible since the introduction of global positioning systems (GPS). GPS technologies allow us to determine our position, map fields, including weeds and topographic features then apply treatments to previously identified areas.

Environmental loading of herbicides and herbicide costs could be reduced by site-specific application while maintaining weed control and crop tolerance. However, this technology has challenged our understanding of weed biology and distribution and our assumptions concerning herbicide prescriptions.

The objective of this research is optimal determination of locally-varying herbicide rates for practical field-scale application.

Methods and Materials

In a field near Lloydminister, Alberta, in 2000, wild oat distributions were tagged using a GPS equipped all terrain vehicle to record wild oat density on a 20 m interval. The wild oat were tagged as less than 10 plants per m^2 for low density, 10-50 plants per m^2 for medium and greater than 50 wild oat per m^2 as high (Figure 1). A map prescribing variable rates of clodinafop was developed; the fields were sprayed at the 2-3 leaf stage of wheat and control assessed. High, medium and low weed populations were identified and 19.6 ha received a low rate (24.3 ml/ha) while 2.6 ha received a medium rate (30 ml/ha) and 40.1 ha received a high rate (34.4 ml/ha). Clodinafop was applied with a Flexicoil sprayer equipped with dual booms. Paired plots were established in areas identified by weed tagging as having low, medium and high wild oat populations with one of the paired plots covered during spraying. Wild oat were counted in treated and untreated plots and four weeks following application, wheat and wild oat biomass was determined. Data was analyzed using GLM in SAS. Means were separated using Student-Newman-Keul.

Results and Discussion

Where wild oat was treated with site-specific variable rate herbicide applications, wild oat populations varied considerably. Wild oat averaged 84 plants/m^2 and ranged from 0 to 212 plants/m^2.

There were no significant differences in wild oat density or biomass in areas that were identified as having low, medium or high wild oat populations (Figure 2). While herbicide treatment significantly decreased biomass, there were no differences in the percentage reduction in biomass in the areas which received different herbicides rates. In this field, scouting failed to correctly differentiate between levels of wild oat populations and increasing the herbicide did not alter the control of wild oat. There were no easurable differences between wheat biomass in areas that were identified as having differential wild oat populations, but herbicide treatment did significantly increase wheat biomass. In this field where wild oat populations were more uniform, scouting failed to provide an accurate picture of wild oat infestations. The low rate of clodinofop provided a 94.5 % reduction in biomass, while medium and high rates provided 96.4 and 96.3%, respectively. Site specific clodinofop application reduced herbicide use by 9.6%.

Weed-scouting procedures for wild oat have not proved consistently accurate. Variable herbicide rates can be applied using currently available application equipment. However the response of wild oat populations to variable herbicide rates is more difficult to predict.

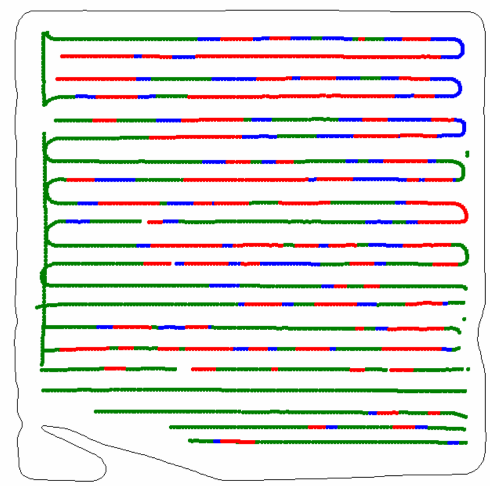

Figure 1. Wild oat scouting using a GPS equipped all terrain vehicle in a field of wheat, in which wild oat density was tagged as low, medium or high.

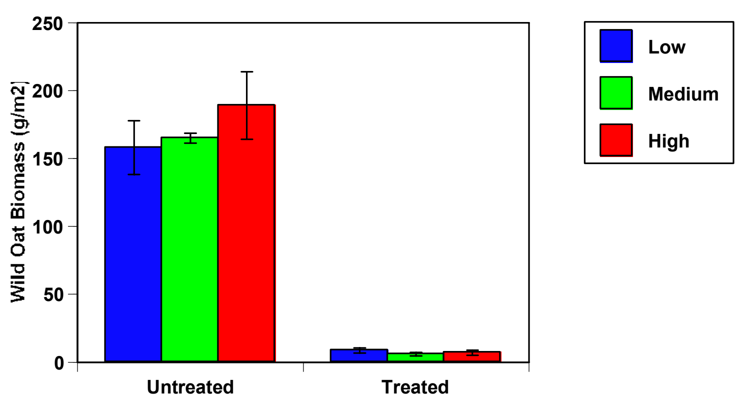

Figure 2. Wild oat biomass after herbicide application in treated and untreated plots established in areas that had been identified by weed tagging as having high, medium or low wild oat populations.

The Impact of Seed Treatment, Cultivar, and Crop Density on Canola (*Brassica napus*) Competitiveness

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Introduction

With the loss of lindane based canola seed treatments, some producers are concerned about the control of flea beetles and soil-borne pathogens in their canola crops. In light of increasing input costs, other producers are questioning the value of seed treatment altogether, especially in no-till cropping systems where flea beetles are not as big of a problem. Studies from Alberta have demonstrated that under no-till, simply increasing seeding rate will compensate for flea beetle damage (Dosdall et al, 1999). Furthermore, by using hybrid crops producers can grow vigorous, quickly establishing crops that may elude long term damage caused by these organisms.

The impact of increased seeding rate on weed suppression is well documented (O'Donovan et al, 1988), but the added competitive benefit seed treatments provide by maintaining plant vigor has not been investigated, nor has the potential competitive benefit of using hybrid canola. What do each of these inputs (seed treatment, hybrid canola, increased seeding rate) contribute to canola production in terms of increasing crop competitiveness and weed suppression? If we eliminate seed treatment are we losing a competitive advantage that may not be fully compensated for by increased seeding rate? If that benefit is maintained, what is the price of the substitution? Is there a different optimum seeding rate for hybrid seed when seed treatment is and is not used?

The objectives of this study were:

1. Evaluate Helix relative to lindane and terbufos seed treatments.
2. Examine the effect of seed treatment on crop competition between canola and volunteer barley.
3. Determine what inputs (seed treatment, hybrid canola, increased seeding rate) contribute to canola production in terms of increasing crop competitiveness and weed suppression.

Materials and Methods

Five field experiments on three soil types were conducted during two years, in the Aspen Parkland Ecoregion of Manitoba. Soil types were a sandy loam soil south of Brandon, a clay soil at the Brandon research station, and a clay loam soil north of Brandon. The experiments were conducted in a randomized complete block factorial design. Factors were as follows:

1. Cultivar (Invigor 2273 & Exceed)

2. Seeding Rate (target plant densities of 37.5, 75, 150 & 300 plants of m^2)
3. Seed Treatment (Helix, Vitavax RS (lindane), Vitavax RS + Counter (terbufos) & None treated control)
4. + of - weeds (volunteer barley seeded in row to a target density of 20 plants of m^2)

Canola was seeded using a hoe drill seeder at 20cm row spacing. Nitrogen (46-0-0-0) was mid-row banded and phosphorus (11-52-0-0) was placed with the seed. Sulfur (21-0-0-24) was broadcast prior to seeding. Weeds were chemically controlled as needed to ensure only canola and volunteer barley were present in the plots.

Measurements included: establishment counts, visual flea beetle damage ratings, digital image analysis of canopy closure, crop biomass, stem disease ratings, seed yield and dockage.

Results and Discussion

Using a seed treatment increased the number of canola plants emerging relative to non treated plots suggesting protection from soil-borne pathogens. The hybrid variety also had higher emergence at 4 of 5 site years. Population loss experienced when seed treatment was not used could be compensated for by increasing seeding rate however, there were proportionally more plants lost at higher seeding rates.

Flea beetle damage was prevented when seed treatment was used. Cotyledon damage ranged from 0% area destroyed by feeding for the treated plots to 70% for the non-treated plots. Cultivar selection only influenced flea beetle feeding in 2 of 5 site years and seeding rate had little to no effect on flea beetle damage with only 1 of 5 site years having significantly more damage at the higher seeding rates.

Seeding rate was the most significant factor effecting canopy closure rate followed by cultivar then seed treatment. This was reflected in biomass production. Invigor produced larger plants than Exceed in 3 of 5 site years, which may have contributed to its faster canopy closure. Higher seeding rates produced smaller plants due to increased crowding but had faster canopy closure due to individual plants having to grow proportionately less to fill the same area. Canola biomass production was positively affected by seed treatment in only 2 of 5 site years, otherwise it was insignificant. Barley biomass decreased with increased seeding rate in 4 of 5 site years demonstrating the suppressive benefit of higher seeding rates. Invigor decreased barley biomass in 3 of 5 site years suggesting it was more competitive with volunteer barley relative to Exceed. Seed treatment affected barley biomass in only 1 of 5 site years, decreasing it relative to non treated plots.

The major canola stem diseases present were Sclerotinia (*Sclerotinia sclerotiorum*) and Black leg (*Leptoshaeria maculans*). There were no major differences in disease among seed treatment, cultivar, or seeding rate. Overall disease infestation was low with only 5-19% of the plants infected.

Canola yield was affected by seed treatment in 4 of 5 site years. Invigor had significantly higher yield when weeds were and were not present in all site years. Exceed experienced greater yield loss due to barley relative to Invigor at all sites, again suggesting Exceed is less competitive against barley. Due to it's increased competitiveness and higher yield potential, Invigor yielded similar to Exceed when Invigor had barley present and Exceed did not (figure 1).

This suggests genetics can compensate for weed control in terms of grain yield. Canola yield response to seeding rate was a typical rectangular hyperbolic response for both cultivars, with the horizontal asymptote shifting upward for Invigor under both weedy and weed free conditions. For both cultivars, increasing seeding rate by approximately four times compensated for the lack of weed control.

Summary and Conclusions

Results show that seed treatment is a very effective tool for protecting canola from flea beetles, with Helix performing similar to lindane and terbufos based seed treatments. However, due to the extreme plasticity of canola when growing conditions are optimal, it's ability to compensate and recover from early insect damage diminishes the effect seed treatment has on final grain yield. As a consequence, seed treatment seems to have a minor influence on the competitiveness of canola, overshadowed by the effect of cultivar and seeding rate.

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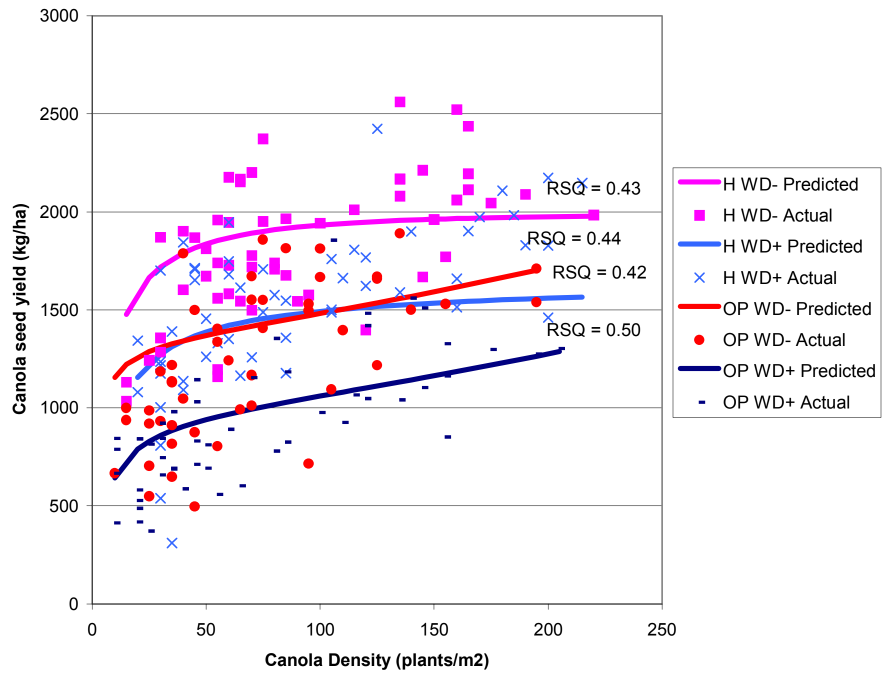
Figure 1: Canola seed yield in 2000 at the clay site with (WD+) and without weeds (WD-), hybrid (H) and open pollinated (OP).



Poster abstracts

Pre-emergent tillage in field pea effective, but timing critical. E.N. Johnson and M. E. Nielsen. Scott Research Farm, Scott, Sk.

On the semi-arid prairies, it is generally recommended that field pea be seeded early and at a depth of 5 to 7.5 cm. However, it is known that crops that emerge prior to weed emergence suffer a lower yield penalty than crops that emerge at the same time or after weed emergence. Therefore, delayed seeding at a shallow depth may allow for faster crop emergence and better weed competition. A study was conducted in 1999 and 2000 at the Scott Research Farm to identify combinations of seed date, seed depth, and pre-emergent weed control to optimize yield in field pea grown without the use of herbicides. Field pea (*cv.* Grande) was seeded at 3 seed dates (early, mid and late May), two seed depths (2.5 cm, 7.5 cm) and three weed control systems (untreated, post-seed/ pre-emerge tillage, and herbicide). The post-seed/ pre-emerge tillage treatment for the 2.5 cm depth was done with a tine-harrow, while the 7.5 cm depth received a post-seed/pre-emerge rod-weed treatment. Highest field pea yields were achieved with the early May seed date/herbicide combination. Post-seed/ pre-emerge tillage was not effective on the early seed dates as weeds had not emerged. Delayed seeding until mid-May, followed by pre-emerge tillage was very effective in reducing weed interference and increasing crop yield. Crop yields obtained were 85 to 90 % of that obtained by the early May/ herbicide treatment. Delayed seeding until late May resulted in a severe yield penalty, with field pea yields declining by as much as 40% from the earlier seed dates.

How does thy canola volunteer? Let us count the ways. Marie-Josée Simard[1], Anne Légère[1], Julie Lajeunesse[2], Patrick Lévesque[1], Denis Pageau[2] and Suzanne Warwick[3]
[1]AAFC, Ste-Foy, QC, **[2]** AAFC, Normandin, QC, **[3]** AAFC, Ottawa, ON.

Although the presence of canola volunteers is acknowledged, it has yet been documented on a large scale for Québec cropping systems. Our goal was to estimate the frequency and persistence of canola (*Brassica napus*) volunteers by surveying fields that included a canola crop at one point since canola introduction in Québec. Fields were surveyed in the Saguenay-Lac-Saint-Jean area and in the area south of the St.Lawrence, between Québec City and La Pocatière. Fields surveyed included a canola crop, one to five years prior to 2000. Most of the fields seeded in 1998-1999 were sown with Roundup Ready® hybrids (Monsanto Co.). Canola plants that presumably overwintered were observed in no-till fields in the La Pocatière area (1.4% of the volunteer canola). In tilled systems, canola volunteers originated from seeds from the seed bank. Volunteers were found in a wide range of crops, including cereal, corn and soybean. Although volunteer canola density decreases with time, volunteers are still present five years after canola production. An average of 0.21 plants m^{-2} or 2100 plant ha^{-1} were found five years after canola production (n=3 fields). Volunteers themselves probably replenish the seed bank over the years. Volunteers are not always successfully controlled in Québec cropping systems and this management problem is likely to be exacerbated by the introduction of canola with other HT traits. Canola volunteers will also pose a gene contamination problem when trying to revert from an HT to a non-HT canola system. Possible solutions include the development of canola cultivars or hybrids that shatter less or not at all, and improved control of overwintering plants in no-till systems.

Development of Rhizobacteria for Biological Control of Grass Weeds. S.M. Boyetchko, K. Sawchyn, T. Nelson, L. Gibson, and S. Leung. Agriculture and Agri-Food Canada, 107 Science Place, Saskatoon, Saskatchewan, Canada

Wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*) are the two most abundant annual grass weeds in the Canadian prairies. In light of the development of herbicide-resistant populations of these weeds, utilization of weed suppressive soil bacteria for biological control is a viable alternative weed control strategy. Three bacterial strains applied as pre-emergent bioherbicides in different granular formulations using several rates of application were evaluated to determine their efficacy in the field. Results from field trials conducted in 1999 showed that one bacterial strain was able to reduce aboveground biomass and weed emergence of wild oat by as much as 57% and 64%, respectively. Green foxtail emergence and aboveground biomass were reduced by more than 50% using two other bacterial strains applied within furrow with a granular formulation. Although field application of these bacteria is highly feasible, not all granular formulations were compatible with the bacterial strains. The results indicate the necessity for detailed evaluation of various formulations and that their individual ingredients must be carefully scrutinized for compatibility with respect to bacterial survival, shelf life and efficacy in the field.

Biological control of scentless chamomile (*Matricaria perforata*) using plant pathogens Gary Peng*, Karen L. Bailey, and Kelly N. Byer. Agriculture and Agri-Food Canada, Saskatoon Research Center, 107 Science Place, Saskatoon, Saskatchewan, Canada, S7N 0X2. Pengg@em.agr.ca

Scentless chamomile is a noxious weed in Saskatchewan and Alberta. Heavy infestations have been reported in several important cropping areas along the black soil zone in Saskatchewan. Herbicides are generally ineffective at crop-tolerant rates once the weed reaches 4-leaf stage, making the spray window extremely narrow. Preliminary assessment of indigenous fungal pathogens revealed moderate to high effectivity on scentless chamomile beyond 4-leaf stages. Studies were also conducted with combined uses of a fungal agent and post-emergent herbicides to determine interactions of the two different modes of action. In separate experiments, Bentazon or Metribuzin was applied at label rate 24 h prior to foliar inoculation with a spore suspension of fungal agent 99-21A_1. Both herbicides alone significantly affected young plants of scentless chamomile (4-leaves), causing higher than 75% mortality 2 weeks after the treatment. The impact of herbicides on older plants (7 to 10 leaves) was much less significant, although some stunting and necrosis on individual leaves were observed. However, when the older plants were predisposed with either of the herbicides then inoculated with the fungus, 100% mortality was consistently achieved under greenhouse conditions.

Suppression of foxtail barley with selected tame grass species. J. R. Moyer* and A. L. Boswall, Agric. and Agri-Food Canada, Lethbridge, AB. D. Wentz, Alberta Agric. Food and Rural Development, Lethbridge, AB.

Foxtail barley is a short-lived perennial grass that has a competitive advantage over desirable tame grasses on saline soils and in areas that are subject to flooding. Foxtail barley is avoided by grazing animals after heads with stiff awns are formed and foxtail barley infested hay is difficult to sell. Several tame grasses were seeded in replicated experiments at two sites and at a demonstrations site to select grass species that have superior ability to compete with foxtail barley. In the experimental sites tall fescue and creeping foxtail reduced foxtail barley ground cover by 85 % compared to the foxtail barley infestation in orchard grass. Foxtail barley ground cover was at a maximum in orchard grass and pubescent wheat grass and western wheat grass. Meadow bromegrass also had an unacceptable ability to compete with foxtail barley. At the demonstration site creeping foxtail almost completely eliminated foxtail barley from the sward. There are no herbicides available that will provide the level of foxtail barley control achieved in this experiment with creeping foxtail and tall fescue. Therefore, seeding creeping foxtail and tall fescue should be recommended for areas that are subject to foxtail barley infestation. In addition, seeding these grasses in the low saline areas should prevent foxtail barley invasion in areas that are suitable for growing grasses such as orchard grass, meadow brome grass or timothy.

Herbicide detections in Alberta rainfall 1999-2000. Bernard D. Hill*[1], K. Neil Harker[2], Paul Hasselback[3], Jim R. Moyer[1], Dan J. Inaba[1] and Susan D. Byers[1], Research Centres, Agriculture and Agri-Food Canada, [1]Lethbridge and [2]Lacombe, AB, Canada; [3]Chinook Health Region, Lethbridge, AB, Canada.

Herbicides have been detected previously in the rainfall in Europe, the U.S. and other parts of Canada. There is potential for herbicides in rainfall to cause sub-lethal effects in sensitive southern Alberta crops such as sugar beets and potatoes. Therefore, we collected rainfall from April 15 to September 30, 1999 and 2000, at 17 Alberta locations. Samples were collected at 3 to 14 day intervals and analyzed for the following 13 herbicides using MSD-GC with ion-ratio confirmation: 2,4-D, 2,4-DB, bromoxynil, clopyralid, dicamba, dichlorprop, diclofop, fenoxaprop, MCPA, mecoprop, quinclorac, triallate, trifluralin. We detected herbicides at most sample dates at all locations. The herbicides detected most often (in order), and in the highest amounts, were: 2,4-D, dicamba, bromoxynil, MCPA, and mecoprop. The highest herbicide levels occurred in June/early July and were 'spread out' in southern Alberta, but were concentrated into a two to three week period in central Alberta. Herbicide levels were lowest in the 'remote' locations (2,4-D 1-14 $\mu g/m^2$, 0.1-2 ppb), intermediate in the City of Lethbridge (2,4-D 1-36 $\mu g/m^2$, 0.1-10 ppb), and highest in the farming areas (southern AB, 2,4-D 1-149 $\mu g/m^2$, 0.1-53 ppb; central AB, 2,4-D 1-89 $\mu g/m^2$, 0.1-3 ppb). We also carried out indoor bioassays to determine whether the amounts of herbicides detected in rainfall were high enough to cause detrimental effects in tomatoes, sunflowers, sugar beets and potatoes. Plants were treated with a mixture of 2,4-D, bromoxynil, MCPA and dicamba equivalent to the combined maximum levels detected in rainfall. Our results suggest that the highest, combined levels, of these herbicides found in Alberta rainfall could cause transient, sub-lethal effects (P=0.05) in tomatoes and sunflowers, but not in sugar beets and potatoes.

Susceptibility of Row-Planted Soybean (*Glycine max*) to the Rotary Hoe

Maryse L. Leblanc[1] and Daniel Cloutier*[2]. [1]Researcher, Institut de Recherche et de Développement en Agroenvironnement, P.O. Box 480, Saint-Hyacinthe, Québec, Canada J2S 7B8. [2] Researcher, Institut de malherbologie, P.O. Box 222, Sainte-Anne-de-Bellevue, Québec, Canada H9X 3R9.

Mechanical weed control methods are increasingly used in integrated weed management systems in soybean (*Glycine max* (L.) Merr.) production. Environmental and economic concerns related to herbicide use have increased interests in using alternative methods of weed control such as mechanical treatments. A three-year study was conducted to determine soybean susceptibility to physical damage from cultivations done with the rotary hoe. In order to prevent confounding by weed interference, this project was conducted in a weed-free situation by first treating the field with selective herbicides. Plot size was large enough to enable the rotary hoe to be used at a speed of 15 km h-1. The soybeans were systematically cultivated at eight growth stages, from pre-emergence to fourth trifoliate leaf. Two, three and four cultivations were done on a combination of growth stages. Cultivations using the rotary hoe caused some slight visual damage to the crop and decreased crop stand. Soybean population decreased with the number of cultivations but yields were either not affected or significantly increased. The beneficial effects of the rotary hoe, in the absence of any weeds, is probably due to breaking of the soil crust. The hook stage of soybean and of other beans species have been reported as being particularly susceptible to damage by cultivation. The results obtained in this project do not support this concern. However, soil texture, soil structure and seeding depth are factors that could influence crop susceptibility to damage caused by the rotary hoe. According to the results, cultivations with the rotary hoe could be done up to the 4th trifoliate leaf growth stage without risk of decreasing yield.

Susceptibility of Dry Edible Beans (*Phaseolus vulgaris*, Cranberry Beans) to the Rotary Hoe

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Mechanical weed control is a method which represents an excellent potential for bean production systems. Bean growers already use inter-row cultivation to control weeds between crop rows. However, weeds within the rows are not controlled with this type of cultivator. A cultivator that could be used to great advantage is the rotary hoe since it cultivates directly over the crop row and selectively controls young weed seedlings. Depending on the weed species, this type of cultivator is most effective when used on germinating weeds before they emerge or when weeds are at the cotyledon stage. This three-year study was conducted to assess the susceptibility of cranberry bean to mechanical weeding. The rotary hoe was used either singly at the pre-emergence, hook, cotyledons, unifoliate, first to fourth trifoliate stages of bean development or at different combination of these stages. In order to prevent confounding by weed interference, this project was conducted in a weed-free situation by first treating the field with selective herbicides. Cultivation with the rotary hoe did not reduce bean grain yield except for the treatment which received four cultivations at different bean growth stages. Three cultivations improved yield compared with the check without cultivation. A single cultivation done at any of the crop growth stages did not affect grain yield. Crop density at harvest was significantly decreased by 6 % in the treatments receiving two cultivations and by 9 % in the treatments receiving four cultivations compared with the control. The effects of cultivation on grain moisture were inconsistent and differed among years. Seed weight did not differ among treatments in any of the three years of this study. Since this project was conducted under weed free conditions, the beneficial effects of cultivating with the rotary hoe are most probably related to breaking the soil crust, to improving soil aeration, to preserving soil moisture or by promoting mineralization of the nutrients required by the crop.

The Role of Spray Pressure and Nozzle Choice in Weed Control with Low-Drift Nozzles.
Thomas M. Wolf*, Eric Johnson, and Brian C. Caldwell, Agriculture and Agri-Food Canada, Saskatoon, SK.

Low-drift nozzles can produce very coarse sprays that may result in poor herbicide efficacy under some conditions. It is not known whether efficacy reductions are due to poor spray patterns, poor coverage, or an inability to target small weeds. To answer these questions, a study was conducted as Saskatoon and Scott, SK in 1999 and 2000, looking at the interactive effects of application timing (early vs. late), nozzle (Air Bubble Jet (ABJ), Greenleaf TurboDrop (TD), and SprayMaster Ultra (SM)), spray pressure (140, 275, and 515 kPa), herbicide rate (full and half rate), and herbicide (paraquat/diquat (PD) at Saskatoon, glufosinate-ammonium (GA) at Scott). Results were evaluated on three simulated weeds: tame buckwheat, oriental mustard, and tame oats. Spray swath uniformity and deposited droplet size were evaluated under laboratory conditions. Results showed that each herbicide was equally sensitive to the application variables studied. Within each herbicide, tame buckwheat was least sensitive, and tame oats was most sensitive to the tested variables. Late application increased weed control for PD, but reduced it for GA. For tame oats, higher pressures significantly increased weed control for the TD and SM sprays, but had only a small effect on the ABJ. Coarser sprays, either through nozzle or pressure changes, decreased mustard and oat control, but usually did not affect buckwheat control. Early timing and reduced rates increased the sensitivity to nozzle and pressure selection for oats and mustard. Overall, similar control to a conventional flat fan nozzle could be achieved with the ABJ at 275 kPa or greater, with the TD at 515 kPa, or with the SM at 515 kPa, except on tame oats, where the SM had lower weed control event at the highest pressure. Swath deposit uniformity, as measured by Coefficient of Variation (CV) was best with the TD (10%), intermediate for the ABJ (23%) and worst for the SM (28%). Increased pressure increased uniformity, except for the SM, where the intermediate pressure had the best uniformity (CV=20%). Spray coverage on water sensitive paper was similar for all nozzles (about 19%), and did not increase with pressure. Deposited Volume Median Diameter (VMD) was lowest for the ABJ, and highest for the SM, and decreased with pressure, although they were always higher than a conventional flat fan nozzle at 275 kPa. Weed control was related to swath deposit uniformity, but this alone was not a consistent predictor. Multiple regression demonstrated that effects of deposit CV and VMD were additive, and together could predict between 57 and 71 % of weed control variation for GA. Higher CVs reduced weed control more for coarser sprays than for finer sprays.

Ecological risk of transgenic insect resistance under Canadian field conditions. Suzanne Warwick[1], Peter Mason, Lorraine Braun, Anne Légère, and Neal Stewart Jr.[1]Agriculture and Agri-Food Canada (ECORC), K.W. Neatby Bldg., C.E.F.,Ottawa, Ontario K1A OC6

The Research Branch of Agriculture and Agri-Food Canada (AAFC) has teamed up with the Canadian Food Inspection Agency (CFIA) and Environment Canada (EC) in a three-year project to address the need for relevant data to support Canadian risk assessment and risk management decisions for insecticidal transgenes. Currently, no information is available to predict the spread and persistence of insecticidal transgenes in crop and related weed populations. In collaboration with Dr. Neal Stewart from the University of North Carolina, we will develop protocols and generate data to assess ecological effects of *Bacillus thuringiensis* (Bt crylAc) transgene in canola (*Brassica napus*) under Canadian field conditions. In addition, we will investigate the movement of the insecticidal Bt crylAc transgene and an “in vivo marker” transgene (GFP green fluorescent protein) from canola into two closely related weeds, bird rape (*B. rapa*) and wild radish (*Raphanus raphanistrum*) via hybridization and introgression. The fitness of a Bt insecticidal transgene conferring resistance to diamondback moth (DBM), *Plutella xylostella*, in the crop and weeds will be examined using both eastern and western populations of the insect and in both field and laboratory insect bioassays. We will also assess hybridization between wild radish and Ht transgenic lines of canola grown under commercial production in Canada (AB,QB) and potential hybridization in experimental greenhouse and field trials using different genotypes of the weeds from Canada and Europe. It is hypothesized that the spread of Bt transgenes to weeds will accelerate resistance development through continuous exposure of diamondback moth to Bt, reducing the effectiveness of Bt and Bt transgenic plants for DBM control. We will develop probability estimates for the likelihood of insecticidal transgenes to become incorporated into surrounding weed communities and their survival in the presence and absence of selection pressures.

Timing of spring seedbed disturbance changes weed community. Julia Y. Leeson* and A. Gordon Thomas, Agriculture and Agri-Food Canada, Saskatoon, SK; Dan Ulrich and Stewart A. Brandt, Agriculture and Agri-Food Canada, Scott, SK.

The impact of time of spring seedbed disturbances on weed communities in zero and conventional tillage systems was assessed by monitoring weed emergence in ninety-six 50 by 50 cm quadrats from spring thaw until the end of June. The experiment was conducted on fallow phase of a fallow-oilseed-wheat rotation within the Scott tillage study, established in 1978. Spring disturbance treatments consisted of an application of diquat on the zero-till plots or a cultivator pass on the conventional tillage plots. The disturbances were conducted on May 1 (Early), May 15 (Middle) or May 29 (Late). To simulate a rainfall event, water was applied to half of the quadrats within 24 hours after the disturbance. The majority of the weed species were found in the highest densities in the zero-tillage plots. The weed community was dominated by wild buckwheat (*Polygonum convolvulus* L.), associated with the zero-tillage plots. Delaying disturbance allowed more weeds to emerge prior to the disturbance. The number of weeds that emerged after the disturbance declined with later disturbance dates. The addition of water increased emergence but did not change trends. Delaying spring seedbed disturbances in the zero tillage system by two weeks reduced the wild buckwheat biomass by approximately half. The late disturbance date had approximately one tenth of the wild buckwheat biomass found in the plots with the earliest disturbance date. This was the second year of this study, and the results were consistent with the previous years results.

The effects of hexazinone rates, application timing and residue management on Canada thistle (*Cirsium arvense*) control and alfalfa (*Medicago sativa*) seed production. C.D. Myhre[1] and H.A. Loeppky[2]. [1]Agriculture and Agri-Food Canada, Melfort Research Farm, Box 1240, Melfort, SK S0E 1A0. [2]Alberta Agriculture, Food & Rural Development, Lacombe Research Centre, 6000 C&E Trail, Lacombe, AB T4L 1W1

Hexazinone is an effective weed control tool in alfalfa (*Medicago sativa*) seed production. However, both researchers and producers have had variable success in Canada thistle (*Cirsium arvense*) control with hexazinone. The objective of this study was to determine the effects of hexazinone rates, application timing and residue management on Canada thistle control and alfalfa seed production. Two field trials were established with 'Algonquin' alfalfa near Valparaiso, SK and Carrot River, SK in 1998. The Valparaiso trial was located on a fine-textured soil, high in soil organic matter. The Carrot River trial was located on a coarse-textured soil, low in soil organic matter. Three factors (three rates of hexazinone, three residue management treatments and two application dates) were tested in a randomized complete block design. Alfalfa seed yield and Canada thistle: density, dry matter and seed contamination, were determined in 1999. Alfalfa seed yield and Canada thistle control (density, biomass and seed contamination) increased with increased rates of hexazinone at Carrot River but not at Valparaiso. Application timing and residue management had no effect on alfalfa seed yield and Canada thistle control at both sites. No significant interactions between hexazinone rates, application timing and residue management for Canada thistle control were observed. However, residue management by application timing interaction was significant for alfalfa seed yield.

Alfalfa seed yield was significantly higher following a spring burn, with or without hexazinone, at both sites.

Characterization of imazethapyr, thifensulfuron-methyl and atrazine resistance in populations of green pigweed (*Amaranthus powellii S. Wats.*) and redroot pigweed (*Amaranthus retroflexus L.*) in Ontario. Gabrielle M. Ferguson, R. Shane Diebold, Francois J. Tardif , University of Guelph, Guelph, ON and Allan S. Hamill* Agriculture and Agri-Food Canada, Harrow, ON.

In 1997 in Ontario, acetolactate synthase (ALS) inhibiting herbicides were applied to 75% and 34% of the soybean and corn crop, respectively. In the fall of 1997, Ontario farmers reported failure of imazethapyr and other ALS inhibitors to control green and redroot pigweed. Thirty five *Amaranthus sp.* seed samples were obtained from randomly selected plants from patches that appeared to have survived ALS inhibitor treatment. Whole plants were tested for cross-resistance to imazethapyr and thinfensulfuron-methyl and for multiple-resistance using imazethapyr and triazine herbicides at field rates. Resistance to imazethapyr and thifensulfuron-methyl was confirmed in several *Amaranthus sp.* populations. Compared to the susceptible controls, doses required to reduce dry weights by 50% were up to >3400 times higher for imazethapyr and >2400 times higher for thifensulfuron-methyl. One *Amaranthus* population survived both imazethapyr and atrazine compared to the susceptible control. ALS -resistance threatens the availability and longevity of this class of herbicides. Tillage may be necessary to control escaped weeds; however, tillage increases the potential for soil erosion thereby giving access of herbicides into the water system. Escaped weeds may need additional herbicide treatments resulting in increased weed control costs. Alternative herbicides may not control *Amaranthus sp.* well, leaving escaped weeds that compete with the crop, hence reducing yields.

Wild oat (*Avena fatua*) competition in barley is influenced by barley variety and seeding rate. J. T. O'Donovan*, K. N. Harker, G. W. Clayton, and R. N. Pocock, Agriculture & Agri-Food Canada, Lacombe-Beaverlodge Research Centre, Alberta; D. Robinson and J. C. Newman, Alberta Research Council, and L. M. Hall, Alberta Agriculture, Food and Rural Development

Field experiments were conducted at Vegreville and Lacombe, Alberta to determine the influence of barley variety and seeding rate on interference of wild oat with barley. Barley variety and seeding rate affected barley density, seed yield, and wild oat shoot dry wt and seed yield, in most experiments, but there were no variety x seeding rate interactions. As expected, the semi-dwarf varieties, Falcon and CDC Earl, were the shortest. Barley seedling emergence and subsequent plant densities varied among varieties, locations and years. The hull-less varieties Falcon and CDC Dawn had the poorest emergence, in most cases, while AC Lacombe and Seebe had the highest emergence. Wild oat shoot dry matter and seed production were highest in the Falcon, CDC dawn, and CDC Earl plots, suggesting that these were the least competitive with wild oat. Barley yield loss from wild oat interference also tended to be highest in these varieties. Poor emergence of Falcon and CDC Dawn and the shorter stature of Falcon and CDC Earl, likely contributed to their relatively poor competitiveness with wild oat. Increasing the seeding rate improved the competitiveness of all varieties as evidenced by reduced wild oat shoot dry matter and seed production and, in some cases, improved barley yields. The study identifies barley varieties that would be most appropriate for situations where weed control options may be limiting such as organic or low-input farms, or fields where herbicide resistant wild oat is a problem. The varieties AC Lacombe and Seebe consistently reduced wild oat seed production most effectively, and would be most suitable for these situations. The study also emphasizes the need for effective weed control in the less competitive hull-less and semi-dwarf barley varieties to obtain maximum yields. Hull-less varieties such as Falcon were particularly sensitive to weed competition due to both the semi-dwarf stature and relatively poor seedling establishment.

Using microbes and microbial products for control of weeds. Wenming Zhang*, Alberta Research Council, Vegreville, AB; Karen L. Bailey, Agriculture and Agri-Food Canada, Saskatoon, SK.; Dan Cole, Alberta Agriculture, Food, and Rural Development, Edmonton.

Several projects have been initiated to evaluate the possibilities of utilizing microbes (fungi and bacteria) and microbial products for control of weeds and diseases. A fungal pathogen (CL98-103) has been identified to be able to kill cleavers (*Galium spurium* and *G. aparine*) with a supplement of 12-16 h dew. Host specificity test of CL98-103 on 41 plant species has demonstrated that CL98-103 is sufficiently safe as a biocontrol agent against cleavers. A fungal pathogen CW98-235 and a bacterium CW00B006C cause severe diseases on common chickweed (*Stellaria media*). Both the fungus and the bacterium are non-pathogenic to nine major crops including canola, wheat, barley, oats, flax, safflower, field pea, lentil, and alfalfa. Further tests have shown that the bacterium did not attack any of five turfgrass species tested. Another pathogenic bacterium (16 C) causes severe diseases on Canada thistle (*Cirsium arvense*), annual sow thistle (*Sonchus asper* and *S. oleraceus*), and dandelion (*Taraxacum officinale*). Preliminary host range test demonstrated that this bacterium is non-pathogenic to nine major crops. Fractions of secondary metabolites from selected pathogenic fungi collected from diseased cleavers have also been isolated and evaluated for herbicidal and anti-fungal activities. It has demonstrated that one fraction possesses the ability to kill false cleavers seedlings with selectivity between false cleavers and canola. Further study is needed to determine the commercialization potential of the biocontrol agents and their metabolites.

Seedbank dynamics of Scotch thistle, *Onopordum acanthium* L. Qaderi, Mirwais M., Cavers, Paul B. and Bernards, Mark A. Department of Plant Sciences, The University of Western Ontario, London, Ontario N6A 5B7.

Cypselas (seeds) of Scotch thistle (*Onopordum acanthium* L.) exhibit intermittent germination, which is of great concern to agriculturists since these cypselas germinate unpredictably over a long period of time. To better understand this phenomenon, we evaluated the effects of soil type, burial depth and collection time on the emergence patterns of two populations of Scotch thistle. From each of four collections (1996), five lots of 200 cypselas each were placed on the surface or buried at depths of 3 or 15 cm in both sand and silt-loam soils (i.e., field conditions) and emergence was recorded monthly throughout the experiment (Aug. 1996 – Sept. 1999).

Emergence was intermittent over the three years with a higher total percentage from silt loam (17 %) than from sand (9 %). Also, emergence was significantly higher from the 3 cm depth (18 %) than from the surface (8 %). After retrieval, non-germinated cypselas from all depths in silt loam had higher percent germination (89 %) under controlled conditions than those from sand (66 %), yet a significant number still did not germinate until scarified. We have begun to investigate the underlying basis for this differential germination by measuring several chemical properties of the seed coats (waxes, lignins, phenolics) of cypselas that were exhumed from soils after emergence (early germinaters) *vs.* cypselas that remained non-germinated in the incubator but germinated after scarification (cutting 1 mm from the cotyledonary end). With these findings we hope to better understand the factors contributing to intermittent germination.

Spatial distribution of prominent weeds within three Ontario fields. M.J. Cowbrough, H.J. Griffiths, and F.J. Tardif. Department of Plant Agriculture, University of Guelph

Identifying in-field spatial distribution of weeds can determine whether site-specific herbicide applications are appropriate. Prominent weed species within three Ontario fields were mapped in order to identify their spatial distribution. In 1998, and 1999, a field located in Woodstock Ontario, managed under a no-till cropping production system, contained three prominent weed species. Composite maps of the three species showed a patchy distribution. A field located in Guelph, Ontario, under a conventional tillage system for corn in 1999, and no-till system for soybean production in 2000, contained three and four prominent weed species in the first and second years of the survey, respectively. Maps of individual species for this field showed varying degrees of patchiness. However, a composite map of these weeds within the field showed an overall uniform weed distribution. A field located in Ariss Ontario and managed under a conventional tillage system for corn in 1999 contained four prominent weed species. Three of the four species showed no patchiness when mapped individually. A composite map of the four weed species showed an overall uniform weed distribution throughout the field. It therefore appears that although weeds tend to have patchy distribution, this does not always make the fields amenable for site-specific weed management.

Ranking weed response to added nitrogen and phosphorus. Robert E. Blackshaw, Randall N. Brandt and Henry H. Janzen. Agriculture and Agri-Food Canada Research Centre, Lethbridge, Alberta.

Controlled environment studies were conducted to determine the growth response of twenty common prairie weeds to various doses of added nitrogen and phosphorus. Wheat and canola were included as check species. Separate experiments were conducted for each nutrient. Plants were grown in a nutrient deficient soil and nutrients were applied at levels approximating field doses of 0 to 240 kg/ha for nitrogen and 0 to 120 kg/ha for phosphorus. Other macro-and micro-nutrients were maintained at adequate levels. Shoot and root dry weight of each species was determined after six weeks of growth. Results indicated that weeds varied markedly in their growth response to these nutrients, with many weeds responding more to added nitrogen and phosphorus than wheat or canola. Wild mustard was highly responsive to added nitrogen but not to phosphorus. Redroot pigweed and round-leaved mallow were highly responsive to both nitrogen and phosphorus. Russian thistle was one of the least responsive species to both nutrients. Differences in crop and weed growth responses to soil fertility may be exploited by developing agronomic systems that stimulate crop growth over that of weeds.

Integrated control of scentless chamomile: biological control. Garry Bowes, Coordinator, Noxious Weed Program, Saskatoon, Saskatchewan and Clark Brenzil, Provincial Weed Specialist, Saskatchewan Agriculture and Food, Regina, Saskatchewan.

During July of 1999, Saskatchewan started an integrated control program for scentless chamomile. In the province, scentless chamomile is a noxious weed that is spreading rapidly at numerous locations. The purpose of the poster is to show the need and success of a seed weevil for the integrated control of scentless chamomile. In 1999, 55 of the 1995-96 release sites were monitored. The weevil is established on 64% of the sites. In 1999, six sites were suitable for fall weevil collection and re-distribution. In 2000, only one site was suitable for fall collection because invading grasslands had reduced scentless chamomile to a few plants. Low population of scentless chamomile growing in wet permanent grasslands harboured weevils, which consumed 40% of the seed. Biological control agents are an essential part of the integrated control of scentless chamomile. Wet grasslands are permanent sites for scentless chamomile and weevils. Only the future will reveal the full damage that the weevil will have on scentless chamomile. At present, 40% seed consumption is low but the weevil population may still be increasing.

Coming to a field near you: Prairie weed survey. A. G. Thomas, J. Y. Leeson and H. J. Beckie, Agriculture and Agri-Food Canada, Saskatoon, SK; L. M. Hall, Alberta Agriculture, Food and Rural Development, Edmonton, AB; C. Brenzil, Saskatchewan Agriculture and Food, Regina, SK; T. Andrews, Manitoba Agriculture and Food, Carman, MB; and R. Van Acker, University of Manitoba, Winnipeg, MB.

Previous provincial field surveys were conducted between 1995 and 1997 in Saskatchewan, Alberta and Manitoba. Resistant weed surveys began in 1996 and have continued to the present. Many gaps remain in the status of resistance in weeds in different regions of the prairies. An effective program of weed monitoring depends upon the collection of new data at regular intervals. The prairie weed survey project will consist of three equally important components: weed density survey, management questionnaire, and resistance weed survey. It is a cooperative project involving provincial extension staff, federal and university scientists, and agri-business. The 4000 survey sites will be randomly selected with the number of sites in ecoregions allocated in proportion to the area in annual crops. The weighted allocation results in 1200 fields for Alberta, 2200 for Saskatchewan and 600 for Manitoba. Fields seeded to spring wheat, durum wheat, barley, oats, canary seed, canola, flax, mustard seed, dry peas, lentils and chick peas will be included in the survey. The objective of the weed density survey is to measure the species compositions and population densities of the weed communities in the major annual crops during

July of 2001. Details of the farm management practices used on the surveyed fields will be collected in a management questionnaire common to all three provinces. The questionnaire will request information on weed control, resistance management, cropping history, tillage regimes, seeding practices and fertilizer use. By combining the weed density and questionnaire survey data, particular weed management practices that are important determinants of distinctive weed communities can be determined. The objective of the resistance survey component is to determine the nature, distribution, and abundance of herbicide resistance in grass and broadleaf species in Alberta in 2001, Manitoba in 2002, and Saskatchewan in 2003, based on a random sub-sample of the 4000 fields. Approximately 250 fields will be surveyed in Alberta, 150 fields in Manitoba, and 400 fields in Saskatchewan.

About the Canadian Society of Agronomy. Ivany, J.A., Y. Papadoupolos, and Jim Moyer. Regional Directors, Canadian Society of Agronomy.

The Canadian Society of Agronomy is a non-profit, educational and scientific society affiliated with the Agricultural Institute of Canada. The CSA is dedicated to enhancing cooperation and coordination among agronomists, to recognizing significant achievements in agronomy and to providing the opportunity to report and evaluate information pertinent to agronomy in Canada. It provides opportunities for interaction among members and other professional organizations, provide members a united voice for making agronomic concerns known to the public and to other organizations, provide opportunities for members to communicate news and scientific findings to the scientific community. Member benefits include: world class scientific journal, annual meeting, recognition by peers through awards program, competitive awards for graduate students, international projects, career opportunities and representation on various national Expert Committees. A newsletter is published quarterly to disseminate news of members in various regions of Canada, to provide a list of graduate students studying agronomy at Canadian universities and as a forum for reporting Society business. Web page - Check us out at Http://www.agronomycanada.com

The Biology of Canadian Weeds. Current status and new directions. Cavers, Paul B. Department of Plant Sciences, The University of Western Ontario, London, Ontario N6A 5B7

In July 1972, the series on the Biology of Canadian Weeds was initiated with the publication of the format in the Canadian Journal of Plant Science. The first article on *Kalmia angustifolia*, appeared in the following year. By 1979, the first 32 accounts had been collected into a book by G.A. Mulligan and published by Agriculture Canada. This year, the fourth volume of collected papers (numbers 84-102) was published by the Agricultural Institute of Canada. There are now 113 articles in print, including the first updated account (on wild mustard, *Sinapis arvensis*). There is much interest in the series at present, with four submissions currently under review, at least five more expected to be submitted within the next six months, and another fifty species or groups of species assigned to various scientists. Within the past year, eight new offers have been approved. Responsibility for the series rests with a subcommittee of ECW chaired by P.B. Cavers, and with S.I. Warwick and D. Clements as members. Last year the Canadian Journal of

Plant Science Editor appointed P. Cavers as an Associate Editor, with responsibility for the Biology of Canadian Weeds. There are many weed species that are unassigned as yet and new offers are welcomed.

The IR-4 Project – a U.S. National Agricultural Program for Pest Management Solutions in the United States. M. Arsenovic, D. L. Kunkel and J. J. Baron, IR-4 Project, Cook College, Rutgers University, North Brunswick, New Jersey, USA

The Interregional Research Project Number 4 (IR-4), established in 1963, involves cooperation between the USDA's Agricultural Research Service (ARS) and the Cooperative State Research, Education and Extension Service (CSREES), State Agricultural Experiment Stations (SAES), the U.S. Environmental Protection Agency (EPA), agricultural chemical companies, commodity organizations, and individual growers. The IR-4 Mission is to provide pest management solutions to growers of fruits, vegetables and other minor crops. People who benefit from IR-4 are minor crop growers, food processors and consumers. IR-4 develops data for submission to EPA to support the regulatory clearance of new crop protection chemicals on minor food and ornamental crops and assists in the maintenance of existing product registrations. IR-4 provides help in the development and registration of biopesticides and expedites new pest control technologies for minor crops. Since inception, IR-4 has obtained over 5500 food-use clearances, over 8600 ornamental clearances and over 150 biopesticides clearances. These clearances comprise over 40% of the total granted by EPA. As the Food Quality Protection Act (FQPA) of 1996 threatens to restrict or eliminate many long-standing pest control products, IR-4 is focusing on "reduced risk" and safer chemistry to ensure that producers of minor crops have an adequate number of pest control products, both traditional and biopesticides. The year 2000 has been an active year for the IR-4 Project as many herbicide petitions have been submitted to the EPA. A final rule allowing for the registration has been published in the Federal Register for glyphosate in numerous crops and for halosulfuron on cucumber/squash subgroup. IR-4 has worked cooperatively with Canada and other countries in the development and exchange of food crop residue and performance data over the last few years. Residue field trials have been conducted in Canada and overseen by IR-4 as a regular part of IR-4's studies. These trials have been used to supplement and replace U.S trials of similar growing regions. Data packages developed for U.S. registrations have been provided to the Pest Management Regulatory Agency (PMRA) of Canada in support of MRLs that allow use in Canada and for MRLs that support the importation of U.S. agricultural products.

Methods for reducing buffer zone requirements for pesticide spraying adjacent to wetland environments. M.H. Carter[1], R.B. Brown, K.A. Bennett, M. Leunissen, V.S. Kallidumbil[1] and G.R. Stephenson[1]. Department of Environmental Biology1 and School of Engineering, University of Guelph, Guelph, Ontario, Canada, N1G 2W1

A fluorescent tracer was employed to measure downwind spray drift deposits from a conventional boom sprayer for herbicides. Buffer zone widths of 10m and 30m, with and without a snow fence hedge, were compared for adequacy in preventing drift into a simulated wetland set up in an adjacent alfalfa field. Spray drift deposits using a field sprayer equipped with either standard flat-fan nozzles or low drift nozzles, were also compared under moderate and high wind conditions. Deposits were intercepted in the air by filter papers in petri dishes on towers at distances of 0, 3, 10, 50 and 100m downwind from the spray swath. Spray deposits were also monitored in foil pans containing water arranged in a grid pattern within the spray swath and at distances up to 100m downwind from the spray swath. With no buffer zone, no hedge and high wind velocities (>10 mph), moderate to heavy spray drift was intercepted in the air at 100m downwind. With a hedge, the airborne drift at 100m was only light to moderate. At low or moderate wind velocities, there were few detectable traces of airborne drift that were intercepted as far as 100m downwind and there was no apparent effects of either buffer zone width or hedge. Regardless of the wind velocity differences encountered in this study, with a buffer zone of 30 m, there were no detectable deposits of the fluorescent dye in water at distances greater than 30 m into the simulated wetland. At high wind velocities and a 10 m buffer zone, the fluorescent dye was detected at distances up to 60 m into the simulated wetland. At low or moderate wind velocities with or without a hedge, there were very few detectable drift deposits in the simulated wetland. Assuming a wetland with water of 6 inches (15cm), none of these deposits would have posed a risk to aquatic organisms with any of the major field crop herbicides.

Competition of Green Foxtail (*Setaria viridis* L. Beauv.) and Corn (*Zea mays* L.) as Influenced by Varying Nitrogen Rates

R.J. Cathcart and C.J. Swanton
University of Guelph, Ontario

Introduction

The ultimate goal of every crop producer is to minimize costly inputs to the system, while maximizing yields, and hence returns on investment. As such, there are definitely economic concerns to be addressed when dealing with crop inputs to farm fields. These management decisions must be considered in view of long term, environmentally safe and sustainable crop production practices.

The goal of this research is to expand the development of an Integrated Weed Management program to include aspects associated with the increased adoption of of variable N application. Current evidence suggests that as N application rates are reduced to Ontario corn fields, that there is an increase in the relative competitiveness of some weed species. This is particularly important if the decreased N rate leads to a subsequent increase in herbicide use, thus increasing both the cost of weed control and the potential for environmental concerns associated with increased herbicide use.

This poster presents preliminary results from the 1999 field season.

Hypotheses

Specifically, this research concerns whether an increase in the weed competitiveness of Green foxtail (*Setaria viridis* L. Beauv.), associated with decreasing N rates, lowers the economically acceptable weed density threshold in corn. To address this objective, three specific hypotheses will be tested:

Hypothesis 1: *The economic threshold of green foxtail in corn is influenced by variable N rates.*
Hypothesis 2: *The N use efficiency of green foxtail is greater than that of corn, when grown in competition.*
Hypothesis 3: *Management predictions can be made by incorporating weed threshold and N rate data into mechanistic crop models.*

Methodology

Research is being conducted at the University of Guelph's Cambridge Research Station. The interaction of green foxtail (0 - 500 plants m^{-2}) under varying levels of N fertilization (0 - 200 kg N ha^{-1}) was studied. The experiment was conducted as a RCBD, replicated four times. Experimental plots measured 3 x 14m in size.

Corn (var. Pioneer 3905) was planted at approximately 67,000 plants ha^{-1}, and fertilized with P and K as recommended by soil test. Ammonium nitrate and green foxtail seed was broadcast, and raked into the top 5 cm of the soil. Broadleaf weeds were controlled chemically with 2,4-D, and all weed escapes were removed by hand.

Destructive harvest of both corn and weeds occurred four times throughout the growing season (at approximately three weeks prior to silking, at silking, three weeks post-silking, and at harvest maturity). Weed density, $biomass_{(dry)}$, and tissue N; and corn leaf area, $biomass_{(dry)}$ and tissue N were measured at each sampling date. Corn grain yield, and harvest index of each treatment was also measured. Levels of soil N were followed throughout the growing season.

Preliminary Results and Conclusions

Nitrogen rate has been attributed to a significant difference in crop yield regardless of whether the plots contained green foxtail or not. The response was found to be quadratic in nature (Figure 1), with the yield of weed free plots ranging from 4.9-7.7 t ha^{-1} (with N rates 0-200 kg N ha^{-1}), with a MERN (price ratio = 8) of 125 kg N ha^{-1}. A similar response was observed for weedy plots, although both yield and MERN were reduced to 3.2-6.8 t ha^{-1} and 160 kg N ha^{-1}, respectively.

When the influence of both N rate and weed density on 1999 corn grain yield was considered, response surface analysis indicated that a saddle response was obtained, and that the maximum ridge estimate for a crop yield of approximately 7.5 t ha^{-1} occurred at an N rate of 130 kg N ha^{-1} and a weed density of approximately 10 plants m^{-2} (Figure 2).

In conclusion:

- the absolute difference in yield between weed-free and weedy plots was consistent at 1.5-1.8 t ha^{-1}, except when high rates of N fertilizer (200 kg N ha^{-1}) were applied.
- high rates of N fertilizer was able to offset the competitive effect of high weed densities during the 1999 growing season in Ontario.

Acknowledgements

- Foodsystems 2002, Ontario Ministry of Agriculture, Food and Rural Affairs
- Monsanto Canada
- Ontario Corn Producers Association

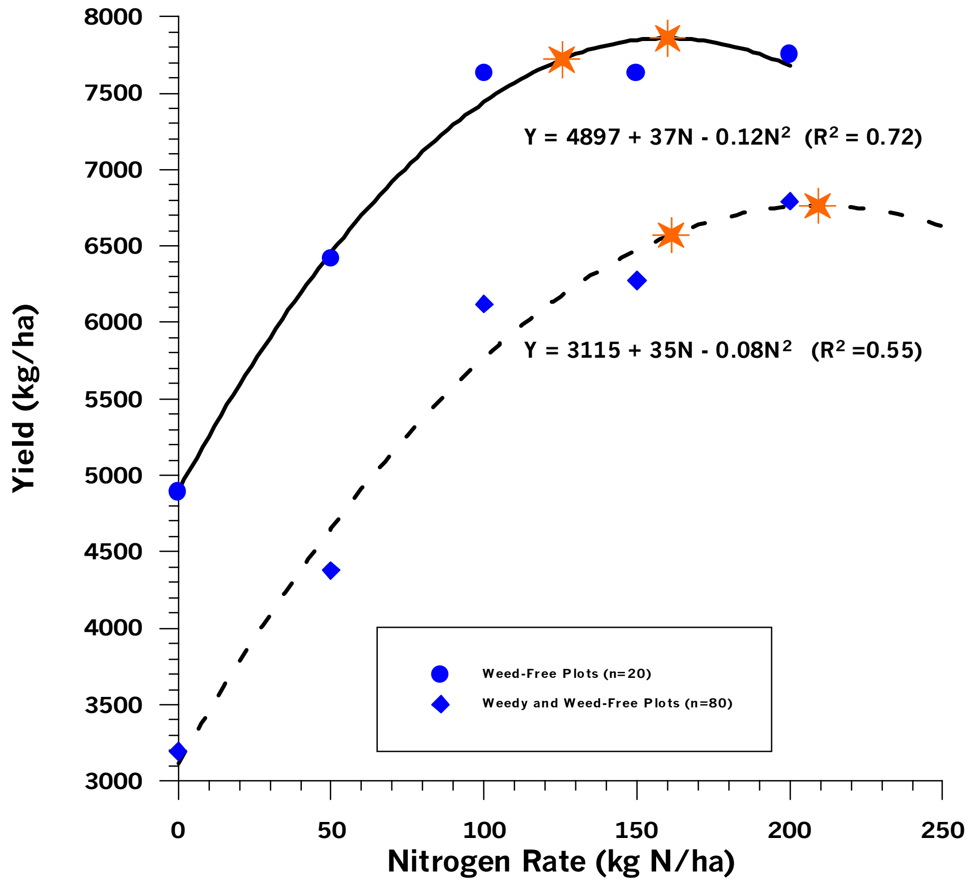

Figure 1. The effect of nitrogen rate on corn (*Zea mays*) yield. The solid line represents the weed-free plots (N=20), and the dashed line represents both weed-free and weedy plots (N=80). Star symbols on each curve represent yield at N_{max} (R) or MERN (L).

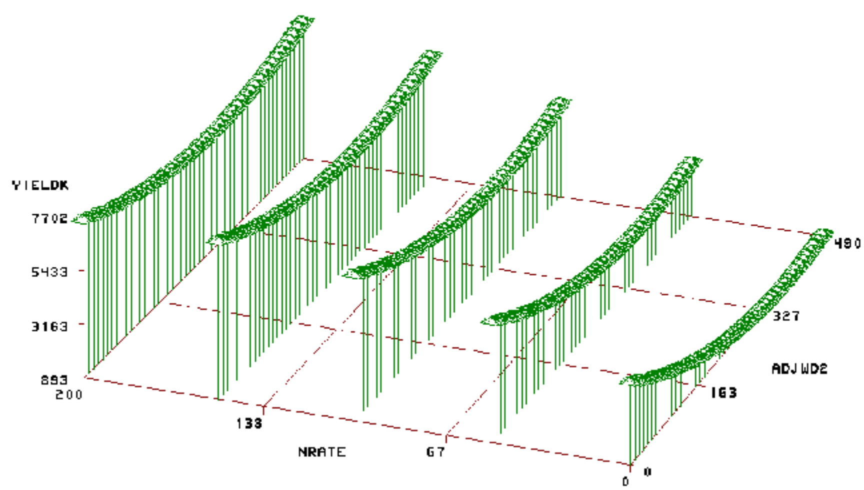

Figure 2. Yield of corn (kg ha^{-1}) (*Zea mays*) as affected by N rate (kg N ha^{-1}) and weed density (plants m^{-2} ground area). Image created using the Proc G3D *Scatter* statement.

Working Groups
Session Summaries

Working Group Report - Application Technology

Panel Discussion

"How should new spray technologies be incorporated into agricultural practice?"

Submitted by Tom Wolf
Agriculture and Agri-Food Canada, Saskatoon, SK

ECW Meeting, Banff, AB Wednesday, Nov. 29, 8:30 – 10:00 am

Background

New spray technologies are introduced into Canada on a regular basis. Many of these change either the spray quality (droplet size), carrier volume, or both. Once introduced, questions arise whether these technologies are safe, work as advertised, whether testing data exist, etc. This can cause some of the following problems for stakeholders:

1. Applicators usually implement new technologies at their own initiative and risk.
2. Products are applied in a manner that was not tested during registration, and when problems arise, chemical companies have little basis on which to make a service decision.
3. The research community conducts only ad hoc testing to provide some answers, but the mandate for such work is diminishing and results are not comprehensive.
4. Nozzle manufacturers receive little guidance from the crop protection industry on desired features of new nozzles.

The ECW Low-Drift Nozzle Initiative

In an effort to overcome some of these issues for air-induced low-drift nozzles, members of ECW voluntarily participated in the low-drift nozzle initiative between 1998 and 2000. Participants used a common protocol that compared the performance of three nozzles in field trials. Results were compiled and summarized for a large number of herbicide products over a three year period. Results from this study have allowed a rapid initial assessment of the suitability and limitations low-drift technology for weed control. However, such an effort cannot realistically be repeated for all new spray technologies.

The Panel

How should new spray technologies be incorporated into agricultural practice? To discuss this issue, a panel comprised of representatives from the crop protection industry, nozzle manufacturing, government research, and custom application was invited to represent their respective viewpoints. The following is a transcript of the panel discussion:

Welcome and Introduction

Tom Wolf
Agriculture & Agri-Food Canada / Pest Management Regulatory Agency, Saskatoon, SK

Welcome to the Application Technology Working Group. This morning we have organized a panel discussion on how best to introduce new application technologies to the marketplace. This will act as a wrap-up of our Low-Drift Nozzle Initiative, which has been going for the past three years. Experts will speak to this issue from a range of viewpoints, but first some background:

The fundamental goals of a spray application are to apply a crop protection agent in accordance with the three E's of application:

- Efficient
- Effective
- Environmentally friendly

Not only should spray technology try to meet these goals, but governments often set lofty objectives for reduction of pesticide use or for pesticide occurrence in the environment. Application Technology is seen a s a pivotal part of these objectives.

To that end, manufacturers of spray equipment regularly introduce new spray technologies that address these issues. We see air assist, electrostatics, pulse width modulation, air-induction, rotary, or pre-orifice technologies, to name a few, in the marketplace. All these technologies were developed to try to meet the 3 Es of application that I mentioned earlier.

But in reality, we see very little displacement of the standard flat fn nozzle in practice. We see no institutional support for the reduction of pesticide rates based on application method. We see no environmental credit give for highly effective low-drift sprays. Why?

Some obvious answers are that in an effort to met some of the 3 Es, others are sacrificed, reducing the overall general utility of the technology. We might see good rate-reducing technology that drifts more, or low-drift sprays that reduce product efficacy. But a more fundamental problem is that we have no framework for the introduction of new spray technology in Canada. This means that a new spray technology can be introduced without any accompanying data to identify its performance characteristics, and an interested applicator assumes all risk during implementation. As a result, many very useful technologies never establish a commercial presence.

To try to address this shortcoming, we have invited a panel to offer their views. We have asked each panelist to summarize the issues as they see them, while attempting to address five similar questions:

- How appropriate are current mechanisms for introducing new sprayer technologies in the marketplace?
- Should a minimum set of efficacy data be required prior to the marketing of new technologies? If not, how should applicators be assured that product efficacy will be satisfactory?
- If there is a performance issue that involves a new spray technology, who is liable?
- Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?
- Should modern spray technologies be mentioned on product labels? If so, what should the data requirements be?

Panelists:

Representing Government Research is Brian Storozynsky of the Agricltural Technology Centre in Lethbridge, Alberta. Brian has been active in the study of spray technology over the past 20 years, studying mechanical aspects of sprayer, spray drift in wind tunnels, and conducting field trials.

Representing the Agrichemical Industry is Lyle Drew. Lyle has worked with Cyanamid/BASF since 1982 in technical service and R&D field scientist positions in Saskatchewan. Within the company, he has been the company's application technology champion. Lyle is now a field biologist with BASF in Regina, and is the chairman of the Crop Protection Industry, Saskatchewan Council.

Representing Custom Application is Dale Fedoruk. Dale is Manager for Agronomic Products and Services with Agricore in Calgary, Alberta, and still retains a strong association with farming through his family farm. With Agricore, Dale is responsible for monitoring farming and custom application trends, and analyzing and reviewing new technologies dealing with farming. Dale assesses the potential of these systems being adapted into Agricore's business.

Representing sprayer manufacturing is Mike Shewchuk, President and CEO of Spectrum Electrostatic Sprayers Canada in Calgary, Alberta. Mike is a licensed applicator, and has been with Spectrum Electrostatic Sprayers for 7 years. His company makes sprayers for the orchard, field, and aerial markets.

Representing spray equipment suppliers is Ralph Walker of Applitech Canada in Port Hope, Ontario. Ralph has had a career in application technology, and brings with him vast national and international experience, primarily with John Brooks Company, but also with FMC Corporation and Sotera Systems. As Managing Director of Applitech Canada, Ralph now represents a number of sprayer component manufacturers across the country.

Representing nozzle manufacturing and consulting is Gary Moffat of Specialized Spray Systems and Moffat Consulting in Lethbridge, Alberta. Gary has extensive experience in the crop protection industry with Oliver, Wilbur-Ellis, and Bayer. For 15 years, Gary managed spray pattern testing for the Canadian Aerial Applicators, and now does this on a consulting basis for aerial and ground equipment. His company also sells spray equipment, including the Air Bubble Jet Nozzle.

A written submission was prepared by Wilf Wilger and Mark Bartel of Wilger Industries in Saskatoon, SK. Both Wilf and Mark have significant experience in the spray business in Canada and the US, manufacturing nozzles, sprayers, and sprayer tanks. Currently, Wilger Industries manufactures a number of sprayer components, including the ComboJet ER nozzle and the new ComboJet DR low-drift nozzle. I will read this presentation to the group after the other panelists' comments.

Government Research Viewpoint

Brian Storozynsky
Agricultural Technology Centre, Lethbridge, AB

I have been attending ECW conferences for the past 12 years, and have not made myself well known to the members but I am very interested in ECW's success. It gives our company a good forum on what industry and government are doing in pest management. I chose to be a panelist, today, to share my views on application technology research and give ECW members an idea on who we are and what we do.

Just a brief background on our company, we are part of Alberta Agriculture's Engineering Services Branch. For the past 12 years, and up until July of this year we were known as the Alberta Farm Machinery Research Centre (AFMRC). For the first 12 to 13 years we were know as PAMI, the Prairie Agricultural Machinery Institute, which was formed in 1975. PAMI was resurrected from a 1950's establishment named the Agricultural Machinery Administration that was based at the University of Saskatchewan. So farm machinery research, development and evaluation has been going on for nearly 50 years in the prairies.

At its peak, PAMI had 3 stations. Each station was assigned specific machines to test. At Humbolt SK, combines, haying and grain processing equipment were tested. In Portage La Prairie, MB, they tested forage and potato equipment. In our Lethbridge station we were responsible for testing sprayers, air seeders and later tractors. We tested every make & model of machine knowing to man. or at least it seemed. At its peak we had 25,000 farmers subscribing to our reports. We published 25 to 50 machinery reports a year.

With time, things change. Governments changed. We changed. The demand for certain machinery information declined with governments' value added and global strategies. Our mandate of providing technological information has not changed, how we go about it has.

Environmental sustainability and resource stewardship are key to many applied research and development projects conducted at the Centre.
So, why are we still working with sprayers? We just simply have not been able to get out of it, no matter how hard we tried. From years of testing we gained a lot of experience and became specialists on specific machines, I with sprayers. Later, there was demand from producers and industry for this expertise.

Producer demand for sprayer information has increased steadily the past 15 years. Most frequently asked questions at the Centre are about sprayers, which outnumber combine, air seeder and tractor questions by 5 to I.

Just in the past 4 years, I have given presentations to nearly 10,000 producers. Recent talks have solely been on nozzles, especially air induction nozzles. Just prior to each spraying season, I normally receive around 400 calls, requesting specific spraying information. In 1997 & 1998, which I call the "venturi years", I received over 1500 calls and the demand for speaking at workshops, seminars, conferences was overwhelming.

From these numbers, I was hoping you would see that there is a tremendous demand for spraying research and information. How we go about generating spraying information in the future is a different story. It is getting harder, due to lack of support and commitment from within our company as well as industry. Like Tom, it seems we kind of sneak this research in on the side.

I was glad when the ECW application technology group formed and initiated herbicide efficacy studies with the induction nozzles. This took a load of our backs, or I should say my back. We are small, with a staff of 15 permanent employees. In spraying there is myself and a summer student or two, if I'm lucky. But we have been successful in generating information that producers use immediately.

1. **How appropriate are current mechanisms for introducing new sprayer technologies in the marketplace?**

New spray technologies are introduced to producers very quickly without much data because of the stiff competition. Also, most chemicals' robust rate structure allow most new spraying technologies to work, even the poor ones. Because of this we have only seen a few mishaps in the past 25 years.

2. **Should a minimum set of efficacy data be required prior to the marketing of new technologies? If not, how should applicators be assured that product efficacy will be satisfactory?**

I do believe if a new sprayer technology falls outside the conventional window, that some efficacy or standards criteria be used prior to marketing the product. Air assist sprayers, automatic rate controllers, extended range nozzles, shrouded sprayers, high clearance sprayers and now some air induction nozzles all had problems in their beginnings. But how many of you here are even aware of what those problems were?

Many of these problems could have been avoided if standards were in place, but I believe too many standards in the long run slow industry progress and development. If it is not an environmental or human health issue, government intervention should be minimal. So far government has been reactive to most new technology performance issues. The closest we came to being proactive was with the venturi nozzles.

3. If there is a performance issue that involves a new spray technology, who is liable?

I would like to see performance issues be the responsibility of the firms introducing the technology. They know what the chemical product requirements are. They have a few avenues available to them to assure their technology is reliable. However, added cost and competition usually prevent firms from using those avenues, especially the new and smaller firms.

4. Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?

I do not believe there should be a mandated criteria for new technologies for carrier volume, travel speed etc. For spray drift yes, since it an environmental issue. Again, my reason centres around restricted progress and development.

5. Should modern spray technologies be mentioned on product labels? If so, what should the data requirements be?

I would like to see chemical companies take interest and use the new technologies with their products. Again, there are avenues out there that can help with this process and a group like ECW's Application Technology Working Group can help establish some of the infrastructure or protocols.

Something will definitely have to be established if rates are restructured or reduced in the future, because instead of mishaps there could be disasters.

Chemical Industry Viewpoint

Lyle Drew
BASF Agricultural Products, Regina, SK

1. Evolution of New Spray Technology

Over the years we have seen an evolution in new spray technology entering the marketplace. Previously, improvements were largely related to design, capacity and ease of use - variations of the flat fan nozzle (i.e. brass to stainless steel, color-coded tips, quick exchange of nozzles, multiple nozzle bodies, etc.). Today, introductions of new spray technology has focused more on application characteristics (i.e. drift reduction, droplet size control, etc.). The introduction of Turbo TeeJet and venturi-type air induction nozzles have made dramatic improvements in terms of reducing drift, but has it affected product efficacy?

2. Introduction Mechanisms

While it is clear that manufacturers of crop protection products research their products well (i.e. strict crop tolerance/efficacy PMRA registration guidelines), new sprayer technologies are introduced to the marketplace largely untested. Data requirements to register unique application methods are not clearly established.

3. Industry Concerns

Crop protection products may be applied in a manner that was not tested during registration process. This has led to several key concerns from industry. Firstly, unsubstantiated efficacy claims have surfaced. New spray technology is often promoted on the basis of 'cut rate' technology. Products may be sold with only farmer testimonial data. This leaves applicators to implement new products at their own initiative and risk. Product inquiries often leave little basis on which to make a service decision (liability?). The crop protection industry is not resourced to test the impact of the increasing number of sprayer modifications entering the marketplace.

4. New vs. Old Spray Technology

New crop protection product labels are largely developed with 'old' technology (i.e. flat fan nozzles, 5-10 gal./acre water volume, 40 PSI). This is because there are limited nozzle choices for small plot research trials (i.e. 8001). Field Research Permit data that is applied with larger field scale equipment is not readily accepted by the PMRA on its own for registration purposes. The ultimate concern from industry is that having to divert resources to testing new spray technology with crop protection products could slow down the registration process – this would be unacceptable to the industry.

5. Industry Suggestions

Suggestions to improve the process would be to place more onus on the equipment manufacturers to supply data to substantiate their claims. These should supply comprehensive testing (more than ad hoc herbicide group testing) with a minimum number of trials (compared to conventional nozzle efficacy). Having a standardized design and data criteria requirements would introduce a level playing field that would facilitate inter-product comparisons (i.e. what works best for a particular pesticide product and under what conditions?). Industry is willing to work with equipment manufacturers to integrate data onto product labels (i.e. co-operative stewardship), not unlike the current minor use program that currently exists.

Custom Applicator Viewpoint

Dale Fedoruk
Manager, Agronomic Products and Services, Agricore, Calgary, AB

Agricore in Western Canada:

We have 140 agro retail outlets and about 220 Certified Crop Advisors (CCA's). We employ about 75 summer field scouts, and currently operate approximately 100 High Clearance Sprayers for application of crop protection products on approximately 2.25 million acres.

Agricore's Objective

- Provide the best Agronomic support & selection of crop protection products to our producers.
- Provide professional & accurate custom application services. With concise application records.
- Become proactive within the scope of our business.
- Ensure that all the operating staff have completed a comprehensive education program.
- Promote environmental stewardship.
- Operate within the guidelines of all pesticide regulations
- Offer application services using new technologies.
- Lastly...kill weeds in the most effective manner!

1. How appropriate are current mechanisms for introducing new sprayer technologies in the marketplace?

The majority of the new technologies are manufacturer and marketing driven. The mechanisms are marginal depending on product positioning. Applicators are reliant on third party testing and in-field testimonials. This is very subjective.

2. Should a minimum set of efficacy data be required prior to the marketing of new technologies?

No. The technology manufactures should be responsible for providing technical information regarding their product.(e.g. droplet size, capacity/flow rates, pressure effects, carriers, % driftable droplets, wind effects, etc.)

If not, how should applicators be assured that product efficacy will be satisfactory?

Always operate within the guidelines of the product label. If there are any concerns, we need to refer back to the pesticide manufacturers.

3. If there is a performance issue that involves a new spray technology, who is liable?

Typically, the applicator is held responsible. Ironically, the technology manufacturers contradict themselves by always stating to follow the label guidelines. If this were true, you would expect the industry to use nothing but flat fan technology!

4. Should there be mandated criteria for new sprayers for carrier volumes, travel speeds or spray drift?

In order to operate responsibly and mitigate liability, the applicators must be able to operate within the label guidelines and the new technology specifications. Therefore, criteria for new technology must overlap with product labels and vice versa.

5. Should modern spray technologies be mentioned on product labels?

Yes, the industry is aware of spray technology other than flat fan nozzles. The pesticide manufacturers need to provide the information on which technologies provide the optimum performance for their products.

If so, what should the data requirements be?

More testing should be done on a field scale level, versus plot testing, to receive registration status.

Sprayer Manufacturer's Viewpoint

Mike Shewchuk
President, Spectrum Electrostatic Sprayers Canada, Calgary, AB

A massive global effort is underway to research and develop methods and products that can assist agriculture in becoming more efficient, environmentally friendly and economically viable. Public concerns have forced farmers and governments worldwide to tackle the issues of pesticide reduction, off target drift, overuse, and pest or weed resurgence.

Research continues to show that current procedures for labeling pesticide application rates are outdated and need to be revised. Researchers in the USA and Canada are reporting that in many cases pesticide label rates are too high.

When research on new and conventional spray systems yield consistent benefits toward reduction of pesticides, government should co-ordinate the establishment of minimum and maximum label rates. At present there are no effective mechanisms for introducing reduction technologies into the pesticide application equipment market.

The farmer relies on his local government and university research facilities to define which technologies are suitable for his operation. Unfortunately, there is a lack of much needed funding for the researchers to carry out the proper research projects. Researchers cannot perform full factorial efficacy and drift studies on every chemical, in every crop, under all environmental conditions whenever a new application technology comes along.

Even if the funds were available, there are simply too many variables to consider a project of such monumental size. Yet, there is an obvious need for more research to establish accurate label rates.

Researchers agree there is a lot of room for improvement in the pesticide development and application technology sectors.

Application technology has taken on a new definition of efficiency. Many new types of delivery systems offer advantages to the farmer looking to reduce his fuel emissions, volume of chemical and/or water applied per acre and ultimately his bottom line.

On many occasions farmers I have spoken to have noted their enthusiasm for improved application technology. However, many impediments stand in their way of utilizing beneficial reduction technologies to apply their pesticides.

These include:

- Regulations that insist on “the label is the law”, and the lack of label rates for new technologies, both make it illegal for a farmer to deviate from the label even when the technology can improve their efficiency and reduce the associated environmental impact of their spraying activities.
- The lack of proper research by credible government researchers. Most producers rely on these research institutions for evaluation of any new technology before they invest.
- The fact that there are no “Eco-label” or other incentives for the farmer wishing to purchase a more environmentally friendly method of application.

When all of these points are considered it becomes obvious that changes need to be made to the way pesticides are researched, registered for use, and labeled.

If these expectations are placed on any one of the parties to this matter, accurate label rates will never transpire. And the farmer will have no choice but to continue applying pesticides at higher volumes.

Simply put the equipment manufacturers neither have the resources or the authority to implement the needed changes. The farmer has no choice but to follow the label. The chemical company is also very unlikely to fund research that would potentially affect their profits. As well, the chemical company has no incentive or requirement to provide data on how their products perform using volume reducing technologies.

The biggest problem with reduction of pesticides is that although almost all the parties concerned as well as the public are talking about it, very few individuals or organizations are actually doing something credible towards a solution. Yet they all know chemical rates can be cut and chemical companies realize farmers do cut rates, from time to time.

If the government is truly interested in promoting sustainable agriculture and the environment, minimum data sets need to be established for all systems. There is also the issue of social responsibility over our food supply. Who is responsible for the safety of our food supply? At times it seems that everybody but government is moving forward, producers are looking at "good agricultural practices" which include "good spray quality". The retailers are demanding "trace-ability"; we already see this with "Star Link" corn and the recall of taco shells in the USA.

There is a bigger picture here. Two hundred million acres a year are sprayed by aircraft each year in the United States. A custom applicator using a Spectrum Aerial Electrostatic System is now cutting his out-billing cost to spray each acre by a minimum of one dollar. That equates to minimum potential savings to farmers of $200 million dollars. Simply by allowing the use of a more efficient spraying technique. This is money that normally would flow out of agriculture into the petroleum sector, to cover higher fuel and chemical expenses, at the currently recommended high water and chemical volumes per acre.

This is the same logic that prompted the California Energy Commission to offer low interest loans to farmers who purchase electrostatic sprayers, based on the fuel and emissions savings alone. i.e.: more energy efficient pesticide application methods.

1. **How appropriate are current mechanisms for introducing new sprayer technologies in the Canadian marketplace?**

For the most part they are non-existent.

2. **Should a minimum set of efficacy data be required prior to the marketing of new technologies?**

Minimum data sets need to be established for all systems. Data sets should include the following variables, efficacy, required liters of water and chemical per acre, and drift potential.

3. **If there is a performance issue that involves a new spray technology, who is liable?**

If the system has been evaluated, label rates established, and the farmer follows the directions, then liability should rest with the chemical company or the manufacturer of the equipment. Establishing maximum and minimum label rates for all technologies would abate these issues, leaving the farmer to adjust as necessary for adverse spraying conditions.

4. **Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?**

Yes, but the same should hold true for all spray systems.

5. **Should modern spray technologies be mentioned on product labels? If so, what should the data requirements be?**

YES minimum and maximum label rates, efficacy, and drift potential, again this should apply to all systems.

Impediments on new technologies need to be removed.

Spray Equipment Supplier Viewpoint

Ralph Walker
Managing Director, Applitech Canada, Port Hope, ON

1. **How appropriate are current mechanisms for introducing new sprayer technologies in the marketplace?**

My first thought was "what current mechanism?". Is it because Canada has had other major issues to legislate or that government, life sciences and supporting industries have cooperated over the last half century of vegetation control in Canada? The nozzle industry has had full benefit of advanced technology in industrial applications where target coverage can be very precise. Electrostatic, air assist, air atomizing, and air-induced technology were first introduced to many industrial applications. It is likely that future generations of agricultural nozzles are already on the shelf waiting for other applications in crop care. Is it appropriate that a company located anywhere in the world could make a cheap copy of a nozzle, post it on the internet, and sell the finished product direct to farmers here, and not break any laws in doing so?

2. **Should a minimum set of efficacy data be required prior to the marketing of new technologies? If not, how should applicators be assured that product efficacy will be satisfactory?**

While we don't need more regulations, we do need more formal procedures and guidelines, particularly for foreign product coming to Canada through distribution channels. It seem reasonable that any company creating an application device should first have to provide certain data specific to pattern quality, VMDs, etc. Currently, nozzle manufacturers test their nozzles with water at 70 ºF. It is not appropriate for them to test every chemical field mix to determine pattern integrity. Even the facilities in Lethbridge and Saskatoon and Ridgetown cannot conduct a full field evaluation and generate efficacy data without the full financial support of life science companies. The applicator does have to rely on life science companies for product efficacy, keeping in mind that there are more variables at time of application that rely solely on the applicators' experienced judgement.

3. **If there is a performance issue that involves a new spray technology, who is liable?**

If it is a sprayer component, it would be covered under a warranty. Such a warranty would cover workmanship and material defects for a given period of time. It is interesting that Hypro pump warranties are for one year, even though during that time more than 30,000 acres of spraying can be done. Most sprayer related performance issue are resolved to the satisfaction of the equipment owner/operator.

4. Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?

The sprayer industry is consolidating to the point that the large tractor/implement manufacturers now build a very high percentage of the sprayers used in North America. Their equipment is used to apply more than 60% of chemical acres sprayed every year. These companies will have a positive influence on other sprayer manufacturers in the overall efficiency of sprayers. As this consolidation continues, nozzle manufacturers will also become active in advancing application technology.

5. Should modern spray technologies be mentioned on product labels? If so, what should the data requirements be?

This begs two further questions: Is there room? Would the operator read it? There is an abundance of technical and practical information available from nozzle manufacturers. This same information is now available electronically from most sprayer component manufacturers. In Europe, there is a nozzle code and a spray quality classification. The British Crop Protection Council (BCPC) uses the following: nozzle type, spray angle, tip output, rated pressure. Spray classification provides the following detailed information: spray quality, typical droplet size, and drift potential. While these are too lengthy for a label, they could be produced in a standardized mini-booklet form for inclusion with the chemical.

Looking back over the past 25 years, application technology has made significant changes. The sprayer of the 70s was a $1,000 to $1,500 retail machine:

- Brass tips and nozzle bodies, non-aligning
- Felt filters
- Galvanized tanks
- Outside cab manual boom controls
- Pressure drops of 15 psi
- Self propelled sprayers used floodjet tips on 60” centres
- Agitation was an option

Perhaps in the next five years, application equipment will change just as much again.

Consultant's Viewpoint

Gary Moffat
Specialized Spray Systems, Lethbridge, AB

My testing is done in the field in conditions that are not always ideal but often as the farmer may be faced with. We try to use products that simulate actual pesticides and then compare and analyze nozzles, rates, patterns and coverage. Our goal is to direct the highest amount of product to the target in the most economical way.

1. How appropriate are current mechanisms for introducing new sprayer technologies in the marketplace?

The new technologies are an addition to current practices. Most often we try incorporate these new technologies with outdated methods. Our mechanisms are government agencies that are not up on advancements in technology and have not had the equipment to quickly test and analyze in the field.

2. Should a minimum set of efficacy data be required prior to the marketing of new technologies? If not, how should applicators be assured that product efficacy will be satisfactory?

Efficacy is one of the main goals of the producer. The chemical manufacturer has already done extensive efficacy trials. We must be able to introduce new technologies by analyzing the testing of the new technology compared to the testing by the manufacturer, then moving the new technology to the producer quicker. It is not necessary to reinvent the wheel with three years or more of efficacy testing to outdated standards every time a new technology is introduced. Common sense analyzing will assure the applicators that product efficacy is satisfactory .

3. If there is a performance issue that involves a new spray technology, who is liable?

Who is liable? I personally have consulted on Performance issues. It has been my experience that everything has to be analyzed - field, fertilizer, seed, applications, pesticide, weather. Only then can some type of liability be assessed.

4. Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?

Carrier Volumes, Travel Speeds or Spray Drift! ! ! Industry has driven the spray manufacture to build sprayers to meet the market but seldom reaching into new technology. There is very little communication between sprayer manufacturers, chemical manufacturers, nozzle manufacturers and regulatory agencies. Everything comes after the fact! Sprayers have advanced rapidly - criteria should be to deliver a spray pattern that is evenly dispensed across its boom width without turbulence caused by the sprayer itself. Today's and the future's new nozzle technology will help reduce drift and set carrier volumes. There is a need to communicate more better!

5. **Should modern spray technologies be mentioned on product labels? If so, what should the data requirements be?**

Product labels today cannot keep up to new technology .New product labels must change -stating required droplet sizes / spectrums and spray quality.

Nozzle Manufacturer's Viewpoint

Wilf Wilger and Mark Bartel
Wilger Industries, Saskatoon, SK

From face to face discussions with thousands of applicators, both commercial & farmer, ground & aerial, the results, efficacy, drift. etc., achieved with any application tool and chemical vary from applicator to applicator. What works well for one applicator may not work as well for another applicator (at least in the opinion of each applicator). The results achieved by any applicator may not be consistent with the results achieved in research.

Many applicators tend to look at research as being done under ideal conditions which may or may not apply to their "real world". However most applicators do consider results achieved in research because it does provide significant benchmarks to compare new products to what they have tried or are using.

1. **How appropriate are current mechanisms for introducing new sprayer technologies into marketplace?**

Current mechanisms for introducing new sprayer technologies vary and do not seem to be clear. Speaking as a nozzle manufacturer, everyone has an equal opportunity to promote their new nozzles through advertising etc. depending on the resources available. However, lesser known manufacturers or inventors may not have the knowledge, resources, or contacts to have their new products tested or reviewed.

Timing can also be a factor. For instance, a significant amount of research was done on spray nozzles by the Spray Drift Task Force in the mid 90's. This work is widely published, used and referred to and could well be used to write laws or label recommendations. New developments in nozzles since this research are not included in the reports and can be overlooked if the SDTF data is the only source used.

The present mechanisms include nozzle manufactures or even individuals with creative, inventing skills and the resources to see the product through to market. Although there is a risk to the user (and possibly the environment) that some new nozzle technologies introduced and promoted do not prove to be very desirable, we feel that it would be wrong to put strict controls on the industry and thus to stifle creativity and research. Any additional efforts by other organizations such as chemical companies, and government, university, or other. research institutions to create new technologies would certainly be helpful. Probably, greater cooperation between these organizations and manufacturers would be very useful and we as manufacturers would welcome it.

2. **Should a minimum set of efficacy data be required prior to the marketing of the new technologies?**

It would be difficult to establish the minimum set of efficacy data. The data on relative efficacy comparisons between products is very useful. It would be difficult if not impossible to have data for all conditions that applicators face. As an example, applicators may have to use drift reduction nozzles to spray in more windy conditions and should be aware that efficacy could be reduced. The timing of the application can be more critical than the potential for reduced efficacy.

We feel that basic efficacy measurement methods should be established and the nozzle manufacturers and the users should be made aware of them. Whether efficacy criteria should be mandatory or voluntary depends on the reliability of the measurement methods, costs to put new technology through the tests, the suitability of the tests to new technology, intended use of the technology, etc. In general, it should not be a major deterrent to new technology creation and introduction.

If not, how should applicators be assured that product efficacy will be satisfactory?

Pest control is not an exact science. While all of the players need to do their utmost within their resources to try to achieve satisfactory results, that fact must be acknowledged and users must recognize that there is risk. However, available test results relating droplet size, efficacy and drift, for example, could be useful in decision making on the use of new technology.

3. **If there is a performance issue that involves a new spray technology, who is liable?**

The results achieved by different applicators or even the same applicator using the same equipment, chemicals, and techniques can vary. The choice of technology for their application is the responsibility of the user. Each user should test new technology to determine suitability for their needs. Given the large number of variables, it would ultimately benefit no one except the legal profession if claims were made to have absolute answers as to what is good and what is unacceptable in spray technology.

4. **Should there be mandated criteria for new sprayers for carrier volumes, travel speeds, or spray drift?**

Mandated design criteria would be difficult. Users select equipment for the particular crops or applications. Some of the equipment is designed to suit the specific crops and may not be suitable for other applications. Sprayer designs are constantly changing for steadily increasing application speeds for user economics. It seems that the maximum has been reached but not too many years ago we also thought 6 MPH was the highest application speed that would ever be needed.

Of this list, only spray drift should possibly be mandated as it effects individuals other than the operators, as well is the environment. In the other areas, researched guidelines and corresponding recommendations are sufficient.

5. Should modern spray technologies be mentioned on the product labels? If so, what should be data requirements be?

It is important that the labels or laws not use nomenclature or brand names that are specific to a given nozzle manufacturer. As an example, if a label or law called for a DR8002 nozzle instead of a drift reduction nozzle, users may feel compelled to use only the DR8002 to protect themselves. This would be great for Wilger but a disaster for competitors.

Nozzle manufacturers should give a relative range of droplet sizes, i.e., Fine, Medium, Coarse, etc. rather than specific droplet sizes. The results of droplet size studies vary from machine to machine and even among operators on the same machine.

More flexible labels could allow applications in less than ideal environmental conditions. As stated earlier, the timing of an application at a given stage in a crops development is critical. Under windy conditions, applicators may then choose to use nozzles producing larger droplets, fully aware that efficacy might be lower than using the recommended application technology under ideal conditions. But in this case, lower is preferred to none. It would be difficult to include all of the possible conditions on the label.

Working Group Report – Biological Control

Submitted by Gary Peng
Agriculture and Agri-Food Canada, Saskatoon, SK

The spatial dynamics of *aphthona* flea beetle impact on leafy spurge: a landscape perspective

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Successful biocontrol of leafy spurge (*Euphorbia esula* L.) requires that agents become distributed over the landscapes upon which they are released. 'Manual' redistribution of agents often is economically and/or physically impractical, thus assessment of the abilities of biocontrol agents to disperse from initial release sites, colonize isolated patches and reduce weed densities on those colonized patches are important weed biocontrol issues. In 1999 and 2000, we monitored the spatio-temporal changes in 2 biocontrol agents and leafy spurge densities over a 2 x 2 km landscape consisting of 260 spurge patches. *Aphthona lacertosa* was released at a single point on this landscape in 1997, while a second species – *A. nigriscutis* – dispersed into the area from releases conducted prior to 1997. Linear regression and kriged maps of changes in spurge and beetle densities indicate that *A. lacertosa* had significant impact on leafy spurge density within 400 m of its 1997 release site whereas *A. nigriscutis* had little or no impact on spurge density. Densities of both beetle species increased from 1999 to 2000. A*phthona lacertosa* densities, in both years, were highest within 400 m of its 1997 release site but its distribution in 2000 had expanded by an additional 200 m from the release site. *A. nigriscutis* densities increased substantially from 1999 to 2000 throughout much of the landscape but in general where lower than *A. lacertosa*. We expect that *A. nigriscutis* will have significant impact on spurge densities in subsequent years. Many studies of the impact of weed biocontrol agents focus only on changes in weed density at initial release sites. However, biocontrol agents disperse from initial release sites and interact with their target weed at broader spatial scales than that of the initial release site. Consideration of multiple spatial scales, the release patch and the landscapes surrounding those patches, will improve our understanding of causes of biocontrol successes or failures.

Potential applications of molecular tools for biological control

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Inundative biological control artificially shifts the ecological balance of the system in favor of the pathogen by either introducing new strains, increasing the concentration of an indigenous strain, or by increasing the virulence of a strain. When a microorganism is released into a target area, it may be difficult to differentiate or even re-isolate the biocontrol strain from similar ones in the environment. Procedures are needed to quantify specific strains of microorganisms for the risk assessment process.

Traditional methods for quantifying microorganisms from soils, plant tissues, residues, and water include direct counting of propagules, such as sclerotial bodies that may be sieved from soil or retrieved from plant stems. Dilution plating and the concurrent use of semi-selective media are widely used and are relatively inexpensive. For example, the addition of the fungicide benomyl to media inhibits the growth of Ascomycetes but not Oomycetes. However, the dilution plating method cannot distinguish between closely related species or strains, pathogenic vs nonpathogenic types. It also overestimates the number of fast growing fungi. Baiting techniques, where living plant substrates are reinfected with the pathogen, are very sensitive to finding pathogenic strains and simplify re-isolation, but are very labor and space intensive. Immunological tests using monoclonal antibodies are highly specific, but expensive to develop. Mutation has been used to create marked strains (i.e. antibiotic resistance) or select for genetic markers (i.e. inability to use a substrate or enzyme; color change), but often the microorganisms have reduced fitness levels since more than one gene is affected by the mutation process.

Molecular tools can be used to insert marker or reporter genes into microorganisms. The insertion of these specific genes with molecular tools means that only the gene of interest is inserted leaving the rest of the genome unaltered. Examples of these markers include B-glucuronidase (GUS), antibiotic resistance (hygromycin B phosphotransferase), green fluorescent protein (GFP), lac Z enzyme to cleave lactose to simple sugars by bacteria, and lux genes for expressing bioluminescence in bacteria. PCR (polymerase chain reaction) methods may be used to develop probes for sequences of DNA that are of specific interest or sequences of unknown function. RNA or DNA hybridization allows for radioactively labeled probes to detect the presence or absence of the probe in unknown samples placed on a membrane. The advantages of these molecular tools are the specificity and the sensitivity of the detection. PCR may detect quantities as low as 10^2 - 10^4 cells/ml quickly and easily. The disadvantages are the need to have specialized equipment and trained personnel. These tools are best used for determining presence vs absence of the strain and may need to be combined with dilution plating for quantifying population numbers.

The best use of molecular tools in biological control will be for the enhancement of control and for monitoring related to environmental assessment. The transformation of microorganisms with genes providing tolerance to herbicides will enhance weed control by allowing the microbes to work in the presence of the chemicals which could be inhibitory to spore germination and possibly to allow the pathogens to work with the chemicals in a synergistic manner (ie. greater disease severity by pathogen when applied with glyphosate which inhibits phytoalexin production by plants). The virulence of the pathogen may be improved by incorporating genes that govern enzyme production for penetration or genes that increase the microbe's ability to produce a phytotoxin. Biocontrol agents may be contained or limited to target areas with genes that change their reproductive capacity (i.e. non-sclerotial forming isolates) or capacity for growth (i.e. nutritonal auxotrophy). Pathogen marking will allow for the positive identification and re-isolation of specific biocontrol strains, assess its growth, dispersion, distribution, survival and persistence in a natural environment with other indigenous flora and fauna present. It will also permit the assessment of potential gene transfer among closely related organisms.

To date, there are few examples of the release of transgenic microorganisms in small-scale field testing. Kluepfel et al. (1991. Phytopathology 81: 348-352) released a marked strain of a root colonizing bacteria to compare the marked and wild strains in the field for movement, persistence, root colonization, and transfer of genes to other organisms. They concluded that except for the traits that had been purposely incorporated, the wild type and the transgenic strains were identical. Both colonized wheat roots in the first two weeks after application and then the populations declined to barely detectable levels after 31 weeks. There was limited lateral dissemination from point of application (up to 18 cm) and vertical dissemination was limited to 30 cm deep. There was no genetic transfer observed between the two strains for up to 31 weeks. In 2000, the EPA website (www.epa.gov/pesticides/biopesticides/) listed a notification of a small-scale field trial for the release of a transgenic strain of *Metarhizium anisopliae* for control of cabbage looper. Results of this trial have not yet been posted.

Given our limited state of knowledge on microbial dynamics and the impact of releasing inundative biocontrol agents, we need to develop methods to be able to conduct risk assessments and make decisions with a high degree of confidence. Molecular tools may provide a unique way to help broaden our level of understanding. Presently there is very limited experience with the release of inundative biocontrol agents and even less with transgenic microorganisms. We need to focus on building a database on microbial ecology of both native and transgenic strains to gather the data required to make risk assessment decisions with confidence.

Utility of soil bacteria for biological control of grass weeds: field testing and monitoring

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The quest for biological weed control agents worldwide has become more prevalent over that last couple of decades. Often, one of the major challenges from initial discovery to proof of concept is the practical implementation of these agents in the field. However, effective delivery systems, particularly in relation to the availability of suitable formulations is considered to be the crucial difference between an agent remaining in the laboratory and reaching the farmer as a commercial weed control product. In addition, while considering field performance of the biocontrol agent, the environmental risk of applying the organism into the field must be carefully scrutinized as part of the registration process. This is often conducted by monitoring the introduction of the microbial agent under field conditions.

At the Saskatoon Research Centre, several bacterial strains have shown tremendous promise as pre-emergent biological control agents of wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*). Field trials were set up at two locations (Saskatoon and Scott, Saskatchewan) to evaluate the field performance of the bacteria using two formulations (peat prill and pesta) with different rates of application. Weed emergence was monitored 4 and 8 weeks after application and aboveground biomass was assessed after 8 weeks. Using the peat prill formulation, weed emergence and biomass were reduced by up to 67% and 73%, respectively, depending on the bacterial strain. Using the pesta, weed emergence and biomass were reduced by up to 83%. Monitoring and detection of bacteria in the formulations was conducted using spontaneous rifampicin-resistant bacteria. Depending on the characteristics of the formulation, the bacteria were released into the soil during the course of the growing season, with the bacterial populations decreasing over a 4-month period. The pesta formulation acted as a quick-release formulation while the peat prills had slow-release characteristics. The following spring, no bacteria were detected in the soil. Two major disadvantages of using the rifampicin-resistant mutants is that it is not a highly sensitive technique and the desirable characteristics of the bacterial strain (i.e. weed suppressive properties) may be altered. Other techniques that may be more reliable and sensitive include PCR amplification to detect specific DNA probes, *lux* genes encoding for enzymes involved in bioluminescence and green fluorescent protein that allows visual inspection of fluorescence activity.

What are the limits of resolution for molecular markers used to track biocontrol fungi?

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The first line of control for many weeds is achieved through the use of chemical herbicides. While there have been many advances to reduce the amount of herbicide deployed, there is still considerable public opposition to the use of chemicals and a general call for development of alternatives. One such alternative is the deliberate use of one or more organisms to suppress the growth or reduce the population of another organism to a level where it is no longer an economic problem. This approach is termed biological control (Hawksworth *et al*., 1995; Templeton *et al*., 1979). There are many applications where a biological control could replace chemical herbicides but the question remains: Are biological controls indeed a safer alternative to the use of chemical herbicides? This question can be addressed by examination of the environmental impacts and environmental fate for any organism used as a biocontrol. Potential impacts can be reduced by careful selection of the organism chosen for development. Non-indigenous organisms would pose a greater risk to the environment as it is difficult to predict impacts on the local non-target species. With the importation of an exotic pathogen there is always the risk of artificially creating an epidemic as the normal environmental checks and balances would not be present. This strategy has been termed the “classical” biocontrol approach and requires extensive testing of potential impacts before any field release can be done. The preferred approach is the development of a native species that can be incorporated into an inundative control strategy. This involves the targeted release of a local isolate of a relatively weak pathogen. Efficacy of the weak pathogen is often enhanced by creating a favorable micro-environment for infection during deployment. Ideally isolates chosen for development should be genetically similar to local populations to reduce the risk of the introducing novel alleles into a local ecosystem. For the use of a single isolate across ecozones it should be established that there has been sufficient gene flow between the regions that the risk of introduction is minimized as there is a risk that rare virulence alleles may introgress into the local population of the pathogen. The first step therefore is to assess the extent of genetic variation within local and continental populations of the pathogen.

The development of molecular markers has been applied to population genetic studies for many fungi which have historically contributed to wide-spread epidemics but fewer studies have been done on potentially beneficial organisms. Selected molecular markers have been found to differ in their resolving power and it is best to consider a spectrum of markers having a range of genetic resolutions when the population structure is unknown. Genetic markers with a high degree of resolution enable us to track specific genetic individuals or their genes. It is possible to measure the impact of introducing a unique genotype into a local population by measuring the occurrence of specific markers within the local populations prior to any release and then monitoring changes in the frequency of these same markers following the introduction of a unique genotype. This is akin to taking a genetic snapshot of the population before and after release.

A relatively low-resolution marker is found in the ribosomal DNA (rDNA) repeat. Amplification of the non-transcribed spacer region of the rDNA followed by restriction pattern analysis can often reveal differences between populations. There is relatively low variation in this region hence this marker is useful for resolving populations at the continental scale (Ramsfield et al, 1996). The intergenic region is generally well conserved amongst members of the genus permitting genus-specific amplification of the intergenic region. This allows the quick identification of the released organism from a background of competing DNAs of other organism such as would be found in raw soil and organic samples (Becker et al, 1999). Randomly amplified polymorphic DNA (RAPD) markers are useful for screening differences between individual within a population. Amplification using a random-sequence oligonucleotide pair (i.e OPD-13 GGGGTGACGA) will usually result in the amplification of 5 to 7 bands ranging in size from two hundred to several thousand basepairs in length. The next step is to catalogue the presence of rare amplification products in the population and to compare the frequency occurrence of markers of the released isolate to the general population. This requires the collating of large data sets for meaningful interpretation. A more refined approach is to clone and sequence characterize the primary RAPD products and redesign a primer pair having a higher annealing temperature and hence a higher specificity to the target DNA. This type of primer pair (SCAR) usually amplifies a single band from the source DNA. If this band represents a band amplified from the released organism and rarely found in the local population it can be treated as a rare allele in a population genetic study to measure post-release impact. If by chance the primer pair recognizes a repetitive DNA element, the SCAR primers will simultaneously amplify many related yet distinct sequences (Becker et al, 1999). The resulting pattern allows genetic individuals to be fingerprinted by revealing similar repetitive elements throughout the genome. Each amplification product in such a fingerprint is informative and can be used to measure the relatedness of individuals by pair-wise comparisons and the construction of a hierarchy of relatedness between members of a population. All of these markers have corresponded to anonymous pieces of DNA and may not necessary correlate with specific traits. They are merely indicators of differences between isolates. The best indicator for risk assessment would be the occurrence of specific pathogenicity alleles within a population. This requires the cloning and sequence analysis of specific pathogenicity determinants. While this is possible for many biocontrol fungi the basis for pathogenicity is not always known and may result from the interaction of several alleles in combination. Certain indicator genes have been cloned and sequence analysis of both coding regions and promoter elements may reveal the molecular basis of what constitutes and effective pathogen.

Which level of resolution is the best to use? It depends entirely on the question being asked. Surveying all of these markers will give an indication of whether two populations have been reproductively isolated or whether there has been recent mixing of the genes. If it can be demonstrated that there is high similarity between populations occurring in spatially separated ecozones, the risk of deployment of an isolate from one population into the other would be decreased. Low restrictions on gene flow among isolates of the biocontrol organism across the continent would suggest that the risk involved in using one isolate across the country is also relatively low. It is therefore important to determine the population structure with a fairly high degree of resolution. For the development of any biocontrol t is important to evaluate population structure in relation to regional ecozones and to establish a standard for risk evaluation. In this way the biocontrol could be used to provide the greatest benefit against the targeted weed with the least risk to the environment.

Becker, E. M., Ball, L. A., Hintz, W. E. 1999. PCR-based genetic markers for infection frequency analysis of the biocontrol fungus *Chondrostereum purpureum* on Sitka alder and trembling aspen. Biological Control 15:71-80.

Ramsfield, T., Becker, E., Rathlef, S., Tang, Y., Vrain, T.C., Shamoun, S., and Hintz, W. 1996. Geographic variation of *Chondrostereum purpureum* detected by polymorphisms in the ribosomal DNA. Can. J. Bot. 74: 1919-1929

Potential of using microbes and microbial products for control of selected weeds

Wenming Zhang, Alberta Research Council, Vegreville AB T9C 1T4

Several projects have been initiated to evaluate the possibilities of utilizing microbes (fungi and bacteria) and microbial products for control of weeds and diseases. A fungal pathogen (CL98-103) has been identified to be able to kill cleavers (*Galium spurium* and *G. aparine*) with a supplement of 12-16 h dew. Host specificity test of CL98-103 on 41 plant species has demonstrated that CL98-103 is sufficiently safe as a biocontrol agent against cleavers. A fungal pathogen CW98-235 and a bacterium CW00B006C cause severe diseases on common chickweed (*Stellaria media*). Both the fungus and the bacterium are non-pathogenic to nine major crops including wheat, barley, oats, flax, safflower, field pea, lentil, and alfalfa. Further tests have shown that the bacterium did not attack any of five turfgrass species tested. Another pathogenic bacterium (16 C) causes severe diseases on Canada thistle (*Cirsium arvense*), annual sow thistle (*Sonchus asper* and *S. oleraceus*), and dandelion (*Taraxacum officinale*). Preliminary host range test demonstrated that this bacterium is non-pathogenic to nine major crops including wheat, barley, oats, flax, safflower, field pea, lentil, and alfalfa. Fractions of secondary metabolites from selected pathogenic fungi collected from diseased cleavers have also been isolated and evaluated for herbicidal and anti-fungal activities. It has demonstrated that one fraction possesses the ability to kill false cleavers seedlings with selectivity between false cleavers and canola. Some fractions also showed the potential for the control of diseases such as blackleg. Further study is needed to determine the commercialization potential of the biocontrol agents and their metabolites.

Working Group Report – Extension and Teaching

Submitted by Carol Bubar
Olds College, Olds, AB

November 29, 2000 – Banff, Alberta

The meeting began with two excellent presentations on diagnostic field schools. Dr. Linda Hall of AAFRD outlined her experiences with the school held annually in July at the Ellerslie Research Farm south of Edmonton. She also discussed her involvement instructing several field schools in Australia this past August. Dr. Rene Van Acker of the University of Manitoba gave an overview of the Manitoba school held both in Carmen in July and at the University for two days in March.

Provincial reports were given highlighting extension activities and publications over the past year. Noteworthy were the cuts and changes to extension personnel in Nova Scotia, New Brunswick, Ontario and British Columbia. On a more positive note, new weed publications were announced in both Quebec and Alberta.

Members had a brief discussion on how the extension and teaching group should operate. It was agreed that the chairmanship should be on a two year basis and that the position should rotate from east to west. Carol Bubar (Olds College) will continue as chair in 2001 and Leslie Huffman (OMAFRA) will take over for 2002-2003. The suggested agenda for the 2001 meeting in Quebec City is on minor use registrations for horticultural crops.

Daniel Cloutier inquired whether the group wished a chat room on the ECW-CEM website. A chat room will be established in the new year and members are encouraged to bring forth items for information and discussion, including any additional suggestions for the 2001 meeting agenda. In addition the weeds publication list, with appropriate links, should be up and running on the website within the next few months. Everyone is asked to review the list and make additions or deletions where appropriate to help make the information as accurate and current as possible for all ECW members.

Working Group Report – Herbicide Resistance

Submitted by François Tardif
University of Guelph, Guelph, ON

Chair: François Tardif, department of Plant Agriculture, University of Guelph
Co-chair: Todd Andrews, Manitoba Agriculture, Winnipeg.

Four speakers were on at this meeting. Attendance was high and participation from the audience was extensive. It seems that the interest in resistance is still high.

Hugh Martin
Ontario Ministry of Agriculture Food and Rural Affairs, Guelph, Ontario

Update on the resistance in the East. Resistance to ALS inhibitors in green and redroot pigweeds is still around in South Western Ontario but does not seem to cause much concerns. Few calls have been made to report new cases. Resistance to linuron and other photosystem II inhibitors has been confirmed in a population of green pigweed from Keswick, Ontario. This population was from a carrot filed with probably a long history of selection with linuron.

There have been reports of possible resistance in Eastern-black nightshade to imazethapyr and in common ragweed to chlorimuron-ethyl. Seed have been obtained and testing is to be conducted at the University of Guelph in the winter of 2001.

Scott Meers
Alberta Agriculture

Wheatland County Herbicide Resistance Project

For three years (1997 to 1999) the Agricultural Service Board in Wheatland County, and the Strathmore District Office of AAFRD have been carrying out a herbicide resistance survey. The purpose of this survey was to confirm local herbicide resistance and to educate farmers on the management and prevention of herbicide resistance. The survey included interviewing 100 farmers per year for 3 years regarding their cropping and herbicide rotation practices.

From the survey sheets, 30 high risk fields per year were sampled for resistance testing of Wild Oats. The testing identified resistant wild oats in significant percentage of fields tested. Resistance was found to Group 1, Group 2, and Group 8 herbicides.

In 2000 the original producers (1997) were surveyed again. The re-survey showed a heightened awareness of herbicide resistance, herbicide groups and herbicide rotation. It also showed that back to back use of group 1 and 2 herbicides had decreased in those producers but the level of Group 1 and Group 2 herbicide use had not fallen.

In the end it shows how hard it is to change herbicide use patterns unless there is a strong economic incentive to do so. Some but not all producers are willing to be proactive and manage ahead but certainly these producers are in the minority. For the majority of producers such incentive may only come as a result of herbicide failures rather than simply warnings of such failures.

Lyle Friesen
Plant Science Department, University of Manitoba, Winnipeg, Manitoba

A wild oat survey in the fall of 1993 in Treherne, Manitoba showed that approximately two-thirds of fields at high-risk to developing Group 1 herbicide resistance (based on Manitoba Crop Insurance corporation records of Group 1 use) contained resistant wild oat. Wild oat seedlings were collected from fields in this area, prior to spraying, in 2000. These seedlings were tested for resistance to fenoxaprop and sethoxydim.

Of the 15 fields surveyed, 10 fields had wild oat seedlings that were resistant to fenoxaprop and 3 had seedlings resistant to sethoxydim. The proportion of seedlings that were resistant in each fields varied between 3% and 50% of those tested.

Although two thirds of the fields had resistant wild oat seedlings, the proportion of seedlings that were resistant was lower than expected. This was supported by observations which indicated that relatively few wild oats survived after the application of Group 1 herbicides in some fields. This scenario contrasts with other cases of herbicide resistant weeds such as trifluralin resistant green foxtail and Group 2 resistant kochia where whole fields became infested in a relatively short time.

Further research is planned to determine the movement of Group 1 Resistant wild oat in fields with confirmed resistance in 1993. MCIC data shows that Group 1 herbicide use has continued to be high since this time. It may be possible that the tendency for wild oat to colonise and regenerate in patches has limited their spread.

Todd Andrews
Manitoba Agriculture and Food, Carman

A seed-based petri dish bioassay was developed at the University of Manitoba in 1995 for the purpose of testing wild oat seeds for Group 1 resistance. Since then, several laboratories have offered wild oat resistance test services, presumably using the University of Manitoba protocols as a basis for their procedures. There has been concern that results from these bioassays were inconsistent and that the interpretation of these results for field management was difficult. A project was developed to compare the results of commercial testing labs with those of field trials. The petri dish tests varied in their potential to identify resistance. This was particularly the case for the fenoxaprop tests. In general, one of the commercial testing laboratories overestimated both the number of samples that contained resistant seeds as well as the proportion of resistant seeds within these samples. Conversely, the other commercial testing laboratory underestimated these variables.

The difficulty in extrapolating seed based petri dish bioassays to the field was illustrated in this project as no lab results were completely consistent with those from the postemergence field trials. When using the results of the commercial testing labs then, it is important to consider the context of the situation that prompted sampling and testing in the first place. This would include those conditions that need to be satisfied in order for a wild oat patch to arouse suspicion of resistance:

- ✓ Poor control with a Group 1 product even though conditions at the time of spraying were satisfactory.
- ✓ Field records that showed repeated use of Group 1 herbicides (all documented Group 1 resistance cases have so far shown herbicide selection pressure to be a major factor in the development of resistance).
- ✓ Good control of susceptible grass weeds other than wild oat eg green foxtail.
- ✓ Irregular patches of wild oats not controlled.

If these conditions are satisfied, then the results of the Group 1 resistance test is simply confirmation of a problem waiting to happen. Regardless of the outcome of the resistance test, some integrated management techniques (a more diverse crop and herbicide rotation is an excellent start) need to be adopted.

Working Group Report – Integrated Weed Management

Submitted by Anne Légère
Agriculture and Agri-Food Canada, Ste-Foy, QC

November 29, 2000 – Banff, Alberta

The following is a summary of what was said at the Integrated Weed Management Working Group session. In my own personal view, the session lacked focus and was only partly successful in that we did not even come close to a clear view of what needs to be done, how, by whom, and when. I was naively hoping for an action plan for our IWM working group. I recognize that it is difficult to achieve such an objective with a large group. I maybe should have planned the session differently. I am not even sure of what this working group is supposed to achieve. I was hoping to come out of the session with a clear view of what is ahead for the working group. This did not happen. However, many points were brought up in the discussion and we can maybe think of carrying the discussion throughout the year. We may be closer than I think to a plan of action of some sort. So, expect to hear from me during the year.

For the benefit of those that did not attend, here are a few notes on the session: I made a few introductory remarks, then asked Karen Bailey (AAFC, Saskatoon) and Ian Jonsen (AAFC, Lethbridge) to briefly address the IWM issue from a pathologist's and entomologist's point of view. The contributors to the IWM Symposium held the previous day were also asked to comment on what needs to be done. There were comments from the floor throughout the session.

I hope that the following lines will reflect the comments of each and everyone. I ask all contributors to please forgive me for any omission or misinterpretation. Finally, I would like to thank Steve Shirtliffe and Claudel Lemieux for taking notes during the session. I could not have written the following without their help.

Anne Légère
Chairperson, IWM Working Group
2001.01.18

Introduction (Anne Légère)

- My own take on yesterday's Symposium. There were a few reasons suggested for why some (many?) producers are not adopting IWM: producers have other priorities and problems, and some options would apparently be difficult to implement. Using Matt Liebman's little hammer analogy, we can maybe identify some reasons that are beyond the realm of weed science, which may explain why IWM isn't quite making it. Little hammers that are good from a weed science point of view may not be so good for the overall well-being of the crop. For example: if little hammer #1 is high seeding rate, we may be favoring diseases in some crops. If little hammer #2 is mowing/spraying field edges, we may be destroying refuge habitat for beneficial insects. If little hammer #3 is planting dates, we may favor synchrony between insect population peak and the most vulnerable growth stage of the crop. Maybe we need to harmonize the use of our little hammers with the use of other tools in the box, because you cannot grow a crop only with hammers; you need a boxful of tools.

- Some of the broad IWM issues requiring attention would include:
    - extension: we were told yesterday that we urgently need an IWM package for canola;
    - product development: need for new herbicides & bio-herbicides, improved machinery;
    - regulatory issues: PMRA, CFIA, SECAN [eg - should the latter introduce a (mandatory?) rating for competitiveness of cultivars?];
    - political issues: society at large wants IWM/sustainable ag practices - should the burden of cost of IWM/sustainable ag practices be solely on producers? Could there be a premium system for producers practicing IWM/IPM/soil conservation/etc.?
    - research and development??? Didn't seem a priority to anyone. Maybe it's a given?

- Our discussion should focus on what needs to be done.

The pathology point of view (Karen Bailey)

- With respect to pathology and disease/weed interaction, the focus should be on: crop rotations; foliar/soil borne diseases; row spacing (air borne diseases); plant density (soil born diseases); clean edges vs refuges; weed/pathogen interactions (including herbicide/pathogen interactions).
- Overall, much still needs to be done, as plant pathology research has traditionally focussed much more on breeding than on management.
- Multidisciplinary long-term studies should be planned and carried out in a way to allow for a stronger plant pathology component.

The entomology point of view (Ian Jonsen)

- Gaps/needs for research are: understanding habitat and habitat modification in relation to cropping and management (includes landscape modifications, planting density, crop rotations, woody corridor/fence rows); using the proper scale at which to look at interactions (crop/weed/pest/beneficial insects); implementing real integration (ie. much of what has been done has focussed on individual pieces of the puzzle, rarely on the whole picture).

Comments from Symposium Speakers and Session Participants:

Len Juras
- We should keep in perspective that progress only comes in small steps. We rarely consider all the consequences of what we do.
- We should try not to focus on the immediate problem but rather try predicting/working on the upcoming problem(s) - a proactive rather than a reactive approach.
- However, decisions are generally based on immediate economic scenarios

Audience

- Bottom line is net balance. Producers cannot always plan ahead. Last minute changes to crop rotations driven by economics. Economics drive extreme simplification of crop rotations.

Rene VanAcker
- IWM is not sold in a jar. Extension should be one on one. IWM should be knowledge-based.
- Extension services are dramatically downsizing.

Audience
Trend in Québec is to rely on private consultants. Few provincial agronomists left.
Should food produced with IWM/IPM be labelled as such?

Jerry Ivany
- Too much focus on top growth and not enough on soil and below ground.
- The grower needs independent information.

Steve Sutherland
- Downsizing of extension services occurred in Australia as well, but there was a reaction from producers.
- We should use good images to spread the data, not just data.
- Patch management is impaired by farm size (scouting).
- More education and extension is needed.

John O'Donovan
- Our work should not be economically driven.
- We will continue, as researchers, to work on IWM. We are curious people!
- Farmers are not interested in IWM when times are bad.
- Are we at the end of IWM? Is there enough out there? Maybe we need to look at all the little hammers in long-term systems research; consider interactions with other production issues.

Clarence Swanton
- Should move from volume to quality - value-added commodities (IWM should equal quality). This could expand markets for Canadian products.
- An IWM/IPM label could help. ISO labelling is linked to IWM
- There should be some mechanism identifying/prioritizing science & projects needs. This would take us a step farther in terms of IWM.

Rick Holm
- Concurs that quality is important ==> We should emphasize our forces and focus on the fact that we (relative to others) are using relatively little pesticides.

Neil Harker
- We need basic biology work (germination, dormancy, patterns of emergence).
- Diversified cropping systems is what we need.

David Kelner
- We already have good data in many cases (eg. barley).
- We should put it together and promote use (eg. quality umbrella is a good idea).
- Direct contact with the producer is needed.
- Information available should be summarized for publications such as crop production guides. Who should collect and write the info? ECW? others?

Daniel Cloutier
- Extension is not static like a web page or a guide; information should be passed to the producer directly by the extension specialist.
- Maybe we need more players! Eg. The maintenance of a decision support system likely requires 1 computer scientist and 10 agronomists; right now, we can depend on roughly on 1 computer scientist (when we're lucky!), and 1 or 2 agronomists!

Rene VanAcker
- Technology must be coupled to people with knowledge.

Hugh Beckie
- Focus IWM on reducing herbicide use.
- The is a lot out there (few novelties arise from yesterday's symposium).
- System research is ongoing but there should be more. Synergies between IWM tactics should be investigated.
- Farmers should be involved: there should be more on-farm participatory research.
- Lobby for more funding (stressed by VanAcker as well); IWM cannot (or hardly) be funded by matching investment initiatives.

Denise Maurice
- Maybe the information presented at the Symposium was not new for research people but it was for extension specialists.
- We should not focus solely on herbicides.
- IWM adoption is a long term affair.

Claudel Lemieux's afterthoughts

With regard to Clarence's comments, it is difficult to see who has the magic crystal ball to decide of research priorities. In our system, who is going to decide of the way to go? The ability to decide on research direction is heavily affected by partners who financially support the research. Also, a lot of breakthroughs in science are made by erring on the side of unpopular directions.

Comments made at the session were really all over. Only a few people insisted on the fact that knowledge is at the base of extension. People were insistent on the fact that resources were lacking for extension, but few mentioned the lack of resources for basic research (biology, ecology, interactions, etc.).

Goals and objectives of this working group need to be clarified. We seem to have ended up in a dead-end. What are we supposed to come up with: recommendations, priorities, suggestions? Something more than a list of discussion items? Discussion did not address the initial goal of the session, which was to determine clearly "what needs to be done".

Working Group Report
New Pesticide Products and Herbicide Characterization

Submitted by Marvin Faber
Dupont Canada Inc, Missisauga, ON

November 29, 2000 – Banff, Alberta

Dr. Francois Tardif began the session with a presentation on the mode of action of HPPD and PPO inhibitors. With herbicide resistance concerns on the rise it was valuable to visit products with different modes of action and gain a clearer understanding of how they work since they will likely be strong tools in the future.

Two presentations were made by industry partners, BASF Canada Inc. and Dow AgroSciences Canada Inc. Leighton Blashko from BASF presented information on their new Clearfield Wheat system and Dr. Len Juras from Dow AgroSciences presented an overview of their new cereal herbicide, florasulam. For additional information, Leighton and Len can be contacted at blashkl@basf-corp.com and ltjuras@dowagro.com, respectively.

Overall, I feel that the session was a success and I wish to thank the other members of the working group for their assistance. I would also like to thank the attendees of this working group for their enthusiastic participation. I look forward to serving as Chair for this working group at next years meeting in Quebec. After this, my 3-year term will be completed and it will be time to appoint a new chairperson. Please send your nominations to myself and I will bring the list to the Quebec meeting where we can vote in the new chair for this working group.

Presentations

To bleach or not to bleach…How some light-activated herbicides work
François Tardif, Shane Diebold, Mike Cowbrough. University of Guelph, Guelph, ON
This was a Microsoft PowerPoint presentation and it is presented as a separate document.
The file name is Bleachers.pdf

FLORASULAM™, a new post-emergence cereal herbicide
Dow AgroSciences
This was a Microsoft PowerPoint presentation and it is presented as a separate document.
The file name is Florasulam.pdf

Adrenalin™ Herbicide*

New Pesticide Products and Herbicide Characterization Working Group Session
ECW
Banff, AB, November 26-28, 2000

BASF

CLEARFIELD - Global Production System

Global Brand Name and Identity
Crosses Crops and Continents
Agronomically Strong Seed Varieties
Custom Designed Herbicides with Extended Weed Control
Optimized Farm Management Opportunities

CLEARFIELD Production System for Wheat

Controls off-types of wheat - increases crop quality
Controls volunteer cereals - increases crop quality
Opportunity to change cropping rotations
Weed management tool:

- Controls all volunteer crops (grass and BLF) including canola
- Controls Group 1 and 8 resistant wild oats
- Controls Group 1 and 3 resistant green foxtail
- Two modes of action on key broadleaf weeds

Ease of use: one package, one pass, one rate

CLEARFIELD Wheat Lines
Candidates : BW 755 and BW 754
Developed by Crop Development Centre
Distribution through SWP/Agricore
Agronomically Strong Varieties
CWRS Quality
Non-GMO Status - Traditional Plant Breeding

Regulatory Status - Clearfield Wheat
Completed 3rd year of co-op trials in 2000

PNT Registration clearances granted:

Unconfined release	March 3, 1998
Feed Clearance	March 3, 1999
Food Clearance	Nov 15, 1999

PRRCG* review in February 2001

Herbicide Properties:

Herbicide Groups 2 and 4
Post-emergent, systemic

Formulation and Packaging

Imazamox 120 g/L Aqueous Solution
2,4-D LV700 ester
1 case treats 40 acres
Very safe product
Tank Cleanout: Standard Procedures
No Concerns

Use rate:
Imazamox - 20 g ai/ha
2,4-D Ester - 560 g ai/ha
Use with 0.25% v/v Non-Ionic Surfactant

Application Timing:
Grassy weeds: 1-4 true leaf stage (early tillering)

Broadleaf weeds: Cotyledon-4 leaf stage

Crop Tolerance

Excellent Crop Safety, comparable to standards

Adrenalin - Weed Activity

Grassy Weeds

Volunteer Wheat
Volunteer Barley
Volunteer Oats

Wild Oats

Green Foxtail
Persian Darnel

Barnyard Grass

Broadleaf Weeds

Stinkweed	Redroot Pigweed
Shepherd's Purse	Smartweed
Kochia	Cleavers
Wild Buckwheat	Volunteer Canola (all types)
Ragweed	Cow Cockle
Lamb's Quarters	Sow Thistle (top growth)
Bluebur	Flixweed

Prickly Lettuce	Wild Radish
Pineappleweed	Russian Thistle
Mustards	Canada Thistle (top growth)
Narrow-Leaved Hawk's Beard	

Symptomology on Weeds:
Weeds stop growing within 24 hours

Grasses:

Yellowing of growing point
Inter-veinal chlorosis
Newest leaves affected

Broadleaf weeds:

Twisting of growing point (epinasty)
Yellowing of growing point
Initial symptoms appear soon after application

Weed death (necrosis) occurs within 14-21 days, dependent upon species and environmental conditions.

Follow-Crop Options:

BASF research shows that the year following an Adrenalin application the following crops can be grown:

wheat	peas
barley	lentils
oats	beans
canola (all types)	alfalfa
sunflowers	flax

Any other crops should use a field bioassay in the year prior to planting to confirm tolerance.

Regulatory Status:

* Adrenalin Herbicide is not currently registered. It has been submitted to the PMRA for review.

Working Group Report – Noxious Weeds

Submitted by Roy Cranston
B.C.Ministry of Agriculture and Food, Abbotsford, B.C.

November 29, 2000 – Banff, Alberta

Chair: Roy Cranston
Present: Danielle Bernier, David Clements, Carol Bubar, Derek Oudit, Dan Cole, Kevin Davis, Travis Goebel, Paul Cavers, Cathy Preston, David Bilyea, Hugh Martin, Shaffeek Ali, Don Hare, Bill McGregor.

Roy Cranston reviewed the NWWG Goals/Terms of Reference to update new attendees:

- To provide expert advice on noxious weed legislation/regulation to federal and provincial regulatory agencies
- To provide the Expert Committee on Weeds with links to other organizations involved in noxious weed control and regulation
- To provide a vehicle for the exchange of information, ideas and trends in noxious weed legislation of importance to Canadian agriculture
- To provide an informal means of exploring integration of provincial and national noxious weed regulatory policies and practices
- To meet once a year at the annual meeting of the ECW

Correspondence

The group undertook discussion of the ECW letter sent to the Minister of Agriculture requesting development of a national policy to address weed and invasive plant quarantine and control. This letter resulted from a Resolution that was passed at the 1999 ECW meeting in Ottawa. The response from Minister Lyle Vanclief acknowledged that the CFIA is responsible for developing programs to protect the agricultural and forestry sectors and that invasive plants and noxious weeds bring new and additional challenges to his Ministry. He also acknowledged that a comprehensive strategy to deal with invasive species is under consideration and invited the ECW to contribute to the development of a national policy.

The NWWG agreed to prepare a letter to the CFIA, under the signature of the ECW Chair, suggesting establishment of a Noxious Weed Task Group and that this Task Group be charged with the responsibility for formulating a Noxious Weed Policy Strategic Plan, with set timelines. The ECW would offer the collective expertise of its members in assisting such a Task Group.

Discussion occurred on whether the NWWG should be involved/concerned with aquatic weed issues such as the recent introduction of Fanwort to Ontario. It was agreed that any invasive noxious weed is of concern to the group and that perhaps assisting CFIA in risk assessment for this specie may be a good test case for a task group initiative.

Chair, Roy Cranston sent a letter (Oct. 19/00) introducing the NWWG to Dr. Paul Chamberland, Environment Canada, Chair Interdepartmental Committee on Alien Invasive Species. The letter offered the expertise of NWWG members as they develop networks relating to invasive plants. The letter also requested the Terms of Reference for the Interdepartmental Committee and asked for an update on progress. There has been no response to date.

Provincial Reports

Reports on provincial enforcement initiatives, "Alerts", new invasives were presented for New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia. Full text Provincial Reports are available in the 2000 ECW Proceedings.

Other Business

Daniel Cloutier, has offered to develop a **NWWG Discussion site** on the ECW webpage. This will be developed in 2001 and will provide a repository for web-based links to information on noxious weeds and invasive plants as well as NWWG Minutes and a forum for discussion of noxious weed biology/ecology, control, awareness/education and regulatory issues.

2001 Agenda items suggested for the NWWG meeting in Quebec City included:

1. Continued discussion on an initiative for federal noxious weed legislation
2. Developing Weed Risk Assessments
3. How to Expand Awareness of Invasive Noxious Weeds

Working Group Report – Site Specific Agriculture

Submitted by Linda Hall
Alberta Agriculture, Edmonton, AB

The following presentations were made to the working group. Presentations were followed by discussion and planning of future research needs.

Site-specific weed control: it's decision, decision, decision.

François J. Tardif, Department of Plant Agriculture, University of Guelph, Guelph Ontario and Heather J. Griffiths, Ontario Ministry of Agriculture, Food and Rural Affairs, Ridgetown, Ontario

We have been successful in previous years in our attempts at targeting weed patches in a corn and soybean rotation using a Direct Injection Sprayer (DIS) that had been developed by Ken Bennett and Ralph Brown at the Department of Engineering of the University of Guelph. We have reported on those studies at previous ECW meetings (1998 and 1999). Further to these reports, we have found that using a 6 m grid to guide our sampling was accurate enough for field horsetail and spiny-annual sowthistle but not fine enough for lambsquarters. We have also looked at the correspondence between the distribution maps of the weeds, as extrapolated from the krigging process, and the actual presence of weeds in the sampling quadrats and found a generally good agreement between the two. Errors in targeting the herbicides due to interpretation of the krigged maps could be of two types. Over-application occurred when a herbicide was sprayed on a location that did not warrant it according to the actual weed presence data. Conversely, under-application occurred when an area was not treated while there was enough weeds present. The incidence of over application ranged from 6.6 to 18.2 % while that of under-application ranged from 0.2 to 5.8% dependng on the species. We believed that, of the two types of error, over-application is the one that presents the least risk for the growers in terms of weed management. We found the relatively low incidence of under-application error to be encouraging when compared to over-application errors.

Why Are Weeds in Patches?

Steven Shirtliffe, University of Saskatchewan, Saskatoon

Two hypotheses can be used to explain the spatial heterogeneity of arable weeds. The edaphic factors hypothesis holds that weed patchiness is due to spatial heterogeneity in edaphic resources and environmental conditions. The dispersal and fate hypothesis holds that weed patchiness is controlled by chance dispersal of a seed to a given location. The purpose of this paper is to discuss the dispersal and fate hypothesis of spatial heterogeneity of weeds. This paper will attempt to address the paradoxical association between long distance weed seed dispersal and patchy spatial pattern. If seeds are dispersed a sufficient distance, it would seem obvious that the species should eventually spread and completely cover a suitable area. However, observed weed populations display highly aggregated spatial patterns that seem to have a degree of spatial stability in time. One explanation for this aggregation is that very few weeds seeds are dispersed long distances. Although combines can disperse wild oat seeds up to 150 m, interpretation of this results using simulation modelling reveals that only a very small proportion of seeds are dispersed this far. Factors contributing to the low proportion of seeds which are dispersed long distances by combine harvesters include herbicide mortality of weeds, pre-harvest seed dispersal and export of weed seeds with harvested grain. Because of the low proportion of weed seeds that are dispersed a long distance, the weed seeds can be confined to well developed patched. Simple probability dictates that most of these sites will occur within established weed patches where there is a high density of weed seeds in the seed bank. Characteristics of the seed dispersal curve may also lead to a patchy weed spatial pattern. Theoretical models of seed dispersal and the resulting spatial pattern suggest that if the tail of the seed dispersal curve declines at less then an exponential rate, the species expands by establishing new colonies establishing beyond the original patch, rather than as advancing front. Weeds may exhibit a patchy spatial pattern because of dispersal and fate even in the absence of edaphic and environmental heterogeneity.

Provincial Reports

2000 Report to the ECW
Alberta

Prepared by Linda Hall, Dan Cole, Keith Topinka and Shaffeek Ali

Alberta Agriculture, Food and Rural Development

General

Weather conditions varied considerably across the province in 2000. The southern region experienced hot, dry conditions for most of the growing season, while the central and Peace River regions were cool and wet. Crop yields were reduced and harvest delayed. Frost was reported in June in central and Peace regions and many canola crops were damaged or lost.

Problem Weeds

Crop Weeds

Problematic weeds noted by crop specialists across the province were Canada thistle, cleavers, stork's-bill, scentless chamomile, and sow thistle. Correct identification between perennial and annual sow thistles species remains a challenge. Toadflax and wild buckwheat appear to be expanding their range. In the Peace country, yarrow, horsetail, and fireweed were noted in fields, while spotted and diffuse knapweed infestations along railroad right of ways required control measures. Despite a bull thistle control program in the Valleyview area, this weed is on the increase. White cockle is becoming more prevalent around Leduc, while prostrate vervain has been recorded in direct seeded fields and disturbed areas in southern Alberta. Volunteer perennial and annual ryegrass are becoming difficult problems in following crops in southern Alberta. Leafy spurge is becoming more common in central Alberta.

Roadside Weeds

A provincial survey of rural municipalities identified Canada thistle, tansy, toadflax, perennial sow thistle and scentless chamomile as the major problem weeds in non-field areas (pasture/range, industrial sites, and roadsides). The agricultural fieldmen's association recommended that saltcedar and common crupina be added to the restricted list. They also noted the spread of Yellow hawkweed into new areas.

Forage, Pasture and Rangeland Weeds

White cockle, tall buttercup, Canada thistle, wild caraway, absinthe and ox-eye daisy continue to be problem weeds in central and western Alberta. Trials are being conducted on the control of Canada thistle in pastures, white cockle in established alfalfa, and integrated control of dandelions in pastures and hay land. Infestations of orange and meadow hawkweed are being addressed in central Alberta, as well as hound's-tongue south of Calgary. Heavy infestations of black-eyed Susan (Rudbeckia hirta) in three pastures west of Olds were a surprise to the local agricultural fieldman. Black-eyed Susan is not recorded as being native to Alberta but is native to Manitoba.

In order to make the weed inspector's job easier, the difference between ox-eye daisy and Shasta daisy is being addressed. A co-operative effort with the nursery trade has been undertaken.

With the drought in southern Alberta in 2000, there is concern about the spread of noxious pasture weeds with hay movement into the area and also with the damaging effect of over-grazing.

Cleavers and wild oats are the main weeds of concern in grass seed crops in the Peace region of Alberta as there is zero tolerance for the seed in these crops being sold into the U.S. and Europe.

Minor Use

With the interest in alternative crops, sufficient funding from grower organizations and Alberta Agriculture, Food and Rural Development has been obtained to place a part-time Minor Use procurement officer out of Brooks. This individual will do a lot of the leg and paper work in submitting priority Minor Use applications.

Biological Control

The gall midge Rhopalomyia n. sp., first released in 1999 on scentless chamomile, has already established at 31 of 42 releases made in Alberta in 1999. Some plants showed quite heavy galling and severe stunting. The seed weevil Omphalapion hookeri has established at 14 out of 22 releases made between 1996 and 1999 on scentless chamomile. This weevil has now dispersed over 10 km from the Vegreville 1993 release site. A petition will be submitted to request field release of the gall mite Cecidophyes rouhollahi, on false cleavers. Successful leafy spurge control with the root-feeding beetle Aphthona lacertosa has continued with redistribution, monitoring and research of the beetle. A fungal pathogen for control of cleavers, a fungal pathogen and a bacterium for the control of chickweed and a bacterium for the control of Canada thistle, annual sow-thistle and dandelion have been selected for further development as bioherbicides. The joint Alberta/Saskatchewan/Manitoba fact sheet entitled "Biological Control of Weeds on the Prairies" was printed and made available in 2000.

Herbicide Performance

In general, herbicide performance was good to excellent in the central and Peace regions, but poorer in the south. Fewer acres were sprayed in southern Alberta due to drought and poor crop emergence.

Herbicide tolerant canola varieties occupied 75% of the Alberta canola acreage. Glyphosate tolerant acreages predominated and considerable imidazolinone tolerant canola was grown because of the producer's ability to use seed grown on farm. Glufosinate tolerant canola acreage was down.

Weed Free Hay Program

In 2000, Alberta operated a province wide Weed Free Hay Program as a method to prevent the spread of weeds through hay movement. Hay fields were inspected prior to cut for weeds in their propagative stage. If approved, producers were given a maximum 10 days to cut the hay. A certificate was issued and the hay was baled using special color twine. The program was voluntary and the inspection service provided at no cost. This year 35 producers requested inspections and 95% of the over 5000 acres inspected were certified. The program received excellent support from the industry.

Eradication Programs

Diffuse and spotted knapweed, nodding thistle and purple loosestrife eradication programs continued to reduce infestation levels. Ducks Unlimited provided funding to support purple loosestrife control. Several volunteer groups were involved in hand pulling of purple loosestrife.

2000 Report to the ECW
British Columbia

Prepared by Roy Cranston, Plant Industry Branch
B.C. Ministry of Agriculture, Food and Fisheries

Problem Weeds

- "Weed Alerts" (print and internet) were distributed province-wide for **common bugloss** (*Anchusa officinalis*) and **field scabious** (*Knautia arvensis*). The relatively new invasive, bugloss, is spreading rapidly in parts of the Okanagan, Boundary and East Kootenay regions. New infestations of scabious have been found in the Thompson and Boundary regions. Research trials to obtain data for Minor Use registration show excellent control of scabious with metsulfuron-methyl. **Garlic mustard** was discovered at UBC and is now under management. **Marsh Plume Thistle** is expanding rapidly on pastures, roadsides and forest cutblocks in east-central B.C. **Cordgrass** (*Spartina patens*) was discovered at 3 saltmarsh sites.

  Efforts to increase awareness and control of **perennial pepperweed** (3 new infestations found in 2000), **wild chervil, carpet burweed, parasitic dodder, yellow nutsedge, velvetleaf** and **rush skeletonweed** were continued with distribution of "Alert" posters, newspaper/radio presentations, field days, educational seminars, etc. Increased awareness also resulted in discovery of new **tansy ragwort** sites in the Interior and **hound's-tongue** at the Coast. **Orange** and **yellow hawkweeds** continue to expand throughout the southern interior and Central B.C. Research trials continued in an effort to determine cost/effective hawkweed control (picloram plus 2,4-D best to date). **Japanese knotweed** and **Himalayan Balsam,** both horticultural escapes are spreading rapidly in coastal B.C., particularly in riparian habitats.

  Increasing concern regarding introduction of invasive plants through nursery chains, the mail and the Internet resulted in issuance of an **"Invasive Plant Alert"** brochure which was distributed to the nursery trades, Master Gardeners, educational institutions, regional governments, etc. via print and internet media. Arrangements were made with a researcher at the Univ. of Sask. to supply **hoary cress** from the Okanagan for medical research (anti-inflammatory glucosinolate for bowel disease). A **milk thistle** risk assessment was undertaken for a producer who contracted to grow a medicinal crop.

Weed Grants

BCMAF provided incentive Grants-in-aid totalling $225,5000 to regional district governments that undertake the noxious weed control function. Fourteen local Weed Control Programs were funded in 2000. BCMAF grants represent roughly 20% of total program expenditures. Increased funding allowed expansion of efforts to control rush skeletonweed in the Okanagan

Biocontrol

- B.C. (Ministries of Agriculture and Forests) contributed approximately $125,000 to weed bioagent collection, screening and shipment in 2000. Work was targeted at **hound's-tongue, Dalmatian toadflax** and **sulphur cinquefoil**. B.C., in partnership with AAFC, Lethbridge leverages funding as part of an International Consortium on weed biocontrol. **St. Johnswort, nodding thistle** and **bull thistle** are effectively controlled by natural agents. Specialized agents have reduced densities of the **knapweed species**, **tansy ragwort, Dalmatian toadflax** and **leafy spurge** in localized areas throughout B.C. Introduction and provincial redistribution of agents continues. There are currently 57 agents released against 20 serious weeds in B.C. The current popularity of St. Johnswort as a neutracutical crop continues to cause conflict with growers concerned about attack by *Chrysolina* bioagents which were first released to B.C. in the 1940's.

Publications

- Industry sponsors were found to enable continued publication of Crop Production Guides for Vegetables, Berries, Tree Fruits and Grapes. An Integrated Pest Management Guide for Landscapers and Homeowners is "in press." Sponsorship from BC Hydro, Telus, Westcoast Energy and the ministries of Forests and Agriculture resulted in an update and 3rd printing of a "Field Guide to Noxious and Other Selected Weeds of British Columbia.". This guide as well as other weed information such as "Alerts", an IWM Manual and weed monographs are available on the BCMAF Website @ http://www.agf.gov.bc.ca/croplive/cropprot/weeds.htm

Minor Use

- The Minor Use of Pesticides Program continues to be critical to the needs of B.C.'s small acreage nursery, vegetable and berry producers as well as to tree fruit, cereal and forage producers in the Okanagan/Kootenay regions. BCMAF is expediting URMULE's for turf, landscape, forage corn, rangeland. Gene Hogue, AAFC, Summerland (ret.) continues work on tree fruits and special crops and Victoria Brookes, AAFC, Agassiz continues herbicide research on strawberries and nursery. Requirement for GLP testing will have a suppressive effect on undertaking MU herbicide research, at least in the short term.

Legislation

- There were no changes to the B.C.Weed Control Act or Regulations in 2000. The Act is enabling legislation, allowing local governments to enforce provisions, if they so choose. Very little enforcement is undertaken in the province. There are currently 21 weed species designated "noxious" throughout all of B.C. and a further 24 species within the boundaries of specified regional districts.

2000 Report to the ECW
Manitoba

Manitoba Agriculture and Food

General

The 2000 growing season was average to slightly above average for most areas in the province. Crops that were harvested before the fall rains were of good quality but those harvested later suffered severe weathering and sprouting. Most grains harvested earlier were #1 grade while fields harvested after the fall rains came in lower or at feed grades. Feed supplies are good but cattle feeding over the winter may be reduced due to high calf prices. As well, hay is plentiful but quality is variable. Most crops showed an increase in acres compared to last year, mostly because of the wet season in 1999 that saw farmers stuck with more than 3 times the normal amount of summerfallow. There were large increases in the numbers of special crops grown, specifically dry beans and soybeans.

Common Weed Problems

The 2000 growing season would be considered a normal year, especially following the 1999 season where we saw a lot of "wet" weeds due to excess moisture. There was a large increase in dry bean and soybean acres, and most producers have limited options for weed control in these crops. Many of the products registered in Eastern Canada are not legally available for use in Manitoba, however many growers managed to obtain and use them anyway. In particular, fomesafen (Reflex) was widely used on bean fields in Manitoba in various tank mix combinations. Its persistence in soil under Manitoba conditions is not widely known and producers will have to watch crop rotations in 2001 due to its residual activity.

Manitoba producers grew almost 2.5 million acres of canola in the 2000 season, with 70% of these acres as herbicide tolerant varieties. Of that 70%, about 33% of those were Roundup tolerant, almost 20% were Liberty tolerant, 0.2% were of the Navigator/Compas system and close to 18% were the Clearfield system. The number of acres grown under the Clearfield system more than doubled from 1999 as this herbicide tolerant system is not currently labelled as "genetically modified". With the number of herbicide tolerant canola acres steadily increasing (from 14% in 1996 to 70% in 2000) producers will have to be careful with herbicide rotations and volunteer canola control.

Research Initiatives

Work continued in buckwheat (sethoxydim) for Minor Use application.

A large research project was undertaken in the forage seed area, as well as smaller trials in hemp and corn with new or unregistered products.

Pesticide Amnesty

Manitoba is planning to run a program for the collection and disposal, at no cost to the producer, of unwanted, unused, or obsolete pesticides and adjuvants that are being stored on farms. We are planning to collect and dispose over a two-year period, starting in 2001 and ending in 2002. Collection dates will be in the late fall with half of the province done each year (similar to Saskatchewan's 3 year recovery program initiated in 1999). Applications for funding have been made to the Crop Protection Institute of Canada as well as various government funding agencies to cover the costs of the program.

Weed Survey

Manitoba Agriculture will be initiating another Weed Survey in the 2001 season. This project will be similar to Weed Surveys of past years and will be coordinated with other provinces.

Biological Control

The majority of the work in Manitoba is focussed on leafy spurge, with the Manitoba Leafy Spurge Stakeholders Group (LSSG) heading up this issue. The LSSG is comprised of representatives from various producer groups and government departments and relies on funding from donations and government programs to operate. The LSSG conducted a province-wide survey in 1999 to determine the extent of infestation of leafy spurge. They found that spurge is present on over 340, 000 acres costing over $19 million annually in primary and secondary economic impacts. The LSSG plans to further refine the economic analyses and continue an awareness and education campaign. Research initiatives studying new and existing biocontrol release sites have been undertaken, using Matching Investment Initiative (MII) funding from Agriculture and Agri-Food Canada in Lethbridge, AB.

2000 Report to the ECW
New Brunswick

Prepared by Kevin McCully, Provincial Weed Specialist
New Brunswick Department of Agricultur, Fisheries, & Aquaculture

Weather Summary: The spring of 2000 was considered a more normal season than it has been the past couple years. May and June GDD and CHU were only slightly above normal and moisture was adequate. July was considered cool and wet with frequent sporadic thundershowers. August provided warmer and drier conditions early in the month, but cooler and wetter later in the month. There were hardly more than 3 sunshine days in a row during August. Early frosts resulted in September but days were generally dry and warm. Overall for the 2000 season, GDD days since June 1 were 1392 compared to the 30 year average of 1417. Corn Heat Units were 2324 since June 1 as compared to the 30 year average of 2368. Precipitation was 416 mm as compared to the 30 year average of 469. Sunshine hours were down.

Weed Control Summary: Weed control was generally considered satisfactory in most crops. Adequate moisture was received to activate pre emergence herbicides. Post emergent treatments were applied with no significant problems.

Weed Problems in 2000:

Alfalfa:	dandelion, quackgrass, corn spurry, hempnettle
cereals	quackgrass, rough bedstraw, wild oats
wild blueberry	bracken fern, wild rose, poverty oatgrass, three toothed, cinquefoil, barren berry, spreading dogbane, black huckleberry, St.John's Wort, vetch, bulrush, goldenrods, trailing blackberry, lamb's quarters, old field toadflax
pastures/hay	smooth bedstraw, tansy ragwort, thistles, dandelion
strawberries	toadflax, stitchwort, field pansy, groundsel, buttercup, sedges, bladder campion
vegetables	quackgrass, purslane, smartweed, yellow nutsedge
potatoes	marsh hedge nettle, goldenrod, perennial sow thistle
corn	quackgrass, triazine resistant weeds, annual grasses

Weeds on the increase:

Smooth bedstraw	triazine resistant weeds	St. John's Wort
common groundsel	purple loosestrife	rough bedstraw
toadflax	marsh hedge nettle	Angelica
field violet	stitchwort	

Research Trials:

Wild Blueberries	*Evaluation of mid summer applications of Spartan (tribenuron methyl) for bracken fern control.
Cranberries	*Evaluation of registered herbicides for use on newly sanded cranberries . *Evaluation of registered herbicides for use on unsanded cranberries. *Evaluation of herbicides for woody weed control with wipers (demo). *Evaluation of triclopyr for late fall woody weed control with a wiper (demo).
Apples	*Demonstration of herbicides for use on planting year Honeycrisp apple trees
Pasture	* Evaluation of weed control methods for use in pastures

Crops in which more research is required:

Ginseng - lack of herbicides registered
Alfalfa - lack of herbicide options
Vegetables - lack of herbicide options
Cranberries - lack of herbicide options
Strawberries - lack of post emergent weed control options

Biological Weed Control Program:

The NB Biological Weed Control Program was first initiated in 1990. Since then numerous insect releases have been made on 7 targeted weeds. Activities associated with the project have been reduced due to loss of funding. In 2000 no new insect releases were made, but previous release sites were monitored to help determine the success of previous releases. Lack of funding in the future may threaten the program. The NB Biological Weed Control Program is presently comprised of the following weeds and insects:

1) Canada Thistle:	*Urophora carduii*; *Larinus planus; Ceutorhynchus litura*
2) Tansy ragwort:	cinnabar moth (*Tyria jacobaeae*); *Cochylis atricapitana*; *Longitarsus jacobaeae*.
3) Toadflax:	*Gymnaetron antirrhinii*; *Brachypterolus pulicarius*; *Calophasia lunula*
4) St. John's wort:	*Chrysolina* beetles; *Aphis chloris*
5) Perennial sowthistle:	*Cystiphora sonchi*.
6) Purple Loosestrife:	*Galerucella pusilla*; *Galerucella calmariensis*
7) Scentless chamomile	*Apion hookeri*.

Issues and Concerns:

- No Weeds Act in N.B. (One was drafted in 1969 but never proclaimed).
- Importation of weed seeds through seed and feed (ie wild oats, velvetleaf)
- increased costs associated with GLP requirement for URMULE submissions
- Wild oats slowing moving into other areas.
- Chemical Sensitivity issue - number of municipalities looking at implementing bans on cosmetic use of pesticides (mainly herbicide use) or right-to-know bylaws.

Extension:

The NB Department of Agriculture is currently undergoing a major restructuring, and at one point all agrologists positions were eliminated. The decision has since been reversed but roles and responsibilities are still being determined. It appears that the Weed Specialist position will be covered off under an IPM heading. The new structure will be fully operational by April 1.

Numerous requests for information on weeds and their control were answered by telephone, fax, e-mail, letters and farm visits. Weed control information was also presented in various newsletters. Presentations at numerous meetings were also given.A number of guides were updated. Newsletter articles were also written.

Cranberry operations and Canola grown for hybrid seed were carefully monitored for weed problems to help ensure these “new to NB” speciality crops were successful.

Through the plant health diagnostic lab 58 weed species were sent in for identification. Herbicide injury was also diagnosed on 3 samples. Weed seeds were also sent in for positive identification.

2000 Report to the ECW
Ontario

Prepared by Hugh Martin and Leslie Huffman
OMAFRA, Weed Management Specialists

Weed Control

Weed control was challenging this year. The early spring allowed winter annuals, and perennial weeds to get a head start, making burndown treatments more challenging. Pre-emergent treatments worked very well assuming you could get them on due to extremely wet conditions. Early planted corn emerged quickly, which limited the ability to apply pre-emergent herbicides and burndown treatments.

One of the main challenges was to be able to spray on time. Heavy rains leached some herbicides down to the crop roots and caused some injury. Wet and windy conditions hampered spraying, with weeds often well advanced, reducing the effectiveness of postemergent programs. Windy conditions at spraying hampered the progress of spray operations and raised concerns of spray drift. Low drift nozzles were widely adopted by both growers and custom applicators.

Post-emerge applications went on beyond the optimum stage, especially in corn. This reduced weed control on some species and increased yield losses since weeds were able to compete with the crop during the critical periods for weed control.

Spreading atriplex is an increasing problem, especially in no-till soybeans. Prickly lettuce was very common this year. Foxtails were a frequent escape in 2000 and proso millet is increasing in some areas. Soybean canopies also showed a significant amount of ragweed and volunteer corn at mid season.

Resistance

Red root and green pigweed are now becoming more common, especially in the areas first identified in 1997. Multiple resistance with atrazine and ALS herbicides was also confirmed at one location on green pigweed. In 2000, samples of suspect ragweed and Eastern black nightshade were also collected for testing. Awareness of the issue is high among farmers but concern and management is fairly low on the resistance issue. There was also one farm confirmed with pigweed resistant to linuron following a long history growing carrots.

GMO Issues

Roundup Ready soybeans and canola generally performed very well again this year, but market uncertainty will continue to temper the growth of this GMO technology. Herbicide tolerant corn hybrids are still at low market share. There was very little change in GMO acreage in 2000 from 1999 due to market issues.

Weed Control Act
There were approximately 500 weed orders issued in 2000 which is similar to records for 1999 and 1998. The majority of these are in urban areas. Currently there are plans to review the list of noxious weeds for Ontario.

Minor Use Program for Herbicides
Currently there are 110 active minor use requests for herbicides of interest to Ontario growers. As well, there are 15 more proposals ready for submission and plans for another 8-10 proposals to be prepared soon. 7 herbicides were registered through the MUPP program this year that will be included in the 2001 Publication 75.

Extension Activities
Extension Services were reorganized during 2000 in Ontario. Regional delivery and one on one contacts were reduced. Staff was reduced about 25% and the number of offices was reduced from 35 to 13 with the remaining offices focussed on being resource centres rather than general information offices. A Contact Centre was set up with an 1-800 line for answer general inquiries from growers.

- Guide to Weed Control (Pub 75) remains as an annual publication. There have been efforts in the past 2 years to improve the formats and refine the rating tables.
- Ontario Weeds (Pub 505) is in revision with the hope to reprint in 2001 (35 new species)
- New Factsheets include Herbicide Mode of Action Categories and Herbicide Resistance (not yet released).
- Website information has been updated quite substantially during the past year. The Notes on Herbicides and Notes on Adjuvants sections can be searched by product name. There is a series of infosheets on the Basics of Weed Management, Integrated Weed Management, Precautions with Pesticides, Application Technology, etc. The Ontario Weed Gallery includes over 200 photos of weeds. Newsletter articles on weed management from several Ontario newsletters are also indexed on the site.

2000 Report to the ECW
Québec

Prepared by Danielle Bernier
In collaboration with Michel Letendre, Alain Garneau and C.J. Bouchard
Direction des services technologiques, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec

General information :

Several regions of the province of Quebec dealt with cold temperatures and humidity this spring. Sowing was delayed and producers had to modify their cultures (ex.: sow soybeans instead of corn because of later dates to sow). Herbicide applications preemergence and postemergence were difficult to do. This spring's rain and cold hindered the application and later again rain and intense winds made the operations even more difficult. The efficacy of the treatments was variable. However when herbicide applications were done under good conditions the control results were excellent.

Diagnostic Laboratory :

The Diagnostic Laboratory is as busy as ever. Phytotoxicity evaluations have considerably increased this year. Environmental conditions and the stress level of the cultures at the time of the treatments are partially responsible for these problems. Many cases of drift were also identified. Phytotoxicity cases due to carry over of herbicides from the second group are more frequent. Vegetables, cultures as well as soya and corn have been damaged to different degrees. The dryer seasons like 1998 and 1999 explain certain cases. Soil working techniques explain others. However the expanding use of products on field crops causes headaches for crop rotation planification.

Throughout the year, courses, conferences and practical formation concerning herbicides were dispensed.

Weeds Committee :

The Quebec Weeds Committee is doing ever so well. July 5^{th} and 6^{th} 2000 were two successful days in the Quebec region for « The Weed Tour ».

225 people gathered to the « Weed Tour » to hear « La protection de vos grandes cultures êtes-vous à jour » a symposium on « Field crop protection ».

In early February 2000, « Traitements herbicides – Grandes cultures 2000 » was available, and sold for 15 $. We have completely revised and transformed this edition. The guide was modified to a more practical size; its new visual presentations and binding make it casier to consult. The addition of a new section was greatly appreciated by users concerning information on different herbicides with more than satisfactory comments.

The update of the guide « Traitements herbicides – Grandes cultures 2000 » is a major priority of the Committee for the beginning of this coming year.

Next year's priority will be the writing of « Traitements herbicides – Horticulture 2001 ». We need 30 000 $ to have a person to do part of the work. Several grants have been asked for, however none are granted so far. For the first time we are questioning the future of this document.

The herbicide trial network continued its activities at Laval University and at the Macdonald Campus throughout this year.
Consultations with members of the Committee are at a project stage to eventually join the « Commission de malherbologie » and the « Commission de protection des cultures ».

Legislation :

Throughout 2000 the nomination of weed inspectors was maintained. For other activities concerning the Noxious Weed Act (LRQ, c. A. 2) section IV refer to the 1999 report, because no or few development actions have been made.

Phytosanitary strategies :

The phytosanitary strategies began their activities in 1992 by the Ministry of Agriculture, Fisheries and Food (MAPAQ) with the participation of partners such as the Ministry of Environment (MENV) and the Agriculture Producers Union (UPA). Due to its repositioning in 1997, significant and durable actions have been taken to reduce pesticide use and risks related to their use. This way the Ministry of Agriculture, Fisheries and Food (MAPAQ) joined its partners for the following objectives:

- Reduce up to 50 % the use of pesticides in Quebec agriculture between now and year 2000.
- Improve from now until year 2000 the proportions of agricultural areas in Quebec using agroenvironmental practice management. To ensure :
  - an acute protection of the environment and its users
  - a better food quality
  - a more favourable visibility for our produce on exterior and interior markets
  - the development of a durable agriculture extracts from the phytosanitary strategie website

Many actions have been taken in the weed science sectors because the majority of pesticide usage is herbicides.

The following is a non exhaustive activity list concerning specifically weeds and their repression during 1999-2000.

Communication activities:

Mechanical weeding workshop
Integrated repression
Courses on herbicides (modules 1.23)
Courses on spayer calibration (ramps and orchards)
Publicity in agricultural journals and magazines

Document publications :

Mechanical weeding equipment
Reduced rate
Posters of « Less and better Pesticides »
Magnetic stickers
Posters « Herbicide groups and weed resistance »

Minor use:

Quebec obtained a modification of Poast delay between the application and the harvest in cranberry cultures. The delay is now 60 days instead of 100 days.

The delay of Ultra Poast was modified from 60 to 15 days in snow pea cultures.

Quebec obtained for the 2000 season an emergency registration for Basagran in the cucumber used for transformation.

Quebec supplied efficacy results to Ontario to add to its demand of registration for Pursuit in cranberry.

Quebec forwarded to Ontario results of trials with Goal in strawberry to support their demands.

Quebec forwarded to Ontario results of trials with Prowl in onion cultures to support their demands.

A minor user registration form was filled for Fusilade II and Upbeat with endive cultures.

Additional contraints have been added due to the necessity of supplying information from different sub sections on zone 5. These additional requests will no doubt cause a loss of important usage for Quebec and Ontario.

Another point that evidently will reduce minor use is the lack of human resources apt and certified GLP to conduct necessary trials in the process of pesticide evaluation in Quebec.

Monitoring for « *Ambrosia* » in Quebec :

This plant is a major preoccupation for public health. Just about 10 % of Quebecers are allergic to the pollen of *Ambrosia*. Annually the fight to *Ambrosia* is estimated to a minimum of 49 millions dollars. In 1999, the health sector put forth an intersectorial provincial Committee the Quebec Committee for *Ambrosia*. This committee gathers members from the Ministry of Agriculture, Fisheries and Food, people from public health, Ministry of Transport, Environment, Ministry of municipal Affairs, representative of Canadian National Railway, Hydro-Quebec, the farmers the Union of Municipalities of Quebec and the Association against *Ambrosia*.

The committee's objectives are to ease the interaction between different organisms in order to improve the efficacy of *Ambrosia* control. A good technical documentation is available for identification, management and control of *Ambrosia* in urban conditions.

This information is readily accessible through the report of the *Ambrosia* Committee. « Le Flash herbe à poux » (Ragweed Flash). These publications easily reach all Quebec municipalities.

Reglementry control is supported by the committee as a complementary mean to other intervention controls.

The Committee for *Ambrosia* had several interventions in the municipal area, but is attempting to reach agriculture for example.

The major object of the committee is to gather all information and experiences from different areas of intervention to achieve its first goal which is to improve the life quality of the population against the rhinite seasonal allergy caused by *Ambrosia*.

2000 Rapport au CEM
Québec

Préparé par Danielle Bernier
En collaboration avec Michel Letendre, Alain Garneau et C.J. Bouchard
Direction des services technologiques, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec

Informations générales

Plusieurs régions du Québec ont eu à faire face à un printemps froid et humide. Plusieurs semis ont été retardés. Des producteurs ont dû modifié leur culture (ex: semer du soya au lieu du maïs en raison des dates tardives de semis). Les applications d'herbicides de prélévée et post levée ont été difficiles à réaliser. Au printemps la pluie et le froid ont nuit aux applications et plus tard toujours la pluie et les vents intenses ont rendu les opérations difficiles. L' efficacité des traitements fut variable. Lorsque les traitements ont été effectué sous de bonnes conditions la répression fut excellente.

Laboratoire de diagnostic

Le laboratoire est toujours très actif. L'évaluation de la phytotoxicité a connu une augmentation considérable cette année. Les conditions environnementales et l'état stressé des cultures au moment des traitements est en partie responsable de ces problèmes. Plusieurs cas de dérive on aussi été identifiés. Des cas de phytotoxicité par la rémanence des herbicides du groupe 2 notamment sont de plus en plus signalé. Les cultures légumières, en plus du maïs et du soya sont endommagées à des degrés divers. Les saisons plus sèches que nous avons vécus en 98 et 99 expliquent certains cas. Les techniques de travail du sol réduits en expliquent d'autres. Cependant l'utilisation croissante de produits pour grandes cultures cause de plus en plus de soucis pour la planification des rotations .

Des cours, conférences et formations touchant le domaine des herbicides ont aussi été présentés tout au long de l'année.

Commission de malherbologie

La commission de malherbologie se porte bien. Le 5 et le 6 juillet 2000, la "Tournée des mauvaises herbes" a connu encore une fois un vif succès dans la région de Québec.

Dans le cadre du Salon de l'agriculteur, le colloque "La protection de vos grandes cultures: êtes-vous à jour?" a attiré 225 personnes. Le colloque faisait le point sur les nouveautés dans le maïs, soya et canola.

Le guide "Traitements herbicides-Grandes cultures 2000" a été disponible au début de février 2000. Le guide se vend 15 ,00 $. C'est une édition rajeunie et complètement transformée que nous avons réalisée. Le guide a un nouveau format plus pratique. La nouvelle présentation visuelle et le reliage facilitent la consultation du guide. L'ajout de nouvelles sections, notamment celle contenant l'information sur les différents herbicides apporte un complément d'information apprécié par les intervenants du milieu. Les utilisateurs nous transmettent des commentaires plus que satisfaisants sur cette nouvelle édition.

La mise à jour du guide "Traitements herbicides-Grandes cultures 2000" est un dossier important de la Commission pour la début de l'année 2001.

Un autre dossier important pour la prochaine année est la réalisation du guide Traitements herbicides-horticulture 2001". Nous avons besoin d'un montant de 30 000,00$ pour engager une personne pour réaliser une partie du travail. Plusieurs demandes de subventions ont été faites. Jusqu'à maintenant toutes le réponses furent négatives. Pour la première fois nous devrons nous questionner sur l'avenir de ce document.

Le réseau d'essais herbicides a poursuivi ses activités à l'Université Laval et au Campus MacDonald en 2000. Le réseau continuera ses activités en 2001 si les ressources financières le permettent.

Un projet de consultation auprès des membres est prévue pour discuter de la possibilité d'une éventuelle fusion entre la Commission de malherbologie et la Commission de Protection des cultures.

Législation

La nomination d'inspecteurs et d'inspectrices des mauvaises herbes s'est maintenu en 2000. Pour les autres activités concernant la loi sur les abus préjudiciables à l'agriculture (L.R.Q., c. A-2)Section IV- Mauvaises herbes se référer au rapport de 1999 car il n'y a pas eu de ou de développement dans les dossiers.

Stratégie phytosanitaire

**La Stratégie phytosanitaire a été initiée en 1992 par le ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ), avec la participation de partenaires, dont le ministère de l'Environnement du Québec (MENV) et l'Union des producteurs agricoles (UPA). À la suite de son repositionnement en 1997, des actions plus significatives et durables ont été mises en place pour réduire la quantité de pesticides utilisés et les risques liés à leur emploi.*
Ainsi, le ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ) souscrit, avec ses partenaires, aux objectifs suivants :
· Réduire de 50 % la quantité de pesticides utilisés en agriculture au Québec d'ici l'an 2000.
· Augmenter, d'ici l'an 2000, la proportion des superficies agricoles cultivées au Québec utilisant des pratiques agroenvironnementales (lutte raisonnée et lutte intégrée) de gestion des ennemis des cultures respectueuses de l'environnement.

De façon à assurer :
· une protection accrue de l'environnement et de la santé des utilisateurs;
· une meilleure qualité des aliments (innocuité);
· le positionnement favorable de nos produits, tant sur les marchés intérieurs qu'extérieurs;
· le développement d'une agriculture durable.

*extrait du site web de la stratégie phytosanitaire

Plusieurs activités ont été mis en place notamment dans le secteur de la malherbologie puisque la majorité des pesticides utilisés sont des herbicides:

Voici une liste non exhaustive d'activités touchant spécifiquement les mauvaises herbes et leur répression réalisées durant la période 1999-2000.

Activités de communication;

Ateliers en désherbage mécanique
Ateliers en lutte intégrée
Cours sur les herbicides (modules 1,2,3)
Cours sur le réglage des pulvérisateurs (à rampe et à vergers)
Publicité dans les revues et journaux agricoles

Publications de documents:
Appareils de désherbage mécanique
Doses réduites d'herbicides en grandes cultures
Affiche "Pesticides moins et mieux"
Autocollants magnétiques
Affiche "Les groupes d'herbicides et la résistance des mauvaises herbes"

Emplois mineurs

Le Québec a réussi à obtenir la modification du délai entre l'application et la récolte du Poast dans la culture de la canneberge. Le délai est passée de 100 à 60 jours.

Le délai du Poast Ultra a aussi été modifié de 60 à 15 jours dans la culture du haricot mange-tout.

Le Québec a obtenu pour la saison 2000 une homologation d'urgence du Basagran dans le concombre de transformation.

Le Québec a fourni des résultats d'efficacité à l'Ontario pour ajouter à sa demande d'homologation du Pursuit dans le haricot Cranberry.

Le Québec a envoyé des résultats d'essais du Goal dans les fraises pour supporter la demande faite par l'Ontario.

Le Québec a fourni des résultats d'essai du Prowl sur l'oignon pour supporter la demande de l'Ontario.

Une demande d'emploi mineur a été faite pour le Fusilade ll et le Upbeet dans l'endive.

L'exigence de fournir des données provenant de différentes sous section de la zone 5 ajoute des contraintes supplémentaires. Ces demandes supplémentaires pourront se traduire par perte d'usage important pour le Québec et l'Ontario.

Le manque de ressources aptes et certifiés BPL pour réaliser les essais nécessaires au processus d'évaluation des pesticides au Québec est un autre facteur qui pourrait nuire au programme d'emplois mineurs.

<u>L'herbe à poux, une mauvaise herbe sous haute surveillance au Québec.</u>

Cette plante est un sujet préoccupant pour la santé publique. En effet, environ 10 % des québécois sont allergiques au pollen de l'herbe à poux. Cela entraîne des coûts économiques évalués à un minimum de 49 millions de dollars annuellement.

En 1999, le milieu de la santé a mis sur pied une Table intersectorielle provinciale, la Table québécoise sur l'herbe à poux. Elle réunit des représentants de directions de la santé publique, des ministères de l'Agriculture, des Pêcheries et de l'Alimentation, des Transports, de l'Environnement, des Affaires municipales et de la Métropole, des représentants du Canadien National, d'hydro-Québec, de l'Union des producteurs agricoles, de l'Union des municipalités du Québec et de l'Association de lutte contre l'Ambrosia.

L'objectif de la Table est de faciliter l'arrimage entre les diverses organisations afin d'améliorer l'efficacité des interventions face à l'herbe à poux. Une bonne documentation technique sur la reconnaissance de la plante,sur la gestion et le contrôle de l'herbe à poux en milieu urbain est disponible. La transmission de ces informations se fait notamment par le bulletin de la Table, *Le Flash herbe à poux*. Ces publications rejoignent l'ensemble des municipalités du Québec.

Le contrôle réglementaire est vu par la Table comme un moyen complémentaire à d'autres interventions de contrôle.

La Table québécoise sur l'herbe à poux a déjà axé plusieurs interventions auprès du milieu municipal, mais elle tente aussi de rejoindre d'autres milieux comme celui de l'agriculture par exemple. Son objectif est de réunir le savoir et l'expérience de tous les milieux pour parvenir à atteindre le but premier poursuivi, soit l'amélioration de la qualité de vie de la population aux prises avec la rhinite allergique saisonnière provoquée par l'herbe à poux.

2000 Report to the ECW
Saskatchewann

Prepared by Clark Brenzil, P.Ag., Provincial Weed Control Specialist
Saskatchewan Agriculture & Food (SAF)

Legislation

No new initiatives were undertaken with respect to changes to The Noxious Weeds Act, 1984 (Sask.). Background research is underway to review the Act in the near future.

Attention given to "servicing the clients (municipalities)" of the Act has been scant in the past. This has resulted in a decline in the level of knowledge and attention given to enforcement activities. A new training initiative was undertaken in Spring 2000 to deliver training clinics to municipal Weed Inspectors. Clinics were delivered at six locations around the province and for the inaugural year of an ongoing program the uptake ranged from encouraging to disappointing depending on location.

A series of articles on the various aspects of The Noxious Weeds Act were initiated for placement in "the Rural Councillor", a monthly new magazine for municipal councillors distributed to each Rural Municipality in the province. These articles will continue on an ongoing basis.

The number of Weed Inspectors appointed in 1999 was 75. The total number of Rural Municipalities is 297 plus about 10 cities that might be expected to appoint Weed Inspectors. In 2000, 120 Weed Inspector appointments notices were received including 3 cities and 2 towns. This suggests that the effort to assist enforcement activities at the local levels is effective at raising interest and should continue.

Future efforts will continue to deliver training to enforcement officials as well as "selling" the benefits of strengthening the municipality's enforcement relationship within the community.

In the winter of 1999/2000 problems with hunting outfitters purchasing elevator screenings to use as wildlife feed transporting noxious weeds into forested areas of the northern province. In some cases the screenings were transported by truckload from far south in the province to the northern forest boundary where it was dumped and rebagged for transport into the forest. The manpower resources of the local municipality to deal with this situation were limited and the jurisdiction of enforcement in provincial forests is still in question. Discussions with the provincial Environment Ministry have come to a provisional solution, but this issue will need to be addressed in future revisions in the *Noxious Weeds Act* as well.

Weed Issues

A new weed is showing a potential for invasion in east central Saskatchewan. Field Scabious (*Knautia avrvensis* (L.) Duby or *Scabiousa arvensis* L.) has established in a location just a few miles south of the City of Yorkton. The infestation has been progressing northward in a ditch a poorly drained basin that is subject to flood each spring. The local Weed Inspector is monitoring it and treatment with herbicides is underway.

Common Tansy (*Tanacetum vulgare*) is an increasing concern for municipalities in the northern parts of the province and in some cases is of greater concern than scentless chamomile. In most areas it is an intense ditch weed, but has not progressed much into cropland. There has been some movement into pastures as well. One producer is using triclopyr (Remedy, Garlon, Fencerow) as a backpack spray with some success on Tansy.

The combined effect of the growth of both zero till and pulse acres in the west-central portions of the province has seen an increase in vetches (*Astragalus sp*. *Vicia sp*.) and prickly lettuce (*Lactuca scariola*) in these areas. A change in herbicide management practices is likely a contributing factor.

Leafy spurge (*Euphorbia esula*) and scentless chamomile (*Matricaria perforata or Triplerospermum perforatum)* are the primary focus of enforcement activities in many municipalities. Weed inspectors report that yellow toadflax (*Linaria vulgaris*.) and field bindweed (*Convolvulus arvensis*) is more conspicuous in 2000 than other years and that blue lettuce (*Lactuca puchella*) is more prevalent on roadsides. Neglect of Canada thistle (*Cirsium arvense*) by land owners and occupants is raised often by Weed inspectors in southwestern areas of the province.

A survey of municipalities to map roadside infestations of scentless chamomile conducted by Dr. Garry Bowes of the Integrated Noxious Weeds Management Program (INWMP) in 1999, indicates that scentless chamomile (*Matricaria perforata or Triplerospermum perforatum)* has continued to spread into dark brown soil zones since previous surveys in 1988. INWMP is a term-funded program through the Saskatchewan AgriFood Innovation Fund (AFIF) designed to raise awareness of scentless chamomile and distribute biological control agents in the province. The survey was conducted again in 2000 to include railways and waterways. The Saskatchewan Highways and Transportation has initiated several spraying contracts based on these surveys.

Nodding thistle (*Carduus nutans*) appeared in heavy stands in pastures and roadsides for the first time in three years. Weed Inspectors report finding the biological control agent *Rhinocyllus conicus* in the flower heads. This increase in Nodding thistle stands may be due to a low cycle in the insect levels.

Other Items

Native Land Managers in Saskatchewan approached SAF to assist them with extension activities in weed management reflecting a concern over managing new land resources. The Provincial Weed Control Specialist delivered a presentation to the First Nations Land Managers Annual Meeting on the current regulatory environment surrounding noxious weeds, what a noxious weed is and an overview of the various ways to approach the management of problem weeds.