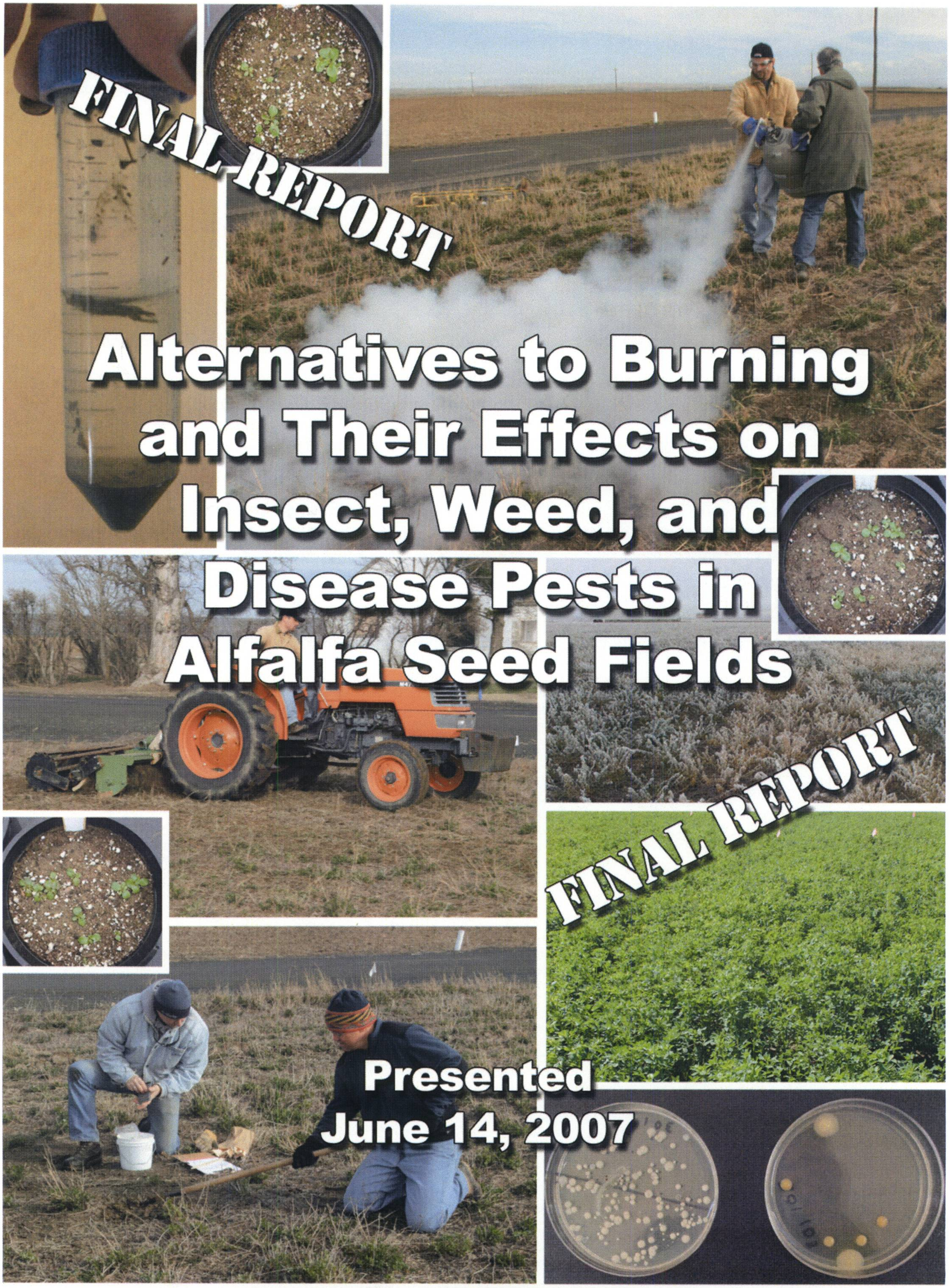

FINAL REPORT

Alternatives to Burning and Their Effects on Insect, Weed, and Disease Pests in Alfalfa Seed Fields

FINAL REPORT

Presented
June 14, 2007

Project Background

In May 2005, we submitted a proposal to the Washington State Department of Ecology Agricultural Burning Practices and Research Task Force. We requested and subsequently received funding for research and knowledge dissemination efforts from 11-1-05 through 1-31-07. Partnering with the Washington State Alfalfa Seed Commission, we conducted an evaluation of the benefits of burning alfalfa seed fields in Washington State by testing several cultural and chemical alternatives to burning. Our project took a multi-disciplinary approach, coordinating weed science (directed by Dr. Rick Boydston, USDA-ARS), plant pathology (directed by Dr. George Vandemark, USDA-ARS), entomology (directed by Dr. Douglas Walsh, WSU), and outreach (directed by Sally O'Neal Coates, WSU Research and Extension Communication Specialist). This is our fourth and final report on our activities during this period; please see also the Project Reports submitted 2-9-06, 6-27-06, and 2-8-07.

Objectives and Outcomes Summary

Our proposal stated four objectives for the project. Following each objective is the outcome, in brief.

Objective 1: Evaluate the efficacy of alternatives to field burning on insect, weed, and disease control.
Outcome: Complete. Results reported 6-27-06 and 2-8-07 and recapped in this report.

Objective 2: Determine the costs and benefits of field burning and alternative practices.
Outcome: Complete. Information reported herein.

Objective 3: Develop a long-term follow-up plan for field burning as directed by state guidelines.
Outcome: In progress. Information developed during the 15 months of this study will prove foundational to eventual deveopment of the long-term follow-up plan. Initial research has shown that some alternatives are far more feasible than others, therefore more likely to be implemented on a commercial scale. Funding is currently being sought to investigate those alternatives.

Objective 4: Disseminate key results of this research to growers via meetings, publications, and the Internet.
Outcome: Almost complete at this writing. Outreach efforts are detailed in this report. The final grower field day is scheduled for next week, June 21, 2007.

WASHINGTON STATE UNIVERSITY EXTENSION

Agricultural Research Service

Trade names have been used in this report for the convenience of the reader, with the intent of simplifying information and product identification; no endorsement is intended. Some products discussed are not registered for use on alfalfa seed. This document describes past, present, and prospective future research, it is not intended to be prescriptive.

Pesticides must always be applied with care and only applied to plants, animals, or sites listed on the label. Individuals mixing and applying pesticides should follow all label precautions to protect themselves and others. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, clothing should be removed and skin washed thoroughly. Pesticides should always be stored in their original containers and kept out of reach of children, pets, and livestock. Some of the pesticides discussed in this report were tested under an experimental use permit granted by WSDA. Application of a pesticide to a crop or site that is not on the label is a violation of pesticide law and may subject the applicator to civil penalties up to $7,500. In addition, such an application may also result in illegal residues that could subject the crop to seizure or embargo action by WSDA and/or the U.S. Food and Drug Administration. It is your responsibility to check the label before using the product to ensure lawful use and obtain all necessary permits in advance.

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Field Establishment

Research plots were established fall 2005 within an existing stand of alfalfa being grown for seed. The field belonged to grower-cooperator Mark Wagoner and was located near Touchet, Washington.

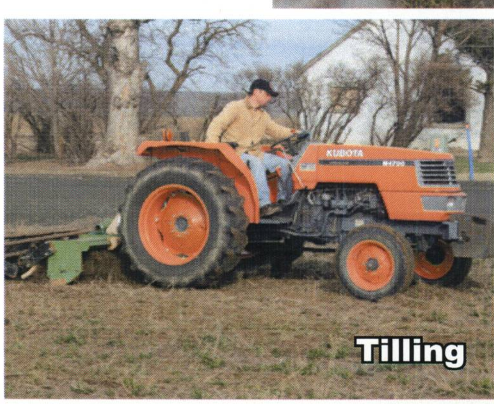
Also in the fall of 2005, the first of two herbicide treatments was applied to the test plots and a small-pot herbicide trial was conducted. (Weed trials are discussed beginning on Page 3). Just prior to implementing our burning and alternative treatments in February, weed seed packets were buried in the plots.

At right: Plots established in Touchet

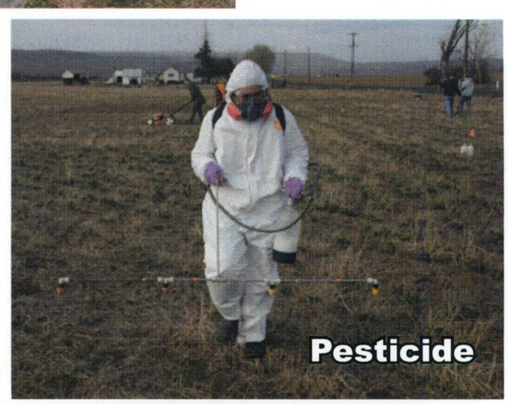
Burning

Mowing

Freezing



Tilling



Pesticide

Burning and Alternatives

Our experimental alfalfa seed plots were subjected to the following seven treatments:

1. leaving field stubble and not burning (control)
2. burning stubble
3. leaving stubble and heating with steam
4. leaving stubble and flash freezing, with nitrogen gas (N2) and/or dry ice (solid carbon dioxide/CO2)
5. removing stubble via mowing
6. burying stubble via tilling
7. leaving stubble and applying pesticide

Burning, freezing, mowing, tilling, and pesticide application took place on February 14, 2006. The steam treatment was performed on March 15, 2006, as the steaming equipment was unavailable at the earlier date.

Weed Management: Small Pot Study

We began our herbicide trials with a series of small pot studies directed against prickly lettuce. Treatments took place at the Irrigated Agriculture Research and Extension Center in Prosser in the fall of 2005.

A total of 11 preemergence treatments were applied with 5 replications of each, using a total of 55 pots. Postemergence treatments also involved 11 treatments with 5 repetitions, and were applied at 3 different timings (1-inch diameter prickly lettuce plants, 3-inch diameter plants, and 6-inch diameter plants) for a total of 165 pots treated and monitored.

All treatments controlled prickly lettuce well. Among the early postemergence treatments, the paraquat alone and flumioxazin plus paraquat killed the prickly lettuce seedlings the quickest.

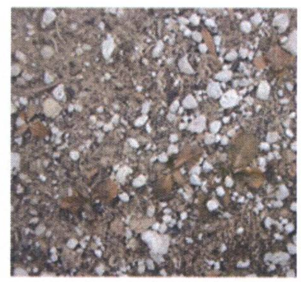
Small Pot Study - Prickly Lettuce Control

Preemergence		Postemergence*	
Flumioxazin	0.09 lb ai/a	Flumioxazin + paraquat	0.09 + 0.5 lb ai/a
Flumioxazin	0.188 lb ai/a	Flumioxazin + paraquat	0.188 + 0.5 lb ai/a
Diuron	1.0 lb ai/a	Diuron + paraquat	1.0 + 0.5 lb ai/a
Diuron	2.0 lb ai/a	Diuron + paraquat	2.0 + 0.5 lb ai/a
Terbacil	0.5 lb ai/a	Terbacil + paraquat	0.5 + 0.5 lb ai/a
Terbacil	1.0 lb ai/a	Terbacil + paraquat	1.0 + 0.5 lb ai/a
Metribuzin	0.38 lb ai/a	Metribuzin + paraquat	0.38+ 0.5 lb ai/a
Metribuzin	0.75 lb ai/a	Metribuzin + paraquat	0.75+ 0.5 lb ai/a
Norflurazon	1.0 lb ai/a	Paraquat	0.5 lb ai/a
Norflurazon	1.5 lb ai/a	Paraquat	1.0 lb ai/a
Nontreated	--	Nontreated	--

**Nonionic surfactant added at 0.25% (v/v) to postemergence treatments*

Nontreated

Karmex + Gramoxone

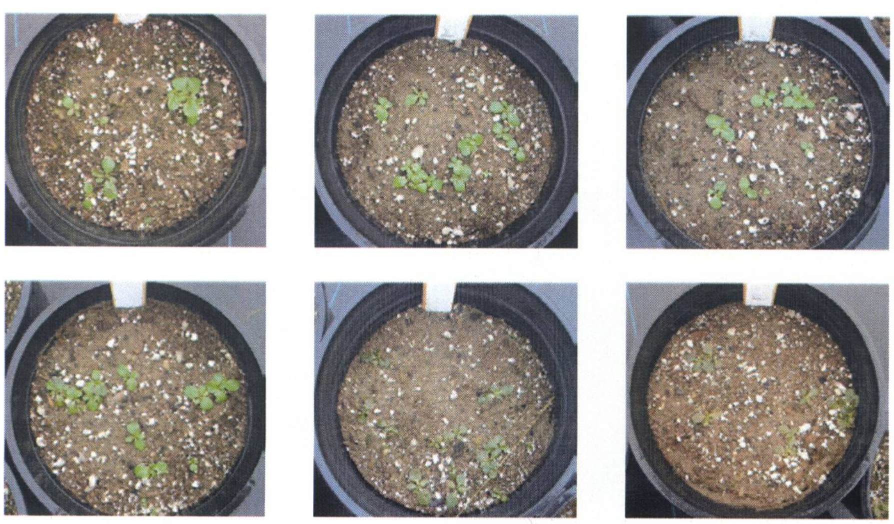


Sinbar + Gramoxone

Sencor + Gramoxone

Chateau + Gramoxone

Gramoxone



Photos above:
Prickly lettuce 2 weeks after treatment.

Photos at left:
Prickly lettuce 6 days after treatment.

Top row, left to right:
Nontreated
Karmex + Gramoxone
Sinbar + Gramoxone

Bottom row, left to right:
Sencor + Gramoxone
Chateau + Gramoxone
Gramoxone

Weed Management: Field Trial

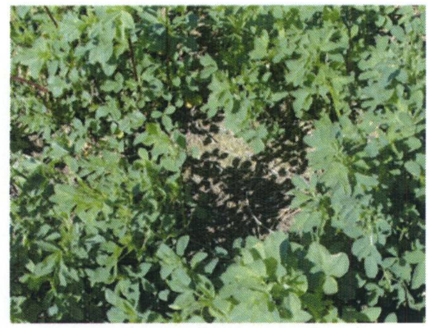
In November 2005, we conducted our first of two in-field herbicide trials on our experimental alfalfa seed plots in Touchet, WA. At the time of application, the prickly lettuce plants were 1 inch in diameter with 1 to 2 leaves. We applied flumioxazin (Chateau) at 0.125 and 0.25 lb ai/a, diuron (Karmex) at 1.5 lb ai/a, and norflurazon (Zorial) at 1.5 lb ai/a. All treatments included paraquat (Gramoxone) at 0.5 lb ai/a and nonionic surfactant at 0.25% (v/v) spray solution. Herbicides were applied with a backpack CO^2 sprayer delivering 25 gpa and treatments were replicated four times in a randomized complete block design.

By mid-December, the paraquat plus flumioxazin treatments (at either of the two different rates) and the paraquat plus norflurazon treatment provided 97 to 99% control of prickly lettuce, whereas the paraquat plus diuron treatment controlled the weed 90%. By February 7, 2006, all fall-applied herbicide treatments had totally eliminated prickly lettuce.

As planned, the entire trial was burned on February 14, 2006. Following this stubble burning, we found that emerged prickly lettuce seedlings were only partially suppressed.

Next, we made a spring herbicide application of pendimethalin (Prowl) at 1.7 lb ai/a as planned on March 1. Prickly lettuce plants were 1.5 to 3 inches in diameter with 3 to 5 leaves at the time of this application.

We evaluated prickly lettuce control again in April and in June by counting emerged weed seedlings, using a scale of 0 = no control to 100 = total control. Prickly lettuce control from all herbicide treatments was 99 to 100% except the plot involving norflurazon (Zorial/ Solicam), which showed a control rate of 94%. Results are summarized in the table below.



Spring alfalfa following Chateau treatment. Very little alfalfa plant injury was observed following the various herbicide treatments.

Crop injury was assessed by observing plants in March and April and by comparing seed yield at harvest in August. Very little alfalfa plant injury was noted from any of the herbicide treatments tested and seed yield did not differ significantly among the treatments.

Karmex and Solicam are both labeled for use in alfalfa seed production and both controlled prickly lettuce well applied in fall or spring. Chateau also controlled prickly lettuce well, did not injure alfalfa appreciably, and is being considered for labeling in alfalfa seed production.

While our seed viability study (detailed on Page 5) indicated that field burning had a positive effect on reducing prickly lettuce seed germination, this experiment shows that it had little effect on emerged seedlings. Use of effective herbicides probably has more total impact than burning on prickly lettuce populations in alfalfa seed production.

Prickly Lettuce Control, Alfalfa Injury, and Seed Yield Following Herbicide Treatments[1]

Herbicide Treatment	Rate lb ai/A	Herbicide Application Date	Prickly Lettuce Density Feb. 7, 2006[2] no./ft^2	% Prickly Lettuce Control April 24, 2006	% Prickly Lettuce Control June 21, 2006	% Alfalfa Injury April 24, 2006	Alfalfa Seed Yield Aug. 16, 2006 lb/A
Flumioxazin + paraquat	0.125 + 0.5	Nov. 21	0 b	99 a	100 a	1.8 a	1269 a
Flumioxazin + paraquat	0.25 + 0.5	Nov. 21	0 b	100 a	100 a	2.0 a	1163 a
Diuron + paraquat	1.5 + 0.5	Nov. 21	0 b	99 a	100 a	0.5 a	1398 a
Norflurazon + paraquat	1.5 + 0.5	Nov. 21	0 b	100 a	99 a	3.0 a	--
Flumioxazin + paraquat	0.125 + 0.5	March 1	13 a	98 ab	99 a	3.8 a	1170 a
Diuron + paraquat	1.5 + 0.5	March 1	17 a	99 a	99 a	2.5 a	--
Norflurazon + paraquat	1.5 + 0.5	March 1	12 a	94 b	94 b	0 a	--
Nontreated weedy check			13 a	0	0	0	--

[1]The entire field was burned Feb. 14, 2006. All treatments received pendimethalin at 1.7lb ai/a on March 1, 2006.
[2]Means followed by the same letter within columns are not significantly different according to Fischer's Least Significant Difference test at the 5% level.

Weed Management: Seed Viability Study

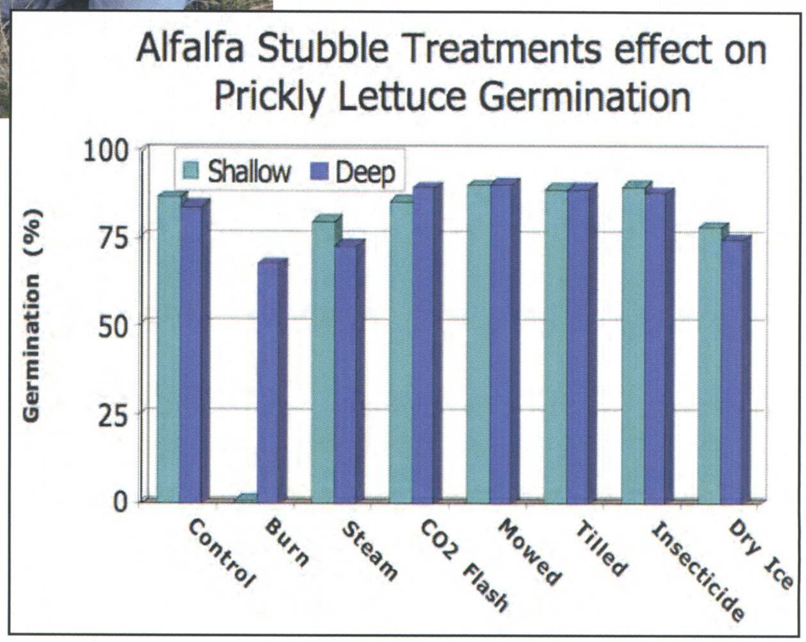
As an additional means of evaluating the pest control implications of the various alternative treatments, we undertook a separate study to examine burning, steaming, freezing, mowing, tilling, and insecticide use on the viability of weed seeds in the field.

Burying prickly lettuce seed packets.

Prior to initiation of the February and March 2006 field treatments, we buried small wire mesh packets containing prickly lettuce seeds at two different depths in each of the research plots. The packets measured 4 x 4 in. and were constructed of stainless steel wire mesh. Each packet contained 100 seeds. Packets were buried at depths of 0.125 inch and 0.5 inch. Treatments were replicated 4 times in a randomized complete block. Following the burning, steaming, freezing, mowing, tilling, and insecticide treatments, the packets were retrieved and the enclosed seeds were brought to the laboratory for controlled germination.

Seeds retrieved from each block were germinated in the laboratory at 23°C in Petri dishes beginning on March 20, 2006. We found that about 90% of the seed from the mowed, tilled, and insecticide-treated plots germinated—the same germination rate as the untreated control plot. Germination of the seed from the burned plots varied depending upon the depth at which it had been buried. Germination failed almost entirely on seed from the packets buried at the shallow depth of 0.125 inches, but seed buried 0.5 inches had a germination rate of 68%. Both of the freezing treatments resulted in some reduction of germination in the shallow-buried seeds (78% for the dry ice treatment, 86% for the CO2 flash treatment). Prickly lettuce is small seeded and does not germinate from deeper depths, so the shallow burial treatment is the likely the most relevant to alfalfa seed producers.

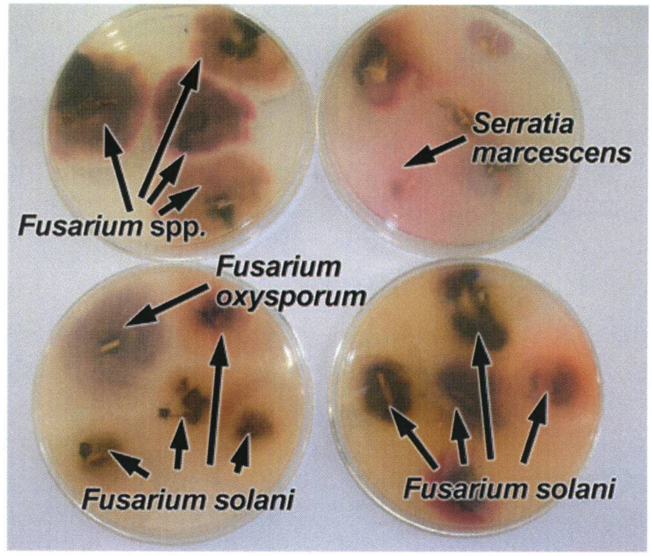
Steam heat treatment reduced prickly lettuce germination to 80% and 73% for shallow and deep placed seed, respectively, but it must be noted that since the steam treatment took place later than the others, this reduction could be due in part to the timing of the seed packet placement in the field, which could have induced dormancy.



We can see from this study that the traditional practice of field burning likely plays a positive role in reducing prickly lettuce seed viability, but our other study, summarized on the preceding page, indicated that use of effective herbicides probably has more total impact on prickly lettuce populations in alfalfa seed production.

Disease Management: Analysis of Field Samples

The disease component of our project sought to survey detrimental and beneficial microorganisms in the test plots following each of the stubble treatments. We quantified fungi associated with alfalfa seed crop diseases as well as soilborne microbes such as *Bacillus* spp., *Pseudomonas* spp., and actinomycetes (filamentous bacteria) that may help suppress soilborne diseases caused by fungi.



Our first step was to isolate the various fungi from the alfalfa plant tissue. Using one plant from each research plot, we sampled tissue from the crown, taproot, fine roots, and crown bud, plating it onto a general medium likely to reveal any *Fusarium* spp., *Sclerotinia* spp., *Rhizoctonia solani,* and oomycete fungi present. We also plated stem and petiole sections in a different manner more likely to detect the presence of *Verticillium* spp. A third method was used on samples from the crown tissue, fine roots, lateral roots, and taproot/fine root junction to isolate *Phytophthora* and *Pythium* spp.

Next, we collected 6-inch x 6-inch x 1-inch soil samples from plots subjected to each experimental treatment: burning, steaming, freezing, mowing, tilling, insecticide application, and nontreated control. We ran these samples through a sieve to detect sclerotia of *Sclerotinia* spp. and also performed a procedure known as "baiting," in which sterilized cracked cucumber seed is added to the sample to isolate and recover oomycete fungi and chytrid fungi from soil.

When we quantified the soil bacteria, we found that the soilborne pathogens implicated in alfalfa crown rot complex were present at some frequency in sampled plants of all treatments. Cortical-rotting *Fusarium* spp. (*F. oxysporum* and *F. solani*, primarily) were absent in the burning and stubble removal treatments but were identified at 25% frequencies in all other treatments. *Serratia marcescens*, a bacterium often associated with the crown rot complex, was present in samples of steaming, burning, and stubble removal treatments as well as in the control plot and *Pythium* spp. were present in the steaming, insecticide/herbicide, stubble removal, and control plots. *Phytophthora* spp. were identified in flash freezing and pesticide plots. While visual assessment of the field seemed to indicate the presence of *Sclerotinia sclerotiorum,* we were unable to isolate its sclerotia from the plant material. *Verticillium albo-atrum*, the causal agent of Verticillium wilt, was not detected in any of the plants sampled.

Presence or Absence of Pest and Beneficial Organisms in Test Plots

	Control	Burning	Stubble Removal	Steaming	Freezing	Pesticide
Pest Fungi ("X" indicates "present")						
Crown Rot	X	X	X	X	X	X
Fusarium spp.	X			X	X	X
Serratia marcescens	X	X	X	X		
Pythium spp.	X		X	X		X
Phytophthora spp.					X	X
Sclerotinia sclerotiorum	?	?	?	?	?	?
Verticillium albo-atrum						
Beneficial Microbe ("X" indicates "present")						
Pseudomonas spp.	X	X	X	X	X	X
Bacillus spp.	X	X	X	X	X	X

No significant differences were observed among treatments for the number of beneficial *Pseudomonas* spp. and *Bacillus* spp. detected, but a trend was observed in that the highest number of both types of bacteria were observed in the control plots, while the lowest numbers were observed in the burning and stubble removal treatments. Within a plot, populations of *Bacillus* spp. tended to be much higher than populations of *Pseudomonas*. In two plots subjected to burning and in a single plot subjected to stubble removal, no *Pseudomonas* spp. could be detected.

Insect Management: Surveys and Quantification

Our team surveyed populations of insects and other arthropods on four dates (March 20, April 10, April 24, and May 10, 2006) using two separate techniques, 15-inch sweep nets and 0.5m^2 ground transect squares. Insects were identified by visual inspection, quantified per sample, and recorded in a field notebook.

The insect abundance estimates were entered into an Excel spreadsheet and imported into Statview™ (SAS 2001). Populations of individual insect species were analyzed by analysis of variance (ANOVA) within each sample date. When differences in population counts were observed at the 5% confidence level, pairwise t-tests were conducted between the non-treated control and each respective treatment.

Insect populations within the plots among all the treatments applied were largely unaffected. The only significant population difference we observed was the adult Lygus bug population abundance measurement on March 20. Adult Lygus populations were significantly reduced in the burning, tilling, and insecticide plots. Trends persisted among the other insect species sampled in that the more disruptive treatments (i.e., burning, mowing, tilling) reduced populations in general. However, differences between treatments did not prove to be statistically significant.

Treatment	Date	Adult Lygus	Nymph Lygus	Lady-birds	Spiders	Minute Pirate Bugs	Big-Eyed Bugs	Ground Beetles	Alfalfa Weevils
Mean Square	df= 6	6.5*	ns	ns	ns	ns	3.2ns	2.0 ns	0.6 ns
Error	df= 21	2					1.8	1.2	0.9
control	20-Mar	2.75	0	0	0	0	2.25	2.25	1.25
burning stubble	20-Mar	0.25a	0	0	0	0	0.5	0.5	0.5
steaming	20-Mar	2.5	0	0	0	0	0.5	1	0.75
freezing	20-Mar	3.25	0	0	0	0	2	2	1
mowing	20-Mar	1.25	0	0	0	0	0.5	0.75	0.25
tilling	20-Mar	0.25 a	0	0	0	0	0.25	1	0.75
insecticide	20-Mar	0.50 a	0	0	0	0	0	0.5	0.25
Mean Square	df= 6	0.5 ns	ns	ns	ns	0.7 ns	5.1ns	0.8 ns	2.5 ns
Error	df= 21	1				0.9	2.8	0.6	1.3
control	10-Apr	1.25	0	0	0	1.5	1.5	1.25	2.5
burning stubble	10-Apr	0.75	0	0	0	0.25	2.75	1	0.5
steaming	10-Apr	0.5	0	0	0	0.75	3.25	0.75	1
freezing	10-Apr	1	0	0	0	0.75	2.75	0	1.75
mowing	10-Apr	0.5	0	0	0	0.5	1	0.5	0.5
tilling	10-Apr	0.75	0	0	0	0.25	0.25	0.25	0.5
insecticide	10-Apr	0.25	0	0	0	0.5	1	0.25	0.5
Mean Square	df= 6	1.7	6.5 ns	3.7 ns	13.7 ns	3.8 ns	2.2 ns	2.8 ns	2.8 ns
Error	df= 21	2	3.2	0.7	6.7	2.3	1.1	2.8	3.9
control	24-Apr	2.75	3.5	1.75	4	2.5	2	2.5	2.5
burning stubble	24-Apr	1.25	0.75	2.75	6.75	0.5	1	1	0.75
steaming	24-Apr	1.5	3.75	0.75	2.25	2.5	2.5	2	2.5
freezing	24-Apr	1.25	2.75	2	2	1.25	2	1.5	0.25
mowing	24-Apr	1.75	2	0.75	3	1.75	1.5	0.75	1
tilling	24-Apr	1.25	1	0	3.75	0	0.5	2.25	0.75
insecticide	24-Apr	0.75	0.5	0.75	1.25	0.75	0.75	1	1.75
Mean Square	df= 6	ns	1.5 ns	ns	3.1 ns	ns	ns	1.0 ns	3.1 ns
Error	df= 21		1		7.9			1.3	1.5
control	15-May	0.25	1.5	0	2.75	0	0	0.5	1.5
burning stubble	15-May	0	0.5	0	3.5	0	0	0.75	0.5
steaming	15-May	0	1.25	0	1.75	0	0	0.25	2.25
freezing	15-May	0	1.5	0	1.25	0	0	1.5	0.5
mowing	15-May	0.25	0.25	0	1.25	0	0	0.5	0
tilling	15-May	0	0.25	0	2.25	0	0	1.5	0
insecticide	15-May	0	0.25	0	3	0	0	1	0

ns/ not significant at $p<0.05$ a/ insect population means are significantly lower than in treated plots compared to the nontreated control plots at $p<0.05$

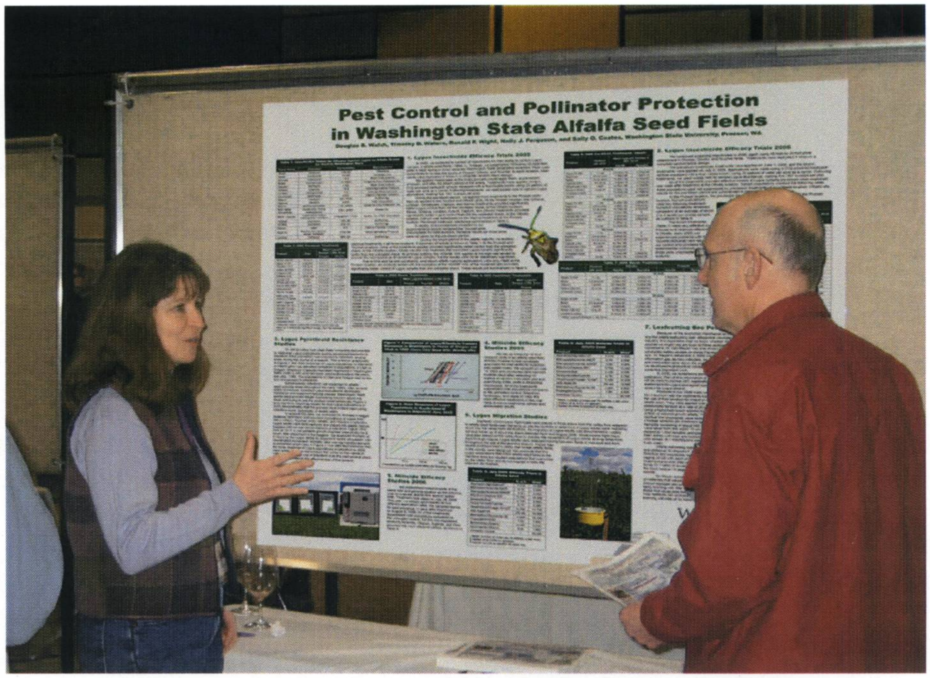
Using a sweep net.

Ladybird beetle.

Adult Lygus.

Information Dissemination: Educational Outreach

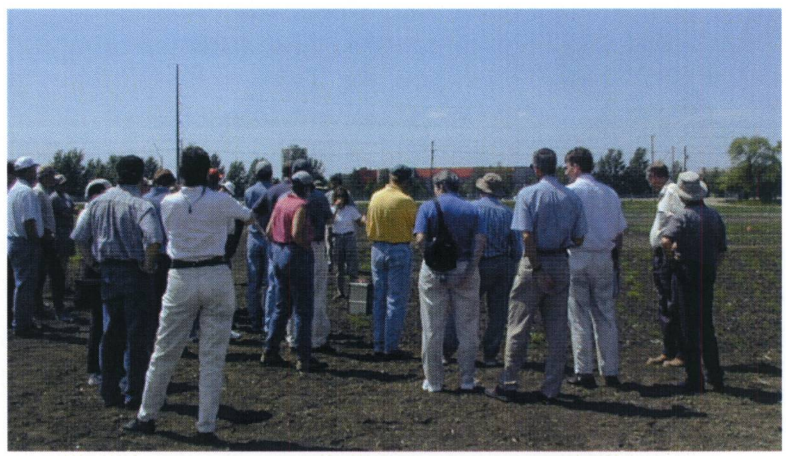
The fourth and final objective of our project, as stated on Page 1, was to "disseminate key results of this research to growers via meetings, publications, and the Internet." Our interdisciplinary research team members, along with our communications specialist, have utilized a variety of methods to disseminate the results of our 2005-2007 research to growers, to supporters, and to other researchers.



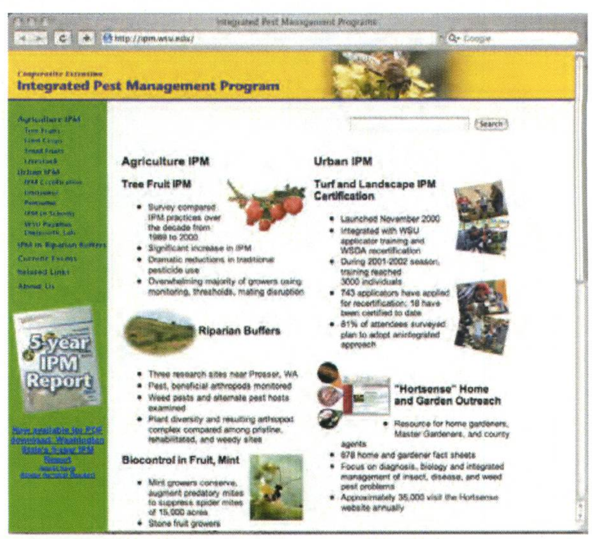
Alfalfa seed research presentations were made at conferences in Virginia, Nevada, and Oregon.

We had opportunities to make formal research presentations in Arlington, Virginia, at the Pesticide Environmental Stewardship Conference; in Portland, Oregon, at two Pacific Northwest Insect Pest Management Conferences; and in Reno (2006) and Las Vegas (2007), Nevada, at Northwest Winter Alfalfa Seed Conferences.

We presented periodic reports to agencies supporting our various alfalfa seed projects, including the Washington Commission on Pesticide Registration and the Washington Alfalfa Seed Commission as well as the Washington State Department of Ecology Agricultural Burning Practices and Research Task Force. During these sessions, we discussed our Ecology-funded alternatives to field burning research in context with our other alfalfa seed work.



Above: Field days are an important means of grower education. Below: The WSU IPM website hosts emerging research results.



Field days were conducted in both Columbia Basin and Walla Walla area alfalfa seed fields in June 2006. Another series of field days are planned for June 2007. These face-to-face meetings in the field are an excellent means of communicating results and having meaningful, informal dialogue with our most important stakeholders: the growers themselves.

Our partners, the Washington State Alfalfa Seed Commission, have also taken an active role in disseminating the results of our research as it has emerged.

Finally, we have placed results in the "field crops" sub-section of the Washington State University Integrated Pest Management website, http://ipm.wsu.edu.

Impacts of Burning & Alternatives: Costs and Benefits

Burned

Mowed

Tilled

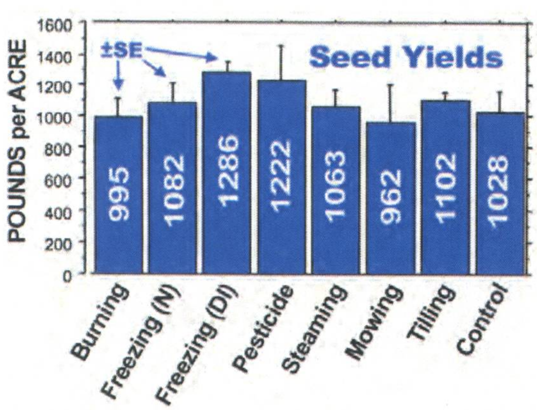
Control (residual left)

Spring Growth

Our first measure of the impacts of the various stubble treatments was to observe the relative vigor of the treated plots in the spring following the February and March treatments. We found that the spring growth of the alfalfa plants was similar among all treatments except the tilled plots, which produced plants with growth reduced by 60% in late April.

Seed Yield

The next measure was seed yield among the plots. Alfalfa seed yield was determined on August 16, 2006 by hand harvesting plants from a 3.25-by-5-foot area in the center of each plot, extracting seed with a belt thrasher. Measures of seed yield were taken in four replications for each treatment, including the untreated control. Yields were slightly higher for the plots subjected to dry ice flash freezing and pesticide application, followed by the plots subjected to tillage, nitrogen freezing, steam heat, and no treatment. However the differences in seed yield were not statistically significant among the treatments.



Net Returns

Our final measure was a cost analysis among the various treatments. We first determined the costs of the treatments on a per-acre basis as follows: burning was $3 for the accelerant; freezing with nitrogen was $80 for 20 lb of gas + $9 for equipment and labor; freezing with dry ice was $800 for the ice + $18 for equipment and labor; treating with insecticide was $14 for product + $9 for equipment and labor; steaming was $19 for propane + $9 for equipment and labor; mowing and tilling were $12 and $14, respectively, for equipment and labor. (Equipment and labor cost estimates from *Cost of Producing Alfalfa Seed in the Columbia Basin of Washington State*, 2006, by Hinman and Kugler, http://farm.mngt.wsu.edu.) The Washington State Alfalfa Seed Commission estimated 2006 seed prices ranging from $1.25/lb to $1.75/lb. Using an average price of $1.50/lb, we multiplied by the yield data and subtracted the comparative costs of treatments to arrive at a statement of comparative net returns.