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Plant, Soil & Insect Sciences  
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307-766-3113

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IAREC  
P. O. Box 2953-A  
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Entomology/Plant Pathology and Weed Science Dept.  
New Mexico State University  
Box 30003, Dept. 3BE  
Las Cruces, NM 88003  
505-646-2328

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DowElanco  
28884 South Marshall Road  
Mulino, OR 97042  
503-829-4933

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VOLUME 47

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 14 TO 17, 1994

THE COEUR D'ALENE RESORT

COEUR D'ALENE, IDAHO

**PREFACE**

The Proceedings contain the written summary of the papers presented at the 1994 Western Society of Weed Science Annual meeting plus summaries of the research discussion groups and of the business transacted by the Executive Board. Authors submitted either abstracts or full papers of their presentations.

In these Proceedings, herbicide application rates are given as acid equivalent or active ingredient unless otherwise specified. Chemical names of the herbicides mentioned in the text are given in the herbicide index. Botanical names of crops and weeds are given in the appropriate index and are not repeated in the text unless their omission may cause confusion. Common and botanical names follow those adopted by the Weed Science Society of America as nearly as possible and Hortus third.

Copies of this volume are available at \$15.00 per copy from Wanda Graves, WSWs Business Manager, P.O. Box 963, Newark, CA 94560.

Cover: Little mallow (*Malva parviflora* L.) also known as malva or cheeseweed. All photographs are courtesy of Jack Schlesselman.

Proceedings Editor: Rodney G. Lym

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## GENERAL SESSION

### PRESIDENTIAL ADDRESS

Doug Ryerson  
Monsanto Agricultural Group  
Great Falls, Montana

It's great to be here in this beautiful facility! I want to welcome you to the 47th annual meeting of the Western Society of Weed Science. John Orr and his local arrangements committee have done an excellent job in preparing for this meeting and I'm confident that everything is in place to make the next 2.5 days enjoyable and productive.

The WSWs continues to enjoy a strong financial outlook. Our current cash reserves total \$158,000. Wanda Graves our Treasurer/Business manager is doing an excellent job and deserves a big thank-you for all of her efforts. I have certainly enjoyed working with her during this past year.

I am relieved to report that you did a great job of pre-registering for this conference. Wanda reports that we had over 248 people pre-registered for this years meeting. Steve Miller was elated, but indicated a willingness to return next year if you slip backwards. Keep up the good work! This years program contains 21 posters and 70 papers. Tom Whitson, Vanelle Carrithers, and Bill Dyer have done an excellent job assembling the program!

The success of any organization depends on its members and their willingness to get involved. The WSWs continues to be blessed with many people that willingly devote their time and effort toward making it a viable and worthwhile organization. In the past year, contributions of many people have kept the WSWs moving forward in a positive way. It has certainly been a pleasure to have been associated with the many people and committees that make the WSWs tick.

Highlights from this past year include:

Successful launch of the Education Enhancement Program. Paul Ogg and his committee have taken a great idea and made it into a reality. This program offers students, or anyone for that matter the opportunity to broaden their horizons and experiences in weed science beyond their own University. There were five participants in this past year's program.

Rod Lym and several other people developed a distinctive logo that will appear on all WSWs publications. I think we all agree this logo is great and will definitely help make our publications recognizable and unique.

Publications are a definite bright spot for the WSWs. *Weeds of the West* continues to be a stunning success and is currently in its third printing. To date there have been in excess of 39,000 copies of this publication sold. We have a cash reserve of \$58,000 from this publication. This reserve will certainly provide a great foundation that can be used to help future WSWs publications become a reality. Tom Whitson and his committee are to be congratulated.

Steve Miller took on the job of editor for the WSWs Research Progress Report. He has done an excellent job of putting this years report together. Through Steve's efforts the Society will save over 50% of the printing cost incurred from last years report. Both Steve Miller and Rod Lym (editor-WSWS Proceeding) deserve a big thank-you for their efforts.

WSWS sustaining memberships have continued to grow. Jeff Tichota and his committee have done an excellent job in enlisting sustaining member support for the Society. I would like to welcome our 21 sustaining members to the WSWs and extend our thanks for their support.

This list could go on and doesn't begin to recognize all the people that are involved in making this Society successful. *I want to thank everyone that has been making things happen in the WSWs. I encourage those of you who aren't involved to get involved!*

It seems that this address usually covers more than a state of the Society. I would like to take this opportunity to express my thoughts on a topic that has received a lot of attention in recent years.

I had the opportunity to participate in the WSSA sponsored Presidents trip to Washington, DC. The major goal for this years trip was to encourage Legislators and Legislative staffers to attend the WSSA Symposium entitled "The Future Direction of Weed Science".

I felt that the symposium was an excellent idea. It certainly began the process of building an influence base that is needed in Washington, D.C. to help Weed Science compete for future funding. I agree with the overall direction set in place at this symposium, i.e., money is needed to support work that will lead to a better understanding of weed physiology, biology and genetics in-order to develop better methods of weed management.

I am however, concerned about the final portion of the program, that I feel, set the tone for the symposium. The message, delivered by an individual from the University of Minnesota, basically said: provided enough money and time, we weed scientists will develop weed control systems based on technologies that were used prior to the development of modern herbicides.

This may be the politically correct position, but in my opinion, it sends a message that may not represent the best interest of agriculture. It says that we are willing to change not because of science but because of public opinion driven by fear and ignorance. To me it represents a willingness, as a discipline, to take a giant step backward in time! I feel that it also indicates that the people trying to obtain funding for future weed science research may have lost touch with the practicalities of food production on a large scale. I predict that such thinking may result in short term funding gains but in the end will do little to bring this discipline forward into the 21st century.

There is no question that agricultural and weed control practices must change. American agriculture may be the most productive system in the world but it probably isn't sustainable with current practices. Poor agronomic practices including lack of crop rotation, excessive tillage and over-fertilization have caused many of the problems facing agriculture today. Our current system tends to result in mining the soil rather than conserving the soil. I firmly believe that if agriculture would do a better job in these areas, many of the other concerns such as reducing pesticide use, reducing erosion, and improving water quality would be easier to address.

In order to tackle these problems, those involved in agriculture production must become better agronomists. Many problems including diseases, insects, and weeds could be solved, or at least the need for chemical inputs reduced, by simply rotating crops. We must encourage integrated approaches to weed management utilizing cultural, chemical, and biological control when available. Much of the information needed has already been developed, but has not been adopted. Our current system has dealt with killing weeds for too long instead of managing both weeds and crops. It is time for a change!

Long-term we must, as emphasized by the symposium, learn more about the physiology, biology and genetics of weeds. Work in this area will undoubtedly open the doors for future advances in weed science I am confident that when this expanded knowledge base is combined with the tools emerging in the field of biotechnology, we will find and develop sound weed control practices that are socially acceptable, based on sound science, and practical for the farmer.

Change will take efforts by both the private and public sector. If we work together we can make a difference that makes sense and meets the expectations of society. Let's make sure we step forward instead of backwards into the 21st century!

I have enjoyed serving as President of the Western Society of Weed Science. I encourage you to have fun and take advantage of this meeting to cuss and discuss where we're going and what we want to look like when we get there! I hope you enjoy the meeting. Thank-you!

**ESTABLISHING STRONGER COALITIONS WITH OTHER SOCIETIES AND AGENCIES.** Alex G. Ogg, Jr., President - Weed Science Society of America and Plant Physiologist, USDA-ARS, Pullman, WA 99164-6416.

As farm populations have decreased, the influence of agriculture in the decision making process in the U.S. has decreased. Individual disciplines and organizations within agriculture are having less influence also. This decline in agriculture's influence has been reflected after adjustment for inflation in decreased support for agricultural research. This is especially true for small disciplines such as weed science. If agriculture and in particular weed science are to have the resources to solve tough problems such as environmental protection and still keep farming profitable, then we must be able to convince policy makers that our needs are important.

In order to expand our base of support, we must form coalitions with other societies, agencies, and organizations. A coalition is "a group of individuals or organizations working together in a common effort for a common purpose to make more effective and efficient use of resources" (1).

There are a number of advantages to forming coalitions, including:

- a) combining the resources of two or more organizations allows programs to reach more people or to have a greater impact on policy makers;
- b) improving communications between organizations that will result in all partners providing more consistent and reliable information;
- c) improving the public image of the organizations. The general public and policy makers like to see organizations involved with controversial issues working together. Positions that are supported by several organizations will be received more favorably by the public;
- d) coalitions with other groups not only combines the resources of groups, but frequently increases funding, access to the media, and the attention of policy makers. These are a few of the obvious advantages of coalitions.

There are some disadvantages in establishing coalitions and these need to be recognized and dealt with at the beginning. They include:

- a) Turf protection and mistrust frequently block the actions or cause dissolution of coalitions. If there is turf protection and mistrust there cannot be the openness and information exchange that are needed for the coalition to achieve its goals. With turf protection and mistrust there will be no willingness to share resources or burdens. To avoid these two problems, groups need to have clear objectives and goals and to establish at the beginning to what they can and cannot agree.
- b) The more players there are in the game, the longer it takes to reach consensus. The process and time frame by which each group reaches a decision must be explained and established at the beginning of the coalition.
- c) Most groups have limited resources, therefore when a coalition is formed resources are usually diverted from other priorities. Due to limited resources, some groups who would be valuable partners in the coalition are unable to participate. Limited resources is often a major problem with organizations such as Weed Science societies that operate on volunteered time. We can't do everything at once, but must establish priorities.
- d) Sometimes a coalition may take a position that is inconsistent with the policy of one of its partners. The likelihood of this happening can be minimized if in the beginning if there is a clear understanding of the objective of the coalition and the procedures to be followed.
- e) During a crisis, cooperation among members of the coalition may decrease. Withdrawal of support by a key member or outside pressure from individuals or groups who disagree with or don't understand the coalition's purpose may cause a crisis. Clear and frequent communication among the coalition members and by the coalition to outside groups is the only way to avoid this problem.

Although some of the disadvantages of coalitions seem troublesome, weed science organizations must be willing to overcome their apprehensions and must be willing to form coalitions with other groups.

How are coalitions established? I don't have any hard and fast rules for this process. What has worked in the past is to:

- a) Write a letter to the organization stating why you are interested, what are your goals and objectives, and list the name and address of a person to serve as a liaison.
- b) Attend a meeting of the organization and listen and be open to new ideas. Participate actively in discussions and look for common ground. For example, the common ground may be simply that weeds must be managed for both organizations to obtain their goals.
- c) Make personal contacts with individuals with whom you find you can communicate. This is frequently the way coalitions begin.

Listed in the table on the next page are a number of organizations with whom the Weed Science Society of America has established various levels of coalitions.

Table. Organizations with which the Weed Science Society of America has established coalitions.

Name of organization

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American Society of Agronomy  
Council for Agricultural Science and Technology  
Animal and Plant Health Inspection Service  
Environmental Protection Agency  
National Agricultural Chemicals Association  
Crop Science Society of America  
Society for Range Management  
Grazing Lands Forum  
American Chemical Society, Agrochemicals Division  
National Research Council  
National Biological Survey  
American Institute of Biological Sciences  
American Association for the Advancement of Science

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WSSA has a strong coalition with the American Society of Agronomy and the Council of Agricultural Science and Technology. On the other hand, we have only a communications link through a liaison with the National Biological Survey, American Institute of Biological Sciences, and American Association for the Advancement of Science. Often the degree of interaction is dependent upon the interest level of the liaison.

Coalitions don't have to be with organizations that are closely aligned with your organization. Look at controversial issues as opportunities. For example, WSSA recently published a jointed position paper on nonindigenous, invasive plants with the Natural Resources Defense Council. Usually, these two organizations are on the opposite sides of a debate. However, because two individuals, one from each organization, recognized some common ground and because they established a personal communication link, the two organizations were able to work together for the common good.

Another example and on a local scale was a coalition that was formed between weed scientists at Montana State University and the Alternative Energy Resources Organization (AERO) in Montana. In 1989, AERO published a white paper calling for three main needs for agriculture research. One of those needs was "to develop weed species-specific information and education on non-chemical weed control methods". This focus was no doubt related to the informal but highly effective coalition between AERO and the Montana State University weed scientists.

Lets now look to see what coalition opportunities there exists for the Western Society of Weed Science. The problem of noxious, invasive weeds threatening native species and natural ecosystems presents the WSWS with a tremendous opportunity for coalition building. The WSWS needs to be working cooperatively with organizations such as:

- a) Bureau of Land Management
- b) Forest Service
- c) National Park Service
- d) Nature Conservancy
- e) Natural Resources Defense Council

Another group that has common ground with WSWS is the Society for Range Management. I congratulate your President-Elect, Dr. Tom Whitson, for already moving ahead with a coalition with the Society of Range Management.

The newly established National Biological Survey will have a regional office in Seattle, Washington. This organization is very much interested in weedy plants and their threat to biodiversity. It is another golden opportunity for WSWS. I urge the WSWS to establish new coalitions and to strengthen established coalitions. If we want to see significant progress towards our goals we must join with other groups where ever possible. If we don't, our effectiveness and influence will continue to diminish.

I wish the Western Society of Weed Science well. You have an excellent program and I am looking forward to hearing the rest of the discussions.

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**WEED CONTROL ON PUBLIC LANDS.** Buck Waters, U.S. Department of the Interior, Bureau of Land Management, Washington, DC 20050.

I would like to discuss with you a little history of how the Federal agencies as a whole are viewing weeds and what most of us would like to see happening.

First I will speak to the Bureau of Land Management situation since we have the most weeds (or at least admit it). In 1991, we determined to take a hard look at the BLM weed program and where it should be. This evaluation was done by four BLM personnel and four helpers from outside BLM representing the Society of Range Management, The Wildlife Society, State Department of Agriculture, and the National Association of County Commissioners.

The major findings were no surprise to most of us involved with weeds but for the record the major findings were:

1. Weeds are expanding rapidly.
2. Lack of qualified personnel.
3. Lack of funding.
4. Attitudinal impediments.
5. Lack of policy guidance and awareness.
6. Lack of training, communication, and coordination.

Since the BLM evaluation, the US Forest Service looked at its weed program and the results were not greatly different. If other agencies did an evaluation, I believe the results would be much the same.

The BLM currently has about 8 million A of weeds. This is best described in the chart. This chart is based on admittedly loose data but in 1985 our efforts showed 3 million A infested on BLM. During the 1991 evaluation we found that weeds had expanded to approximately 6 million A. By the year 2000 we anticipate 15 to 20 million A. They are increasing exponentially.

Now-the big question is what is BLM and the other agencies doing about the problem? Put simply, we are trying to get our collective act together. All agencies directly involved in weed control are forming a group to raise the awareness in the Federal agencies, to work together, to develop policies as closely similar as possible, and to keep management apprised of progress. The BLM and the Forest Service have already joined policies and have taken the lead on getting this group formed. With the help of Deputy chief of Staff for the Secretary of Interior, B. J. Thornberry has sponsored this group and we expect to have a Memorandum of Understanding (MOU) signed by the end of April. The agencies expected to participate are the National Park Service, Fish and Wildlife Service, BLM, Bureau of Reclamation, Bureau of Indian Affairs, Forest Service, Animal and Plant Health Inspection Service, Agricultural Research Service, Extension Service, Soil Conservation Service, the Department of Defense, the Department of Energy, and the Department of Transportation.

One of the first jobs of this committee will be to seek state MOU's and try to get some common inventory procedures developed. The Federal agencies are committed to working together and with State and county governments to the extent possible. The biggest drawback is funding for the vast acreage that we have, and the late start most of us are making.

The Federal agencies are handicapped somewhat in needing a wide variety of support for our programs to be effective. This means that to compete for scarce dollars, we must have broad support both inside and outside the agencies. To gain this support we must shift paradigms. The old paradigm was crop oriented, economics driven. Those involved in crop production know the problem that weeds are causing but these people are small in numbers. We are shifting the emphasis to resources protected and impacts prevented. Basically the goal has not changed, that we are seeking biological diversity and a healthy ecosystem. Nothing on the Federal grounds is causing a greater loss of biodiversity than weeds.

Last year the Office of Technology Assessment published a report on non-indigenous species. Weeds were identified in this publication as a major problem that people have accepted. Therefore, BLM will be often using the terminology invasive, exotic species as opposed to weeds which better describes the species we are most concerned about. This goes back to gaining wider support and how to make weeds more relevant to the public. Interest only rises when "you" are impacted so we need to make invasive exotics important to the public. We need to let them know how they are being impacted. It is not easy to draw attention to weeds.

In conclusion, what we Federal managers are aiming for is a well balanced mix of native grasses, forbs, and shrubs on the rangelands. What we want to do is avoid monocultures that are occurring. To gain this end we must convince, the public that loss of waterfowl habitat is occurring due to purple loosestrife, that soil loss is occurring, that invasive, exotics are out competing the threatened and endangered species we are supposed to protect, and that wilderness as we know it will be forever changed, and recreation sites are being lost if we do not act now.

The Federal agencies can not do the job alone. We can do the planning, we can do the policies, we can do the training of agency people, and do some prevention work, but we must have your help if we are to succeed. The Forest Service and the BLM are committed to working together because of the joining of our lines in so many cases. We have just about completed an MOU on joining together to seek out partnerships with other organizations, agencies, and people who may want to work with us on this problem at a national, state, or local level. We hope you will be receptive when we come knocking on your door. We can grease the skids to get this program going, but you on the outside must do the pushing for us to compete for scarce dollars to run a program. We need to hear from you at all levels.

**INVASIVE WEED CONTROL ON LANDS OWNED BY THE NATURE CONSERVANCY.** Cynthia C. Lunte, Idaho Land Steward, The Nature Conservancy, P. O. Box 165, Sun Valley, ID 83353.

#### INTRODUCTION

Weeds are a well recognized threat to agricultural and residential activities. However their threat to natural areas is just beginning to be acknowledged. The Nature Conservancy is a land management based conservation organization which has over 1300 preserves in the United States. We have identified weeds as one of the most serious threats to the properties we manage. This paper will explain first who we are and what we do. Next, it will give examples of the types of weed management problems we face on our preserves. Third, it will give examples of actions we are taking to combat these problems, and finally illustrate ways that we can and need to work with individuals, organizations like the WSWS, and local and federal agencies.

#### WHO IS THE NATURE CONSERVANCY AND WHAT DO WE DO?

The Nature Conservancy is a non-profit conservation organization with offices in each of the 50 United States and additional programs in Canada and Latin America. Our mission is direct, but extremely challenging: to preserve the plants, animals and natural communities that represent the diversity of life on earth by protecting the lands and waters they need to survive.

We believe in a hands on approach to conservation. In Idaho I am responsible for overseeing the science and management activities on thirteen different preserves. These preserves are found in many ecosystems and require a variety of management strategies.

The Nature Conservancy also believes that cooperative strategies are most effective. Thus, we avoid litigation (like the plague) and concentrate on ways to work positively with our neighbors and other organizations in ways that will help us succeed in our mission without threatening others.

As a brief example of how we operate, I will use one of our oldest and best known preserves in Idaho, the Silver Creek Preserve. The Silver Creek Preserve first came into existence in 1975 with the purchase of 479 A along the headwaters of Silver Creek. Even after several additions to the property we quickly realized that owning 845 A of land along a stream could not protect it adequately, so we began working cooperatively with our neighbors to improve the watershed's management.

Working with numerous landowners, we have now put into place voluntary conservation easements which will permanently protect from development and prevent damage to the stream system on over 4000 additional A. In addition, the Preserve proper is open year round for public use, including fly fishing, canoeing, hiking and restricted waterfowl hunting. As this illustrates, being a part of the community has made us much more effective in our goal of protecting the stream system at Silver Creek.

#### WHY WE ARE WORRIED ABOUT WEEDS

Many people assume that after we purchase a piece of property all we need to do is build a fence around it to keep out trespassers and it is "protected". Unfortunately, this is far from the truth. Many of our most serious threats do not recognize lines drawn on a tax map. These can include activities which are occurring in the watershed above us or even the lack of processes that used to sustain the communities, like periodic fires in the southeastern pine forests or herds of grazing animals in the Great Plains.

An even more perplexing and often more threatening problem can be the presence of plants or animals that were not part of the original communities. These outsiders have arrived without the host of natural predators which kept them in check in their native homelands. This gives them a competitive advantage which will allow them to persist and even dominate a community for long periods of time. The most serious threat is posed by those species which can change the area they are invading to such a degree that the interwoven relationships between plants, animals and even the microclimate can be radically altered. Even some of our most "pristine" areas are under threat.



At the Garden Creek Preserve located on the Snake River about 40 miles south of Lewiston, Idaho, we own some of the most beautiful open grassy slopes of bluebunch wheatgrass (*Pseudoroegneria spicata*) and arrowleaf balsamroot (*Balsamorhiza sagittata*) that you have ever seen. Several years ago we noted with worry the aggressive weed yellow star thistle (*Centaurea solstitialis*) on some of the most disturbed areas on the Preserve. During recent drought years this winter annual has spread into stands of bluebunch wheatgrass and forbs which appear to be in excellent condition. This particular weed is a problem on Conservancy preserves in central and northern California and southern Oregon as well. It takes advantage of early moisture available before the native bunchgrasses begin their spring growth spurt. It forms dense monotypic stands which are physically daunting (because of the stiff thorns which circle the seed heads) and appear to be unattractive as forage for wildlife as well.

Surveys also revealed small populations of leafy spurge at Garden Creek. This particular weed species is especially difficult to deal with from a management standpoint. On the Pine Butte Swamp Preserve in Montana it occupies roughly 1000 A of the 18,000 A preserve. It occupies a variety of different habitat types, from grasslands to limber pine savannas and forms dense stands of near monocultures which can eliminate native species.

Further surveys at Garden Creek also revealed populations of common crupina (*Crupina vulgaris*) spotted knapweed (*Centaurea maculosa*) Russian knapweed (*Centaurea repens*) sulfur cinquefoil (*Potentilla recta*) and white top, *Cardaria* spp. This is just one example of a preserve that is threatened by numerous weed species. Different weeds threaten other preserves.

Purple loosestrife (*Lythrum salicaria*) is an invasive weed species that threatens wetland areas throughout the United States. Originally introduced into the United States as an ornamental, it is currently threatening wetlands along the Snake River at our Thousand Springs Preserve in Idaho. It has also been found on preserves in New York, Connecticut, Wisconsin, Minnesota and Oregon.

Tamarisk, *Tamarix* spp., is a relatively new threat in Idaho but a widespread problem in other areas. This woody shrub transpires enormous amounts of water and can dry up entire springs and pools, sometimes completely eliminating rare habitats for fish and other animals in the deserts of the southwest. On one of our California preserves, water from a spring began flowing again almost immediately after the tamarisk were removed.

As illustrated by these examples, The Nature Conservancy considers the invasion of aggressive weeds a very serious threat to the plants and animals we are trying to protect. Without management, these exotics can destroy the natural values of our preserves.

#### STRATEGIES FOR DEALING WITH WEEDS

When the Conservancy approaches a weed problem, we approach it from the stand point that we want to protect or restore the natural biological community. We look for strategies that will not only eliminate the problem species, but that will help restore the community to a condition where it will better resist invasion from new weed species. Often our first step is to learn as much as possible about the native community and the physical and biological processes that have helped form it. Next, we need to understand what it is about the invasive species that gives it the competitive advantage to gain a stronghold in the community.

Each situation is evaluated individually. The land manager makes his or her decision on the strategy to take based on the best information available.

At Garden Creek we began by gathering as much information as possible on both the native plant communities and the weed species in the area. We quickly realized that we did not know enough about what and where our problems were. Because of the large expanses and rugged terrain we decided to purchase a global positioning system to help us with our mapping and monitoring. After starting our survey work it became apparent that we had several weedy species that were very aggressive but still in small enough populations to be easily attacked. This became our top management priority. Our management strategy varied with the species.

In certain sandy soiled areas we organized volunteer parties to hand pull common crupina. A small patch of Russian knapweed was also hand pulled. The two leafy spurge patches demanded immediate attention. The larger area, near an ephemeral stream, was sprayed with dicamba, the smaller area, on a north facing hillside, was covered with a thick black plastic and only the perimeter was sprayed, this time with picloram.

Our second priority was to continue our survey work looking for additional weed populations while they were still of manageable size. This allowed us to identify and control additional small patches of weeds.

The third priority was given to monitoring areas where yellow star thistle appeared to be moving into healthy bunchgrass communities. Our initial monitoring shows that in an average to high moisture year the number of yellow star thistle plants in the 20 A area of high quality grassland surveyed declined. We believe that this may be because the extra moisture favored the established bunchgrasses.

We are currently pursuing our fourth and final priority, which is to begin restoration of areas where yellow star thistle has become well established. At this time we have established two test plots where we have either burned then drilled in native grass seed or sprayed and drilled in native grass seed. This next year we hope to begin trying experiments using livestock to trample in broadcast seed onto steep hillsides to reestablish native grasses.

Other preserves have used different strategies. At the Thousand Springs Preserve we farmed an abandoned hay field to reduce the weed crop before reseeding in the native species. Other Conservancy stewards have used fire very effectively to reduce weed populations. At the Pine Butte Swamp preserve in Montana the Conservancy has recently approved the release of the biocontrol agent *Aphthona nigricutis* to feed on the leafy spurge. However, because of the potential for damage to native plant and animal species, biocontrol agents are approached with caution and cannot be released on Conservancy preserves without the approval of our national board.

The Conservancy is willing to try a variety of methods to control weeds. Many people are surprised that we use herbicides. While we prefer to avoid widespread use of herbicides we recognize their effectiveness as a tool for specific situations. John Randall, weed specialist for the Conservancy, compares our use of herbicide to a surgeon performing surgery. If necessary, we will use herbicides to control weeds, but we also recognize that, just as a surgeon causes harm to his patient when he performs surgery, herbicides can damage the biological community. However, if the surgeon does not perform the surgery the patient may die. If we do not use herbicides we may risk losing what we are trying to protect. Whenever we use herbicides we must use caution and be as direct as possible in their application.

#### COOPERATION IS THE KEY TO CONTROLLING WEEDS

The Nature Conservancy does not have the ability to deal with all of the problems of weeds threatening our native communities. We would like to work closely with researchers from the weed science community, with organizations like WSWS and with other land managers to tackle these sometimes overwhelming problems. I have personally relied very heavily on researchers at different universities and from groups like the local RC&D and federal agencies for ideas and support.

Specific ways that we can work together include sharing information on the location and spread of weed species, educating the public about the threat of weeds to our wild areas and our wildlife, researching methods to restore disturbed areas, and working with landowners to deal with major weed problems cooperatively. Rather than emphasizing the differences between our groups we need to seek the common goals and needs which can bring us together.

## POSTER SESSION

**PLANT AND SMALL MAMMAL COMMUNITY DIVERSITY IN SAGEBRUSH STANDS THINNED WITH TEBUTHIURON.** K. H. Johnson, R. A. Olson, T. D. Whitson, G. L. Kurz, and R. J. Swearingen, Research Assistant and Assistant Professor, Department of Range Management, and Associate Professor and Research Assistants, University of Wyoming, Laramie, WY 82071.

**Abstract.** The big sagebrush ecosystem comprises 100 million ha of North American rangeland. Native wildlife species rely on sagebrush for forage and cover. Conversions of sagebrush rangeland to grassland monocultures to benefit livestock have sabotaged wildlife habitat and biodiversity.

In 1992 and 1993, we examined 10-ha plots at a site in northcentral Wyoming to assess the site-specific ecological implications of thinning sagebrush to various levels with the herbicide tebuthiuron. Plant and small mammal communities served as the research foci. Both years, small mammal community diversity was strongly dependent on plant community diversity. Lowest diversity values were found each year in the plot in which big sagebrush had been virtually eradicated; greatest diversity occurred in the plot in which sagebrush had been reduced from pretreatment cover of 31% to 12%. The positive, linear association of plant and small mammal community heterogeneity is significant at  $\alpha=0.10$ .

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**DICLOFOP-RESISTANT ITALIAN RYEGRASS IN NORTHERN IDAHO.** Traci A. Brammer, Donald C. Thill, and Carol A. Mallory-Smith, Graduate Research Assistant, Professor, and Post-Doctoral Research Fellow, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83844.

**Abstract.** Italian ryegrass is a weed that can reduce cereal crop yield significantly. It usually is controlled with diclofop, an acetyl-coenzyme A carboxylase (ACCase) inhibiting herbicide. However, diclofop-resistant Italian ryegrass biotypes that occur in the United States cannot be controlled with diclofop. In 1992, two sites of diclofop-resistant Italian ryegrass were discovered in Latah county of northern Idaho. A survey was conducted in Latah and Nez Perce counties of Idaho in August 1993, to determine the extent of the diclofop resistance. Fields selected for the survey had a long history of frequent diclofop use. Seed was collected from 30 plants in each of 18 fields in a "W" pattern. Fall samples were tested in the greenhouse for resistance or susceptibility to diclofop by spraying each sample with 0.56, 1.12, and 3.36 kg/ha diclofop applied preplant incorporated or postemergence to one- to two-leaf Italian ryegrass plants. The experiment was arranged as a randomized complete block factorial with four replications and was repeated. Known susceptible and resistant Italian ryegrass populations were included in every herbicide rate by field sample treatment. The preplant incorporated diclofop did not control known susceptible populations of Italian ryegrass. The percent survival was calculated by counting the number of living plants and dividing by the number of plants in the control times 100. About 30 to 50% of the samples had one or more plants survive diclofop applied at 3.36 kg/ha rate. Some plants in most field samples survived 1.12 kg/ha of diclofop. All samples had plants that survived diclofop applied at the 0.56 kg/ha. Samples were divided into three resistance categories: resistant, mixed (resistant/susceptible), or susceptible. The samples included four resistant, eight mixed, and six susceptible populations. Survey results indicated that diclofop-resistant Italian ryegrass is not widespread in northern Idaho. Prompt initiation of specific resistant weed management practices may reduce and/or eliminate the spread of diclofop-resistant Italian ryegrass in the area. Practices include, but are not limited to, cultural controls, rotation to herbicides with different sites of action, and improved sanitary practices.

#### **A BLESSING FOR WEEDS? KENTUCKY BLUEGRASS SEED PRODUCTION WITHOUT BURNING.**

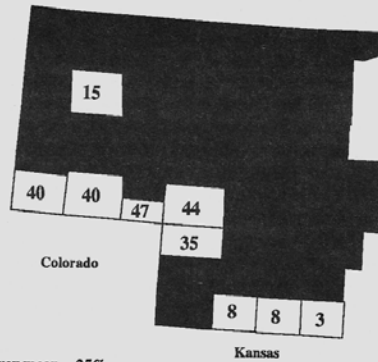
Kathryn A. Hamilton, Donald C. Thill, and Glen A. Murray, Graduate Research Assistant, Professor and Professor, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83844.

**Abstract.** The control of weeds and other grasses is a principal production problem in Kentucky bluegrass grown for seed. Annual weeds are one of the major factors limiting successful stand establishment. No grass seed is harvested during the establishment year. Planting a companion crop such as spring wheat with Kentucky bluegrass could allow some economic return during the establishment year, but also may reduce Kentucky bluegrass stand establishment. A competition study was established in May 1993 to assess the competitive effects of a 'Wakanz' spring wheat companion crop and wild oat against Kentucky bluegrass. Wheat and wild oat were planted in a split-plot randomized block design, and the densities attained were 33, 58, 95, 142 and 146 plants/m<sup>2</sup> for wild oat and 40, 59, 104, 161 and 184 plants/m<sup>2</sup> for wheat. Kentucky bluegrass variety 'Glade' was seeded perpendicular to the crop and weed on the same day at 3.4, 6.7 and 10.1 kg/ha. Kentucky bluegrass biomass at late boot stage of wheat was reduced to 28% and 25% of the control, at the lowest density of wild oat or wheat, respectively. The Kentucky bluegrass seed harvest in July 1994 should demonstrate whether the bluegrass is able to recover from this early competition to sustain adequate yields. The substitution of established burning practices for residue removal with non-thermal methods is likely to have a great impact on the weed population and spectrum. A crew-cutting vacuum machine that removes residue is being tested in combination with herbicides to determine the effects on weed control in established Kentucky bluegrass. In a randomized complete block design 1 spring applied and 8 fall applied herbicide treatments were tested on a crew-cut area of Kentucky bluegrass at two locations. Both sites were in the second seed year. At both locations the spring applied treatment of fenoxaprop-MCPA-2,4-D injured the Kentucky bluegrass 98% which was reflected in the reduced number of panicles and low seed yield. Most of the other herbicides controlled weeds effectively.

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**LOOKING FOR JOINTED GOATGRASS AT THE GRAIN ELEVATOR: A SURVEY.** Drew J. Lyon, John A. Smith, and David D. Jones, Assistant Professor Agronomy and Associate Professor Biological Systems Engineering, University of Nebraska, Scottsbluff, NE 69361; and Assistant Professor Biological Systems Engineering, University of Nebraska, Lincoln, NE 68583-0726.

**Abstract.** Winter wheat grain contaminated with jointed goatgrass joints is often discounted as much as 20% by grain buyers. A mail survey to Nebraska farmers in 1984 identified jointed goatgrass as one of the ten worst weed problems in winter wheat, but a field survey to the same area in 1986 found it in less than 1% of surveyed fields. The objective of this survey was to map the geographic distribution and severity of jointed goatgrass contaminating winter wheat grain in western Nebraska. Wheat samples of approximately 1.4 to 2.4 kg were collected from trucks delivering new crop to grain elevators in the nine leading wheat producing counties of Nebraska. A total of 1295 samples were collected and screened for jointed goatgrass from 1990 to 1992. Jointed goatgrass was found in 25, 29, and 20% of all wheat samples collected in 1990, 1991, and 1992, respectively. Nebraska counties bordering Colorado were found to have the highest percentage of wheat samples contaminated with jointed goatgrass joints, ranging from 23% in Cheyenne county in 1992 to 61% in Keith county in 1991 (Figure). Winter wheat-fallow is the predominate rotation in these counties. Counties bordering Kansas had the lowest jointed goatgrass contamination rates. Three-year rotations of winter wheat-corn or sorghum-fallow are common in these counties due in part to higher precipitation levels.



Three year survey mean = 25%

Figure. Average percent of winter wheat samples collected at harvest in nine western Nebraska counties from 1990 through 1992 that contained at least one jointed goatgrass joint.

**CONTROL OF DUNCECAP LARKSPUR (*Delphinium occidentale* (WATS.) WATS) AT TWO GROWTH STAGES WITH VARIOUS HERBICIDES.** Tom D. Whitson, Ron J. Swearingen, Gerald E. Fink, and Jim R. Gill, Extension Weed Specialist and Associate Professor, Research Associate, Plant, Soil and Insect Sciences Dept., University Extension Educator, Johnson and Washakie Co., University of Wyoming, Laramie, WY 82071.

**Abstract.** Duncecap larkspur, a deep-rooted palatable perennial, growing on high elevation rangelands, contains up to 20 alkaloids which vary in toxicity. Larkspurs are the leading cause of cattle deaths on mountain rangeland and causes greater economic loss to the range cattle industry than any other poisonous plant in the 17 western states.

Six studies were established starting in 1987 in the Big Horn Mountains of Wyoming to study the control of duncecap larkspur with applications of various herbicides. Two initial studies with 25 treatments were applied at two growth stages to determine herbicidal activity on duncecap larkspur. The herbicides picloram and metsulfuron provided effective control the first and second years following application. Two other studies were initiated in the vegetative and bloom stages of duncecap larkspur in 1989 to determine rates and application timing necessary for picloram and metsulfuron. Metsulfuron at 0.038 lb/A and above applied in the 4- to 5-leaf stage and picloram at 1.5 lb/A and above applied in the early bloom stage provided greater than 86% control 4 yr following treatments. A study was initiated in 1991 comparing the effect of 2,4-D combined with metsulfuron and picloram. There were advantages for combining metsulfuron with 2,4-D while control was reduced when picloram was combined with 2,4-D.

**DISSIPATION OF ATRAZINE AND METOLACHLOR IN FURROW IRRIGATED, CONVENTIONAL TILL AND MINIMUM TILL GRAIN SORGHUM.** J. Schroeder and R. R. Parra, Associate Professor and former Sr. Research Assistant, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003.

**Abstract.** Field experiments were conducted in 1991 and 1992 near Clovis, New Mexico on a Pullman clay loam soil (fine, mixed, thermic Torrertic Paleustoll, pH 7.4, 1% O.M.) to determine the influence of furrow irrigation and tillage practice on the movement and persistence of atrazine and metolachlor. Treatments were minimum or conventional tillage in a randomized complete block design with four replications. Plot size was 5 m (5 raised plant beds) by 25 m. Metolachlor and atrazine were applied at 5.6 kg/ha in 280 L water/ha with a CO<sub>2</sub> backpack sprayer preemergence to grain sorghum. Petri dishes containing 13 g dry sieved soil were placed in the plots to determine application rate. Plots were furrow irrigated immediately after herbicide application and after the 35 d sampling date each year. Soil samples to a depth of 60 cm were taken from the top of the raised plant bed and the furrows between the plant beds around day 7, 14, 35, 77, and 360 after treatment and divided into 7.5 cm segments. Three samples were taken from each area per plot and subsamples from equivalent segments were composited, air dried, sieved, and stored frozen for herbicide analysis. Herbicides were extracted from 10 g samples by shaking with a water/methanol (50:50) solution. Extracts were evaporated to dryness, the residue dissolved in benzene, and an aliquot injected into a <sup>63</sup>Ni electron capture detector equipped gas chromatograph. Lower limit of detection was 50 ng/g soil for metolachlor and atrazine.

Dissipation of metolachlor and atrazine from the 0 to 7.5 cm depth was slower in the bed under conventional till than minimum till in 1991. Tillage did not influence dissipation from the 0 to 7.5 cm depth in the furrow. Dissipation in the furrow compared to the dissipation under minimum till in the bed. No rain fell 18 d prior to 1991 treatment or 14 d after treatment. Furrow irrigation saturated the soil under the furrow with greater lateral movement into the bed under minimum till management. Atrazine was not detected below a depth of 15 cm in the furrow and 23 cm in the bed. Metolachlor was not detected below a depth of 23 cm in the furrow or the bed. Atrazine and metolachlor were not detected at any depth 365 d after treatment.

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**MANUAL CONTROL OF DYERS WOAD ON HEAVILY INFESTED RANGELAND AND NON-CROP SITES IN NORTHERN UTAH.** H. E. Dorst, S. A. Dewey, and J. O. Evans, Professor Emeritus, Associate Professor, and Professor, Department of Plants, Soils, and Biometeorology, Utah State University, Logan, UT 84322-4820.

**Abstract.** Volunteers contributed more than 3175 h during 14 summers from 1980 through 1993, manually controlling dyers woad on heavily infested non-crop sites and foothill rangelands near Logan, Utah. The project began with one person pulling dyers woad on 16.5 A, and eventually expanded to include over 200 volunteers controlling the weed on approximately 750 A. Since 1992, most of the volunteer groups have been troops of 12- and 13-year-old Boy Scouts.

The total project area was divided into units of varying acreages to accommodate the size and capabilities of individual volunteer groups. The number of land units included in the project has increased from one in 1980, two in 1985, and nine in 1986; to a total of 23 in 1993.

Control methods consisted primarily of hand-pulling, hoeing, or digging flowered plants. However, most crews also removed obvious dyers woad rosettes and seedlings. Mature fruits encountered on advanced plants were stripped into buckets or plastic bags and removed from the site. Work crews covered each infested area an average of twice per season; once in mid- to late-May when dyers woad plants were approaching full bloom, and again approximately 3 to 4 wk later. Annual reductions in the number of worker-hours required to accomplish the task were carefully recorded, and used to approximate changes in dyers woad density on individual land units.

Work hours required annually in each of six representative land units are listed in Tables 1 and 2. Reductions in average annual labor requirements from the six land units are contained in Table 3. An average 49% fewer h were required to control dyers woad in the second season of manual control, and all units reached at least a 50% reduction in required worker h within at least 4 yr after manual control was initiated. There was a 75% or greater reduction in time required to control dyers woad in the second or third season on four of the six reported study units. Within 8 yr after beginning manual weed control efforts, average worker time requirements had been reduced by 90%. Significant reductions in dyers woad density were visually apparent each year to most crews assigned to work on the same land unit for 2 or more consecutive yr. Variability in the number of years needed to achieve a consistently high level of control was attributed to a combination of variables, including initial dyers woad density, site-specific environmental factors, ruggedness of terrain, and worker commitment.

Once low dyers woad densities were achieved, they were relatively easy to maintain by annually monitoring and pulling remaining scattered plants. Eradication was not achieved on any land unit, but actual control equalled or exceeded 95% (visual estimates) on most units retained in the program for 8 or more yr. Percent reductions in worker-hours do not correspond perfectly to percent dyers woad control, especially when woad densities become low. This is because a minimum number of hours are required to patrol each land unit, even if the dyers woad control were 100%. Constant reintroduction of seed from heavily infested adjacent lands will require ongoing annual control on all units in order to maintain low dyers woad density levels.

Table 1. Annual reductions in hours required to manually control dyers woad each on sites I, II, and III.

Year	Land Unit I (16.5 A)		Land Unit II (52 A)		Land Unit III (66 A)	
	Time	Reduction*	Time	Reduction*	Time	Reduction*
	h	%	h	%	h	%
1982	75	--				
1983	56	25				
1984	48	36				
1985	59	21	82	--		
1986	35	53	18	78	84	--
1987	46	39	23	72	20	76
1988	25	67	23	72	27	68
1989	14	81	20	76	24	71
1990	3	96	10	88	26	69
1991	2	97	14	83	42	50
1992	2	97	4	95	26	69
1993	2	97	2	98	11	87

\*Percent reduction for each year is based on a comparison with the hours required in the first year of control.

Table 2. Annual reductions in hours required to manually control dyers woad each on sites IV, V, and VI.

Year	Land Unit IV (64 A)		Land Unit V (10 A)		Land Unit VI (70 A)	
	Time	Reduction*	Time	Reduction*	Time	Reduction*
	h	%	h	%	h	%
1986	44	--				
1987	22	50	24	--	144	--
1988	6	86	20	17	72	50
1989	4	91	10	58	28	81
1990	4	91	9	63	12	92
1991	3	93	6	75	11	92
1992	2	95	5	79	8	94
1993	2	95	4	83	4	97

\* Percent reduction for each year is based on a comparison with the hours required in the first year of control.

Table 3. Average relative labor requirement (percent of Year 1) for manual control of dyers woad on six representative land units.

YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12
100	51	33	32	24	26	18	10	3	3	3	3

**HERBICIDE SYMPTOMS, CLASSIFICATION BY MODE OF ACTION.** Barry R. Tickes, Dave Cudney, and Clyde Elmore, University of Arizona Cooperative Extension, Yuma, AZ 85364 and University of California Cooperative Extension, Riverside, CA 92521 and Davis, CA 95616.

Herbicides are applied with the goal of injuring or killing unwanted plants. Many of the herbicides used in California are selective because they injure weeds and cause minimal disruption of desirable plants. Occasionally, however, desirable plants are injured. This can happen through soil residues of herbicides from applications in previous crops, from spray drift of herbicides moving "off target", or from mistakes in application rates or improper herbicide choice. Crop injury can be caused by many factors and may not be due to herbicides. Nutrient deficiencies, salinity, drought, insect, disease and nematode injury can all produce crop symptoms that can be mistaken for herbicide damage. It would be helpful to know what types of injury to expect from the herbicides that are most commonly used.

The following project was established in order to capture pictorial evidence of the symptoms produced by the most common herbicides. These herbicides were grouped into 10 categories or "families" based on their modes of action. Seven crops were selected and treated with levels of herbicides sufficient to produce symptoms characteristic of their "herbicide family". The seven crops were: bean, tomato, sugarbeet, cotton, corn, wheat, and woody plants. Approximately 25 herbicides were grouped into the 10 "families". Both pot studies and field studies were used to produce the herbicide symptoms. The goals of the project are: 1) to produce a slide set which would be useful to weed scientists and others who work with herbicides, 2) to produce a book with descriptions and pictures of herbicide symptoms which would be a useful reference to those trying to discern herbicide injury from other crop injury symptoms. The 10 herbicide "families" grouped by mode of action consisted of:

1. The growth regulator herbicides (2,4-D, MCP, dicamba and triclopyr). These are mostly foliar applied herbicides which are systemic and translocate in both the xylem and phloem of the plant. They mimic natural plant auxins causing abnormal growth and disruption of the conductive tissues of the plant. The injury from this family of herbicides consists of twisted, mal-formed leaves and stems.
2. The inhibitors of amino acid synthesis (glyphosate, imazethapyr, sulfosate, chlorsulfuron and sulfometuron). Both foliar and soil applied herbicides are in this family. Glyphosate and sulfosate translocate in the phloem with photosynthate produced in the leaves. Others in this family move readily after root or foliar absorption. These herbicides inhibit certain enzymes critical to the production of amino acids. Amino acids are the building blocks of proteins. Once protein production stops, growth stops. Symptoms are stunting and symptoms associated with lack of critical proteins.
3. Cell membrane disrupters (oxyfluorfen, lactofen and acifluorfen). Soil and foliar applied with limited movement in soil. These herbicides enter the plant through leaves, stems and roots, but are limited in their movement once they enter the plant. Membrane damage is due to lipid peroxidation. Symptoms are necrosis of leaves and stem.
4. Lipid biosynthesis inhibitors (diclofop, fluzafop, sethoxydim and clethodim). Foliar applied (diclofop has both soil and foliar activity). Herbicides in this family move in both the xylem and phloem of the plant and inhibit enzymes critical in the production of lipids. Lipids are necessary to form plant membranes which are



essential to growth and metabolic processes. Symptoms include stunting and death of tissue within the growing points of plants.

5. Pigment inhibitors (norflurazon, fluridone and amitrole). Soil applied and move in the xylem except amitrole which moves in both phloem and xylem. These herbicides inhibit carotenoid biosynthesis leaving chlorophyll unprotected from photo-oxidation. This results in foliage which lacks color. Symptoms include albino or bleached appearance of foliage.

6. Growth inhibitors of shoots (thiocarbamide herbicides including: EPTC, cycloate, pebulate and molinate). Soil applied and somewhat volatile, requiring incorporation. Enter the plant through the roots and translocated through the xylem with the transpiration stream to the growing points in the shoot. Mode of action is unclear, but, affect developing leaves in growing points of susceptible plants. Symptoms include stunting and distortion of seedling leaves, leaves often stick together.

7. Growth inhibitors of both shoots and roots (chloroacetamide herbicides including: alachlor, metoachlor and lutachlor). Soil applied herbicides which enter the plant from the soil through roots and shoots. Movement within the plant is limited once the herbicide is absorbed. These herbicides interfere with protein synthesis and normal cell division. Symptoms include stunting and distortion of seedling leaves.

8. Herbicides which disrupt cell division (trifluralin, DCPA, oryzalin, pronamide, pendimethalin and napropamide). All are soil applied with limited movement in the soil. Absorbed through roots or emerging shoot tips. Once absorption takes place movement is limited (site of action is near the site of absorption). These herbicides inhibit cell division or mitosis, except pronamide and nupropamide which stop cell division before mitosis. Symptoms include stunting and swollen root tips.

9. Cell membrane disrupters (paraquat and diquat). These herbicides are foliar applied with no soil activity or movement in the soil. They enter the plant through the leaves and stems and do not move significantly within the plant once absorbed. These herbicides receive energy from the light reaction of photosynthesis resulting in the formation of destructive compounds within the leaves and green stem tissue. Symptoms include necrosis of the leaves and stem.

10. Inhibitors of photosynthesis (atrazine, simazine, metribuzin, cyanazine, diuron, linuron, tebuthiuron and bromacil). These are soil applied herbicides, however, all except simazine also have foliar activity. They move readily in the plant in the xylem with the transpiration stream where they concentrate in the leaves at the site of photosynthesis. Once there they block the electron transport system of photosynthesis causing a buildup of destructive high energy products which destroy chlorophyll and ultimately the leaf tissues. Symptoms include yellowed chlorotic leaves which become necrotic.

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**WEED CONTROL IN FIELD CORN WITH METRIBUZIN APPLIED POSTEMERGENCE ALONE OR IN COMBINATION.** E. J. Gregory, R. N. Arnold, and D. Smeal, Professor, Pest Management Specialist, and College Assistant Professor, New Mexico State University Agricultural Science Center at Farmington, Farmington, NM 87499.

**Abstract.** Weeds compete vigorously with corn for light, nutrients, and moisture. Season-long interference from weeds can reduce corn yields as much as 90%. A field experiment was conducted in 1993 at Farmington, New Mexico to evaluate the response of field corn (Grand Valley 1230) and annual grass and broadleaf weeds to postemergence applications of metribuzin applied alone or in combination. Metribuzin applied at 0.19 and 0.28 lb/A caused the highest injury rating of 41 and 75%, respectively. In both rating periods, prostrate pigweed, cutleaf nightshade, green foxtail, and barnyardgrass control was excellent with all treatments except the check. Redroot pigweed control was better with all treatments in July as compared to June except for metribuzin applied at 0.28 lb/A. Russian thistle control was good to excellent with all treatments except metribuzin applied at

0.09 lb/A and the check. Data further showed that there were no significant differences among treatments for plant height and stand count. Yields were 10 to 20 bu/A higher in the herbicide treated plots as compared to the check. Metribuzin applied at 0.28 lb/A had lower yields than any other treatment except the check.

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**BROADLEAF WEED CONTROL IN FIELD POTATOES.** R. N. Arnold, E. J. Gregory, and D. Smeal, Pest Management Specialist, Professor, and College Assistant Professor, New Mexico State University Agricultural Science Center at Farmington, Farmington, NM 87499.

Abstract. Weeds compete vigorously with potatoes for light, nutrients, moisture, and interfere with harvesting operations. A field experiment was conducted in 1993 at Farmington, New Mexico to evaluate the response of 'Snowden' potatoes and annual broadleaf weeds to herbicides. No crop injury was observed in any of the treatments. In June and July, metolachlor II applied at 1 lb/A gave poor control of prostrate pigweed and Russian thistle. Black nightshade control was good to excellent with all treatments except metolachlor II applied at 1 and 1.5 lb/A. Redroot pigweed control was good to excellent with all treatments except the check. Potato yields for grading size 1.88 to 3 inches were 286 to 89 cwt/A higher in the herbicide treated plots as compared to the check. Dimethenamid plus metribuzin applied at 0.75 plus 0.3 lb/A was the highest yielding treatment for grading size 1.88 to 3 inches of 424 cwt/A.

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**EFFECT OF BROOM SNAKEWEED STAGE OF PLANT GROWTH ON PICLORAM UPTAKE AND PICLORAM-INDUCED ETHYLENE PRODUCTION.** T. M. Sterling, N. K. Lownds, and L. W. Murray, Assistant Professor and Associate Professors, Department of Entomology, Plant Pathology, and Weed Science, Department of Agronomy and Horticulture, and Department of Experimental Statistics, New Mexico State University, Las Cruces, NM 88003.

Abstract. Broom snakeweed is a perennial rangeland shrub widely distributed in the western United States. It reduces forage production and is poisonous to livestock. One of the primary herbicides used for broom snakeweed control is picloram; however, efficacy can vary when applied during different times of the year.

A 3 yr study was conducted to evaluate the effects of stage of plant growth and environmental factors prior to application on herbicide uptake and the picloram-induced response, ethylene production. Plants were permanently marked on the USDA Jornada Experimental Range located near Las Cruces. Every 2 wk, two stems (ca. 10 cm long) were excised from each plant, cut ends were submerged in a 15-ml vial containing 2 ml distilled water, and all samples were brought to the lab for herbicide treatment. Picloram was applied as five 0.25- $\mu$ l droplets (770  $\mu$ m diam) per leaf to the adaxial surface of two leaves located 2 to 3 cm from the shoot apex. Treatment solutions contained 266 MBq ml<sup>-1</sup> of picloram-2,6-<sup>14</sup>C and <sup>12</sup>C-picloram to reach a final picloram concentration of 6.2 mM with equimolar KOH at pH 9.5. Immediately following droplet application, stems were placed in a growth chamber at 28/20 C day/night temperatures and 50% relative humidity. Twenty-four hours after treatment, treated leaves were removed from the stems and surface picloram residue was removed with two 1-ml rinses of 50% aqueous methanol. Ethylene production by treated leaves and untreated tissues was determined by placing tissues in 10-ml test tubes and capping. Tubes were incubated at 30 C for 2 h after which ethylene production was determined by removing a 1-ml headspace sample and quantified using gas chromatography. Tissues were weighed and oxidized. Radioactivity in each sample was quantified using liquid scintillation spectrometry. A multiple regression model was developed for the response, picloram uptake (% of applied, nmol picloram, nmol picloram g fresh weight<sup>-1</sup>) using predictor variables maximum, minimum, and average temperature and average precipitation 1, 2, 7, and 14 d prior to application. Similarly, picloram-induced ethylene production by treated leaf, untreated tissue, or total tissue, was modelled using predictor variables minimum, maximum, and average temperature and average precipitation 1, 2, 7, or 14 d prior to application and

tissue picloram content (nmol or % of applied) or concentration (nmol g fw<sup>-1</sup>). An ANOVA was conducted for months (averaged over 3 yr) and means separated using LSD.

Picloram uptake was best predicted by average precipitation and minimum temperature 7 d prior to treatment. Picloram-induced ethylene production in total tissue was best predicted by picloram concentration and average precipitation and minimum temperature 7 d prior to treatment. Picloram uptake was greatest in July and August and picloram-induced ethylene production was greatest in July, August, and September when plants were regreening and flower buds emerging.

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**CONSUMPTION DIFFERENCES AMONG WOOLLY LOCO VARIETIES BY A SPECIALIST WEEVIL.** D. C. Thompson, J. A. Parreira, and T. M. Sterling, Assistant Professor, Graduate Assistant and Assistant Professor, Department of Entomology, Plant Pathology and Weed Science, New Mexico State University, Las Cruces, NM 88003.

**Abstract.** Woolly loco is a harmful rangeland weed of New Mexico. Chemical and mechanical methods for the control of woolly loco are not economical on New Mexico rangelands. Biological control of woolly loco is an alternative to these two methods. A potential biological control agent *Cleonidius trivittatus*, has been found for woolly loco. This weevil was found on one variety of woolly loco in Gladstone, New Mexico. Six woolly loco varieties have been identified in New Mexico.

No-choice and choice feeding tests were undertaken during the fall of 1993 to evaluate weevil feeding differences on the different varieties of woolly loco and silky crazyweed. One weevil and pieces of leaf tissue between 2 to 2.1 cm<sup>2</sup>, from one type of locoweed, were placed into a 10-cm-diameter petri dish containing dampened filter paper for the no-choice test. One weevil and seven whole leaves of each locoweed type were placed into a 15-cm-diameter petri dish containing damp filter paper for the choice test. In the choice test the leaves were arranged in a circle and were 2.1 cm from each other. All leaves used were between 0.28 and 0.92 cm<sup>2</sup>. Before weevils were put into the petri dish they were starved for 24 h in both the choice and no-choice test. Leaf area was measured before and 24 h after feeding. Silky crazyweed, a close relative of woolly loco, was used to confirm specificity for woolly loco in both the choice and no-choice test.

No-choice test average consumption (mean ± se) for woolly loco varieties and silky crazyweed by the weevil was 1.056 ± 0.076 cm<sup>2</sup> for variety *mollissimus*, 1.065 ± 0.087 cm<sup>2</sup> for variety *thompsonae*, 1.041 ± 0.105 cm<sup>2</sup> for variety *mathewsii*, 0.851 ± 0.093 cm<sup>2</sup> for variety *earlei*, 0.644 ± 0.068 cm<sup>2</sup> for variety *mogollonicus*, 0.700 ± 0.096 cm<sup>2</sup> for variety *bigelovii* and 0.004 ± 0.002 cm<sup>2</sup> for silky crazyweed. Choice test average consumption (mean ± se) was 0.226 ± 0.055 cm<sup>2</sup> for variety *mollissimus*, 0.110 ± 0.033 cm<sup>2</sup> for variety *thompsonae*, 0.207 ± 0.042 cm<sup>2</sup> for variety *mathewsii*, 0.210 ± 0.051 cm<sup>2</sup> for variety *earlei*, 0.035 ± 0.012 cm<sup>2</sup> for variety *mogollonicus*, 0.102 ± 0.035 cm<sup>2</sup> for variety *bigelovii* and 0.018 ± 0.008 cm<sup>2</sup> for silky crazyweed. Results suggest that silky crazyweed is not consumed and that there are differences in the consumption of woolly loco varieties by the weevil, *C. trivittatus*. Because of these results, further studies on genetic distance and environmental differences between woolly loco varieties will be undertaken to better understand the feeding preference of the weevil for the woolly loco varieties.

**DIFFERENTIAL CLOMAZONE RESPONSE IN PICKLING CUCUMBER.** Kassim Al-Khatib, Sorkel Kadir, and Carl R. Libbey, Assistant Weed Scientist, Research Associate, and Agricultural Research Technologist II, Mount Vernon Research and Extension Unit, Washington State University, Mount Vernon, WA 98273.

#### INTRODUCTION

Clomazone has been widely used as a preplant incorporated herbicide for weed control in many horticultural and agronomic crops. Clomazone would be a desirable herbicide for use in cucumbers because it controls several weeds that are difficult to control including shepherdspurse, chickweed, lambsquarters, barnyardgrass, and foxtails. However, clomazone has not been registered for use in cucumbers because of questionable crop safety. Howard *et al.* (1) demonstrated that clomazone caused severe injury symptoms in cucumbers. However, these symptoms did not reduce yield.

Although clomazone may cause visible injury symptoms on cucumber plants, yield may increase due to weed control as compared to a weedy crop (1). Therefore, it is impossible to determine the tolerance of crops or cultivars to herbicide unless the environment is weed-free. By removing the confounding factor of weeds, the herbicide injury to crops can be determined.

Visible phytotoxicity ratings have been widely used to evaluate clomazone damage on crops (2, 3). However, this visual estimation may not accurately predict yield losses because plants might recover from clomazone damage with no yield reduction (1). The reliability of visible symptoms to predict crop injury could be evaluated by comparing visible injury with yield reduction, if the confounding factor of weed competition is removed.

Green peas, snap beans, summer squash, cucumbers and watermelons have displayed variable cultivar tolerance to clomazone (2, 3). However, this differential cultivar tolerance was based on visual symptoms. The objective of this research was to evaluate the tolerance of five pickling cucumber cultivars to clomazone. In addition, phytotoxicity ratings were compared with actual yield reduction to determine the correlation of visible injury symptoms with yield.

#### MATERIALS AND METHODS

**Field studies.** This research was conducted in 1992 and 1993 at the Mount Vernon Research and Extension Unit, Mount Vernon, WA, on Skagit silt loam. Soil organic matter was 2.6% and 2.3% in 1992 and 1993, respectively. Soil pH was 5.9 in both years. Conventional tillage practices were followed and plots were maintained weed-free by hand hoeing.

'Quest', 'Prince', 'Calypso', 'Sunre 3537', and 'Pioneer' pickling cucumbers were planted on June 10, 1992 and June 28, 1993. Seeding rate was 250,000 seeds ha<sup>-1</sup>. Plots consisted of four 4.5 m rows spaced 106 cm apart.

Clomazone was applied preplant incorporated at 0, 0.28, 0.56, 0.84, and 1.68 kg ha<sup>-1</sup>. Clomazone was incorporated with a rototiller to a 2.5 cm depth. The herbicide was applied with a tractor-mounted compressed-air sprayer. The sprayer was equipped with 8002LP flat fan nozzles delivering 140 L ha<sup>-1</sup> at 103 kPa. The experimental design was a split plot where cultivars were the main plots and the clomazone rates were subplots.

Plants were observed for symptoms every 5 d. Injury ratings were estimated visually every 10 d. Injury rating was based on 0 = no injury, 100 = complete kill. Cucumber population was determined by counting number of cucumber plants in each plot 30 d after planting. Cucumbers were harvested when 50% of the fruits were 8 cm long.

**Greenhouse studies.** 'Quest', 'Prince', 'Calypso', 'Sunre 3537', and 'Pioneer' pickling cucumbers were germinated in vermiculite moistened with half-strength Hoagland solution. One-week-old seedlings were transplanted into opaque containers. Each container held four plants and one liter of half-strength Hoagland solution. One wk

after transplanting, the Hoagland solution was replaced and clomazone was added to obtain solutions with 0, 0.125, 0.25, 0.50, or 1 ppm clomazone.

Plants were sampled for leaf area, chlorophyll content and dry weight 14 d after clomazone treatments. Leaf area was measured with a photoelectrical meter. Leaf chlorophyll content was measured by using the Arnon method. Cultivars and clomazone rates were arranged in randomized complete block design. Treatments were replicated three times and the experiment was repeated twice. The data were analyzed using standard analysis of variance and regression analyses on appropriate data.

## RESULTS AND DISCUSSION

**Field studies.** All clomazone rates caused symptoms 30 d after treatment. Clomazone symptoms ranged from slight, at the lowest rate, to severe, at the highest rate (Figure 1). Symptoms included stunting, interveinal chlorosis, and marginal chlorosis. In general, symptoms were more severe in 'Sunre 3537' and 'Pioneer' than other cultivars. 'Prince' and 'Calypso' showed the least clomazone injury. Clomazone rates that caused 50% injury were 0.62, 0.64, 0.82, 0.92, and 1.1 kg ha<sup>-1</sup> in 'Sunre 3537', 'Pioneer', 'Quest', 'Prince', and 'Calypso', respectively. At 45 to 55 d after treatment, plants recovered from injury at the lower two rates of clomazone. Recovery was more rapid in 'Calypso' and 'Prince' than other cultivars.

Clomazone reduced cucumber populations when applied at rates higher than 0.56 kg ha<sup>-1</sup>. Again, this reduction was more severe in 'Sunre 3537' and 'Pioneer' than in other cultivars (Figure 2).

Cucumber yields were reduced by clomazone at rates higher than 0.28 kg ha<sup>-1</sup> (Figure 3). Clomazone reduced yields more in 'Sunre 3537' and 'Pioneer' than other cultivars. Clomazone rates that caused 50% yield reduction were 1.02, 1.03, 1.13, 1.17, and 1.2, kg ha<sup>-1</sup> in 'Sunre 3537', 'Pioneer', 'Quest', 'Calypso' and 'Prince', respectively. In general, clomazone rates that caused 50% yield reduction were higher than the rates which caused 50% injury symptoms. These results showed that clomazone injury symptoms are not a reliable indicators for yield reduction ( $r = -0.53$ ).

**Greenhouse studies.** At 7 d after clomazone treatment, symptoms of clomazone injury were similar in all cucumber cultivars. However, 'Calypso' and 'Prince' showed rapid recovery from injury symptoms. Fourteen d after clomazone treatment, differences between cultivars in the intensity and number of leaves that showed symptoms were evident. Leaf area, chlorophyll content, and total dry weight were reduced more in 'Sunre 3537' and 'Pioneer' as compared to other cultivars. 'Calypso' and 'Prince' were the least sensitive cultivars, and 'Quest' was intermediate. Leaf area and total dry weight was more affected by clomazone than chlorophyll content (Figure 4).

## CONCLUSIONS

'Quest', 'Prince', 'Calypso', 'Sunre 3537', and 'Pioneer' cucumbers showed good tolerance to clomazone at rates lower than 0.56 kg ha<sup>-1</sup>. However, at higher rates, cultivars responded differently to clomazone with 'Sunre 3537' and 'Pioneer' being the most sensitive cultivars and 'Prince' and 'Calypso' being the least sensitive cultivars.

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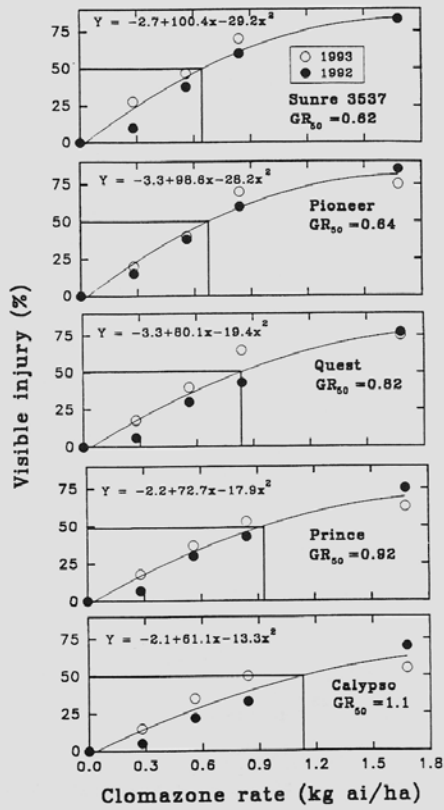


Figure 1. Visible clomazone injury to five cucumber cultivars 30 d after planting.

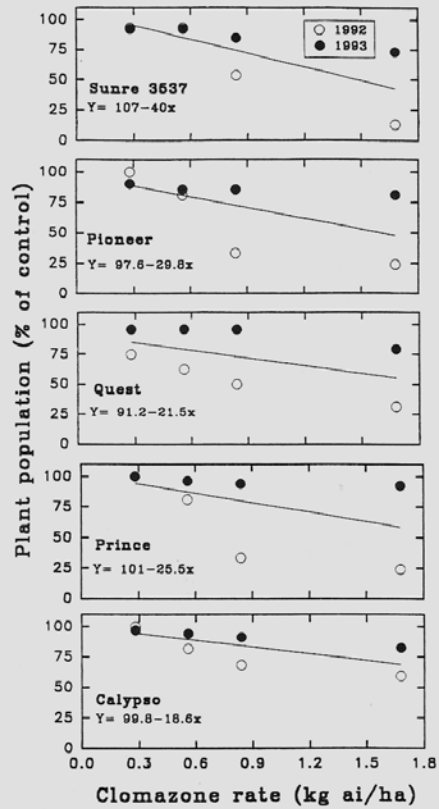


Figure 2. Population of five cucumber cultivars as affected by clomazone.

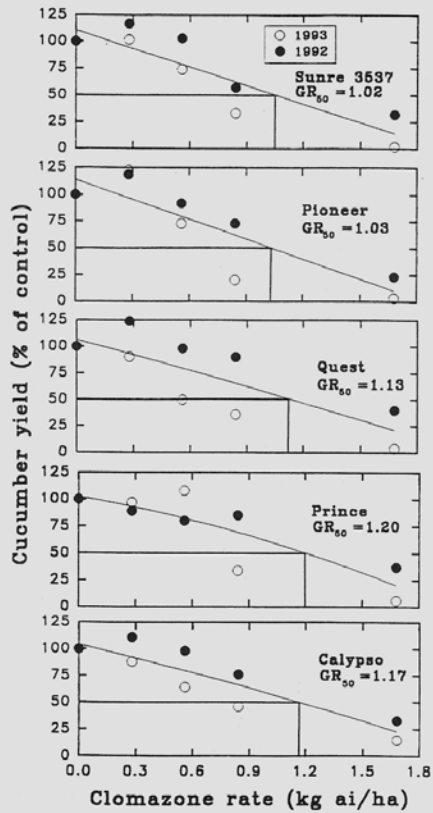


Figure 3. Yields of five cucumber cultivars as affected by clomazone.

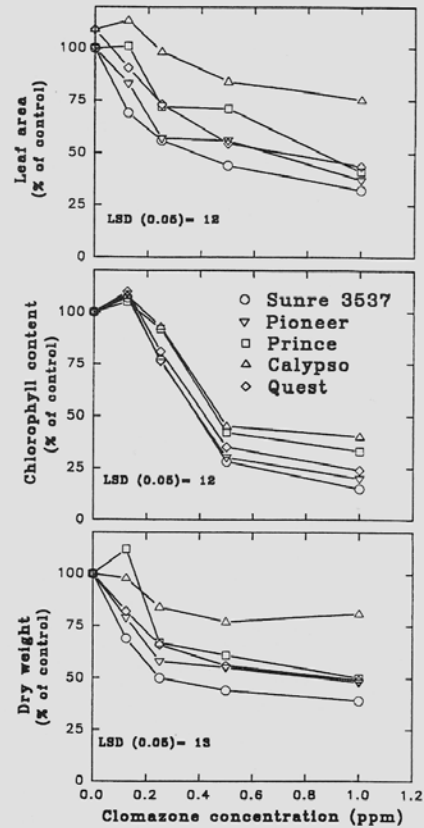


Figure 4. Leaf area, chlorophyll content, and total dry weight of cucumbers grown in hydroponic system as affected by clomazone.

**W.E.E.D.S. 2.0: COMPUTER-ASSISTED WEED IDENTIFICATION FOR THE WESTERN UNITED STATES.** R. H. Callihan, S. L. Carson, and R. T. Dobbins, Extension Weed Specialists and Research Assistants, Dept. of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83844.

Abstract. Weed identification is a serious deficiency in land management. Weed management is tantamount to a war in which the defenders do not know how to recognize the enemy. Contrary to prevailing conceptions, however, weed identification *need not be difficult*.

Education in weed identification is part of the University of Idaho extension specialist program to enhance the ability of land managers to recognize and deal with present and future weed problems. In the past, the University of Idaho extension weed specialists experienced a continual high frequency of requests from Extension and others to present special and other classes and workshops on weed identification. We received an average of 1 to 2 specimens per day for identification. The need to increase our capabilities in recognition of alien weeds became apparent when we saw that species have been reported each year in Idaho alone each year. There are about 1000 weed species in weed reference books used in the western U.S., over 1200 more in the U.S. that threaten to invade the western States, and many more potential invaders from other countries. Because of the admitted lack of competence on the part of county agents, some system of upgrading their competence and resources was needed.

A computerized system was developed to function as (1) a programmed learning tool for county agents to use for personal study, (2) clientele instruction, and (3) clinical use. The motivation for developing this was Idaho's need, but the need is worldwide. The software system is now in its first revision, and is called WEEDS 2.0. WEEDS 2.0 is adapted to the western U.S. and western Canada and contains 970 species. Every species in each of the major illustrated weed guides used by weed specialists in the western United States is included. WEEDS 2.0 uses a random access process that is unlike dichotomous keys. The user observes attributes seen on an unknown specimen, then chooses menus and enters those attributes into the program. A novice can quickly identify the majority of weed species in the U.S. and Canada. The process teaches *plant recognition, not technical taxonomy*. The program allows common technical errors such as calling the head of a plant in the aster family a "flower", calling a flower red when the true color is orange or multicolored, calling a leaf oval when it is technically ovate. The user's guide directs the user to descriptions and illustrations in one or more of over a dozen books selected for, and used by weed specialists in, each region. The user's guide contains a simple tutorial, descriptions of the program functions, an illustrated glossary of terms with sketches of each characteristic used in the program, a table that shows the exact page numbers where every weed species can be found in illustrated weed books or floras, and a list of common names of all species in the data base.

The system requirements are for an IBM or compatible computer, DOS 3.1 or higher, and 400K RAM. Simplicity and on-screen cues to the use of function keys enable any computer novice to easily and independently learn the system in less than an hour.

In addition to WEEDS 2.0, databases have been developed for the other WSSA regions. These additional software packages are: SOWEEDS, for the southern U.S., with 925 species; NCWEEDS 2.0, for the north central U.S. and central Canada, with 780 species; and NEWEEDS 2.0, for the northeastern U.S. and eastern Canada, with 780 species. Considering overlap of species among regions, over 1300 recognized weed species are included to date.

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**MAPPING REGIONAL WEED INFESTATIONS AND OTHER DATA WITH COMPUTERS.** L. W. Lass and R. H. Callihan, Postdoctoral Fellow, and Extension Weed Specialist, Dept. of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83844.

Abstract. One of the difficulties limiting the ability of weed science to document the significance of weed infestations for program planning, administration, fund generation and other critical information needs is the



difficulty in maintaining files of updated maps. REGIONCAD is mapping software that allows the novice user to manipulate map information, such as weed infestations, on a regional scale. A data base enables the computer to generate an editable map of one or more states in United States. Each of the 48 contiguous states and Hawaii are contained in a single data set, and Alaska is contained within five data sets.

The data base provides displays of major highways, railroads, rivers, lakes, reservoirs, and boundaries of county and federally administered land. REGIONCAD has about the same position accuracy as a road atlas and units are measured in feet. REGIONCAD is ideal for displaying noxious weed or other pest infestations, crop production, pest quarantine or restricted crops, road conditions, and any other geographically-distributed data. Positions or boundaries of weed populations and other things are easily entered with a mouse or digitizer. REGIONCAD can record 240 layers or kinds of information. These records can be tracked for many years using 15 color codes and 256 symbols and shadings. With combinations of these, a total of 100,800 records are possible. Data may be exchanged with Geographical Information Systems (GIS) packages to be combined with other databases such as topography or soils. The program runs on any IBM or compatible computer with a hard disk and printer. Best performance is obtained on a 386 with a math co-processor, or on a 486. A mouse, color monitor, and laser printer improve efficiency. This mapping software will allow for simple record-keeping of pest locations and management planning. The advantage of this software over GIS is lower cost and simplicity, and the advantage over most low-cost map programs is the amenability to editing.

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**BRASSICA GREEN MANURE CROPS SUPPRESS WEEDS.** Rick A. Boydston and Kassim Al-Khatib, Plant Physiologist, United States Department of Agriculture, Agricultural Research Service, Prosser, WA 99350, and Associate Professor, Washington State University, Mt. Vernon, WA 98273.

#### INTRODUCTION

Weeds, nematodes, insects, and diseases can greatly reduce yield and quality of potatoes and are currently managed with multiple pesticide applications and crop rotation. Brassica green manure crops have shown potential for providing control of several common potato pests including soil borne diseases, nematodes, and weeds (1, 5, 6, 7, 8). Brassica species contain glucosinilates, which breakdown to isothiocyanates when decomposing in the soil (2, 3, 4). Isothiocyanates are also breakdown products of several commercial soil fumigants that suppress nematodes, diseases, and weeds.

Fall-planted Brassica green manure crops grown over the winter and disced in prior to planting potatoes in the spring suppress nematodes and weeds and provide winter cover to prevent wind erosion (1, 8). These studies were conducted to evaluate weed control using green manure crops of rapeseed (*Brassica napus*) and white mustard (*Brassica hirta*).

#### MATERIALS AND METHODS

**Greenhouse.** 'Jupiter' rapeseed or 'Martigena' white mustard were grown in 23 cm diameter pots in the greenhouse and harvested at 8 and 4 wk, respectively. Shoots and leaves were chopped into 0.5 cm<sup>2</sup> pieces and 20 g of fresh weight was mixed into 450 g dry soil. Weed seed was planted immediately and pots were watered daily and fertilized weekly. In studies conducted at Mt. Vernon, pots were sealed with plastic wrap until weed emergence. A non-amended soil was included as a check. Greenhouse temperatures were maintained at 30/20 C day/night. The number of weeds emerged were counted weekly and weed biomass was measured at 2 wk after emergence. Samples of green manure plants were freeze dried and total glucosinilates measured using a gas chromatograph.

**Field.** 'Jupiter' rapeseed was seeded at 7 kg ha<sup>-1</sup> in mid August in 1991 and 1992 near Prosser, WA, on a loamy sand soil. A fallow plot and a sudangrass green manure crop were included for comparison. Rapeseed was

either incorporated with a rototiller on March 12, 1992, and March 18, 1993, or incorporated with a strip tiller immediately before planting potatoes. 'Russet Burbank' potatoes were planted on April 22, 1992, and April 20, 1993. Pendimethalin plus metribuzin (1.1 + 0.4 kg/ha<sup>1</sup>) were applied as split treatments to one-half of each plot on May 6, 1992, and May 5, 1993.

Weed counts were taken in mid July and weed biomass and counts were measured from three 1 m<sup>2</sup> quadrants per plot in September of both years. Potato tuber yield, size, distribution, and specific gravity were measured in October.

## RESULTS

**Greenhouse-Mt. Vernon, WA.** Rapeseed leaves mixed into a LaConner loamy sand soil and covered with plastic until weed emergence reduced shepherdspurse, kochia, and green foxtail emergence with shepherdspurse being the most sensitive (Figure 1a). Dry weights of shepherdspurse and kochia were reduced by 88% and 29%, respectively, by adding rapeseed to the soil, but green foxtail dry weight was not significantly reduced (Figure 1b). White mustard leaves mixed into soil reduced emergence of all three weed species but did not significantly reduce weed biomass.

**Greenhouse-Prosser, WA.** Rapeseed tissue incorporated into a Quincy loamy sand soil did not affect emergence of shepherdspurse, kochia, green foxtail, and hairy nightshade, but reduced emergence of puncturevine. Hairy nightshade, puncturevine, and longspine sandbur biomass were greatly reduced when rapeseed was added. Suppression of hairy nightshade growth with rapeseed residues was greater when pots were kept covered until weeds emerged than when pots were left uncovered. Emerged plants were stunted and chlorotic and often died after several weeks. Shepherdspurse, kochia, and green foxtail biomass were not significantly affected by adding rapeseed.

White mustard tissue incorporated into soil reduced emergence of all five weed species with shepherdspurse being the most sensitive and green foxtail the least sensitive (Figure 2a). Biomass of all five weed species was reduced from 43 to 99% when adding white mustard residues to the soil (Figure 2b.) Total glucosinolate content of white mustard and rapeseed grown in the greenhouse averaged 4 and 5  $\mu$ moles per g dry weight, respectively.

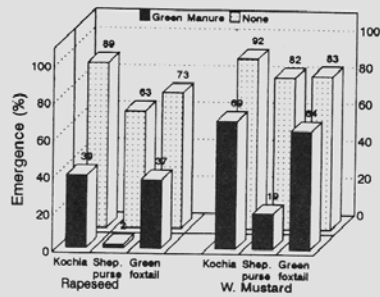
**Field.** In 1992, growing a rapeseed green manure crop before potatoes reduced weed biomass in the potato crop by greater than 90% compared to no green manure crop or a sudangrass green manure crop (Figure 3a). The main weed species present were common lambsquarters and redroot pigweed. In plots where no herbicides were applied, potato yields were greatest (32 T/A) when a rapeseed green manure crop had preceded potatoes. Potatoes produced the greatest yields when both herbicides and a green manure crop of rapeseed were used (35.9 T/A) (Figure 3b).

In 1993, rapeseed reduced weed density and biomass in the potato crop by 50% compared to no green manure crop. The main weeds present were redroot pigweed and common lambsquarters. In plots where no herbicides were applied, potato yields were greatest (27.4 T/A) when a rapeseed green manure crop had preceded potatoes than when fallow had preceded potatoes (20.8 T/A). Potatoes following rapeseed plus a herbicide treatment yielded 34.5 T/A, whereas potatoes following fallow with a herbicide treatment produced 31.8 T/A.

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1 a.



1 b.

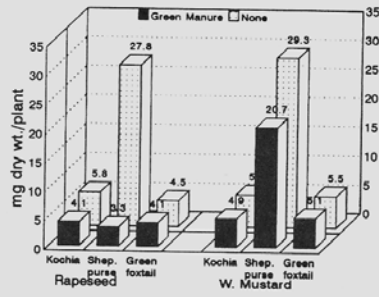
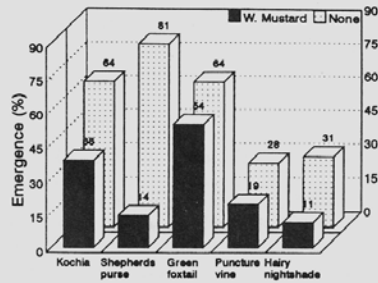


Figure 1. Weed response to rapeseed or white mustard added at 20 g fresh weight per 450 g dry weight of soil. (a) weed emergence; (b) mg dry weight per plant.

2 a.



2 b.

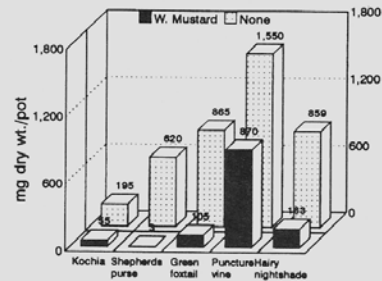
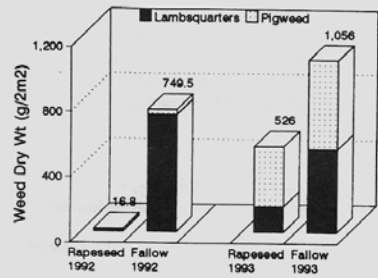


Figure 2. Weed response to white mustard added at 20 g fresh weight per 450 g dry weight of soil. (a) weed emergence; (b) mg dry weight per pot.

3 a.



3 b.

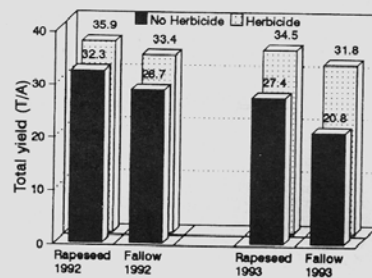


Figure 3. Weed dry weight (a) and potato yield (b) following a fall-planted rapeseed green manure crop.

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**DIFFERENTIAL DISPLAY: A NEW TECHNIQUE FOR ISOLATING GENES BASED ON mRNA ABUNDANCE.** Harwood J. Cranston, Russell R. Johnson, and William E. Dyer, Research Assistant, Postdoctoral Research Associate and Assistant Professor, Department of Plant, Soil and Environmental Science, Montana State University, Bozeman, MT 59717-0312.

Abstract. All organisms control their patterns of development and responses to the environment by regulating gene expression. This phenomenon has traditionally been studied by differential screening of cDNA libraries enriched for differentially expressed mRNAs by subtraction hybridization. This approach has been successful in several cases, but the method is time-consuming, laborious and most importantly biases the results towards highly abundant cDNAs. Because of this low sensitivity, rare mRNAs are very difficult if not impossible to isolate. Here we present a new approach to studying differential gene expression using dormant and nondormant wild oat embryos as a model system. The method, known as differential display, was first described in 1992 by Arthur Pardee (Liang, P. and A. B. Pardee. 1992. Differential display of eukaryotic messenger RNA by means of the polymerase chain reaction. *Sci.* 257:967-971). cDNA is synthesized from total RNA isolated from dormant and nondormant embryos using reverse transcriptase and an anchored oligonucleotide primer specific for the polyA tail of a subpopulation of mRNAs. Following PCR amplification using anchored and unique primers with 35S-dATP labeling, the PCR products are displayed side by side on a DNA sequencing gel. Differentially expressed mRNAs produce bands of unequal intensity, allowing rapid and straightforward identification of potentially interesting genes. Bands of interest are excised from the gel, re-amplified using PCR, and subcloned. The resulting cloned DNA can be sequenced in order to determine gene identity and used in northern analysis to characterize mRNA tissue specificity, timing of expression, and correlation with the dormant state. This approach has provided a rapid, convenient, sensitive, and reproducible technique for obtaining differentially expressed genes involved in seed dormancy in our laboratory and can be easily applied to other questions in plant science.

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**BANDING NITROGEN: AN EFFECTIVE MANAGEMENT TOOL FOR GREEN FOXTAIL IN CONTINUOUS BARLEY.** A. D. Yochim, J. T. O'Donovan, D. W. McAndrew, and M. Gorda, Research Assistant and Research Scientist, Alberta Environmental Centre, Vegreville, Canada T9C 1T4, and Research Scientist and Technician, Agriculture Canada, Vegreville, Alberta.

Abstract. Banding nitrogen together with herbicide use reduced green foxtail populations in the soil seed bank to a greater extent than herbicide use alone in a 4 yr study. Experiments conducted at two locations in Alberta from 1989 to 1992 were designed to investigate the effects of conventional tillage, zero tillage, and four levels of nitrogen on continuous barley production. Urea (46-0-0) was banded in 40 cm spacings to achieve levels of 60, 120, and 180 kg nitrogen/ha under both zero and conventional tillage. Plots to which no urea was applied were used to determine the effects of residual nitrogen. Diclofop methyl/bromoxynil (1989, 1990 and 1991) and propanil/MCPA (1992) were used for green foxtail control. In spring 1991 and 1992, plant counts were taken to determine the level of green foxtail recruitment from the soil seed bank. Populations in the soil seed bank were determined from soil samples taken in the fall of the same years. At Alliance, green foxtail populations in the recruitment study were higher in conventional than in zero tillage in both 1991 (48 and 28 plants/m<sup>2</sup>, respectively) and 1992 (73 and 33 plants/m<sup>2</sup>, respectively). Populations in the soil seed bank were significantly higher in conventional compared to zero tillage in 1992 (1123 and 494/m<sup>2</sup>, respectively), but not in 1991. In the recruitment and seed bank studies, green foxtail populations in conventional and zero tillage were highest where residual nitrogen was present and tended to decrease as nitrogen level increased. Similar decreases in green

foxtail populations in the soil seed bank were evident at Hairy Hill. The results indicate that banding nitrogen has the potential to be an effective tool for green foxtail management in both conventional and zero tillage systems, resulting in less dependence on herbicides for controlling this weed. (Published with the approval of the Alberta Environmental Centre).

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**CROP ROTATION AND TILLAGE EFFECTS ON WEED POPULATIONS.** Robert E. Blackshaw, Weed Scientist, Agriculture and Agri-Food Canada, Lethbridge, AB T1J 4B1.

**Abstract.** Weed control is a critical component of successful conservation cropping systems. A long-term study was conducted to determine the response of weed populations to various crop rotations and tillage treatments.

The crop rotations were continuous winter wheat, winter wheat-fallow, winter wheat-spring canola, and winter wheat-lentil (flax replaced lentils from 1989 onward). Both phases of a rotation were grown each year and represented main plots in a randomized block design with six replicates. The tillage treatments conventional, minimum, and zero till were subplot treatments randomized within each main plot. Conventional tillage consisted of disking and rodweeding prior to planting and during the fallow period tillage with a wide blade cultivator. Minimum tillage consisted of one operation with a wide blade cultivator and rodweeding prior to planting and tillage with a wide blade cultivator during the fallow period. Zero till plots were treated with glyphosate at 0.42 kg ha<sup>-1</sup> prior to planting and the commercial mixture of glyphosate/2,4-D at 0.7 kg ha<sup>-1</sup> during the fallow period. Trifluralin at 0.8 kg ha<sup>-1</sup> was applied before planting lentil and canola. Bromoxynil/MCPA was applied at 0.56 kg ha<sup>-1</sup> in early spring in winter wheat. Sethoxydim at 0.25 kg ha<sup>-1</sup> tank mixed with bromoxynil/MCPA at 0.56 kg ha<sup>-1</sup> was applied when flax was 8 cm tall. Sethoxydim at 0.25 kg ha<sup>-1</sup> was applied at the four leaf stage of canola. Weeds were counted by species in twelve randomly chosen 0.25 m<sup>2</sup> quadrats in each subplot in early-May, mid-June in the spring crops (prior to application of postemergence herbicides), and late-October.

Weed density and species differed with rotation, tillage, and date of sampling within each year. Winter wheat-fallow consistently had less weeds than continuous winter wheat, winter wheat-lentil, and winter wheat-canola rotations. A dense infestation of downy brome developed over years in the continuous winter wheat rotation. Over all rotations, more weeds occurred in zero tillage plots than in either minimum or conventional tillage plots. Dandelion and perennial sowthistle densities increased slightly over years in the minimum and zero tillage treatments. Flixweed, field pennycress, wild buckwheat, and common lambsquarters densities decreased in zero till but densities of downy brome, redroot pigweed, and Russian thistle increased. Herbicides used in the various crops affected weed populations. Russian thistle was not well controlled with trifluralin in canola and it became a greater weed problem over years in the winter wheat-canola rotation.

## WEEDS OF RANGE AND FOREST

### THE EFFECTS OF HERBACEOUS AND SHRUB COMPETITION ON DOUGLAS-FIR SEEDLINGS.

M. O'Dea, E. Cole, and M. Newton, Research Assistant, Senior Research Assistant and Professor, Forest Science Department, Oregon State University, Corvallis, OR 97331.

#### INTRODUCTION

Douglas-fir seedling growth benefits significantly from the control of herbaceous and shrub competition during the first and second growing seasons following field transplantation. In a previous study, Newton and Preest (1) demonstrated that the greatest increment of seedling growth occurred when weeds were controlled in the same growing season that seedlings were transplanted to the field. They found less seedling growth when weeding release occurred in the second or third growing season. First year survival is dependent upon the availability of soil moisture throughout the growing season, especially during the drier summer months. It is during the summer months that transpiration potential exceeds the water storage capacity of surface soil. If not controlled, the herbaceous cover can exhaust the soil moisture available to seedlings early in the growing season (1, 2). By controlling the ability of other vegetation to compete for soil moisture, the seedling is able to allocate more photosynthate to crown and root development. It was therefore hypothesized that by controlling vegetation in the first and second growing season seedlings would have a significant growth advantage over seedlings weeded only once following transplantation, or weeded at some undetermined time following transplantation.

The purpose of this study was to evaluate, in an operational context, seedling growth when it had been a) released only during its first growing season, b) only during its second growing season, and c) during its first and second growing season. In addition, seedling growth was evaluated d) without any release treatment (control), e) within a conventional forestry treatment of one broadcast release following plantation establishment, f) by controlling vegetation around seedling with a directed spray, and g) by a continuous weed-free treatment.

#### METHODS AND MATERIALS

Four sites were selected in Oregon and Washington. One in coastal Oregon (Coos Bay, Site II), two in central western Cascade foothills (Springfield, Site III) and one in coastal Washington (Hoquiam, Site II). Only two sites received site preparation prior to planting. The Coos Bay site was lightly scarified and the slash piled, and Mt. Nebo was broadcast burned. At each site a completely randomized study with seven treatments was established with three replications. For each plot 100 1+1 Douglas-fir stock-type seedlings were planted on a 10 by 10 foot grid, with a 10 foot buffer between plots. Within each plot, the 36 core seedlings were measured annually for height, basal diameter (15 cm), diameter at breast height (137 cm), percent herbaceous and shrub overtopping, and cover around each seedling within a meter radius.

Study treatments were as follows: (1) Untreated - plant, with no vegetation control; (2) Conventional release - plant, followed by a one-time broadcast release in Year 1 or 2, as judged appropriate; (3) Year 1 release - plant, early-season broadcast application (4) Year 1 and 2 release - plant, same protocol as for Year 1 release with an additional application in Year 2 to maintain competitive cover at less than 10%; (5) Year 2 release - plant, same protocol as in Year 1 release, except that it occurs early in the second growing season; (6) Directed - plant, followed by a one-time directed spray application; and (7) Weed-free - plant and maintained weed-free for 5 yr.

Data were analyzed using analysis of variance and covariance, with initial seedling height as the covariate using SAS®. However, even though initial height was a significant covariate, it was not used in the analysis of variance since it did not contribute greatly to the sums of squares. Natural log transformation of seedling growth parameters was used due to slight heterogeneity of the variance. Regression and correlation analyses was used to determine the relationship between the natural log of stem volume growth and total vegetative cover in Years 1, 2 and 3. The same analyses were used for the natural log of basal area growth and height growth.

The Coos Bay and Mt. Nebo sites were characterized by a shrub and broad leafed herbaceous plant community. Coos Bay was dominated by red alder (*Alnus rubra*), vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), *Senecio spp.* and Australian fireweed (*Erechtites minima*). The plant community at Mt. Nebo was predominately vine maple (*Acer circinatum*), hazel (*Cornus californica*), and thistle (*Cirsium spp.*), trailing blackberry (*Rubus ursinus*), bracken fern (*Pteridium aquilinum*), and forbs.

The Hoquiam site was characterized by a predominance of salal (*Gaultheria shallon*), a woody, evergreen shrub. In addition, the plant community at Hoquiam was dominated by cascara (*Rhamnus purshiana*), salmonberry, groundsel (*Senecio sylvaticus*), thistle, and trailing blackberry. The plant community at the Mocal site was dominated by vine maple, hazel, salal, thistle, trailing blackberry, and forbs.

## RESULTS

**Comparison of treatment effect on seedling growth.** For height, basal area and volume growth, seedlings within the Year 1 and 2 release treatment were significantly ( $p \leq .05$ ) larger than those within other treatments, except for the weed-free treatment. In addition, within the Year 1 and 2 release treatment total percent cover of competitive vegetation (35%) was not significantly ( $p \leq .05$ ) different from the weed-free treatment (33%) (Table 1). At this stage of the study the results indicate that there is no significant differences between the Year 1 and Year 2 release treatments. In addition, the seedlings within the directed release are significantly ( $p \leq .05$ ) larger than those within the conventional release treatment.

Table 1. Third year seedling means for treatments over all sites\*.

Treatment	Height growth 1992-1993	Basal area growth 1992-1993	Volume growth 1992-1993	Total cover 1993
	(cm)	(cm <sup>2</sup> )	(cm <sup>3</sup> )	%
Untreated	35.2 <sup>bc</sup>	1.1 <sup>d</sup>	45.8 <sup>c</sup>	51 <sup>ab</sup>
Conventional	33.8 <sup>cd</sup>	0.88 <sup>e</sup>	35.4 <sup>d</sup>	55 <sup>a</sup>
Yr 1 release	36.2 <sup>bc</sup>	1.2 <sup>c</sup>	57.4 <sup>b</sup>	52 <sup>ab</sup>
Yr 1 and 2 release	47.4 <sup>a</sup>	2.2 <sup>b</sup>	116.4 <sup>a</sup>	35 <sup>bc</sup>
Yr 2 release	33.2 <sup>cd</sup>	1.6 <sup>c</sup>	54.7 <sup>b</sup>	46 <sup>abc</sup>
Directed	31.0 <sup>d</sup>	1.2 <sup>cd</sup>	53.2 <sup>bc</sup>	48 <sup>abc</sup>
Weed-free	39.7 <sup>b</sup>	3.0 <sup>a</sup>	133.5 <sup>a</sup>	33 <sup>c</sup>

\* Means followed by the same letter are not significantly ( $p \leq .05$ ) different using Bonferroni's LSD.

**Comparison of seedling growth within each site. Coos Bay.** Seedlings within the Year 1 and 2 release treatment had significantly ( $p \leq .05$ ) greater height and volume growth than all other treatments. There was no significant differences between the Year 1 and 2 release and the weed-free treatments for basal area or basal area growth. Seedlings within the weed-free treatment were significantly ( $p \leq .05$ ) larger than seedlings in the remaining treatments other than the Year 1 and 2 release (Table 2). Because of some animal browsing and herbicide damage within the weed-free treatment, seedling height growth was not at expected levels.

**Hoquiam.** At this site there was less difference between treatments than at any other site. The seedlings within the weed-free treatments had significantly ( $p \leq .05$ ) greater volume, basal area and volume growth than all other treatments. The seedlings within the Year 1 and 2 release, conventional and directed treatments were larger than the seedlings in the remaining treatments (Table 3). The plant community at this site is dominated by an evergreen shrub community of salal, unlike those at the other sites which are predominately herbaceous. It is this difference in the plant community that probably explains the greatest differences in treatment efficacy. It is also notable that on many treatments, woody competition is increasing, and the continuation of earlier trends may not continue.

Table 2. Third year seedling means for Coos Bay site\*.

Treatment	Height 1993	Height growth 1992-1993	Basal diameter 1993	Basal area growth 1992-1993	Volume 1993	Volume growth 1992-1993
	(cm)	(cm)	(cm)	(cm <sup>2</sup> )	(cm <sup>3</sup> )	(cm <sup>3</sup> )
Untreated	143.5 <sup>d</sup>	54.0 <sup>d</sup>	23.7 <sup>d</sup>	3.3 <sup>cd</sup>	228.6 <sup>bc</sup>	188.4 <sup>d</sup>
Conventional	140.6 <sup>bc</sup>	55.3 <sup>cd</sup>	21.0 <sup>c</sup>	2.6 <sup>d</sup>	192.1 <sup>a</sup>	156.5 <sup>f</sup>
Yr 1 release	151.6 <sup>bc</sup>	57.2 <sup>bcd</sup>	24.9 <sup>cd</sup>	3.9 <sup>c</sup>	300.0 <sup>d</sup>	250.6 <sup>cd</sup>
Yr 1 and 2 release	187.9 <sup>a</sup>	77.5 <sup>a</sup>	33.3 <sup>a</sup>	6.3 <sup>a</sup>	614.4 <sup>a</sup>	499.5 <sup>a</sup>
Yr 2 release	159.9 <sup>b</sup>	58.2 <sup>bcd</sup>	27.8 <sup>b</sup>	4.9 <sup>b</sup>	397.0 <sup>c</sup>	329.1 <sup>e</sup>
Directed	155.1 <sup>b</sup>	63.4 <sup>b</sup>	26.2 <sup>bc</sup>	4.0 <sup>c</sup>	317.4 <sup>d</sup>	264.5 <sup>cd</sup>
Weed-free	155.7 <sup>b</sup>	62.9 <sup>bc</sup>	32.2 <sup>a</sup>	6.6 <sup>a</sup>	494.4 <sup>b</sup>	421.1 <sup>b</sup>

\* Means followed by the same letter are not significantly ( $p \leq .05$ ) different using LSMEANS LSD.

Table 3. Third year seedling for Hoquiam site\*.

Treatment	Height 1993	Height growth 1992-1993	Basal diameter 1993	Basal area growth 1992-1993	Volume 1993	Volume growth 1992-1993
	(cm)	(cm)	(cm)	(cm <sup>2</sup> )	(cm <sup>3</sup> )	(cm <sup>3</sup> )
Untreated	137.7 <sup>a</sup>	44.0 <sup>ab</sup>	15.3 <sup>d</sup>	0.99 <sup>d</sup>	100.3 <sup>cd</sup>	67.5 <sup>e</sup>
Conventional	137.6 <sup>ab</sup>	47.4 <sup>ab</sup>	18.3 <sup>bc</sup>	1.7 <sup>bc</sup>	147.5 <sup>b</sup>	107.0 <sup>d</sup>
Yr 1 release	127.3 <sup>b</sup>	41.8 <sup>a</sup>	15.7 <sup>d</sup>	1.0 <sup>d</sup>	93.6 <sup>d</sup>	63.2 <sup>e</sup>
Yr 1 and 2 release	142.1 <sup>a</sup>	48.8 <sup>a</sup>	17.8 <sup>c</sup>	1.4 <sup>c</sup>	134.5 <sup>bc</sup>	94.7 <sup>bc</sup>
Yr 2 release	139.4 <sup>a</sup>	43.4 <sup>ab</sup>	15.8 <sup>d</sup>	1.2 <sup>bc</sup>	107.7 <sup>cd</sup>	75.1 <sup>e</sup>
Directed	134.4 <sup>ab</sup>	44.9 <sup>ab</sup>	19.6 <sup>b</sup>	1.8 <sup>b</sup>	164.3 <sup>b</sup>	118.0 <sup>d</sup>
Weed-free	139.5 <sup>a</sup>	46.4 <sup>ab</sup>	25.2 <sup>a</sup>	3.4 <sup>a</sup>	276.3 <sup>a</sup>	209.9 <sup>a</sup>

\* Means followed by the same letter are not significantly ( $p \leq .05$ ) different using LSMEANS LSD.

**Mocal.** Seedling growth results were confounded as a result of heavy deer and elk browsing. During the second growing season 85% of all seedlings were browsed, where 40% had been browsed in the first. Seedling height, basal area and volume growth were significantly ( $p \leq .05$ ) greater in the Year 1 and 2 release treatment than in the others, except for the weed-free treatment. Seedling volume and volume growth are significantly ( $p \leq .05$ ) greater within the Year 1 release than they are within the Year 2 release treatment (Table 4).

Table 4. Third year seedling means for Mocal site\*.

Treatment	Height 1993	Height growth 1992-1993	Basal diameter 1993	Basal area growth 1992-1993	Volume 1993	Volume growth 1992-1993
	(cm)	(cm)	(cm)	(cm <sup>2</sup> )	(cm <sup>3</sup> )	(cm <sup>3</sup> )
Untreated	87.1 <sup>e</sup>	30.7 <sup>b</sup>	12.7 <sup>d</sup>	0.92 <sup>cd</sup>	48.3 <sup>d</sup>	8.3 <sup>cd</sup>
Conventional	91.2 <sup>e</sup>	30.9 <sup>b</sup>	12.2 <sup>d</sup>	0.65 <sup>d</sup>	45.6 <sup>d</sup>	31.6 <sup>e</sup>
Yr 1 release	92.5 <sup>e</sup>	30.7 <sup>b</sup>	15.1 <sup>c</sup>	1.1 <sup>c</sup>	70.3 <sup>c</sup>	49.8 <sup>e</sup>
Yr 1 and 2 release	105.4 <sup>b</sup>	38.7 <sup>a</sup>	17.6 <sup>b</sup>	1.7 <sup>b</sup>	100.3 <sup>b</sup>	77.7 <sup>b</sup>
Yr 2 release	82.8 <sup>cd</sup>	23.8 <sup>c</sup>	13.1 <sup>d</sup>	0.81 <sup>cd</sup>	42.3 <sup>d</sup>	29.4 <sup>d</sup>
Directed	77.8 <sup>d</sup>	16.9 <sup>d</sup>	13.3 <sup>d</sup>	0.61 <sup>d</sup>	43.3 <sup>d</sup>	23.9 <sup>d</sup>
Weed-free	113.8 <sup>a</sup>	42.9 <sup>a</sup>	23.4 <sup>a</sup>	3.4 <sup>a</sup>	276.3 <sup>a</sup>	157.2 <sup>a</sup>

\* Means followed by the same letter are not significantly ( $p \leq .05$ ) different using LSMEANS LSD.



Mt. Nebo. Seedling growth results were also confounded by severe browsing at this site. Elk browsed 98% of all seedlings during the second year, with approximately 85% of all seedlings having been browsed in the first. However, the consistent trend of the Year 1 and 2 release and weed-free treatments demonstrating the greatest gains in seedling growth was apparent. Seedling height growth, basal area growth, volume and volume growth were significantly ( $p \leq .05$ ) greater within these two treatments than in other treatments. The differences between the Year 1 and 2 release and weed-free treatments are not likely the result of treatment effect, but of severe animal damage (Table 5).

Table 5. Third year seedling means for Mt. Nebo site\*.

Treatment	Height 1992	Height growth 1992-1993	Basal diameter 1993	Basal area growth 1992-1993	Volume 1993	Volume growth 1992-1993
	(cm)	(cm)	(cm)	(cm <sup>2</sup> )	(cm <sup>3</sup> )	(cm <sup>3</sup> )
Untreated	85.7 <sup>a</sup>	35.2 <sup>b</sup>	13.7 <sup>a</sup>	1.1 <sup>d</sup>	48.3 <sup>d</sup>	39.5 <sup>d</sup>
Conventional	68.6 <sup>d</sup>	22.1 <sup>c</sup>	11.5 <sup>d</sup>	0.64 <sup>e</sup>	27.0 <sup>a</sup>	19.5 <sup>a</sup>
Yr 1 release	98.5 <sup>b</sup>	39.9 <sup>b</sup>	16.0 <sup>f</sup>	1.6 <sup>cd</sup>	77.8 <sup>e</sup>	64.8 <sup>c</sup>
Yr 1 and 2 release	115.7 <sup>a</sup>	49.1 <sup>a</sup>	24.4 <sup>a</sup>	3.3 <sup>a</sup>	171.1 <sup>a</sup>	149.8 <sup>a</sup>
Yr 2 release	85.2 <sup>a</sup>	32.6 <sup>b</sup>	15.0 <sup>f</sup>	1.4 <sup>cd</sup>	58.5 <sup>cd</sup>	48.8 <sup>cd</sup>
Directed	72.4 <sup>d</sup>	23.1 <sup>c</sup>	13.7 <sup>a</sup>	1.1 <sup>d</sup>	46.7 <sup>ab</sup>	37.3 <sup>ab</sup>
Weed-free	95.4 <sup>ab</sup>	35.4 <sup>b</sup>	19.3 <sup>b</sup>	2.4 <sup>b</sup>	108.5 <sup>b</sup>	91.1 <sup>b</sup>

\*Means followed by the same letter are not significantly ( $p \leq .05$ ) different using LSMEANS LSD.

Cover response to treatment. For all sites in Year 3, the Year 1 and 2 release treatment was consistently the better treatment for maintaining the lowest percent of herbaceous and shrub cover, with the exception of the weed-free. At Coos Bay, total plant cover within the Year 1 and 2 release (43%) treatment was significantly ( $p \leq .05$ ) lower than the untreated (62%), Year 1 release (58%), and the directed (60%) treatments. Only the weed-free treatment (13%) had cover significantly ( $p \leq .05$ ) lower than the Year 1 and 2 release treatment. At the Mt. Nebo site, the Year 1 and 2 treatment is only significantly ( $p \leq .05$ ) different from the conventional treatment (55%), but not from the other treatments where total cover ranged from 33 to 52%. Herbaceous plant communities dominated these sites, with forbs predominant at both sites, and bracken fern prominent at the Mt. Nebo site.

At the Hoquiam and Mocal sites the plant communities are dominated by evergreen shrubs, such as salal and dwarf Oregon grape, deciduous shrubs, such as bigleaf (*Acer macrophyllum*) and vine maples, and forbs. At Hoquiam, although the Year 1 and 2 release treatment does not have the lowest cover (66%) compared to the directed treatment (55%), it is not significantly ( $p \leq .05$ ) different from any other treatment, except for the weed-free treatment (28%). At the Mocal site, cover within the Year 1 and 2 release treatment (27.0%) was significantly ( $p \leq .05$ ) lower than all other treatments, except for the weed-free treatment (19.0%) (Table 6).

It is notable that the percent total cover is a two-dimensional measure of cover area and may not represent the actual leaf area of the individuals being counted. For example, the number and leaf area of individuals within the weed-free treatment may be considerably less than that of individuals within another treatment, yet both have the same percent cover.

Table 6. Total percent cover of competing vegetation at each site for all treatments at Year 3<sup>a</sup>.

Treatment	Coos Bay	Hoquiam	Mocal	Mt. Nebo
Untreated	62.4 <sup>a</sup>	77.9 <sup>a</sup>	63.7 <sup>a</sup>	51.8 <sup>ab</sup>
Conventional	57.8 <sup>ab</sup>	64.5 <sup>abc</sup>	59.1 <sup>a</sup>	55.0 <sup>a</sup>
Yr 1 release	62.9 <sup>a</sup>	74.2 <sup>ab</sup>	63.3 <sup>a</sup>	52.3 <sup>ab</sup>
Yr 1 and 2 release	42.7 <sup>b</sup>	66.6 <sup>abc</sup>	27.0 <sup>b</sup>	35.3 <sup>bc</sup>
Yr 2 release	48.2 <sup>ab</sup>	58.5 <sup>bc</sup>	58.1 <sup>a</sup>	46.3 <sup>abc</sup>
Directed	60.2 <sup>a</sup>	54.9 <sup>c</sup>	54.3 <sup>a</sup>	47.9 <sup>abc</sup>
Weed-free	13.3 <sup>c</sup>	28.3 <sup>d</sup>	19.1 <sup>b</sup>	33.0 <sup>c</sup>

<sup>a</sup>Means followed by the same letter are not significantly ( $p \leq 0.05$ ) different using LSMEANS LSD.

For regression analyses, data were divided by browsed and unbrowsed. In Year 3, there was a weak relationship between percent cover in Years 2 and 3 and the natural log of third year seedling height, basal area and volume growth. Although growth was negatively correlated and significantly ( $p \leq 0.0001$ ) affected by the percent cover in Years 2 and 3, cover explained very little of the variation in seedling growth ( $r^2$  ranged 0.16 to 0.25).

#### DISCUSSION

Over all sites the Year 1 and 2 release treatment was consistently the best operational treatment despite inherent site differences and animal damage. Only the weed-free treatment had seedling growth greater than the Year 1 and 2 release treatment. In comparison among the release methods over all sites, the directed release treatment appears to be more effective in promoting greater seedling growth than the conventional release or site preparation treatments (Table 1). Moreover, at the Mocal and Mt. Nebo sites, Year 1 release is clearly more effective than the Year 2 release, whereas it is only slightly different at the Hoquiam site. At the Coos Bay site the opposite trend appears to be occurring, and these results are due to specific site conditions. Because of the scarification during site preparation, the majority of the vegetation did not occupy the site until later in the season following treatment application. However, when the Year 2 release treatment was applied the site was fully occupied and a better determination of treatment effect could be evaluated.

There is evidence that interaction of vegetation cover types with treatment is pronounced. Where the vegetation community type was primarily herbaceous with scattered shrubs, the soil residual treatment (hexazinone) was effective in reducing and maintaining a reduced plant community. However, at Hoquiam, where the salal and other woody shrubs dominated the plant community, the triclopyr ester in the directed and weed-free treatments were more effective than the broadcast treatments. This difference in seedling growth may be the result of seedling damage from the broadcast application, or the rate and efficacy of the broadcast application, or both. In addition, it is also probable that the release treatments were not the most appropriate choices for the salal dominated plant community, which is classically herbicide resistant.

The efficacy of the various treatments to maintain the lowest levels of competing vegetation varied between the sites, due in part to the range of vegetation types within each plant community, and herbicide and plant interactions. However, the consistent trend of the Year 1 and 2 release treatment being the best operational treatment was apparent. Only the weed-free treatment had percent cover consistently lower. Although the percent cover of competing vegetation significantly ( $p \leq 0.0001$ ) affected seedling growth, it explained little of the variation in seedling growth. At the Mocal and Mt. Nebo sites these results were most likely confounded by the severe amount of animal browsing damage. Nevertheless, in this study and in others, tolerance to browsing pressure appears to be greatly enhanced by effective broadcast weed control. The seedling volumes within the best treatments were consistently between three or more times greater than those within the poorest treatments. Thus, this study demonstrates that regardless of location or browsing intensity, 2 or more yr of weeding provides seedling growth enhancement and animal damage evasion.

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**CONTROL OF COMPETITION TO ENHANCE CONIFER PRODUCTION IN THE NORTHERN ROCKY MOUNTAINS--A REGIONAL OVERVIEW.** R. J. Boyd, Research Forester (Retired), US Forest Service, Intermountain Research Station, Moscow, ID 83843.

Abstract. The sheer variability of topography, altitude, plant and animal communities, soils and climate make prescriptions of vegetation management treatments for the 10 most prevalent conifer species in the Northern Rocky Mountains a difficult and uncertain task. While few of the competing plant species have the stature to provide long term interference with conifers, tall shrub species such as Rocky Mountain maple, willow, cherry, alder, and medium shrubs such as the evergreen ceanothus, red stem ceanothus, snowberry, ninebark, and ocean spray can affect conifer survival and growth for many years. Perhaps an even more important component of conifer competition are the herbaceous plants, particularly pinegrass, beargrass, sedges, and rapid invaders such as fireweed and Canada thistle. Other alien species such as spotted knapweed are on the increase and benefit from over grazing, excessive mechanical disturbance and fire.

Machine work is limited by topography and is fraught with the problems of surface soil removal, displacement, and compaction. Hand scalping sufficient to consistently benefit conifers is extremely expensive. The most common site preparation treatment is prescribed burning, but the effects on competing vegetation are temporary at best. Burning does provide a flush of nutrients and a few years of improved soil moisture, but competing vegetation is quick to occupy the site via resident plants, stored seed, or dispersal from outside the area. Delays in planting or natural regeneration severely reduce survival and growth of planted or natural seedlings severely. Grazing to reduce competition is probably feasible, but requires more careful control of animal numbers and attention to timing. Chemical treatments are probably the most effective and potentially the most environmentally gentle of methods-but are rife with many legal, social, safety, and environmental concerns, either real or imagined. Any of the methods may produce counter productive side effects which can be avoided by other methods. Site preparation and conifer release to suppress competing vegetation influences the ecosystem's herbivores either to the benefit or the detriment of conifers. Snowshoe hare, pocket gophers, voles, big game, domestic livestock, and insects have all been affected by our attempts to enhance conifer performance via vegetation management. Careful consideration of the entire ecosystem, both flora and fauna, is needed to avoid possible problems in immediate or future stand development. Many problems with competition can be reduced by prompt planting of large, healthy, genetically adapted stock and by taking full advantage of desirable microsites when planting.

**ENHANCEMENT OF CONIFER PRODUCTION WITH HEXAZINONE IN THE NORTHERN ROCKY MOUNTAINS.** R. J. Boyd, J. M. Mandzak, S. D. McLeod, and H. L. Osborne, Research Forester (Retired), US Forest Service, Intermountain Research Station, Moscow, ID 83843; Forest Research and Management Consultant, Huson, MT 59846; Forester, Champion International, Russellville, AL 35661; and Assistant Professor and Experimental Forest Manager, University of Idaho, Moscow ID 83843.

Hexazinone, a potent herbicide first registered by DuPont in the early 1970's, and its several formulations, has become a standard for conifer site preparation and release in the Northern Rocky Mountains since the early 1980's. Elsewhere, especially the Southeast, it has been used primarily as a spot soil treatment to release conifers from competing hardwoods. In the Northwest, it is used primarily to control herbaceous vegetation, especially grasses, sedges, and forbs, but has not been consistent as a shrub herbicide.

First marketed as a water soluble powder (Velpar), subsequent formulations have produced a mixable liquid (Velpar L), various pelleted (Grid Balls), and granular (ULW) products, some of which have been discontinued. Currently a granular form, (Pronone manufactured by Pro-Serve), is being used widely for forestry applications.

Hexazinone, in its various formulations, has found a place in agriculture as a weed control agent in alfalfa, sugarcane, coffee, cocoa, palm oil, pecans, rubber trees, and pineapple. As such, it is probably going to be available for continued use in forestry. Research has shown hexazinone to be relatively non-toxic to humans and other life forms when used as directed. Neither persistence in the environment nor off-site movement have been found to be a significant problem with hexazinone use in the forested environments.

Research on hexazinone as a site preparation and conifer release herbicide got underway in the Northern Rocky Mountains in the late 1970's and early 1980's by several organizations including the Intermountain Research Station, Potlatch Corporation, and Champion International. From 1979 until 1984, the Intermountain Research Station installed studies involving hexazinone and other candidate herbicides (glyphosate, atrazine, dalapon) on 24 herbaceous vegetation sites, ranging from eastern Idaho, western Montana, through northern Idaho, to northeast Washington. Most of the trials also included a mechanical (hand) scalp and all had an untreated control.

Early (1979) trials with the original hexazinone formulations resulted in mixed results, due primarily to the tendency of hexazinone to precipitate out of solution at low temperatures in the field. In spite of this, our oldest, and most outstanding result was a 14- to 15-fold improvement relative to controls in the 6 yr performance of ponderosa pine spot treated with hexazinone at 3 lb/A a few weeks after planting. Of the 11 tests conducted in 1979 and 1980, hexazinone proved the most consistent and generally the greatest improvement in ponderosa pine, lodgepole pine, and Douglas-fir performance as measured by "Plantation Growth Index" (PGI; the product of survival percent and stem volume) 5 to 6 yr after treatment. If, due to abundant growing season precipitation, survival was not improved by competition control, subsequent growth (up to 3 yr) improved.

In 1982 and 1983, we wrote a plan to extensively test the use of hexazinone (liquid and granular), glyphosate, dalapon, atrazine, scalping, and, of course, no treatment. Various field units of the Forest Service, Boise Cascade Corporation, and the Colville Tribal Forestry volunteered to install and measure results on ponderosa pine, lodgepole pine, and Douglas-fir plantations. Abundant growing season precipitation resulted in excellent first year survival on treated and untreated controls on most of these studies. Subsequently, many of these studies (at least 5 out of the original 13) have been destroyed by pocket gophers, and none were remeasured beyond three years following treatment. Hexazinone L was among the best treatments, but few passed the test of statistical significance for a particular study.

Unfortunately, our work with hexazinone (along with other herbicides) suffered from the public and media chemophobia during the 1960s and 1970s which continues into the present. One had to be thoroughly convinced of the benefits to be achieved, or a fool, to continue in spite of the adverse publicity one was subjected to.

The Intermountain Research Station discontinued herbicide research in the fall of 1985. However, your senior author has stayed on as a volunteer and is continuing herbicide research as a Forest Service volunteer.

University of Idaho researcher, contract researcher, and consultant. Since then, nine more studies involving hexazinone have been established on or in the vicinity of the University of Idaho Experimental Forest.

These studies have explored: (1) the effect of spot size on established ponderosa pine with pinegrass competition, (2) the effect of spot and broadcast hexazinone L and hexazinone G on the performance of established ponderosa pine, (3) site preparation type treatments with hexazinone L, MCI (a discontinued granular hexazinone product with added fertilizer), hexazinone G, cultivation plus atrazine, and cultivation on a Ponderosa Conservation Reserve Program (CRP) plantation, (4) comparison of hexazinone L applied to 2-0 bare root and 1-0 container ponderosa pine, and (5) concurrent, fallow, and no-treatment comparisons on ponderosa pine, lodgepole pine, Douglas-fir, white pine, grand fir, larch, and western red-cedar.

The spot size study has shown that in pinegrass, a four foot diameter spot maximizes soil moisture at spot center during the first season. Spots up to 6 feet in diameter provide for the best 5 yr growth (60-200% increase for 4, 5, and 6 ft diameter spots, and a 70% increase for 3 ft spots). Comparisons of hexazinone L and hexazinone G, both broadcast and spot treated over established ponderosa pine, have shown a 5 yr post-treatment response in favor of broadcast treatment (160-325%), but a significant positive effect of spot treatments (100%) as well. In a CRP planting of container grown ponderosa pine in 1988, 5 yr results show a four-fold increase in volume production of hexazinone L, atrazine, and MCI compared to a two-fold increase over the controls for cultivation and hexazinone G. In an "old-field" planting of ponderosa pine near Moscow, early post-plant hexazinone L treatment of bare root and container stock has improved survival, diameter, and height growth resulting in seven- and eight-fold increases in PGI respectively.

Hexazinone L was included in a recent study of spring and fall applications of different rates of imazapyr over ponderosa pine near Moscow. Observations clearly show hexazinone L to be the superior treatment both from the standpoint of competition control and tree performance. In addition, recent trials sponsored by DuPont near Moscow will provide information on comparisons of hexazinone L, hexazinone G, sulfometuron, and mixes of hexazinone and sulfometuron on ponderosa pine, lodgepole pine, white pine, Douglas-fir, and western larch.

Hexazinone L, hexazinone G, and sulfometuron have also been featured in University of Idaho cooperative trials of the "TOPS" (Trees On the Palouse) program in eastern Washington. Ponderosa pine seedfall into one of our "band" treated plantations resulted in a 10-fold greater first year seedling count on hexazinone L treated ground than on untreated ground. At 4 yr, there are twice the seedlings on treated as on untreated ground.

Judging from a personal communication with Wilbur-Ellis folks, the main supplier of herbicide for forestry in the Northern Rocky Mountains, hexazinone is currently the leading herbicide with enough hexazinone L sold to treat 2000 A and enough hexazinone G sold to treat 3500 A, each figured at 2 lb/A. Glyphosate comes in at 1000 A and atrazine at 250 A.

Hexazinone products have been one focus of in-house research efforts at Champion in western Montana since 1980. Research studies have examined various hexazinone formulations for use as a site preparation tool with several species, different seasons of application, fallow periods, stocktypes, rates and types of application. Recent studies have been installed to test the potential for use of hexazinone 10G as a release tool in stands ranging from seedlings to small sawtimber, to examine the interactions with fertilizer and explore its use as a chemical thinning tool.

The first hexazinone study conducted by Champion research personnel examined hexazinone L spots versus a simulated broadcast application in a site preparation mode for use with ponderosa pine. First year results showed large increases in initial survival. Longer term results (10 yr) demonstrated significantly improved growth and continued higher survival with treatment. An economic analysis indicated that herbicide treatment yields higher net present values than does traditional site preparation on these relatively harsh sites.

The next series of trials experimented with the use of hexazinone L as a site preparation tool for use with lodgepole pine seedlings. These studies tested differing rates (2 and 4 lb/A), season of application (fall and spring), stocktype (styro-4 and bare root), season of planting (fall and spring), and delay since application (none,

6 mo, and 1 yr). Short-term results indicated that the best combination in terms of a PGI was the spring planted bare root stock with the spring treatment at 4 lb/A. The increase in mortality over the 2 lb rate was small but the differences in tree size were quite large. Long-term results also showed that the container stock survival and growth were usually improved by treatment.

An early release trial applied hexazinone L at 2 lb/A over the top of a 2 yr old ponderosa pine plantation. After 9 yr, the treated seedlings were 38% taller, had double the dbh, and had stem volumes 91% greater than untreated seedlings. Tree crowns were also significantly larger. The treated area had about 10% more seedlings as well.

On-going studies into the physiological effects of hexazinone G release applications have revealed significant reductions in pre-dawn water stress in trees of small sawtimber size as well as in sapling sized trees. Dry sites and relatively wet sites both show reductions in water stress of about 30%. Combining hexazinone G with fertilizer appears to increase efficacy of control on some of the more resistant shrubs. The effect on trees is profound in terms of greener and longer needles, an effect demonstrated in seedlings as well. Growth results will not be available until more time has passed.

A recent trial demonstrated that fallow periods of 1 or 1.5 yr after hexazinone G application were sufficient to virtually eliminate herbicide induced mortality of our most susceptible conifer, western larch.

In another recent study, soil water probes were installed in a calcareous and a typical upland site to trace the movement of hexazinone through the soil profile. A pulse of hexazinone was detected moving through the soil a few weeks after application, but the amount was very small. After 1 yr, hexazinone was detectable in a few soil samples, but the concentrations were less than 0.1 ppm.

Hexazinone products consistently provide for excellent control of grasses, sedges, and many forbs. Most shrubs have higher resistance and are only marginally damaged. Control can last for many yr; some research applications show decreased percent cover and/or changed species composition 10 yr after treatment. Others appear to lose their efficacy within two growing seasons.

In general, we have found benefits of two types; often both will occur. First is a significant improvement in seedling survival, sometimes as great as a five-fold increase on the harsher, drier, grassed-in sites. The second benefit is a period of competition-free growth ranging from 2 to several yr. In wetter sites or years, this extended free growth period can result in seedlings reaching breast height 10 yr sooner than untreated seedlings. Mortality after the first two growing seasons also appears to be reduced.

Following some promising research results operational application of hexazinone began in 1982 and enjoyed a high degree of success. Hexazinone G is now an accepted and commonly used tool for preparation of grassy, difficult-to-regenerate sites throughout Champion's Montana ownership. Large treatment units are generally treated with hexazinone G in the fall by helicopter. The sum of acres treated annually is typically much less than 1% of the company lands. A new emphasis is being placed on small spot treatments to reduce herbicide impact on sensitive sites.

Although very few problems have been encountered they are worth mentioning. When higher rates (4 lb/A) are applied to heavy lacustrine silts, significant mortality may be caused to sapling sized lodgepole pine trees. Also, on one occasion, movement off-site has been observed on these types of soil when a heavy runoff occurs. It is important to properly assess site factors such as soil texture, drainage, and hydrologic properties to determine appropriate rates and adequate buffer zones for sensitive sites. Lacustrine silts and other fine textured soils with reduced permeability and very coarse textured shallow rocky soils both demand special attention but for different reasons.

**TRICLOPYR FOR CONTROL OF BIGLEAF MAPLE: BASAL THINLINE APPLICATIONS IN DECEMBER, FEBRUARY, AND APRIL.** Paul F. Figueroa and Vanelle F. Carrithers, Weyerhaeuser Company, Centralia, WA 98531, DowElanco, Mulino, OR 97042.

#### INTRODUCTION

Bigleaf maple is an important hardwood on the west side of the Cascades in the Pacific Northwest. It can be important as a commercial fiber source, given proper size and form. It can also be a major conifer competitor when it occurs in sufficient densities. Bigleaf maple is competitive because of its ability to resprout vigorously from cut stumps and its rapid juvenile growth (1, 3, 10). These growth attributes can result in significant reductions in Douglas-fir height growth and survival through overtopping and moisture depletion (7, 11).

There are several herbicide application methods used to control bigleaf maple, including aerial broadcast applications, aerial spot applications using the Slo-fly method, and ground application methods that treat either the foliage or stems. A common ground application method has been the thinline basal technique. Thinline is a basal-bark application where a narrow band of herbicide solution is applied to the entire circumference of each stem in the clump.

The success of thinline application depends on (a) proper herbicide stem coverage, or the banding of every sprout in each clump (3, 4, 8); (b) proper timing of the herbicide treatment (12); and, (c) delivering adequate herbicide dosage to the entire clump that has been defined for triclopyr (3, 6, 12).

#### METHODS

This study was established to determine the minimum threshold level of herbicide needed to control bigleaf maple stump sprouts (LD 90) using triclopyr (formulated as the butoxyethyl ester), applied as a basal thinline application. The study design tested the control efficacy of diluted triclopyr as a basal thinline treatment. The test compared time of application and herbicide efficacy. Application timings ranged from the beginning to the end of winter dormancy period. An additional treatment was evaluated using a diluted pre-mix of triclopyr plus picloram (Access herbicide containing 2 lb/gal butoxyethyl ester, triclopyr, and 1 lb/gal isooctyl ester, picloram) applied only in February.

The study was located in western Washington on Weyerhaeuser's Southwest Washington, Mt. St. Helens Tree Farm. The soil on the test site is an Abernathy series which is a deep, well-drained soil developing from siltstone and fine sandstone (2). Douglas-fir soil-site index was estimated at 130 feet at breast height age 50 yr. Elevation is 400 feet and the topography is level. The test area was logged with ground-based machinery in summer 1988 and broadcast burned during the winter. The study area was shovel-planted in April 1989 using 2+1 Douglas-fir seedlings grown at the Weyerhaeuser Mima Nursery. Across the 40 A site, bigleaf maple density averaged 10 clumps/A. Two yr later, at the time of study installation the Douglas-fir plantation averaged 2.6 feet (range 1.4 to 3.9 feet) in height while the bigleaf maple clumps averaged 9.6 feet in height (range 3.9 to 15.8 feet).

Bigleaf maple clumps were blocked according to their pre-treatment height and crown volume size classes. Treatments were randomly assigned within each clump size class. Ten clumps were treated with each herbicide concentration and timing. The non-treated check and triclopyr plus picloram treatments had ten clumps each. Mor-Act was used as the diluent for all treatments. Mor-Act is a paraffin-base petroleum oil product that has been used extensively and effectively for basal-bark applications in the Pacific Northwest.

Thinline treatments were applied using a Weed Systems HQ300 CO<sub>2</sub> spray applicator. Pressure was regulated at 30 psi at the tank head. A Spray Systems TP-00015 zero-degree nozzle tip was used with a 50 mesh screen. This system dispenses a solid straight stream of solution approximately 1 to 2 inches wide at a distance of 10 to 12 feet. Delivered volume averaged 0.31 oz/sec (SD 0.02). Agmark Agricultural Dye Marker (P2) basal-bark dye was added to each treatment at 0.0025% v/v. Each clump was treated such that all stems

were banded on at least two sides. Stems larger than 2 inches basal caliper were banded to have complete 360 degree herbicide coverage. Mean clump application was 3.3 oz and ranged between 0.9 and 9.2 oz/clump.

Measurements were made prior to thinline applications and annually for 3 yr after treatment. Clump height and crown widths were measured at each period. Total height was measured from the average ground line to the tallest live leaf. Crown width was the average north-south and east-west crown width measurements. A clump was considered to be alive if any live foliage was present.

The experimental design was a completely block randomized design using an analysis of variance with equal sample sizes across all triclopyr treatments (9). The null hypothesis tested was that herbicide concentration level, timing of application, or interaction of level and timing have no impact on bigleaf maple height and percent crown volume. If F-values were significant at the 10% level, treatment differences were separated using Duncan's Multiple Range test.

## RESULTS

**Survival.** Averaging all herbicide concentrations by timing, first-year bigleaf maple survival was higher when triclopyr was applied in December compared to February or April (Table 1). Several apparently dead clumps resprouted across all timings, during the second and third year after treatment. Survival differences among application timings narrowed during the second and third year. Survival differences among herbicide concentration, averaged across all application timings (Table 2). Resprouting during the second year occurred on all treatments except the triclopyr plus picloram treatment. The increase was greatest at the 12.5% triclopyr concentration. Observations made on live and resprouting clumps showed their vigor was high. This indicates that those high vigor resprouts would continue to grow well and could develop into conifer competitors. The triclopyr plus picloram treated stumps had no resprouting and the stumps and stems were rapidly degrading and decomposing. Rapid degradation is indicative of treatments above the lowest level where triclopyr and imazapyr have shown to be effective preventing bigleaf maple resprouting (5).

Table 1. Effects of application timing on bigleaf maple survival, averaged across all triclopyr concentrations.

Treatment	Survival		
	Year 1	Year 2	Year 3
	%		
Check	100	100	100
December	26	42	40
February	18	36	38
April	10	34	24

Table 2. Effects of triclopyr concentration level on bigleaf maple survival averaged across all application dates.

Treatment	Herbicide product concentration	Solution strength	Survival		
			Year 1	Year 2	Year 3
	%	lb/gal	%		
Check			100	100	100
Triclopyr	6	0.24	63	80	70
Triclopyr	12.5	0.5	23	60	53
Triclopyr	25	1	3	33	33
Triclopyr	50	2	0	13	10
Triclopyr	75	3	0	3	3
Triclopyr+picloram*	50.0	1+0.5	0	0	0

\*Triclopyr as Garlon 4 (4 lb), triclopyr plus picloram applied as Access (2 lb + 1 lb).



**Height.** Comparing clump height 1 yr after treatment showed significant differences among triclopyr concentrations, timing, and the interaction. The clump height 2 and 3 yr after treatment showed significant differences only among triclopyr concentrations and not for timings or the interaction. These data show that differences among timings significantly decreased during the second and third years after treatment (Table 3). There were significant differences among herbicide concentrations and differences increased with time (Table 4). Triclopyr concentrations of 25% and greater significantly reduced clump height in the first and second years. By the fourth year, all treatments were significantly different. All treatments were shorter than the mean Douglas-fir. Only the 25% and greater treatments were taller than the shortest Douglas-fir.

**Table 3.** Effects of application timing on bigleaf maple total height averaged across all triclopyr concentrations.

Treatment	Total height		
	Year 1	Year 2	Year 3
	ft		
Check	11.9 <sup>a</sup>	12.8	14.8
December	1.8 a <sup>b</sup>	2.4 a	3 a
February	1.2 ab	2.3 a	2.7 a
April	0.7 b	1.7 a	1.9 a

<sup>a</sup>The non-treated check plots and the triclopyr plus picloram were not tested against triclopyr only treatments since they were not replicated over application dates.

<sup>b</sup>Treatments with same letter in a column are not significantly different at  $p = 0.10$  using Duncan's Multiple Range test.

<sup>c</sup>Triclopyr as Garlon 4 (4 lb), triclopyr plus picloram applied as Access (2 lb + 1 lb).

**Table 4.** Effects of triclopyr concentration level on bigleaf maple total height, averaged across all application dates.

Treatment	Herbicide product concentration	Solution strength	Total height		
			Year 1	Year 2	Year 3
	%	lb/gal	ft		
Check			11.9 <sup>a</sup>	12.8	14.8
Triclopyr	6	0.24	4.6 a <sup>b</sup>	5.6 a	6.3 a
Triclopyr	12.5	0.5	1.3 b	3.3 b	4.1 b
Triclopyr	25	1	0.2 c	1.2 c	1.9 c
Triclopyr	50	2	0 c	0.4 c	0.4 d
Triclopyr	75	3	0 c	0.1 c	0.1 d
Triclopyr+picloram <sup>c</sup>	50	1+0.5	0 <sup>a</sup>	0	0
Tallest Douglas-fir	- height (feet)		5.6	7.8	11.2
Mean Douglas-fir	- height (feet)		3.8	5.3	7.6
Smallest Douglas-fir	- height (feet)		2.1	2.3	3.9

**Crown Volume.** Crown volume was calculated using crown width and total height assuming clump shape was a cylinder. Crown volume change was calculated as the percentage growth or loss relative to its pre-treatment crown volume. Significant treatment differences were shown for first-year crown volume change among triclopyr concentrations, timing, and the interaction. Second- and third-year crown volume change had significant treatment differences among triclopyr concentrations only, and not due to timing, or the interaction. Differences among application timing were not evident after the first year after treatment (Table 5). There was a time progression for concentration and effectiveness of treatments. The first and second year after treatment only the 6% concentration was significantly different. During the third year, the 12.5% concentration separated (Table 6).

**Table 5.** Effects of application timing on bigleaf maple effective crown volume growth, averaged across all herbicide concentrations.

Treatment	Crown volume growth		
	Year 1	Year 2	Year 3
	%		
Check	50.4 <sup>a</sup>	62.8	139.7
December	-97.9 a <sup>b</sup>	-96.2 a	-92.8 a
February	-99.6 a	-98 a	-91.2 a
April	-99.9 a	-98.9 a	-93.7 a

<sup>a</sup>The non-treated check plots and the triclopyr plus picloram were not tested against triclopyr only treatments since they were not replicated over application dates.

<sup>b</sup>Treatments with same letter in a column are not significantly different at  $p = 0.10$  using Duncan's Multiple Range test.

<sup>c</sup>Triclopyr as Garlon 4 (4 lb), triclopyr plus picloram applied as Access (2 lb + 1 lb).

**Table 6.** Effects of triclopyr concentration level on bigleaf maple effective crown volume growth, averaged across all application dates.

Treatment	Herbicide product concentration	Solution strength	Crown volume growth		
			Year 1	Year 2	Year 3
	%	lb/gal	%		
Check			50.4 <sup>a</sup>	62.8	139.7
Triclopyr	6	0.24	-95.8 a <sup>b</sup>	-91.4 a	-77.1 a
Triclopyr	12.5	0.5	-99.9 b	-97.4 b	-88.1 b
Triclopyr	25	1	-99.9 b	-99.8 b	-97.9 bc
Triclopyr	50	2	-100 b	-99.9 b	-99.8 c
Triclopyr	75	3	-100 b	-99.9 b	-99.9 c
Triclopyr+picloram <sup>c</sup>	50	1+0.5	-100 <sup>a</sup>	-100	-100

## DISCUSSION

The main goal of vegetation management is to apply only that level of herbicide necessary to reduce competition such that crops can grow in an economically free-to-grow condition. Weed mortality of 100% is not necessarily needed or even desirable. Eliminating a weed species ability to cause crop mortality or growth loss can be equally effective as killing the weed. It is important to integrate knowledge of herbicide thresholds with competition threshold data to determine vegetation management control strategies.

At this time, a competition threshold between bigleaf maple and Douglas-fir has not been defined. Observations of how Douglas-fir growth is impacted by various bigleaf maple densities suggests there are levels where the overall conifer stand growth is not impacted. We have estimated the density where bigleaf maple does not economically impact Douglas-fir stand growth to be between 3 and 8 clumps/A. This is based on observations of bigleaf maple maximum crown occupancy of mature maple in second-growth Douglas-fir stands. Site quality (site index, moisture, soil depth, growing conditions), age differential between Douglas-fir and bigleaf maple, site preparation methods, and pre- and post-harvest vigor of bigleaf maple will affect competitive ability of bigleaf maple on any given site. Higher vigor bigleaf maple with lower site quality Douglas-fir would be impacted with low maple density. Low vigor maple stands coupled with higher Douglas-fir site quality would require higher maple densities before impacts were noted. Big game browse can also play a large role in reduced maple vigor and growth. Selection of a herbicide concentration to reduce bigleaf maple competition should take into account all of the above factors.

Douglas-fir survival, vigor, and height were measured from an adjacent study on the same soil and site, established to evaluate long-term effects of bigleaf maple on planted Douglas-fir. A series of five 0.05 A plots was measured to assess Douglas-fir growth. The Douglas-fir data were used to compare its relative stand position to the treated and non-treated bigleaf maple.

Bigleaf maple overtopping is the primary competition component that causes conifer growth or survival losses. Bigleaf maple overtopping was summarized to compare treatment efficacy with bigleaf maple's ability to overtop Douglas-fir. Table 7 shows the percentage of bigleaf maple that overtopped the shortest Douglas-fir from 1 to 4 yr after treatment. These data shows that triclopyr levels of 25%, 50%, and 75% had 23%, 3%, and 0% of the bigleaf maple overtopping Douglas-fir 4 yr after treatment.

These data can be used to determine the most effective triclopyr level to reduce long-term bigleaf maple overtopping. For example, a site with 30 bigleaf maple clumps/A treated with a 12.5% triclopyr concentration would be estimated to have 11 (37% of initial) surviving clumps overtopping the shortest Douglas-fir 4 yr after treatment. If 11 maple clumps/A was determined to be above the threshold of impact for Douglas-fir growth, then 12.5% concentration would not be effective for that site. As a comparison, a site having 10 clumps/A treated with a 12.5% triclopyr concentration would be estimated to leave 3.7 clumps/A overtopping the shortest Douglas-fir 4 yr after treatment. This number of residual bigleaf maple would be below the expected competition impact threshold level thus making that herbicide prescription acceptable for that site.

Economic considerations for herbicide costs are equally important for treatment prescriptions. The potential economic benefits of selecting the proper level of triclopyr or triclopyr plus picloram are shown in Table 8. Treatment costs could be as low as \$0.30/clump or as high as \$1.48 (based on the average 3.3 oz. solution/clump for this study). The triclopyr plus picloram treatment gave 100% control, but at \$1.62/clump cost. This points out the need for additional data to develop the minimum control threshold for triclopyr plus picloram treatments.

Table 7. Percentage of bigleaf maple that would resprout after treatment and would overtop the smallest Douglas-fir yr 1 through 4 yr after treatment. Years 1, 2 and 3 are actual data, yr 4 was estimated based on expected bigleaf maple and Douglas-fir growth.

Treatment	Herbicide product concentration	Solution strength	B.L.M. overtopping the smallest Douglas-fir post-treatment			
			Year 1	Year 2	Year 3	Year 4
	%	lb/gal	%			
Check			100	100	100	100
Triclopyr	6	0.24	60	77	67	63
Triclopyr	12.5	0.5	23	67	50	37
Triclopyr	25	1	3	20	23	23
Triclopyr	50	2	0	10	3	3
Triclopyr	75	3	0	0	0	0
Triclopyr+picloram*	50	1+0.5	0	0	0	0
Tallest Douglas-fir	-- height (feet)		5.6	7.8	11.2	14.6
Mean Douglas-fir	-- height (feet)		3.8	5.3	7.6	9.9
Smallest Douglas-fir	-- height (feet)		2.1	2.3	3.9	5.5

Table 8. Comparison of treatment cost based on 3.3 oz herbicide solution per bigleaf maple clump.

Treatment	Herbicide product concentration	Solution strength	Solution strength	Cost <sup>b</sup>
				clump
	%	lb/gal	lb/clump	\$
Triclopyr	6	0.24	0.0062	0.30
Triclopyr	12.5	0.5	0.0129	0.41
Triclopyr	25	1	0.0258	0.62
Triclopyr	50	2	0.0516	1.05
Triclopyr	75	3	0.0773	1.48
Triclopyr	100	4	0.1032	1.91
Triclopyr+picloram*	50	1+0.5	0.0258+0.0129	1.62

\*Triclopyr as Garlon 4 (4 lb), triclopyr plus picloram applied as Access (2 lb + 1 lb).

<sup>b</sup>Based on the following 1993 herbicide costs: Garlon 4 (4 lb triclopyr) \$74/gal; Access (2 lb triclopyr + 1 lb picloram) \$118/gal; Mor-Act \$7.50 gal.

Most treatments produced clumps that appeared to be dead during the first year yet resprouted in the second or third year. Historically, successful thinline treatment was dependent on complete stem banding of every sprout in the clump. Some of the inconsistencies in mortality among treatments may have been due to the inability to completely band every stem. An evaluation of several stems that sprouted in the first year showed some had small stems, usually less than one-foot tall growing amongst many other larger stems that may have received incomplete coverage. Also, several stems were growing along the ground in the litter layer making treatment difficult. These branches had to be lifted out of the litter before treatment is applied. These factors may have had an influence in increasing survival rates and resprouting. It is incumbent upon the operator to ensure a quality application is done.

#### CONCLUSIONS

During the third year after treatment, significant resprouting, height growth, and crown volume growth can occur with 6 and 12.5% triclopyr concentrations. Combining all concentrations levels (6, 12.5, 25, 50, 75%), there were no differences in bigleaf maple control for treatments applied from the beginning through the end of the dormant season based on 3-yr efficacy data. Triclopyr plus picloram (50:50 v/v with Mor-Act) gave 100% bigleaf maple control for 3 yr. The level of decomposition suggests there is a minimal risk of resprouting in the future. All concentrations reduced bigleaf maple total height and below the mean height of planted Douglas-fir.

A bigleaf maple competition model must be developed. In the interim period, the user must define the number of bigleaf maple clumps that cause conifer growth or survival losses. Evaluating the long-term risk of bigleaf maple overtopping Douglas-fir shows that rates as low as 25% triclopyr concentration can be effective reducing bigleaf maple competition.

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**IMAZAPYR FOR CONTROL OF BIGLEAF MAPLE: BASAL THINLINE AND GROUND APPLIED GRANULES.** Paul F. Figueroa and Thomas E. Nishimura, Weyerhaeuser Company, Centralia, WA 98531, American Cyanamid Company, Lake Oswego, OR 97034.

#### INTRODUCTION

Bigleaf maple is a hardwood common to the west side of the Cascades in the Pacific Northwest. It is a major competitor in conifer plantations. Conifer survival can be significantly reduced under bigleaf maple crown canopy. Growth can be impacted as well in competition with bigleaf maple even at relatively low competition densities. Bigleaf maple resprouts vigorously from cut stumps following harvesting. The literature reports first-year stump sprout growth of 3 feet, 4.7 and as high as 10 feet during the first year following cutting (1, 5, 14).

Bigleaf maple caused 30% reduction in Douglas-fir height growth after 5 yr for seedlings growing within 3 feet of sprouting clumps. Significant Douglas-fir mortality has been reported on trees planted within one foot of stump sprouts (11). The primary effect of bigleaf maple is overtopping with crowding and moisture depletion having a secondary growth impact on Douglas-fir (15).

Thinline is a common ground application method for controlling bigleaf maple. Thinline is a basal bark application where a 1- to 2-inch-wide band of herbicide solution is applied to the bark such that each stem in the clump is banded with solution usually 1 to 1.5 feet above the ground line. Key elements to effective control are herbicide coverage and dosage. If herbicide banding is not complete, bigleaf maple control is significantly reduced (5, 7, 12). The methodology of application for thinline was developed based on ensuring the herbicide dosage is at or above the minimum threshold level (5, 16).

Imazapyr is an effective herbicide used for bigleaf maple control. Application methods include broadcast foliar, ground applied spot-foliar, and cut-stump applications (1, 5, 6). Three imazapyr formulations are registered for forest use. Two liquid formulations are available for basal bark application to control bigleaf maple; imazapyr as an emulsifiable concentrate (Chopper EC) and a imazapyr as a ready-to-use (Chopper RTU). In addition there is a 5% imazapyr granule product available for ground applied vegetation control on right-of-ways.

#### METHODS

The study was established to define the lowest control threshold of imazapyr for bigleaf maple control when applied using the thinline application method. A comparison of imazapyr RTU formulation and the 5% G treatments were also included. The study was located in Cowlitz county in western Washington on Weyerhaeuser's Mt. St. Helens Tree Farm. The study was located on an Abernathy soil series which is a deep, well-drained soil developing from siltstone and fine sandstone (3). Douglas-fir soil site is estimated at 130 feet at breast height age 50 yr. The elevation is 400 feet and the topography is level.

The study area was tractor-logged in summer 1988 and broadcast burned during the winter. The study area was shovel-planted in April 1989 using 2+1 Douglas-fir seedlings grown at the Weyerhaeuser Mima Nursery. Bigleaf maple density was estimated at 10 clumps/A for the 40 A study area. Douglas-fir seedlings averaged 1.7 feet (se 0.1) in height and bigleaf maple averaged 6.7 feet (se 1.7) in height and had a mean crown width of 6.3 feet (se 0.1) at treatment time. Prior to treatment the bigleaf maple clumps were blocked by initial total height and crown volume size classes. Treatments were randomly assigned within each size class. Ten clumps were treated with each of the imazapyr EC and RTU treatments. Seven clumps were treated for each of the granular application rates.

The thinline treatments were applied using a Weed Systems HQ300 CO<sub>2</sub> spray applicator. Pressure was regulated at 30 psi at the tank head using a Spray Systems TP-00015 zero degree nozzle tip. This spray system dispensed a solid stream of solution approximately 1- to 2-inch wide at a distance of 10 to 12 feet. Delivered volume averaged 0.31 oz/sec for all solution strengths. Mor-Act was used as the diluent for all treatments. Agmark Agricultural Dye Marker (P2) basal bark dye was added to the emulsifiable concentrate treatments at 0.0025% v/v. Imazapyr RTU has its own violet colored dye. Each clump was treated such that all stems were banded on at least two sides. Stems larger than 2 inches in basal diameter were banded to have a complete 360 degree herbicide coverage. The granule treatments were pre-measured and placed in individual containers to facilitate application. The contents were then poured onto the ground on the uphill side of the stump in a single location.

Treatments were applied on February 26, 1990. No precipitation followed treatments for 24 h. Bigleaf maple was dormant and exhibited no signs of active bud elongation. Initial bigleaf maple leaf-out occurred on April 17, 1990. Data collections were made prior to thinline applications, and annually during the fall for 4 yr after treatment. Survival, height and crown width were measured. Total height was measured from the average ground line to the tallest live leaf. Crown width was the average of the north-south and east-west measurements. A clump was considered to be live if any green foliage was present.

The experimental design was a randomized block design using a one-way analysis of variance (13). The untreated check plots were not used for statistical comparisons with herbicide treatments. The null hypothesis tested was application of herbicide has no impact on bigleaf maple height and crown volume growth. The liquid and granular treatments were analyzed independently and not compared to each other. If F-values were significant at the 10% level, treatment differences were separated using Duncan's New Multiple Range test.

#### RESULTS

**Survival.** Bigleaf maple survival 4 yr after treatment ranged between 0% and 60% (Table 1). There was a rate differentiation by concentration for imazapyr EC after 3 yr. Rates above 30% maintained 100% mortality. Mortality decreased with decreasing concentration level. The imazapyr RTU resulted in 100% bigleaf maple

mortality. Imazapyr RTU uses a propylene glycol based carrier while Mor-Act is a paraffin based petroleum oil product. The propylene glycol based carrier may give greater basal bark penetration than the paraffin based products for thinline application.

Several treatments had clumps that appeared to be dead in early years but resprouted during the later years. Imazapyr can take up to 3 yr to completely kill bigleaf maple and is more prevalent when applied close to the sub-lethal dose (8). We noted that as imazapyr dosage approaches a sub-lethal level, bigleaf maple develops deformed buds and has fasciculated leaves. Most of those buds and leaves have imperfect development, then die during the growing season. During the following growing season new buds and leaves develop having similar imperfect development. These shoots also can die back or produce very weak sprouts. Many plants that eventually recover from a sub-lethal imazapyr dose have low vigor and grow at rates substantially less than their non-treated counterparts. Most of the sub-lethal dose treated bigleaf maples did not become conifer competitors after 4 yr.

Historically, successful thinline treatment was dependent on complete banding all stems. Some inconsistencies in mortality among treatments may have been attributed to the inability of the operator to completely band every stem. An evaluation of several stems that sprouted in the first year showed some small stems (less than 1 foot tall and protected by other larger stems) may have received less than full thinline coverage. We noted that several stems were growing along the ground in the litter layer making treatment difficult. These branches had to be lifted out of the litter and banded. It is incumbent upon the operator to ensure a quality application is done.

**Height and crown defoliation: thinline treatments.** Analysis of variance showed there were no significant differences among herbicide treatments for bigleaf maple height 1 yr after treatment (Table 2). Two years after treatment there was treatment separation. These data show that none of the imazapyr treatments are growing at a rate that will allow the treated clumps to recover and catch up to the height of non-treated bigleaf maple. Treated bigleaf maple are generally at a low vigor. This low vigor suggest that they may not ever fully recover or become competitors with the Douglas-fir.

**Crown defoliation: thinline treatments.** Percent crown defoliation was calculated using crown width and total height assuming clump shape was a cylinder. Analysis of variance showed no significant differences among treatments through 4 yr after treatment (Table 3). Lower imazapyr EC rates had some resprouting, but those resprouting clumps had significantly lower crown volumes compared to their pre-treatment crown volume or if compared to non-treated clumps.

Table 1. Effects of imazapyr thinline treatments on bigleaf maple survival.

Treatment	Herbicide solution		Survival by year after treatment			
	%	lb/gal	Year 1	Year 2	Year 3	Year 4
Check	-	100	100	100	100	100
Imazapyr EC 3	0.06	10	70	60	60	60
Imazapyr EC 5	0.1	0	30	40	40	40
Imazapyr EC 10	0.2	10	40	40	40	40
Imazapyr EC 20	0.4	0	50	40	30	30
Imazapyr EC 30	0.6	10	40	30	30	30
Imazapyr EC 40	0.8	0	0	0	0	0
Imazapyr EC 50	1	0	0	0	0	0
Imazapyr EC 100	2	0	0	0	0	0
Imazapyr RTU	0.25	0	0	0	0	0

Table 2. Effects of imazapyr thinline treatments on bigleaf maple total height.

Treatment	Herbicide solution		Total height by year after treatment			
	%	lb/gal	Year 1	Year 2	Year 3	Year 4
Check	-	8.3 <sup>a</sup>	10.2	11.7	13	
Imazapyr EC 3	0.06	0.1 <sup>a</sup>	1.4 <sup>a</sup>	1.8 <sup>a</sup>	2.3 <sup>a</sup>	
Imazapyr EC 5	0.1	0 <sup>a</sup>	0.8 <sup>ab</sup>	1.4 <sup>a</sup>	2.1 <sup>a</sup>	
Imazapyr EC 10	0.2	0.2 <sup>a</sup>	0.9 <sup>ab</sup>	0.9 <sup>ab</sup>	1 <sup>ab</sup>	
Imazapyr EC 20	0.4	0 <sup>a</sup>	0.7 <sup>ab</sup>	1.2 <sup>a</sup>	1.1 <sup>ab</sup>	
Imazapyr EC 30	0.6	0.1 <sup>a</sup>	1.0 <sup>a</sup>	0.8 <sup>ab</sup>	1.3 <sup>ab</sup>	
Imazapyr EC 40	0.8	0 <sup>a</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	
Imazapyr EC 50	1	0 <sup>a</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	
Imazapyr EC 100	2	0 <sup>a</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	
Imazapyr RTU	0.25	0 <sup>a</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	

<sup>a</sup>The non-treated check was not tested against the treated clumps.  
<sup>b</sup>Treatments with same letter in a column are not significantly different at p = 0.10 using Duncan's Multiple Range test.

**Mortality and height: granular treatments.** Only the 4.8 oz treatment achieved 100% mortality after 4 yr (Table 4). Observations of the 3.2 and 1.6 oz treatments show they have low vigor but their survival level may remain stable over time. Analysis of variance showed no statistical height differences (Table 5). By the fourth year, the 1.6 ounce treatment was taller than the other two treatments. The trend of mean height of these granule treated clumps have been relatively stable not increasing their annual height growth. The vigor of these clumps were generally low, and they don't appear that they will increase their growth rates to a similar level of the non-treated clumps.

**Table 3.** Effects of imazapyr thinline treatments on bigleaf maple effective crown volume growth. Crown volume expressed as a percentage of the pre-treatment crown volume level.

Treatment	Herbicide solution		Crown volume reduction by year			
	Year 1	Year 2	Year 3	Year 4		
	%	lb/gal	%			
Check			73.8*	175.4	236.7	356
Imazapyr EC	3	0.06	-99.9 <sup>b</sup>	-97.7 <sup>b</sup>	-96.2 <sup>b</sup>	-87.3 <sup>b</sup>
Imazapyr EC	5	0.1	-100	-94.4	-92.6	-77.2
Imazapyr EC	10	0.2	-99.8	-97.4	-98.4	-97.4
Imazapyr EC	20	0.4	-100	-96.6	-95.4	-90.5
Imazapyr EC	30	0.6	-100	-98.2	-98.2	-92.1
Imazapyr EC	40	0.8	-100	-100	-100	-100
Imazapyr EC	50	1	-100	-100	-100	-100
Imazapyr EC	100	2	-100	-100	-100	-100
Imazapyr RTU		0.25	-100	-100	-100	-100

\*The non-treated check was not tested against the treated clumps.  
<sup>b</sup>Herbicide treatments were not significantly different.

**Crown defoliation: granular treatments.** Effective crown volume showed no significant treatment differences among imazapyr 5G treatments in the first year (Table 6). There was a trend toward increasing crown volume of the 3.2 and 1.6 oz treatments from year one to the second year. In both the 3.2 and 1.6 oz treatments several small resprouts develop. Many of their leaves showed signs of fasciculation in the first year but did not die back during the second growing season.

**Table 5.** Effects of imazapyr 5G treatments on bigleaf maple total height.

Treatment	Product volume	Total height by year after treatment			
		Year 1	Year 2	Year 3	Year 4
	oz/clump	ft			
Check		8.3*	10.2	11.7	13
Imazapyr 5G	1.6	3.3 <sup>b</sup>	3.5 <sup>b</sup>	3.3 <sup>b</sup>	4.1 <sup>b</sup>
Imazapyr EC	3.2	2.2	1.8	0.9	1
Imazapyr EC	4.8	0.7	0	0	0

\*The non-treated check was not tested against the treated clumps.  
<sup>b</sup>Herbicide treatments were not significantly different.

**Table 4.** Effects of treatments on bigleaf maple survival for imazapyr 5G treatments.

Treatment	Product volume	Survival by year after treatment			
		Year 1	Year 2	Year 3	Year 4
	oz/clump	%			
Check		100	100	100	100
Imazapyr 5G	1.6	71	71	57	57
Imazapyr EC	3.2	43	43	29	29
Imazapyr EC	4.8	14	0	0	0

**Table 6.** Effects of imazapyr 5G treatments on bigleaf maple effective crown volume growth. Crown volume expressed as a percentage of the pre-treatment crown volume level.

Treatment	Product volume	Crown volume reduction by year			
		Year 1	Year 2	Year 3	Year 4
	oz/clump	%			
Check		73.8*	175.4	236.7	356
Imazapyr 5G	1.6	-82 <sup>b</sup>	-55 <sup>b</sup>	-63 <sup>b</sup>	-25 <sup>b</sup>
Imazapyr EC	3.2	-93	-82	-93	-90
Imazapyr EC	4.8	-99	-100	-100	-100

\*The non-treated check was not tested against the treated clumps.  
<sup>b</sup>Herbicide treatments were not significantly different.

**Overtopping.** Hardwood overtopping is the primary cause of conifer growth reductions (2, 8, 9, 15). Because of the rapid height and crown growth characteristics of bigleaf maple, Douglas-fir can quickly be overtopped leading eventually for crop tree growth reductions or mortality. To further understand the potential competition

effects of bigleaf maple competition following herbicide treatment, a summary of Douglas-fir overtopping was compiled by treatment for each measurement year.

Douglas-fir survival, vigor, and height was measured from an adjacent study on the same soil and site and was planted at the same time as the herbicide trial. This study was established to evaluate the long-term effects of bigleaf maple on planted Douglas-fir. A series of five 0.05 A plots were measured to assess Douglas-fir growth. The Douglas-fir data was used to compare its relative stand position to the treated and non-treated bigleaf maple.

Bigleaf maple overtopping was summarized to compare treatment efficacy against bigleaf maple's ability to overtop Douglas-fir. Table 7 shows overtopping potential of bigleaf maple on this site compared with Douglas-fir. A summary of Douglas-fir by tallest, mean, and shortest Douglas-fir is shown to give a perspective of potential overtopping situations. This data shows that most treatments effectively have reduced bigleaf maple's ability to overtop Douglas-fir. Granule treatments were equally effective except for only the 1.6 oz treatment that would have significant overtopping after 5 yr.

Table 7. Percent of bigleaf maple overtopping the shortest planted Douglas-fir by treatment by year after herbicide application. Years 1 through 4 are actual height data while Year 5 was estimated based on expected Douglas-fir and bigleaf maple growth rates.

Treatment	Herbicide solution		Population overtopping				
			Shortest planted Douglas-fir Douglas-fir				
			Year 1	Year 2	Year 3	Year 4	Year 5
	%	lb/gal					
Check	-		100	100	100	100	100
Imazapyr EC	3	0.06	0	40	40	20	10
Imazapyr EC	5	0.1	0	30	40	40	30
Imazapyr EC	10	0.2	10	20	10	0	0
Imazapyr EC	20	0.4	0	10	20	20	10
Imazapyr EC	30	0.6	0	20	20	10	10
Imazapyr EC	40	0.8	0	0	0	0	0
Imazapyr EC	50	1	0	0	0	0	0
Imazapyr EC	100	2	0	0	0	0	0
Imazapyr RTU		0.25	0	0	0	0	0
Imazapyr 5G		1.6 oz	71	71	57	43	43
Imazapyr 5G		3.2 oz	43	43	29	14	14
Imazapyr 5G		4.8 oz	14	0	0	0	0
Tallest Douglas-fir (feet)			3.9	5.6	7.8	11.2	14.6
Mean Douglas-fir (feet)			2.6	3.8	5.3	7.6	9.9
Shortest Douglas-fir (feet)			1.4	2.1	2.3	3.9	5.5

The goal of managing vegetation is to reduce weed competition only to that point where crop survival and growth losses are above an acceptable level consistent with management objectives. It is not always necessary or desirable to eliminate all weeds from every stand. If the economic or growth threshold are known, the land manager needs to select the herbicide concentration that reduce competition below the impact level. Bigleaf maple densities that range between 3 and 8 clumps/A may not affect long-term Douglas-fir stand growth (10).

For example, if a site had 30 bigleaf maples/A and was treated with 5% imazapyr EC, it would be expected to have 10 surviving clumps (30% of the initial clumps) overtopping the shortest planted Douglas-fir 5 yr after treatment. If 10 clumps/A was determined to be above the threshold and impact Douglas-fir growth, then 5% concentration would not have been effective for that site. However, if the site initially had only 10 clumps/A and was treated using 5% imazapyr EC concentration, only 3 surviving clumps would be estimated overtopping Douglas-fir five years after treatment. If that number of surviving clumps may be acceptable and at a level that



would not impact Douglas-fir growth then the 5% concentration would be acceptable for that specific site. Treatment rates need to be set for the specific conditions of the site rather than blanket application rates.

#### DISCUSSION

Historically, some land managers have used 100% weed mortality as the criteria for determining whether a herbicide treatment was successful. Herbicides, such as imazapyr EC, RTU or 5G have the ability to reduce the long-term health, growth and competitiveness of plants. Eliminating a weed's ability to cause mortality or growth loss can be just as effective as killing the weed. This can only be done if the manager develops and integrates knowledge of weed competition thresholds and competition impact data to develop the minimum level of vegetation control needed. Therefore, it may not be necessary, or desirable to kill all bigleaf maple on a site.

The economic considerations of prescribing the proper herbicide dosage are equally important. Potential economic benefits of imazapyr EC and RTU for thinline application are shown in Table 8. If maple density is known, the potential treatment costs could be as low as \$0.19 per clump and as high as \$2.82 for undiluted imazapyr (based on the average 1.81 oz/clump for this study). An inspection has to be made to insure each stem was completely banded by herbicide. Complete stem banding appears to a factor in bigleaf maple control. There are operational trade-offs between contractor application costs and herbicide costs. The land manager needs to take into consideration the historical quality of herbicide application and adjust his prescription for concentrations up or down accordingly.

Table 8. Comparison of treatment cost.

Treatment	Herbicide solution	Solution strength	Cost/clump
	%	lb/clump	\$
Imazapyr EC	3	0.0008	0.19
Imazapyr EC	5	0.0014	0.24
Imazapyr EC	10	0.0028	0.38
Imazapyr EC	20	0.0056	0.65
Imazapyr EC	30	0.0084	0.93
Imazapyr EC	40	0.0113	1.20
Imazapyr EC	50	0.0141	1.46
Imazapyr EC	100	0.0281	2.82
Imazapyr RTU	100	0.0035	0.42
Imazapyr 5G	1.6 oz	0.005	0.35
Imazapyr 5G	3.2 oz	0.010	0.70
Imazapyr 5G	4.8 oz	0.015	1.05

Based on the herbicide costs: Imazapyr emulsifiable concentrate (Chopper EC) \$200/gal; Imazapyr ready-to-use (Chopper RTU) 30/gal; Imazapyr 5G (Arsenal 5G) \$3.50/gal; Mor-Act \$7.50/gal.

There were differences between the control level using imazapyr EC diluted with Mor-Act and the imazapyr RTU formulations. During application we noted the propylene glycol based RTU formulation coalesced around stems easier and quicker than the paraffin based petroleum Mor-Act carrier. Imazapyr RTU appeared to flow more readily and form a better stem band. The paraffin based petroleum product took longer to flow around the stem. There may be differences in how each diluent assists herbicide penetration into bark and it's ease of uptake and translocation within the stem.

It is estimated that application time to spread low volumes of granules under the drip line of bigleaf maple would be prohibitive compared to standard basal bark application methods. This study has shown that concentrating a granular application at a single spot near the stump can be effective controlling bigleaf maple at 3.2 and 4.8 oz/clump. There may be labor cost trade-off that may lower the overall herbicide plus application

costs of granules compared to liquid imazapyr. On steep slopes, areas with heavy logging slash or other difficult terrain, the use of a packaged granular herbicides could have a cost savings over conventional basal or thinline applications. Contractor costs for thinline application can vary between \$0.75 to \$2.00/clump (4). Delivery systems that allows the operator to place herbicides in a single location could lower contractor costs.

#### CONCLUSIONS

Imazapyr EC is an effective herbicide for bigleaf maple control applied during the dormant season. Levels of imazapyr EC above 30% solution in Mor-Act gave 100% bigleaf maple mortality 4 yrs after treatment. All concentrations reduced bigleaf maple height below that of the mean Douglas-fir height. Imazapyr RTU is an effective herbicide for bigleaf maple control applied during the dormant season that gave 100% mortality. The propylene glycol diluent in the ready-to-use formulation may promote greater bark penetration or herbicide absorption into the stem than paraffin based petroleum diluents. Imazapyr 5 G can be effective for bigleaf maple control applied in a single-spot ground application immediately adjacent to the cut stump. However, rates below 3.2 oz/clump were not effective controlling bigleaf maple.

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#### INFLUENCE OF SURFACTANTS ON CONIFER DAMAGE WITH GLYPHOSATE AND IMAZAPYR APPLICATIONS. Bruce R. Kelpsas, Northwest Chemical Corporation, Salem, OR 97303.

**Abstract.** Applications of glyphosate and imazapyr on forest lands are often necessary to remove competing shrubs and encourage development of conifer seedlings. While labeled use rates are tolerated by many conifer species in broadcast treatments, seedling damage is often observed. Several field trials were established to evaluate the influence of surfactants on conifer damage.

Individual seedlings of Douglas-fir, ponderosa pine and coast redwood were treated with fixed rates of glyphosate or glyphosate-imazapyr combinations and replicated 15 to 60 times per treatment. A total of four surfactants (Entry II™, Activator 90®, R-11® and LI 700®) were evaluated for their phytotoxic contribution when added to the herbicides at concentrations of 0.125 to 0.625% v/v. Untreated seedlings and seedlings treated with only the herbicides served as controls. Seedlings were treated with a hand held boom calibrated to deliver 10 gpa. Evaluation of damage occurred 3 to 10 months after treatment and consisted of visual crown kill or growth injury ratings.

Results indicate that seedlings exhibited little to no injury to glyphosate (redwood) or glyphosate-imazapyr (Douglas-fir and pine) where no surfactant was added. The addition of surfactant and surfactant concentration generally increased conifer damage, but large differences in injury ratings were also observed between type or brand of surfactant in Douglas-fir and pine. Surfactants that contributed little damage in Douglas-fir were LI 700 and Activator 90, while greater amounts were seen with R-11 and Entry II. High levels of injury in ponderosa pine were seen from R-11 and Activator 90, but lower amounts with LI 700 and Entry II. These results suggest that herbicide-surfactant combinations and rates may need to be tailored to specific conifer species to avoid unacceptable injury.

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**HERBACEOUS RADIUS OF INFLUENCE EFFECTS ON WESTERN OREGON DOUGLAS-FIR SURVIVAL AND GROWTH: FIRST YEAR RESULTS.** D. Eric Hanson, Steven R. Radosevich, and Robin W. Rose, Faculty Research Assistant, Professor, and Associate Professor, Oregon State University, Corvallis, OR 97331.

**Abstract.** An study initiated in Spring 1993 in west-central Oregon separates the effects of woody and herbaceous associated vegetation on Douglas-fir [*Pseudotsuga menziesii* (Mirbel) Franco)] growth and survival. In addition, the study addresses the herbaceous vegetation radius of influence (RI) for Douglas-fir. The study was established on three sites, one in the western foothills of the Cascades and two in the Coast Range, with a CRD arrangement of treatments replicated three times per site. Treatments include woody vegetation control only, herbaceous control only, RI control areas of 0.3, 0.6, 0.9, and 1.2 m, and total vegetation control (TVC), as well as an untreated check. For the RI treatments broadcast woody control was used on the entire plot with herbaceous control only within the prescribed distance. Plots are 0.125 ha with a 0.05 ha measurement plot containing 49 trees at 3.1 by 3.1 m spacing. All herbaceous treatments used hexazinone at 1.5 kg/ha in water applied in March at 17.7 l/ha and 165 KPa with a CO<sub>2</sub>-charged backpack sprayer. Woody vegetation was spot-sprayed with 2% triclopyr in diesel. All treatments were maintained through the growing season with periodic spot applications of 1% glyphosate in water. Tree measurements including; height, height to crown base, diameter (approx. 15 cm), and 2-D crown width, were initially taken in March and remeasured in September. Tree mortality was also recorded. Vegetation assessments were conducted in July.

There was an interaction among site for mortality, as well as height, diameter, and crown volume growth. Mortality at the Cascades site and the eastern Coast Range site increase with the 0.3 m RI relative to the control ( $P = 0.007$  and  $0.005$ , respectively). Although a correlation between distance of herbicide application and herbicide injury was suspected, none was found. Also at that Coast Range site, mortality was reduced in the Wo, Ho, TVC, and 4' RI treatments. There were no treatment effects on height or crown volume growth but was a treatment effect on diameter growth in the Cascades and western Coast Range. In the Cascades, diameter growth was greater in the TVC and Ho treatments than the Wo or untreated control ( $P = 0.001$ ): In the western Coast Range, mean diameter growth was marginally greater for the broadcast (TVC, Wo, Ho) treatments than the control ( $P = 0.06$ ), greater for the TVC than the partial vegetation control (Wo, Ho) ( $P = 0.005$ ), and greater for Ho than Wo ( $P = 0.02$ ). Diameter growth also increased with increasing RI for both sites ( $P = 0.001$  and  $0.01$ , respectively). On more moderate sites herbaceous vegetation control is more important than woody and results in a linear relationship between diameter growth and distance of herbaceous control. On more severe sites, large area vegetation control increases survival.

**SPRING LAKE, NEW MEXICO - A SALT CEDAR CONTROL DEMONSTRATION.** Keith W. Duncan, Brush and Weed Specialist, New Mexico State University, Artesia, NM 88210.

**Abstract.** Saltcedar is an exotic phreatophyte which occupies millions of acres of riparian areas throughout the western United States. Saltcedar is an aggressive competitor often growing in near monoculture stands and is suspected of lowering water tables thus destroying wetlands and wildlife habitats.

Saltcedar growing in two 13 A dry lakes near Artesia, New Mexico, were aerially sprayed with a fixed-wing aircraft on August 8, 1989. Imazapyr was applied at 1 lb/A in a total volume of 7 gpa with 0.25% v/v Activator surfactant and 0.25% v/v Nalcotrol. The two dry lakes are approximately 100 yards apart and were permanent spring-fed lakes prior to invasion of the saltcedar.

On August 15, 1989, a 2 inch diameter hole was hand augured into the bottom of one of the two lakes. The hole was bored to a depth of 19.5 feet and a 20 foot joint of pvc pipe inserted into the hole. A removable cap was placed over the end of the pipe to prevent moisture or debris from entering the hole from above ground. A soil sample was removed from the bottom of the hole and soil moisture determined gravimetrically. Soil samples were collected and soil moisture determined at approximately 60 day intervals for 12 months.

An attempt was made to collect soil samples in October, 1990, 14 months after application. However, the water table had risen to a point where water occupied the bottom 3 feet of the hole. Beginning in October, 1990, the depth of the water table was monitored at 30 d intervals.

The monitoring data indicate that the water table at Spring Lake rose approximately 6 to 8 inches each month from October, 1990 to July, 1991. From July to August, 1991, the water table rose 6.5 feet. The water table dropped slightly from August to September, then rose one foot from September to October and continued to rise approximately 0.5 to 1 foot each month until June, 1992 when one foot of water was recorded on the surface of Spring Lake. This was the first recording of water in Spring Lake since 1969. The water depth in Spring Lake increased during winter 1992 to 1993 and fell during summer 1993, but has remained on the surface since June, 1992. The monitoring data indicate the water table at Spring Lake has risen from a depth of greater than 20 feet below the soil surface to the surface within 34 months after application.

On September 28, 1992, saltcedar canopy reduction was visually estimated to be 99%, while saltcedar mortality was determined by stem counts to be 95%.

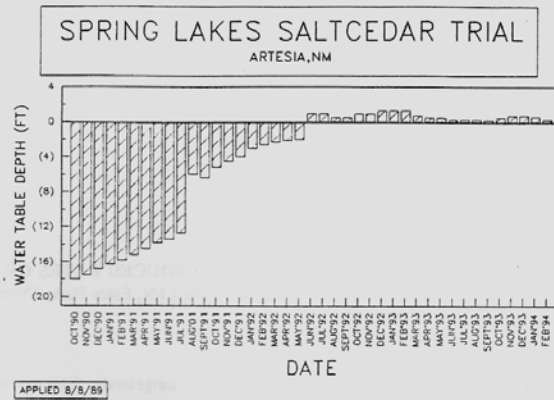


Figure. Water changes at Spring Lake, NM since treatment with imazapyr in August, 1989.

**GERMINABLE SEED PRODUCTION OF DYERS WOAD PLANTS HAND-PULLED AT EIGHT STAGES OF FLOWER OR FRUIT DEVELOPMENT.** S. A. Dewey and J. O. Squire, Associate Professor and Research Assistant, Department of Plants, Soils, and Biometeorology, Utah State University, Logan, UT 84322-4820.

**Abstract.** Many youth groups and other volunteers have participated in work projects to manually control dyers woad within communities and on public lands in northern Utah and southern Idaho. Hand-pulling has also been a common practice among farmers and ranchers trying to rid agricultural lands of scattered dyers woad plants. In order to prevent recontamination of land by viable seed, it has been recommended that dyers woad plants be removed from the site if pulled after the fruits had turned brown. However, some individuals have suspected that plants pulled and left when pods were green and immature might also be capable of producing significant amounts of viable seed.

During 1992 and 1993 a study was conducted to help answer this question. Representative dyers woad plants were pulled at each of eight distinct floral/fruit development stages (Table) to study the relative germinability of their seeds. Stages were based on the development of individual racemes, with plants considered to be in a stage when approximately 25% of the most advanced racemes reached that stage. Three plants per growth stage were collected in 1992, and four plants per growth stage were collected from each of two locations in 1993. Plants were pulled and allowed to dry naturally in a greenhouse for at least 3 months, following which 50 of the largest fruits from each plant were harvested and the seeds carefully removed from each fruit. Seeds were placed on moistened blotter paper in covered petri dishes and allowed to germinate in the dark at room temperature for up to 30 d. Dishes were checked and germinated seeds were removed every 2 or 3 d.

Dyers woad plants pulled as early as Stage 3 produced germinable seeds. Persons pulling dyers woad are now being advised to remove and destroy all plants developed beyond the bloom stage; i.e., plants having any fruiting racemes which totally lack open blossoms.

**Table.** Germination of dyers woad seed from plants pulled at eight stages of raceme development.

Stage	Raceme description	Germination			
		1992-I	1993-II	1993-III	Average
		%			
1	75% blossoms, 25% green fruits	0	0	0	0
2	25% blossoms, 75% green fruits	0	0	0	0
3	All green fruits, medium thickness	16	0	2	6
4	All green fruits, fully thickened	21	18	11	17
5	25% of fruits turning brown	56	94	84	78
6	50% of fruits turning brown	79	65	61	68
7	75% of fruits turning brown	41	66	98	68
8	All fruits fully brown or black	90	85	97	91

**BIG SAGEBRUSH (*Artemisia tridentata*) MANAGEMENT WITH REDUCED RATES OF TEBUTHIURON.** Mary B. Halstvedt, DowElanco, 2155 Carriage Drive LPR, Estes Park, CO 80517.

**INTRODUCTION**

Big sagebrush is a woody shrub dominant on many areas of western rangelands. The vast root system and competitive ability of big sagebrush causes a reduction in soil moisture resulting in lowered water tables,

decreased water volume in creeks and springs, and degraded riparian areas. The prevalence of sagebrush also decreases desirable herbaceous understory and negatively impacts grazing for livestock and wildlife.

Controlling dense stands of big sagebrush has been recognized as a positive range management practice for many years. Fire, raiing, plowing, and herbicides have been used to control sagebrush and increase forage production. Several of these methods such as raiing, plowing and 2,4-D applications not only control big sagebrush but can also damage or eliminate forb and shrub species desirable for wildlife.

A pelleted clay formulation containing 20% active ingredient tebuthiuron (Spike®), was introduced for brush control by Elanco in 1974. The pellets are applied to the soil by ground or aerial application equipment. Rain dissolves the pellets and moves tebuthiuron into the soil where it is rapidly absorbed by the roots of plants and translocated to the shoots. In susceptible plant species, photosynthesis is inhibited and defoliation occurs. Several defoliation cycles may occur before carbohydrate reserves are exhausted and the plant dies.

The efficacy of tebuthiuron on big sagebrush was first reported by Klauzer and Arnold in 1975 (1). Sagebrush was effectively controlled by 1 lb/A of tebuthiuron. Whitson and Alley (2) near Ten Sleep, Wyoming found that rates of 0.3, 0.65, and 0.9 lb/A provided 69, 96, and 99.5% control, respectively. Additional studies by Whitson and Alley (3) showed big sagebrush control with tebuthiuron at 0.53 and 1 lb/A. McDaniel et al. (4) evaluated big sagebrush control with tebuthiuron at 11 sites in northern New Mexico. Big sagebrush mortality across sites averaged 80, 89, 92, 94, 95, and 95% with tebuthiuron rates of 0.39, 0.49, 0.59, 0.69, 0.78, and 0.98 lb/A, respectively. Herbage production was 2.5 to 5.5 times higher on tebuthiuron treated areas compared to untreated rangeland when averaged from 1985 to 1990. McDaniel concluded from a follow-up survey of all sites that big sagebrush had not substantially re-invaded treated plots after 8 to 10 yr. Tebuthiuron continues to be used to effectively control big sagebrush (90+% control) and substantially increase herbaceous cover in the western states at rates from 0.4 to 0.6 lb/A.

In 1989 and 1990, Whitson (5) conducted follow-up evaluations on big sagebrush research established in 1980 and 1982. Results demonstrated that re-establishment of big sagebrush did not occur on plots that had initial partial control (70% or less), 10 yr after treatment. Whitson observed that this "thinning" effect on big sagebrush would fit the objective of many land managers to provide a mixed sagebrush ecosystem essential for wildlife habitat. Further research was conducted to assess diversity in both plant and small mammal communities at various sagebrush mortality levels. Johnson et al (6) found that the plant community diversity was the greatest when sagebrush was reduced by 48 and 66%. Big sagebrush reduction of 85% and the untreated check were the least diverse. Small mammal community diversity increased significantly with plant community diversity.

These results stimulated a new interest in evaluating the concept of thinning sagebrush with tebuthiuron. In 1993, additional sites treated with reduced rates of tebuthiuron during the past 10 yr were selected for evaluation.

#### MATERIALS AND METHODS

Multiple research plots were established throughout the western United States by Elanco in the late 1970's and early 1980's. Three of these plots were selected for evaluation based on tebuthiuron rates and site characteristics (Table 1).

Table 1. Site characteristics at three research locations.

Location	Soil texture	Sand	Silt	Clay	OM	CEC	pH	Avg. rain
Rexburg, ID	Loamy sand	87	7	6	1.9	6.2	7.1	12.6
Vernon, UT	Loam	34	37	29	2.6	18.9	8.4	11.38
Littlefield, AZ	Loam	44	38	18	2.9	17.4	7.9	10.94

Treatment method and herbicide rates varied between the three research locations. Treatments were applied aerially at the Rexburg site to plots measuring 250 ft by 1700 ft separated by a 250 ft untreated buffer. One replication of 0.2, 0.38, and 0.53 lb/A was applied on October 10, 1983. At the Littlefield and Vernon locations, treatments were applied with a hand method to 100 ft by 125 ft plots arranged in a randomized complete block with two replications. Treatments at Littlefield included rates of 0.3, 0.4, and 0.5 lb/A applied on January 27, 1983. The Vernon location included rates of 0.2, 0.3, 0.4, 0.5 lb/A applied on May 18, 1983.

Evaluations were made at the three locations by Elanco personnel in the summer of 1985 by counting live and dead plants in 4 random areas across the plot and calculating a percent kill. Statistical analysis is not available for these data. Evaluations in 1993 were taken by randomly placing eight, 100 foot tapes in each treatment. Live and dead big sagebrush plants were recorded within a 4 foot area on each side of the tape. Percent kill was calculated from these count data. Data were analyzed using analysis of variance and means were separated using Duncan's ( $P \leq 0.10$ ).

#### RESULTS AND DISCUSSION

The effectiveness of tebuthiuron on big sagebrush is dependent on the availability for root uptake. Tebuthiuron is more available for root uptake on a coarse soil with low organic matter. Conversely, on fine textured soils with high organic matter and clay content, a greater portion of the tebuthiuron will be absorbed to the soil material and less is available for uptake.

The Rexburg location would be considered a very active site for tebuthiuron. Sagebrush control at this site with 0.2 lb/A and above was greater than 90%, 2 yr after treatment (Table 2).

Table 2. Big sagebrush control with tebuthiuron at three locations and two evaluation times.

Tebuthiuron rate lb/A	Rexburg	Littlefield	Vernon	Rexburg	Littlefield	Vernon
	% control 2 yr after treatment			% control 10 yr after treatment		
0.2	92		45	71b		58b
0.3	96	76	68	81ab	73c	73a
0.4		83	85	NA	85b	79a
0.5	100	89	90	87a	91a	81a

Note: Values not followed by the same letter are significantly different at  $P \leq 0.10$ .

There was a significant difference in sagebrush mortality between the 2 and 10 yr evaluation at the 0.2 lb/A rate. Big sagebrush control decreased from 92 to 71%, respectively. This change was probably due to several interacting factors including coarse textured soil, minimal soil absorption, fast herbicide uptake, and some tebuthiuron movement through the soil profile. Re-establishment occurred in the 0.3 and 0.5 lb/A plots resulting in 81 and 87% control ratings 10 yr after treatment.

Ten yr results at the Vernon and Littlefield sites were similar due to similar soil characteristics and moisture conditions. The 0.2 lb/A rate provided 58% mortality at Vernon indicating less tebuthiuron availability compared to Rexburg. Results at Littlefield showed a significant difference between the 0.3, 0.4, and 0.5 lb/A rates with control of 73, 85, and 91% control, respectively. There was a slight, but not significant, increase in mortality as rate increased at Vernon with rates of 0.3, 0.4 and 0.5 lb/A providing 73, 79, and 81% control.

Data on the number of live and dead sagebrush plants in each treatment is shown in Table 3. In general, total plants in untreated plots tend to be greater than in treated plots. This could be due to some original dead stems not being identified because of decomposition during the 10 yr period. It was also difficult to distinguish if dead stalks came from one original plant or several plants.

Table 3. Big sagebrush plant counts at three locations 10 yr following treatment with tebuthiuron.

Tebuthiuron rate	Plant counts/A 10 yr after treatment					
	Rexburg		Littlefield		Vernon	
	Live	Dead	Live	Dead	Live	Dead
lb/A						
0.2	577b	1361b			1062b	1575c
0.3	414b	1372b	632b	1650b	762c	1900ab
0.4			316c	1830ab	566cd	2064a
0.5	327b	1906a	191c	1966a	321d	1622bc
Untreated	2472a	664c	2200a	321c	2700a	240d

Note: Values not followed by the same letter are significantly different at P 0.10.

### CONCLUSIONS

These studies indicate that partial mortality of big sagebrush can be accomplished by using reduced rates of tebuthiuron. Results from these locations were similar to the Wyoming studies in that the sagebrush did not re-establish to the original level in a 10 yr period. New research has been initiated by Whitson and Olson in Wyoming to document effects of partial sagebrush reduction on sage grouse and pronghorn antelope habitat. Several demonstration areas with tebuthiuron thinning rates have been established or planned in 1993 and 1994 in Montana, Wyoming, and Colorado.

Tebuthiuron offers the unique opportunity to design a big sagebrush management program for control objectives ranging from high control for herbaceous cover production only, partial control for wildlife enhancement only, or a compromise objective. When developing a big sagebrush management program, the tebuthiuron rate should be selected by considering the control objective, soil characteristics, elevation, and rainfall patterns.

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**SPOTTED KNAWEED CONTROL WITH VARIOUS HERBICIDES APPLIED AT FIVE GROWTH STAGES.** Celestine L. Duncan and Mary B. Halstvedt, Weed Management Services, P. O. Box 9055, Helena, MT 59604, and DowElanco 2155 Carriage Dr. LPR, Estes Park, CO 80517.

**Abstract.** Spotted knapweed is a competitive perennial weed that is widely distributed in the western United States. Picloram, clopyralid plus 2,4-D and dicamba plus 2,4-D are commonly used for control of spotted knapweed in pasture and rangeland. Research data are limited concerning the optimum knapweed growth stage for application of these products. Field trials were initiated in 1991 at Avon and Missoula, Montana to determine the efficacy of picloram, clopyralid plus 2,4-D, and dicamba plus 2,4-D when applied at five growth stages of spotted knapweed. Sites selected for the study were native range and seeded crested wheatgrass at Avon and Missoula respectively. Both sites had about 50% spotted knapweed cover. Herbicide applications were made at the rosette, bolt, bud, flower, and fall regrowth knapweed growth stages. Herbicides were applied



with a CO<sub>2</sub> backpack sprayer in 18 gpa. Plots were 10 by 30 feet and treatments were replicated three times in a randomized complete block design at both locations. Data were analyzed using analysis of variance and means were separated using Duncan's (P0.05).

Mature spotted knapweed control was similar between locations but varied with chemical treatment (Table 1). Results 2 yr after application indicated that picloram at 0.25 lb/A provided greater than 93% spotted knapweed control regardless of plant growth stage at application. Clopyralid plus 2,4-D at 0.18 + 1 lb/A did not differ significantly from picloram at any application timing. However, there was a trend towards less control with the mixture, especially when applied to fall regrowth. Control with dicamba plus 2,4-D at 0.5 + 1 lb/A was higher at the bolt and bud stage, averaging 74% and 83% respectively, compared to 47% at the rosette stage, 56% at the flower stage and 28% at the fall regrowth stage, but none of these differences were statistically significant. Spotted knapweed seedling control showed similar trends (Table 2).

Table 1. Mature spotted knapweed control at Avon and Missoula (Msla) 24 months after treatment.

Plant growth stage at application	Herbicide/rate								
	Picloram 0.25 lb/A			Clopyralid + 2,4-D 0.18 + 1 lb/A			Dicamba + 2,4-D 0.5 + 1 lb/A		
	Avon	Msla	Avg	Avon	Msla	Avg	Avon	Msla	Avg
	%								
Rosette	97	91	94a*	86	80	83a	50	43	47b
Bolt	99	99	99a	99	76	88a	68	80	74b
Bud	99	99	99a	88	93	91a	86	80	83b
Flower	100	97	99a	93	74	83a	88	23	56b
Fall regrowth	99	89	94a	86	55	70a	43	12	28b
LSD (0.05)	Msla = 13.8								
	Avon = 9.3								

Averages not followed by the same letter are significantly different at P 0.05.

\*ANOVA indicated that only chemical differences were significant.

Table 2. Seedling spotted knapweed control at Avon and Missoula (Msla) 24 months after treatment.

Plant growth stage at application	Herbicide/rate								
	Picloram 0.25 lb/A			Clopyralid + 2,4-D 0.18 + 1 lb/A			Dicamba + 2,4-D 0.5 + 1 lb/A		
	Avon	Msla	Avg	Avon	Msla	Avg	Avon	Msla	Avg
	%								
Rosette	99	90	94a*	70	68	69a	38	52	45b
Bolt	99	93	96a	98	78	88a	55	74	65b
Bud	99	97	98a	90	92	91a	56	90	73b
Flower	98	93	95a	94	75	85a	60	45	53b
Fall regrowth	99	87	93a	83	50	67a	40	15	28b
LSD (0.05)	Msla = 24.9								
	Avon = 12.6								

Averages not followed by the same letter are significantly different at P 0.05.

\*ANOVA indicated that only chemical differences were significant.

**DALMATIAN TOADFLAX ENCROACHMENT ON COLORADO RANGELAND.** K. G. Beck and J. R. Sebastian, Associate Professor and Research Associate, Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

**Abstract.** Dalmatian toadflax is native to the Mediterranean and was cultivated as an ornamental for approximately four centuries in Europe. Dalmatian toadflax was imported to the west coast of North America as an

ornamental in about 1874. It since has escaped cultivation and become a rangeland weed in the western United States and western provinces of Canada. Dalmatian toadflax tends to invade dry, open areas however, how quickly it invades an area and to what extent it displaces desirable plants is unknown.

An experiment was established in 1989 near Livermore, Colorado to monitor plant community changes over time where Dalmatian toadflax apparently was beginning to invade an area. Three transects were established, each 25 m long. Each transect was a replicate and the experimental design was a randomized complete block. Dalmatian toadflax cover and density, crested wheatgrass cover, litter cover, and bareground were measured at 1 m intervals along each transect using a Daubenmire frame. These data were taken in October and April from 1989 through 1993 and repeat measures were taken at the same points along the transects. Data were compared over time, subjected to analysis of variance, and means separated by LSD ( $p < 0.05$ ).

Dalmatian toadflax density increased over 12-fold from 0.6 shoots/0.1 m<sup>2</sup> (approximately 2,400 shoots/A) in fall, 1989 to 7.5 shoots/0.1 m<sup>2</sup> (approximately 30,000 shoots/A) in fall, 1993 (Table). Dalmatian toadflax cover increased over 3-fold from 5.7% in fall, 1989 to 18.4% in fall, 1993. Crested wheatgrass cover decreased simultaneously over 1.5-fold from 51.1% in fall, 1989 to 29.8% in fall, 1993. This rapid Dalmatian toadflax encroachment rate apparently at the expense of crested wheatgrass provides impetus for early detection and management of new, small infestations.

Table. Dalmatian toadflax increase and crested wheatgrass decrease over 5 yr on Colorado rangeland.

Year	Toadflax shoot* density		Toadflax* cover		C. wheatgrass* cover	
	Spring	Fall	Spring	Fall	Spring	Fall
	shoots/0.1 m <sup>2</sup>		%			
1989	-	0.6 e	-	5.7 bcd	-	51.1 a
1990	2.1 d	2.2 d	3.3 d	7.1 bc	44.4 ab	35.5 bc
1991	3.5 cd	3.2 cd	3.9 cd	8.8 b	33.7 cd	43.9 ab
1992	4.5 bc	7.4 a	5.5 bcd	10.9 a	31.1 cde	26.5 e
1993	4.9 b	7.5 a	10.8 a	18.4 a	27.5 de	29.8 cde

\*Compare spring and fall data for a plant population measurement within a species. Means followed by the same letter are not different, LSD ( $p < 0.05$ ).

**THE CONTROL OF LEAFY SPURGE WITH INITIAL AND RETREATMENTS OF PICLORAM.** Mark A. Ferrell, Extension Pesticide Coordinator, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82017-3354.

**Abstract.** This research was conducted near Devil's Tower, Wyoming to compare the efficacy of various rates of picloram for leafy spurge control. Plots were retreated to maintain or attain 80% control with light rates of picloram or picloram plus 2,4-D tankmixes. Plots were 10 by 27 feet with four replications arranged in a randomized complete block. The initial herbicide treatments were applied broadcast with a CO<sub>2</sub> pressurized six-nozzle knapsack sprayer delivering 30 gpa at 40 psi May 24, 1989 (air temp. 56 F, soil temp. 0 inch 74 F, 1 inch 77 F, 2 inch 76 F, 4 inch 75 F, relative humidity 45%, wind west at 3-5 mph, sky partly cloudy). Retreatments were applied broadcast with a CO<sub>2</sub> pressurized six-nozzle knapsack sprayer delivering 20 gpa at 40 psi June 6, 1990 (air temp. 72 F, soil temp. 0 inch 87 F, 1 inch 85 F, 2 inch 83 F, 4 inch 75 F, relative humidity 51%, wind south at 10 mph, sky partly cloudy); June 13, 1991 (air temp. 72 F, soil temp. 0 inch 82 F, 1 inch 80 F, 2 inch 79 F, 4 inch 77 F, relative humidity 60%, wind northwest at 5 mph, clear) and June 10, 1992 (air temp. 86 F, soil temp. 0 inch 100 F, 1 inch 95 F, 2 inch 90 F, 4 inch 80 F, relative humidity 30%, wind north at 5 mph, sky 20% cloudy). The soil was a silt loam (22% sand, 58% silt, and 20% clay) with 1.8% organic matter and a 6.3 pH. Leafy spurge was in full bloom and 12 to 14 inches in height, for the initial treatments and in full bloom and 20 inches in height for the retreatments.

Infestations were heavy throughout the experimental area. Visual weed control evaluations were made June 6, 1990; June 13, 1991; June 10, 1992 and June 21, 1993.

Plots with initial treatments of 1.25 lb/A picloram or greater gave 80% or better leafy spurge control and did not require retreatment in 1990. All other plots required retreatment. Initial treatments maintaining 80% control or better in 1991 were two 1.5 lb picloram treatments, one 1.75 lb picloram treatment and all 2.0 lb picloram treatments. The only 1990 retreatment attaining 80% control or better in 1991 was 0.5 lb picloram over an initial 1 lb picloram. Plots with less than 80% control in 1991 were retreated. None of the retreatments applied in 1991 or 1992 attained 80% control in 1992 or 1993. Two of the three initial 2 lb picloram treatments applied in 1989 continued to maintain 80% leafy spurge control through 1992. The control in these treatments dropped below 80% in 1993.

Table. Leafy spurge control with initial and retreatments of picloram.

Treatment <sup>a</sup>	Rate lb/A	Retreatment <sup>b</sup>	Rate lb/A	Retreatment applied			Control <sup>c</sup>			
				3 June 90	6 June 91	6 June 92	1990	1991	1992	1993
				%						
Picloram	0.25	Picloram	0.25	yes	yes	yes	30	43	33	35
Picloram	0.5	Picloram	0.25	yes	yes	yes	48	53	28	23
Picloram	0.5	Picloram	0.5	yes	yes	yes	50	79	71	68
Picloram	0.5	Picloram + 2,4-D amine	0.25 + 1	yes	yes	yes	44	71	74	79
Picloram	0.75	Picloram	0.25	yes	yes	yes	60	78	65	65
Picloram	0.75	Picloram	0.5	yes	yes	yes	65	71	64	55
Picloram	0.75	Picloram + 2,4-D amine	0.25 + 1	yes	yes	yes	63	65	69	73
Picloram	1	Picloram	0.25	yes	yes	yes	76	75	61	58
Picloram	1	Picloram	0.5	yes	no	yes	74	81	60	64
Picloram	1	Picloram + 2,4-D amine	0.25 + 1	yes	yes	yes	71	74	66	66
Picloram	1.25	Picloram	0.25	no	yes	yes	84	74	59	38
Picloram	1.25	Picloram	0.5	no	yes	yes	87	75	69	71
Picloram	1.25	Picloram + 2,4-D amine	0.25 + 1	no	yes	yes	81	63	65	68
Picloram	1.5	Picloram	0.25	no	no	yes	89	80	66	56
Picloram	1.5	Picloram	0.5	no	no	yes	91	80	69	63
Picloram	1.5	Picloram + 2,4-D amine	0.25 + 1	no	yes	yes	87	75	69	74
Picloram	1.75	Picloram	0.25	no	yes	yes	93	78	66	61
Picloram	1.75	Picloram	0.5	no	no	yes	93	84	73	65
Picloram	1.75	Picloram + 2,4-D amine	0.25 + 1	no	no	yes	92	79	69	68
Picloram	2	Picloram	0.25	no	no	yes	95	84	74	70
Picloram	2	Picloram	0.5	no	no	no	97	85	80	70
Picloram	2	Picloram + 2,4-D amine	0.25 + 1	no	no	no	98	87	84	78
Picloram + 2,4-D amine (LSD 0.05) (CV)	0.25 + 1	Picloram + 2,4-D amine	0.25 + 1	yes	yes	yes	35	74	68	65
							10	16	22	25
							10	16	25	30

<sup>a</sup>Treatments applied May 24, 1989.

<sup>b</sup>Retreatments applied to maintain or attain 80% control.

<sup>c</sup>Visual evaluations June 6, 1990; June 13, 1991; June 10, 1992; and June 21, 1993.

## WEEDS OF HORTICULTURAL CROPS

**DODDER (*Cuscuta campestris*) BIOLOGY AND MANAGEMENT IN TOMATOES.** W. T. Lanini and G. Miyao, Extension Specialist and Farm Advisor, DBS, Section of Plant Biology, University of California, Davis, CA 95616.

**Abstract.** Dodder are parasitic plants which attack tomatoes and numerous other crops and weeds. Observations over the past 10 yr have indicated that dodder is slowly increasing throughout the tomato growing areas of California. This 3 yr study examined the dodder phenology, methods of control, and the impact of dodder on tomato yield and quality. Dodder was observed to germinate between March 19 and May 10, with no observed emergence after this time. Dodder first flowered between 50 and 60 d after tomato planting. Viable seeds were initially observed an average of 67 d after tomato planting. At tomato harvest, a single dodder plant occupied an average of 10.4 feet of crop row.

Nonselective control methods, including glyphosate at 2%, burning with a propane flamer, or hand removal all resulted in 100% dodder kill. Hand removal was the least disruptive to tomato growth. Tomato yields were reduced an average of 27% over the area covered by a single dodder plant. Heavy yield reductions were observed in areas close to the original attachment point with much smaller reductions near the edges where attachment occurred later in the development of the tomato. Tomato fruit size or quality (brix) were not affected by dodder; however, tomato fruit number was reduced.

Table. Influence of dodder cover on tomato yield.

Dodder cover*	Tomato yield reduction
- % -	- % -
96	63
80	37
57	22
29	12
4	1

\*This is the average dodder cover from a single plant at harvest, with approximately 2 feet of tomato row represented by each cover class.

## COVER CROPS FOR WEED SUPPRESSION AND BIOMASS PRODUCTION IN RED RASPBERRIES.

D. Kaufman, R. Karow, R. William, and B. Strik, Oregon State University Extension Service, Aurora, OR 97002.

**Abstract.** This is the final report on a 3 yr trial of various cover crops planted in the fall between rows of red raspberries in Sandy, Oregon. Cover crops evaluated this year include: 'Amity' winter oat; 'Flora' triticale; 'Wheeler' cereal rye; 'Stephen's' wheat; 'Galt' barley; 'Micah' barley; 'Saia' oat; Austrian winter pea; hairy vetch; crimson clover; 'Dwarf essex' rape; and an Austrian pea-'Amity' oat mix. A native vegetation control and a clean cultivated control were also included.

In the 2 previous yr, the various cover crops were planted down entire 600 feet long rows in an unreplicated trial. In this final year of the study each treatment was replicated four times in a randomized complete block design with plots 30 feet long and 10 feet wide (i.e. two, 5 feet wide plantings on each side of the berry row).

Due to delays in field preparation, the covers were not planted until October 11, 1992, almost 3 wk later than the September 25th planting dates in 1990 and 1991. The broadleaf covers established poorly and did not provide any appreciable ground cover until spring, at which time the rape and crimson clover were so weedy they were dropped from observations made after April. The grains established well; however, abnormally wet conditions resulted in poor performance by the barleys due to scald disease. The extreme wetness resulted in increased slug feeding which took a toll on the oats and wheat. Metaldehyde bait was applied in February 1993 for slug control and the 'Amity' oat and 'Stephen's' wheat recovered well enough to give acceptable weed suppression. However, the 'Saia' oat did not recover adequately and was dropped from further observation. Each of the remaining cover crops was visually evaluated for weed suppression on May 11 (before mowing on May 15) and June 17. The 'Amity' oat, 'Flora' triticale, 'Stephen's' wheat, and 'Wheeler' rye provided good to excellent weed suppression throughout the season without any apparent adverse effect on raspberry plant vigor or yield. The extent of weed suppression within the Austrian pea, vetch, and oat-pea mix plots depended on the quality of the stand which tended to be patchy and inconsistent. This is the third year that the 'Amity' oat and 'Flora' triticale have provided good to excellent weed suppression. The 'Wheeler' cereal rye has provided excellent weed suppression during the two seasons it was evaluated.

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**EVALUATION OF A WINTER WHEAT COVER CROP SYSTEM FOR WEED CONTROL IN POTATOES.** Charlotte V. Eberlein, Rick A. Boydston, Edward J. Souza, and Mary J. Guttieri, Associate Professor, Plant Physiologist, Assistant Professor, and Research Associate, University of Idaho Aberdeen Research and Extension Center, Aberdeen, ID 83210, and USDA/ARS, Prosser, WA 99350.

**Abstract.** Weeds are an economically important problem in potato production in the Pacific Northwest, but options for mechanical and chemical weed control are limited. Winter wheat is an effective competitor with summer annual weeds that infest potato fields in Washington, Oregon, and Idaho. Therefore, studies using a winter wheat cover crop system for weed control in potatoes were conducted at Aberdeen, Idaho and Prosser, Washington. The experimental area was fall bedded and 'Weston' winter wheat was seeded at 60 kg/ha in late September or early October. The following spring, 'Russet Burbank' potatoes were planted by hand directly into the wheat. The wheat was killed with glyphosate applied with a selective applicator 1 wk before potato emergence (WBE), at potato emergence (EM), or 1 wk after potato emergence (WAE) to determine the optimum time to kill wheat for maximum weed control and minimum effect on potato growth. Both weedy and weed free treatments were included in order to separate the effects of weeds and wheat cover crop on growth and yield of potatoes.

The winter wheat cover crop system provided substantial weed control. For example, at Aberdeen, total weed biomass at the final sampling in early September was reduced 65% compared to the weedy control when wheat was killed 1 WBE and 97% when wheat was killed at EM or 1 WAE. Unfortunately, the winter wheat cover crop also competed with the potato crop. The cover crop shaded the soil and soil temperatures were lower in cover crop plots than in the no cover crop control; shading also resulted in reduced light interception by emerging potatoes. As a result, potato emergence and growth in the cover crop treatments were delayed compared to the no cover crop control. In weed free plots, delayed emergence and growth resulted in lower total and U.S. Number 1 yields in cover crop compared to no cover crop plots. At Aberdeen, total yield in weed free plots was reduced 27, 50, or 93% and yield of U.S. Number 1 tubers was reduced 29, 60, or 97% when the wheat cover crop was killed 1 WBE, at EM, or 1 WAE, respectively. At Prosser, total yields in weed free plots were reduced 12, 42, or 46% when the cover crop was removed 1 WBE, at EM, or 1 WAE, respectively.

In addition to competing with the potato crop, the wheat cover crop also provided a refuge for field mice. Mouse-damaged tubers constituted 3% of the total tuber yield at Aberdeen and a large percent of the culls at Prosser were damaged by mice.

Our results indicate that a winter wheat cover crop can suppress many common summer annual weeds in potatoes. In addition, the residue from the killed cover crop reduces soil erosion by providing about 65% soil

cover (as estimated by the SCS line transect system) during the growing season, and about 30% cover after harvest. However, the wheat cover crop shades the soil, delays potato emergence, competes with potatoes, and reduces tuber yield compared to conventional practices.

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**EVALUATION OF NORFLURAZON FOR THE CONTROL OF YELLOW NUTSEDGE (*Cyperus esculentus*) IN BEARING ASPARAGUS.** Harry S. Agamalian, Farm Advisor, Emeritus, University of California Cooperative Extension, 118 Wilgart Way, Salinas, CA 93901.

#### INTRODUCTION

Most asparagus producing regions in the United States have some infestations of yellow nutsedge. It has been described as one of the world's worst weeds (2) affecting both annual and perennial crops.

California asparagus plantings are kept mainly in production from 5 to 8 yr depending upon their productivity and marketing economics. There are several preemergence and post emergent herbicides registered for asparagus (4) but yellow nutsedge is difficult to control. The growth habit of yellow nutsedge is similar to an annual. The underground tubers and seeds germinate in the spring and the plant dies with the first frost. The plant is able to produce tubers that can persist in the soil seed bank for several years.

When soil applied preemergent herbicides are used to control annual weeds, the absence of competing vegetation thus allows the resulting nutsedge infestation to become the dominant weed. It becomes a major competitor for moisture (3, 5) under irrigated agriculture and can interfere with hand-harvest. Selective control measures in asparagus would greatly enhance crop rotation practices as there are limited herbicides to control this weed. Results from earlier experiments (1) indicated norflurazon had good asparagus tolerance and controlled yellow nutsedge.

#### MATERIALS AND METHODS

A commercial field of bearing U. C. 157 asparagus was selected for the field experiment. Three yr of continuous use of residual herbicides had developed a heavy infestation of yellow nutsedge. Random counts taken at the site indicated 90 to 120 plants/m<sup>2</sup>. The soil texture at this site was 57% sand, 27% silt, 16% clay and had 0.9% organic matter.

Following fern removal, the soil was tilled and reshaped into 1.52 m beds. Individual replications were 7.5 m long, using a randomized complete block design with four replications per treatment. Norflurazon was applied at 2.2, 4.4 and 8.8 kg/ha and a non-treated control was also included. Applications were made in 375 L/ha. Sprinkler irrigation was used to leach the herbicide into the soil using 25 mm of water. These herbicide applications were subsequently retreated in the second and third year following the initial application. All applications were made during the winter dormant period of January and February.

Evaluations of yellow nutsedge control were made at various intervals following nutsedge emergence throughout the harvest period. Harvest of marketable spears was taken over an 11 wk period. These data were collected for the respective 3 yr of treatments.

Following completion of the third year of crop harvest, soil samples were collected for bioassay of norflurazon. Core samples were taken from 0 to 15, 15 to 30 and 30 to 45 cm depths. Three sites per replication were combined and the soil was planted to cucumber, bean and oats. The crops were evaluated for norflurazon symptoms.

## RESULTS AND DISCUSSION

Norflurazon acts as a plant pigment inhibitor. Following root absorption the herbicide is translocated to the growing portion of the plant (1). Yellow nutsedge leaves that first emerged in the norflurazon treatments were chlorotic, lacking chlorophyll. The percentage of nutsedge plants with these symptoms increased as the norflurazon rate increased. Following complete chlorosis of the leaves, necrosis would occur by the time the nutsedge had three to four leaves. Subsequent irrigations during the first year of application resulted in additional germination of nutsedge seedlings with the above symptoms, especially in the 4.4 and 8.8 kg/ha treatments.

Yellow nutsedge control following the second year of application (1990) resulted in a higher percentage of control (Table 1). Yield data collected during the first year (1989) indicated no significant yield difference (Table 2). Harvest data obtained during the second year of application demonstrated a higher yield at the 8.8 kg/ha rate where 92% control of yellow nutsedge was obtained (Table 2).

Evaluations following the third year of herbicide applications (1991) provided commercial control at all three dosages (Table 1). Subsequent harvest of asparagus spears indicated significant yield increases at the 4.4 and 8.8 kg/ha norflurazon treatments (Table 2).

The results from the 3 continuous yr of application indicated the importance of yearly applications of norflurazon for effective nutsedge control. The registered use rates for asparagus are 2.2 to 4.4 kg/ha. The control evaluations indicate that a 3 yr program must be considered for effective yellow nutsedge control. The experimental rate of 8.8 kg/ha indicates asparagus tolerance to norflurazon. One of the major escape weeds in the 2.2 and 4.4 kg/ha treatments was volunteer asparagus seedlings. The evaluation data (Table 1) indicate that a 3 yr program must be considered for effective yellow nutsedge control.

The experimental results indicate the control of yellow nutsedge from using norflurazon would benefit a weed management system. The soil bioassay of this experimental site indicates much of the herbicide remained in the upper 30 cm of soil (Table 3). The long-term dissipation of norflurazon in asparagus culture is not completely understood. The rate of disappearance of norflurazon from the soil environment may limit its usage where extensive crop rotations are practiced.

Table 1. Yellow nutsedge control as influenced by rate of norflurazon during the 3 yr period.

Treatment	Rate kg/ha	Control		
		1989	1990	1991
		%		
Norflurazon	2.2	42	68	82
Norflurazon	4.4	60	75	95
Norflurazon	8.8	72	92	99
Untreated	0	0	0	0

Table 2. Asparagus yields as influenced by the control of yellow nutsedge\*.

Treatment	Rate kg/ha	Yield		
		1989	1990	1991
		kg/11.2 m <sup>2</sup>		
Norflurazon	2.2	14.8	16.3 a	16.3a
Norflurazon	4.4	15.2	16.5 a	17.5 b
Norflurazon	8.8	16	17.2 b	18.1 c
Untreated	0	15.1	15.8 a	15.2a
N.S.				

\*Values followed by different letters within columns are significantly different according to protected LSD test (P=0.05).

Table 3. Soil bioassay of norflurazon from three depths after 3 yr of continuous application.

Treatment	Rate <sup>b</sup> kg/ha	Cucumber/ cm			Bean/ cm			Oat/ cm		
		0-5	15-30	30-45	0-5	15-30	30-45	0-5	15-30	30-45
		injury <sup>a</sup>								
Norflurazon	6.6	9.8	10	0	10	10	0	10	10	2.5
Norflurazon	13.2	10	8	1	10	10	0	10	9	3
Norflurazon	26.4	10	10	4	10	10	3	10	10	3.2
Untreated	0	0	0	0	0	0	0	0	0	0

<sup>a</sup>Evaluation of 3 replications: 0 = no crop injury; 10 = all plants dead.

<sup>b</sup>3 yr total.

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## WEEDS OF AGRONOMIC CROPS

**DOWNY BROME CONTROL IN ESTABLISHED ALFALFA.** R. G. Wilson, Professor, Department of Agronomy, University of Nebraska, Scottsbluff, NE 69361.

**Abstract.** A 4 yr experiment was conducted near Scottsbluff, NE, to evaluate the selectivity of several rates of diuron, glyphosate, hexazinone, metribuzin, MON-13203, paraquat, pronamide, and terbacil for downy brome control in established alfalfa. A November application of hexazinone at 0.28 kg/ha, metribuzin at 0.56 kg/ha, pronamide at 0.56 kg/ha, and terbacil at 0.84 kg/ha provided 90% or greater downy brome control the following spring. Control of downy brome with a fall application of hexazinone, metribuzin, pronamide, and terbacil at the above rates resulted in an increase in alfalfa yield as compared to an untreated control of 1570, 1790, 900, and 1680 kg/ha, respectively, on a dry matter basis. A spring application of glyphosate at 0.31 kg/ha or paraquat at 0.56 kg/ha to dormant alfalfa (less than three trifoliate leaves present) provided 35% or 74% downy brome control, respectively. Control of downy brome with a spring application of glyphosate or paraquat at the above rates resulted in an increase in alfalfa yield as compared to an untreated control of 450 or 1120 kg/ha, respectively. If spring applications of glyphosate or paraquat were delayed until alfalfa had six trifoliate leaves alfalfa yield was reduced.

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**SUMMER ANNUAL GRASS CONTROL IN ESTABLISHED ALFALFA.** Carl E. Bell, Barry R. Tickles, and Nelroy Jackson, Weed Science Farm Advisor, Extension Agronomy Agent, and Product Development Associate, Cooperative Extension, University of California, Holtville, CA 92250, Cooperative Extension, University of Arizona, Yuma, AZ 85364, and Monsanto Agricultural Co., Corona, CA 91719.

**Abstract.** Summer annual grasses are common to most alfalfa fields in the Lower Colorado River Desert. These grasses are controlled by preemergence applications of trifluralin granules or postemergence applications of sethoxydim. The purpose of these experiments were to compare an experimental herbicide, MON-13200, in various formulations to trifluralin and sethoxydim. Research was conducted at the University of California Research and Extension Center in Holtville, CA.

There were two experiments, one initiated in March, 1992 and a second in March, 1993 in an alfalfa field with a known infestation of junglerice and prairie cupgrass. Treatments were similar in both experiments; utilizing a range of dosages of granular and WDG formulations of MON-13200, granular trifluralin, and sethoxydim. Plots in the 1992 experiment were retreated with the same treatments in March 1993. The 1993 experiment included two combination treatments of MON-13200 plus granular trifluralin. Experimental design was a randomized complete block with three replications. Plot size was 5 by 15 m. MON-13200 and trifluralin treatments were made on March 6, 1992 and March 24, 1993, before summer annual grasses had begun germination. Sethoxydim treatments were made when annual grasses were in the four to six leaf stage on June 22, 1992 and July 27, 1993.

Grass control was assessed visually on May 1, May 28, August 5, and August 25, 1992, and on May 5, July 26, and October 11, 1993. In the first year of the 1992 experiment, grass control at the August 5 evaluation was very good for trifluralin, and for all except the lowest rates of MON-13200. By the next evaluation on August 25, only the highest rates were still controlling these grasses. In 1993, the retreated plots from the 1992 experiment had similar results to the first year. Sethoxydim treatments were generally better in 1993 compared to 1992. Results from the experiment initiated in 1993 were similar to the first experiment. Grass control was generally good for most treatments at the July 26 evaluation. At the evaluation on October 11, the two highest rates of the granular formulations of MON-13200 and sethoxydim treatments were still controlling grasses very well.

Alfalfa and grass biomass were assessed at most normal harvests by taking a 1 m<sup>2</sup> sample per plot. Alfalfa and grass were separated and dried before weighing. There were no significant differences ( $P > 0.05$ ) between treatments for any harvest for alfalfa biomass. Grass biomass was generally correlated to the visual evaluation of weed control, but there was considerable variation between plots. Treating plots 2 yr in a row did not seem to improve grass control or increase alfalfa yields compared to the untreated control.

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**CONTROL OF CANADA THISTLE - A REVIEW OF THE ROSETTE TECHNIQUE.** James H. Hunter, Research Scientist, Agriculture Canada, Indian Head, Sask, Canada, S0G 2K0.

**Abstract.** Control of the top growth of perennial weeds is relatively ineffective in killing the weeds. In Canada thistle, with over 90% of the root below the depth of cultivation, herbicides remain the primary means of control and translocation through out the root system is a critical factor. Canada thistle plants require a 14 to 16 hr photoperiod to induce them to elongate. Under Canadian prairie conditions, plants emerging in spring will bolt, produce shoots, and set seed; plants that emerge in August remain as low-growing rosettes. Complete removal of top growth by cultivation of summerfallow during the last week of July results in large low growing rosettes of Canada thistle in mid-August. Compared to the bud stage, application of <sup>14</sup>C herbicides at the August-rosette stage resulted in a four-fold increase in translocation into the roots.

In field experiments half of the plots received summerfallow tillage in spring, Canada thistle were then allowed to grow to the bud stage and herbicides were applied at the end of July. The other half of the plots received normal summerfallow tillage until the last week of July. Canada thistle regrowth remained as low growing rosettes. Herbicides were applied during the last week of August. Canada thistle shoots were counted and dry weight determined in July and September for four seasons. On plots treated in the August-rosette stage with glyphosate at 1.5 kg/ha, 60% of the bud stage rate, shoot density was reduced by 93%.

In a second set of field experiments, all of the plots were summerfallowed until the end of July. Following which all the thistles remained as rosettes. On August 27 half of the plots were tilled, the other half were sprayed with glyphosate at 0.9 kg/ha. In the spring of years II and III, all plots received a pre-seeding tillage, but were not seeded to a crop. In mid July all shoot growth was physically removed to simulate an in-crop herbicide treatment for top growth control. Glyphosate at 0.9 kg/ha or half of the rate recommended for application at the bud stage, applied to Canada thistle in the rosette stage resulted in 98% control 2 yr after treatment.

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**CONTROLLING WEEDS IN CORN ROWS WITH AN IN-ROW CULTIVATOR.** Edward E. Schweizer, Philip Westra, and Donald W. Lybecker, Plant Physiologist, USDA-ARS, Water Management Research; Weed Scientist, Department of Plant Pathology and Weed Science and Agriculture Economist, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO 80523.

**Abstract.** Weeds within the crop row have been controlled primarily with soil-applied and postemergence herbicides since the 1950s. Herbicides may not be needed in some fields if weeds within the crop row could be controlled with only tillage. Thus, a 2-yr field study was conducted at Windsor, Colorado to compare an in-row cultivator versus a standard row-crop cultivator to decisions made with WEEDCAM, a weed/corn management computer decision aid, for controlling annual weeds within the row in irrigated corn. In the absence of herbicides, weeds were controlled better with an in-row cultivator than with a standard row-crop cultivator, with efficacy being influenced more by cultivation timeliness than by the relative time of weed emergence to corn emergence. When weeds emerged simultaneously with corn in 1991 and rain delayed the first cultivation 10 d, the in-row cultivator controlled only 1.8 times more weeds in June than the standard row-crop cultivator; however, grain yield was increased 34% and gross margin \$143 ha<sup>-1</sup>. When corn emerged 3 wk before weeds in

1992 and the first cultivation was timely, the in-row cultivator controlled 99 times more weeds in June than the standard row-crop cultivator; however grain yield and gross margin were similar because corn had a competitive advantage over the weeds. Weed densities each year were about 95% less in the herbicide-treated WEEDCAM plots than in the non-herbicide treated post-planting tillage plots. Grain yields and gross margins were not affected by weed seedbank density, pre-cultivation tillage, or type of cultivator when weed management decisions were made with WEEDCAM. Weeds can be controlled successfully in corn with an in-row cultivator, but success will depend on such factors as weed seedbank density, cultivation timeliness, and relative time of weed and corn emergence. Data from this research will be incorporated in the computer decision aid database to provide producers with additional options to manage weeds in corn and reduce herbicide usage.

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**ACETOCHLOR (SURPASS®) A NEW CORN HERBICIDE.** J. E. Orr and K. C. Volker, Field Development Representatives, Zeneca Ag Products, Western Research Center, Richmond, CA 94804.

Abstract. Acetochlor is a chloracetamide herbicide which has been developed for preplant incorporated and preemergence control of most grass and broadleaf weeds in popcorn, silage, and field corn. Acetochlor is formulated with the safener dichlomid (6:1 ratio) to ensure crop safety.

Acetochlor was applied postplant preemergence with sprinkler incorporation on medium to coarse textured soils. Acetochlor provided 90-100% control of large crabgrass, barnyardgrass, green foxtail, Russian thistle, cutleaf and hairy nightshade, common lambsquarters, and redroot pigweed. In general, acetochlor at 1 to 1.25 lb/A gave equivalent weed control to metolachlor at 1.5 to 2 lb/A or alachlor at 2 to 2.5 lb/A (rates dependent on soil type). Addition of atrazine or cyanazine gave significantly better broadleaf weed control than acetochlor, metolachlor, or alachlor alone.

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**INTERACTIONS BETWEEN SUGARBEET AND WEED AGE AT TREATMENT, PHENMEDIPHAM PLUS DESMEDIPHAM RATE, AND TYPE OF APPLICATION.** Robert F. Norris and John Roncoroni, Associate Professor and Staff Research Associate, Section of Plant Biology, University of California, Davis, CA 95616.

Abstract. Postemergence weed control in sugarbeets using the commercial mixture of phenmedipham plus desmedipham (phen/des) can cause injury to the crop or may not provide adequate control of weeds. Split applications of phen/des improve safety to the crop and increase weed control. Multiple applications of low herbicide rates may further improve weed control and crop tolerance.

Experiments evaluated variations of phen/des application rate, growth stage of crop and weeds at application, and whether the herbicide application was single, split, or multiple. Experiments were conducted at the University of California at Davis research farm during the spring and early summer. Initial irrigations for germination of sugarbeets and weeds were made sequentially such that sugarbeets, and weeds, were at the cotyledon, early two-leaf, two-leaf, early four-leaf and late four-leaf growth stages at the first application. This technique assured that all herbicide applications with respect to plant age were made under the same environmental conditions. Phen/des was applied at 0.5, 1 and 1.3 lb/A, and each rate was applied either as a single treatment, as a split treatment (50% of nominal rate at each application) 7 d apart, or as a multiple sequential treatment with 25% of the nominal rate at each application on a 7-d schedule. Experiments were laid out using a split plot design, with plant age at treatment as mains, and a factorial combination of herbicide rate and treatment type as the sub-plots. All treatments were replicated three times. Effects of treatments were assessed visually. Sugarbeet and weeds were counted; biomass samples were collected and dry weights obtained at the time when herbicide effects were judged to be maximum.

Phen/des at 0.5 lb/A did not consistently alter sugarbeet vigor or stand. Weed control with split applications to either cotyledon or late cotyledon growth stages achieved visually estimated 90% control early but this had decreased to only 80% when determined by weed dry weight. Multiple applications achieved only 60 to 70% control. Even on the youngest weeds (cotyledon stage) control was not adequate.

Single and split applications of phen/des at 1 lb/A caused substantial vigor reductions to cotyledon and early two-leaf stage beets; the single application to cotyledon beets resulted in stand loss. Weed control decreased as weed age at application increased. Split application at the cotyledon stage resulted in the highest weed control, but did cause early injury to the sugarbeets. Multiple applications gave over 95% visually estimated control, and nearly 90% control on a dry weight basis when applied up to the two-leaf growth stage.

Single applications of 1.3 lb/A of phen/des caused stand loss and severe injury to beets at cotyledon, early two-leaf, or two-leaf growth stages at application. This level of injury would not be acceptable commercially. Four sequential applications 0.33 lb/A did not result in stand loss or beet vigor that was consistently different from the untreated plants. Weed control varied between 95% and almost complete for all applications made at the cotyledon, early two-leaf, and two-leaf growth stages. Even split and multiple treatments at this maximum rate were not capable of providing adequate control of weeds treated at the two oldest growth stages.

Beets treated at the cotyledon stage were most sensitive to phen/des, and sensitivity decreased with increasing age at application. Under the conditions of these experiment beets tolerate about 0.5 lb/A per application without causing unacceptable injury. Treatments at less than about 0.33 lb/A per application did not result in adequate weed control. The best treatments were 1.3 lb/A of phen/des applied to two-leaf beets as either a split or a multiple application. The experiments indicated that split or multiple applications at low rates although safe to the beets did not provide adequate weed control.

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**ANNUAL BROADLEAF WEED CONTROL IN BROMOXYNIL RESISTANT COTTON.** William B. McCloskey, Assistant Specialist, Department of Plant Sciences, University of Arizona, Tucson, AZ 85718.

Abstract. Broadleaf weed control, particularly tall morningglory control, in Arizona cotton is difficult due to the lack of selective postemergence and preemergence herbicides. Arizona cotton producing areas are characterized by coarse textured soils containing less than 1% organic matter that have low adsorptive capacity. These soils and production practices in Arizona increase the risk of crop injury when preemergence herbicides such as prometryn are used for broadleaf weed control. The development of bromoxynil resistant cotton by Stoneville and the development by Dupont of the herbicide DPXPE350 will provide growers with the option of using selective, postemergence herbicides that can be applied over-the-top of cotton for broadleaf weed control. In 1992 and 1993, field experiments were conducted at the Maricopa Agricultural Center of the University of Arizona to evaluate the use of bromoxynil and Staple for broadleaf weed control in cotton. Three preemergence herbicide options (no herbicide, trifluralin at 0.75 lb/A, and trifluralin at 0.75 lb/A plus prometryn at 1.2 lb/A) were combined with various postemergence herbicide options. The three most common weed species at the study site were Palmer amaranth, tall morningglory and Wright groundcherry. Preplant incorporated (PPI) herbicide applications were made in mid-April. Seedbeds were prepared and the field was irrigated. Then bromoxynil resistant cotton seed provided by Stoneville was planted to moisture and a dry soil mulch placed over the seed row to conserve moisture in late April. The soil mulch was removed 3 d later and the cotton emerged 5 d after planting. Over-the-top band applications of bromoxynil (1.5 lb/A) and DPXPE350 (1 and 1.5 oz/A) and post-directed band applications of MSMA at 2 lb/A mixed with prometryn at 0.5 lb/A and MSMA at 2 lb/A mixed with oxyfluorfen at 0.25 lb/A were made in late May when the cotton was about 5 inches tall and the weeds were less than 2.5 inches tall. A set of directed postemergence herbicide applications were made on some plots in mid June when the cotton was 15 inches tall and layby prometryn applications were made in early July when the cotton was 24 inches tall. In 1992 the transgenic cotton was destroyed prior to first boll opening and in 1993 the experiment was machine harvested in October.

The weed population densities, particularly Palmer amaranth, were large at the study site so the lack of weed control (*i.e.*, no herbicide applications) resulted in a large reduction in cotton seed yield (lint plus seed) with the weed free control yielding 2,706 lb/A compared to the weedy control which yielded 418 lb/A. The PPI herbicide applications dramatically improved weed control and yield with the trifluralin plus no postemergence herbicide plots yielding 2,159 lb/A while the trifluralin plus prometryn followed by no postemergence herbicide plots yielded 2,300 lb/A. The PPI herbicide alone plots had less than 10% of the weed densities present in the untreated controls. The combination of PPI and postemergence herbicide applications resulted in almost complete control of weeds and in cotton seed yields of 2,500 to 2,800 lb/A which were similar to the yield of the weed free control. Some general observations based on the results of these experiments can be made. 1) In cotton fields with heavy broadleaf weed pressure, the use of selective postemergence herbicides such as bromoxynil and DPXPE350 will not eliminate the need for PPI applications of dinitroaniline herbicides. Fields with lower weed pressures may not need PPI applications of dinitroaniline herbicides for efficient cotton production. 2) When cotton is planted to moisture weeds tend to germinate later and are smaller than the cotton. Over-the-top applications of herbicides to 5 inches tall cotton allowed the escape of small weed seedlings that were shaded by cotton leaves. Thus, both bromoxynil and DPXPE350 should be applied in a band using a nozzle on each side of the crop row to insure adequate coverage and control of weed seedlings. 3) Bromoxynil and DPXPE350 can be sprayed on cotton without injury thus allowing growers to make both earlier herbicide applications and less precise applications in terms of placement of the spray pattern. In comparing the efficacy of bromoxynil and DPXPE350 it was apparent that bromoxynil was more effective on tall morningglory and Wright groundcherry than DPXPE350 in that it killed larger plants and therefore will provide growers with a larger application timing window for effective control. In contrast, DPXPE350 was more effective than bromoxynil in controlling 4 to 6 inch Palmer amaranth seedlings. Future work will investigate the use of bromoxynil in conjunction with other herbicides and in situations where cotton is irrigated up to establish a stand.

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**JOINTED GOATGRASS COMPETITION IN A TALL AND A SHORT WINTER WHEAT VARIETY.**  
Z. Kebede, P. Westra, and K. G. Beck, Research Graduate Assistant and Associate Professors, Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

**Abstract.** Winter wheat at targeted densities of 0, 25, 50, 75, 100, 150, and 200 plants/m<sup>2</sup> was planted in all possible combinations with jointed goatgrass at targeted densities of 0, 20, 40, 60, and 80 plants/m<sup>2</sup>. This research was conducted with 'Baca', a tall growing wheat variety (80 cm) and 'Tam' 107, a semi-dwarf (50 cm) wheat variety. Planting occurred on October 6, 1992. Plot size was 1.5 by 1.5 m. All plant biomass was harvested in July 1993 and plant fruiting structures threshed from remaining biomass. Dry weights were determined for all plant parts and data subjected to regression analysis. As the proportion of jointed goatgrass in total plant biomass changed from 0 to 80%, wheat yields declined from 700 g to 50 g/m<sup>2</sup>. Increasing 'Baca' wheat density had a much greater negative impact on per plant 'Baca' dry weight than did increasing jointed goatgrass density. 'Baca' was much more competitive than jointed goatgrass in this study. 'Baca' wheat at a density of 60 plants/m<sup>2</sup> reduced jointed goatgrass spikelet production by 50% compared to jointed goatgrass growing without competition. 'Baca' wheat was more competitive against jointed goatgrass than 'Tam' 107 which was 2.5 times more competitive than jointed goatgrass. This research will help determine if taller growing wheat cultivars can be effective in helping manage jointed goatgrass infestations.

**SULFOSATE AND GLYPHOSATE FOR WEED CONTROL IN FALLOW.** Joan M. Lish, Donald C. Thill, and Curtis R. Thompson, Research and Instructional Associate and Professor, Plant, Soil, and Entomological Sciences Department, University of Idaho, Moscow, ID 83844, and Extension Specialist Crops and Soils, Southwest Kansas Research and Extension Center, 1501 Fulton Terrace, Garden City, KS 67846-6191

**Abstract.** Experiments were established to compare weed control with sulfosate and glyphosate alone or tank-mixed with dicamba or 2,4-D, to compare weed control with glyphosate liquid and dry formulations, and to compare weed control with glyphosate tank-mixed with each of two surfactants that contain ammoniated salts. Experiments were conducted in fallow south of Lewiston, ID and a second surfactant study was conducted 1 mile west of Potlatch, ID. Treatments were applied with a CO<sub>2</sub> pressurized backpack sprayer. Control was evaluated visually 2 and 4 wk after treatment. Plots were 10 by 20 feet and were arranged as a randomized complete block with four replications.

Glyphosate controlled brome better than sulfosate over all treatments, but the differences were greatest with the 0.25 lb/A rate and with tank-mixes. Glyphosate controlled flixweed better than sulfosate, but the difference in flixweed control was most evident when no broadleaf herbicides were added to the tank-mix.

Weed control with the two soluble granule glyphosate formulations was equal to the current commercial formulation (Roundup-RT). Weed control with one of the two new liquid formulations tested also was equal to the commercial formulation, but weed control with the second liquid formulation was worse than any of the other formulations tested.

At the Lewiston fallow site, downy brome and wild oat control with glyphosate plus S(003) was better than glyphosate plus Cayuse, but flixweed and catchweed bedstraw weed control was not affected. At the Potlatch site, wheat, downy brome, and interrupted windgrass control also was better with the addition of S(003) compared to Cayuse. (Idaho Agricultural Experiment Station, Moscow, ID 83844).

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**WILD BUCKWHEAT CONTROL IN WINTER WHEAT WITH TRIASULFURON.** R. N. Klein and D. J. Thraikill, Professor and Research Technologist, University of Nebraska West Central Research and Extension Center, North Platte, NE 69101.

**Abstract.** For producers in the hard red winter wheat-fallow rotation or in the winter wheat-fallow-row crop-fallow rotation in western Nebraska wild buckwheat is an important weed. Research has evaluated several herbicides and tillage operations for control of wild buckwheat in the past. Many herbicide treatments have given effective control but the biggest problem is the time of application. Wild buckwheat emerges later in the season, therefore many of the herbicide treatments are applied too early to give effective wild buckwheat control in the growing winter wheat crop. Also the producer usually has other weeds in his field which need to be controlled earlier and would need to apply the earlier herbicide treatments. The application of the herbicides which can give effective wild buckwheat control may have to be applied after the joint stage increasing the possibility of crop injury. Probably more important is the application must be done aurally and can not be with the farmers own ground equipment without injury to the wheat. Triasulfuron has shown a greater residual than other currently used herbicides and because wild buckwheat is later to germinate in the spring it may be an effective herbicide treatment. The study was conducted not only to evaluate triasulfuron for wild buckwheat but to evaluate the activity of triasulfuron with and without surfactant when using fertilizer solutions as a carrier. Treatments were applied on April 23, 1993 to well tillered wheat. The only weeds present were a few winter annuals which were not present in amounts to affect yields. Wild buckwheat was not present. The test was conducted at Logan County Nebraska approximately 25 miles north of North Platte.

Treatments 10, 11, and 12 that contained both X-77 and 28-0-0 had 20% visual winter wheat injury 4 d after treatment (Table). Nineteen days after treatment (May 12, 1993) treatments 5, 9, 12, and 13 that contained dicamba all had a slight mosaic (bushy) appearance. There was no color differences on the winter wheat. On

May 12, 1993 injury that was present earlier on treatments 10, 11, and 12 was not visually present. Wild buckwheat control was evaluated on June 7, 1993 or 45 DAT.

Table. Treatments applied April 23, 1993 for the control of wild buckwheat in winter wheat

Trt.	Herbicide	Rate	Control 45 DAT
		-lb/A-	- % -
1	Triasulfuron 75WG + X-77 <sup>a</sup>	0.0134	92
2	Triasulfuron 75WG + X-77	0.0202	97
3	Triasulfuron 75WG + X-77	0.0267	100
4	Triasulfuron 75WG + 2,4-D LVE + X-77	0.0134 + 0.25	97
5	Triasulfuron 75WG + dicamba SGF + X-77	0.0134 + 0.0625	98
6	Metsulfuron 60WG + X-77	0.00375	92
7	Triasulfuron 75WG + 28-0-0	0.0134	78
8	Triasulfuron 75WG + 28-0-0	0.0267	90
9	Triasulfuron 75WG + dicamba SGF + 28-0-0	0.0134 + 0.0625	85
10	Triasulfuron 75WG + X-77 + 28-0-0	0.0134	86
11	Triasulfuron 75WG + X-77 + 28-0-0	0.0267	94
12	Triasulfuron 75WG + dicamba SGF + X-77 + 28-0-0	0.0134 + 0.0625	98
13	Dicamba SGF	0.0625	86
14	Untreated check	-	0

<sup>a</sup>X-77 rate was 0.25% v/v. 28-0-0 solution was diluted 50% with water which = 14-0-0. Spray volume was 15 gpa for all treatments regardless of carrier.

As the rate of triasulfuron increased, wild buckwheat control increased. 2,4-D or dicamba added to triasulfuron at the low rate increased control over triasulfuron alone and gave equivalent control to the middle rate of triasulfuron. Metsulfuron at 0.00375 was equivalent to the low rate of triasulfuron for control. Triasulfuron plus 28% nitrogen diluted 50% by water did not increase control over triasulfuron alone. The low rate triasulfuron was better than the dicamba rate used in the study for control of wild buckwheat.

**FIELD BINDWEED CONTROL WITH QUINCLORAC.** Stephen D. Miller and Terry L. Neider, Professor and Research Associate, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82071.

Abstract. Despite extensive research on field bindweed control, it continues to be the most serious perennial weed infesting cultivated drylands in the Central Great Plains. Field bindweed currently infests over 150,000 A in Wyoming. Dicamba, 2,4-D, glyphosate and picloram are labelled individually and in various combinations for the suppression or control of field bindweed in fallow and/or in certain crop, pasture and rangeland situations; however, results often have not been satisfactory because of poor weed control and/or crop damage. Field experiments were conducted at Wheatland, Wyoming from 1989 to 1993 to evaluate field bindweed control with quinclorac in fallow and the subsequent winter wheat crop when applied alone or in combination with other herbicides. Quinclorac provided effective (>80%) field bindweed control at rates of 0.25 to 0.5 lb/A for up to 24 months. Field bindweed control with quinclorac was not influenced by application date or combinations with other herbicides. Winter wheat tolerance to quinclorac was excellent whether applied in fallow or in winter wheat itself. Field bindweed control in fallow consistently increased wheat yields 10 to 15 bu/A. (Published with the approval of the Wyoming Agricultural Experiment Station.)

**F8426 - A NEW HERBICIDE FOR THE POSTEMERGENCE CONTROL OF BROADLEAVED WEEDS IN CEREALS.** Ronald D. Kukas, Claude G. Ross, Samuel F. Tutt, Frederick W. Hotzman, and James T. Bahr, Senior Research Biologist, Senior Research Biologist, Research Associate, Research Associate, and Manager Herbicide Discovery, FMC Corporation, Agricultural Chemical Group, P.O. Box 8, Princeton, NJ 08543.

Abstract. F8426 is a new selective cereal herbicide being developed by FMC Corporation. Applied postemergence, F8426 results in rapid desiccation of sensitive weed species. It is an inhibitor of protoporphyrinogen oxygenase, with limited translocation from treated tissues. Preliminary data suggest a very short soil half-life. Field testing over several years in the U.S. indicates that F8426 will control a wide range of broadleaved weeds with good tolerance to wheat, barley, and rice. It is effective against the major broadleaved weeds in wheat, including kochia, pigweed, Russian thistle, common lambsquarters, and common sunflower, and a wide range of winter annual mustards (Shepherds purse, flixweed, bushy wallflower, and field pennycress) at an application rate of 35 g/ha. F8426 is expected to offer a useful, non-cross resistant, alternative to sulfonylurea herbicides for low rate control of cereal broadleaved weeds.

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**COMBINATIONS OF F8426 WITH 2,4-D, MCPA, OR DICAMBA FOR THE POSTEMERGENCE CONTROL OF BROADLEAVED WEEDS IN SMALL GRAINS.** James T. Bahr, Frederick W. Hotzman, Claude G. Ross, Ronald D. Kukas, and Samuel F. Tutt, Manager Herbicide Discovery, Research Associate, Senior Research Biologist, Senior Research Biologist, and Research Associate, FMC Corporation, Agricultural Chemical Group, P.O. Box 8, Princeton, NJ 08543.

Abstract. F8426 is a new postemergence herbicide for control of major weeds in small grains being developed by FMC Corporation. Combinations with 2,4-D, MCPA, or dicamba can provide high levels of consistent control of all major weed species. Combinations with 2,4-D ester or MCPA EC formulations are highly effective, but result in some cases of significant cereal crop injury. Combinations with 2,4-D amine or MCPA amine aqueous formulations are also effective, with no increase in crop injury compared to F8426 alone. Improved control with addition of 2,4-D amine or MCPA amine to F8426 is observed with a variety of weed species, especially mustards. Dicamba is effective in improving control of wild buckwheat and Pennsylvania smartweed.

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**THE INFLUENCE OF BARLEY AND WILD OAT DENSITY ON WILD OAT SEED PRODUCTION AT THREE LOCATIONS IN MONTANA.** M. Brelford, B. Maxwell, R. Stougaard, and E. Davis, Research Associate, and Assistant Professors, Plant, Soil, and Environmental Science Department, Montana State University, Bozeman, MT 59717, Northwestern Agricultural Research Center, Kalispell, MT 59901, Central Agricultural Research Center, Moccasin, MT 59462.

#### INTRODUCTION

Wild oats are the most costly and wide spread weed in spring-sown small grains in Montana. The accumulating occurrence of wild oats resistant to herbicides, as well as a growing interest to reduce pesticide inputs, have produced a need to identify wild oat thresholds and subsequent cost effect management decisions. Identifying long-term thresholds requires an understanding of wild oat population responses to the presence of the crop and other wild oat plants.

The objectives of this experiment were to 1) determine the influence of barley density and wild oat density on wild oat seed production at three locations in Montana, 2) determine the influence of relative emergence time of the barley and wild oats on wild oat density and seed production at three locations in Montana, and 3) develop a predictive model of wild oat seed production for Montana.



## MATERIALS AND METHODS

Field experiments were conducted in three geographically distinct regions in Montana over 2 yr. There were a total of three experiments at each site. One experiment was established in 1992 and then recropped in 1993, and a second experiment was established in 1993. The design is a completely randomized strip block, with three replications. Treatments were four levels of barley seeding rates, 0, 30, 64, and 108 kg/ha, five wild oat target densities, 0, 10, 40, 160, and 400 plants/m<sup>2</sup>, and two wild oat planting times to derive a range of relative emergence times.

## RESULTS AND DISCUSSION

At all sites barley proved to be very competitive with wild oats. As barley planting densities increased wild oat seed production was reduced. The relationship between wild oat plant densities and wild oat seed production is not linear, seed production levels off at plant densities greater than 100/m<sup>2</sup>. The effects of relative emergence of wild oats on wild oat seed production indicate that later emerging plants produced fewer seeds. The model that best described wild oat seed production at all three sites in Montana is:  $WOSP = WOD / (a + b * (WOD - 1 + c * BD))$ . This model did not include relative emergence time but fit very well at most sites ( $r^2 > 0.52$ ).

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**EFFECTS OF WILD OAT AND BARLEY DENSITIES ON FOLLOWING YEAR WILD OAT RECRUITMENT.** E. S. Davis, B. D. Maxwell, and R. N. Stougaard, Assistant Professors, Central Agricultural Research Center, Moccasin, MT 59462, Department of Plant, Soil and Environmental Sciences, Bozeman, MT 59717, and Northwestern Agricultural Research Center, Kalispell, MT 59901.

## INTRODUCTION

Wild oats are aggressive competitors with small grains and in some environments under high density infestations, wild oats are capable of reducing cereal grain yields 60 to 80%. In other situations where wild oat densities are low, there may not be significant reductions in grain yield due to wild oat competition. However, seed produced in the current growing season insures infestations the following year which may cause significant yield loss in that years grain crop. The purpose of this research was to measure wild oat recruitment in recrop barley 1 yr following establishment of a wild oat threshold study.

## MATERIALS AND METHODS

Replicated field studies were established in three Montana locations in 1992. The design was a completely randomized strip block, with three replications. Treatments were four levels of barley seeding rates, 0, 30, 64, and 108 kg/ha, five wild oat target densities, 0, 10, 40, 160, and 400 plants/m<sup>2</sup> and two wild oat planting times to derive a range of relative emergence times. Each location was reseeded in 1993 with the same four barley seeding rates and wild oat counts were taken to measure wild oat recruitment from seed rain in 1992. Barley grain yield and wild oat seed yield was determined at harvest in 1993.

## RESULTS AND DISCUSSION

The number of wild oat seeds planted the previous year, the density of plants the previous year, and the number of seed produced the previous year were all found to be inconsistent predictors of wild oat density. These results indicate the need for further study on the demographic processes that impact wild oat seed banks and seedling emergence.

**WILD OAT CONTROL IN BARLEY WITH REDUCED HERBICIDE RATES.** T. K. Keener, R. N. Stougaard, B. D. Maxwell, E. S. Davis, and P. K. Fay, Research Specialist, Assistant Professor, Assistant Professor, Assistant Professor, Professor, Northwestern Agricultural Research Center, Kalispell, MT 59901, Plant and Soil Science Department, Bozeman MT, Central Agricultural Research Center, Moccasin, MT 59462, and Plant and Soil Science Department, Montana State University, Bozeman MT 59717.

Abstract. For years researchers, herbicide manufactures and farmers have observed that as weeds become larger, higher herbicide rates are often needed to maintain acceptable control. Until recently this relationship between weed size and herbicide rates has not been exploited to its fullest potential. If increased rates are needed for large weeds, then reduced rates should control small, seedling weeds. The objective of this research was to determine if early applications of reduced herbicide rates would afford acceptable control of wild oat in spring barley.

Diclofop and imazamethabenz were applied at their respective 0.25, 0.5, and 1X labeled rates at either 1, 2, or 3 wk after barley emergence. The 0.5X rate of imazamethabenz provided the same degree of wild oat control as the 1X rate, regardless of the application timing. The 0.25X rate of imazamethabenz applied 1 wk after barley emergence afforded the same level of wild oat control and barley yield as the 1X rate applied at the standard application timing. Reduced rates of diclofop failed to control wild oat, regardless of the weed growth stage.

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**WILD OAT DENSITY EFFECTS ON FOLIAR AND SOIL APPLIED HERBICIDE PERFORMANCE.**

R. N. Stougaard, B. D. Maxwell, and E. S. Davis, Assistant Professor, Assistant Professor, Assistant Professor, Northwestern Agricultural Research Center, Kalispell, MT 59901, Plant and Soil Science Department, Bozeman MT 59717, and Central Agricultural Research Center, Moccasin, MT 59462.

Abstract. There is a long standing belief that as weed populations increase, herbicide effectiveness declines, and higher herbicide rates are needed to maintain control. It would seem probable then as weed population decline, reduced herbicide inputs should be feasible. The objective of the research is to determine to what extent a relationship exists between wild oat populations and herbicide efficacy, to compare the relationship for soil and foliar applied herbicides, and to develop predictive models which recommend specific herbicide rates based upon the population present.

This experiment was conducted at Bozeman, Kalispell, and Moccasin, Montana as randomized complete block designs with four replications. Wild oat was seeded to obtain final populations of 0, 100, 200, and 400 plants/m<sup>2</sup>. Triallate was applied PPI at 0, 0.34, 0.69 and 1.4 kg/ha. Imazamethabenz was applied at the three- to four-leaf stage at rates of 0, 0.12, 0.25, and 0.51 kg/ha with a nonionic surfactant.

For both herbicides, barley yield decreased as wild oat population increased regardless of the herbicide rate applied. However, the effect was most pronounced with imazamethabenz. When wild oat populations were low, there was little difference in barley yield between the full and half rates of either herbicide, suggesting that herbicide rates can be reduced when weed pressures are low.

**BIOECONOMIC MODEL FOR OPTIMIZING WILD OAT MANAGEMENT IN BARLEY.** Bruce D. Maxwell, Robert Stougaard, and Edward Davis; Assistant Professors, Plant, Soil and Environmental Science Department, Bozeman MT 59717; Assistant Professor, Northwestern Montana Agricultural Research Center, Kalispell, MT 59901; and Central Montana Agricultural Research Center, Moccasin, MT 59462.

#### INTRODUCTION

Wild oat is the most costly and wide spread weed in spring-sown small grain production in Montana. Bioeconomic weed management models are currently being developed in a number of agricultural systems around the United States and the world. One concern in the development of these models is the amount of parameterization that will be required in order to provide cost effective management decisions. Our interest was to examine the site to site and year to year variability in wild oat seed production and barley yield loss. This was accomplished by comparing parameter values in empirically derived yield-density functions fit to data from 2 yr at three sites in Montana. Strictly comparing the parameter values in the yield density functions does not necessarily allow an adequate assessment of relative bioeconomic model performance at the different sites. Therefore, economic injury levels (EIL's) and 3 yr economic optimum thresholds (EOT's) were identified and compared for each site using the bioeconomic model parameterized with data from each site. For our purposes the EIL was defined as the weed density at which the value of the crop loss equals the treatment cost, and EOT as the weed density at which the value of the crop loss equals the profit maximizing treatments over a 3 yr period of continuous cropping.

#### MATERIALS AND METHODS

Experiments were established at Bozeman, Kalispell and Moccasin, Montana in 1992 and 1993. A range of densities of wild oats and barley were planted in a complete addition series established as a randomized complete block design in the field at each site in 1992 and 1993. Plots that were established in 1992 were relocated in 1993 and recropped with barley allowing wild oats to naturally occur in the plot as a result of 1992 populations. No wild oat control was used in any of the experiments.

A set of weed demographic, yield-density and weed management equations were linked in a computer program to produce a preliminary version of the bioeconomic model. Wild oat management strategies including herbicides at a range of rates were included in the model. EIL wild oat densities were interpolated from comparing net profit (NP) over a range of densities with no weed control versus with weed control at a particular herbicide rate. EIL's were then compared for each site. EOT's were interpolated from model results by determining 3 yr net profit maximizing weed control strategies when the model was started with different wild oat densities for the first year of the simulation.

#### RESULTS AND DISCUSSION

The barley yield loss equation that produced the best fit over years and site is as follows:

$$YL = 1 - [D_b / (r + (D_c - 1) + \alpha D_w)]$$

where YL is the proportional crop (barley) yield loss in response to barley density ( $D_b$ ) and wild oat density ( $D_w$ ). The parameter  $r$  was not found to be significantly different from 1 at any of the sites therefore it was set at 1 and  $\alpha$  (the equivalence ratio) was fit with non-linear regression with data from each site (Table 1).

**Table 1.** Barley yield loss equation  $\alpha$  parameter values and approximate  $r^2$  values for Bozeman, Kalispell and Moccasin, Montana, 1992 recrop data.

	Bozeman	Kalispell	Moccasin
$\alpha$	0.58	1.16	0.68
$-R^2$	0.69	0.46	0.57

Wild oat seed production (wosp) was calculated using the following function:

$$\text{wosp} = D_w/[1/a + 1/b(D_w - 1 + \beta D_c)]$$

where a and b are fit parameters that can be interpreted as the maximum seed yield/wild oat plant and the maximum wild oat seed yield/unit area, respectively. The parameter  $\beta$  is an equivalence ratio. All three parameters were fit with non-linear regression using data from each site (Table 2).

**Table 2.** Parameter values and 95% confidence intervals (in parentheses) from wild oat seed production equations fit to data from Bozeman, Kalispell and Moccasin, Montana, 1992 recrop data.

	Bozeman	Kalispell	Moccasin
a	1748 ( $\pm 1521$ )	1304 ( $\pm 1440$ )	813 ( $\pm 511$ )
b	26684 ( $\pm 1907$ )	20725 ( $\pm 2711$ )	27893 ( $\pm 4815$ )
$\beta$	0.57 ( $\pm 0.21$ )	0.46 ( $\pm 0.19$ )	0.55 ( $\pm 0.19$ )
$-R^2$	0.89	0.57	0.80

These results indicate few significant differences in the parameter estimates when the equations were fit to data from each site.

Further assessment of the significance of site to site variation when the above functions were inserted in the bioeconomic model was conducted (Table 3).

**Table 3.** The difference in EIL values between sites was first assessed using the herbicide diclofop to control wild oats at the label rate (1X) and half the label rate (0.5X) and at 2 different crop prices ( $P = \$/\text{bu}$ ).

Diclofop	Bozeman		Kalispell		Moccasin	
	1X	0.5X	1X	0.5X	1X	0.5X
	(plants/m <sup>2</sup> )					
P = \$3.00	43	37	11	8	58	49
P = \$2.19	64	58	16	11	110	84

The EIL's indicate substantial differences between sites, however these comparisons are only qualitative.

Three year EOT's were also compared for the three sites (Table 4).

Table 4. Three year EOT's and net profits for Bozeman, Kalispell and Moccasin, Montana, using 1992 recrop data.

	Bozeman	Kalispell (plants/m <sup>2</sup> )	Moccasin
EOT	0.3	0.1	0.3
3 yr net profit	233	(S/A) 355	125

The site to site differences in EOT and the 3 yr net profits appear to be substantially different which would indicate that at least some parameters in the bioeconomic model would need to be site specific. One parameter that had a large impact on site to site differences was maximum potential barley yield.

#### ACKNOWLEDGEMENT

We would like to thank the Montana Weed Trust Fund Grant Program for supporting this research.

## EXTENSION, EDUCATION AND REGULATORY

**THE DEVELOPMENT AND EXPERIENCES WITH A 3-POINT COMPRESSED AIR SHIELDED PLOT SPRAYER.** R. N. Klein and D. J. Thraikill, Professor and Extension Research Technologist, University of Nebraska West Central Research and Extension Center, North Platte, NE 69101.

Abstract. The West Central District of Nebraska includes 25 counties from the South Dakota Nebraska line to the Kansas Nebraska line. A plot sprayer is needed to efficiently conduct weed control research at these remote locations. Because of travel time, a sprayer is needed that will allow spraying in marginal wind conditions, therefore the boom should be shielded. Ease of changing mixes and of purging the spray system between treatments is critical. A tractor based unit is desired to allow testing of many compounds over a range of conditions and to maintain constant speeds. The sprayer needs to be easy to mount so that it doesn't require a dedicated tractor. A sprayer was built to meet these criteria. The completed sprayer is a 17.5 foot shielded boom, compressed air plot sprayer that mounts on a 3-point hitch. Six nozzles are spaced 30 inches apart for an effective 15 foot spray width. This spacing using nozzles with 110 degree spray angle allows low volume application and 100% overlap.

The sprayer utilizes a three section boom and shield, each have two nozzles. The center section is 76 inches wide. The left and right sections are 67 inches wide. The outside sections of the shield fold for transport and are hinged to "breakaway" if they strike an obstacle while folded out. Transparent "Lexane" panels on the shields allow nozzles to be visible and slide out for access to nozzles.

Compressed air propels the spray solution from the spray containers to the boom and nozzles. A 12 volt electric piston air pump provides compressed air. This compressor is mounted on a 12 gallon air reservoir which in turn is mounted to the center section of the boom. A pressure activated switch senses reservoir pressure and provides automatic control for the compressor. A pressure regulator mounted on the reservoir outlet provides a means of setting boom pressure.

Five liquid tanks are located on the sprayer. Four are 3 gallon stainless steel beverage cans used as spray solution containers. One 10 gallon can be used as a spray container, rinse can, or to store excess spray solutions. The cans are plumbed through a manifold equipped with ball valves to allow the user to select the appropriate container. An electric solenoid valve is used between the manifold and boom allowing a remote switch to be placed in a position comfortable for the driver. This switch initiates flow to the boom. The air supply is also plumbed to the manifold to allow purging of the boom with air and backflushing of the spray system.

With this sprayer, treatments are efficiently applied. Excess spray mixture is minimized and purging is fast and effective. Mounting the sprayer is easy, requiring only to connect the 3-point hitch and one 12 volt connection. Total material cost for the sprayer was approximately \$3500.

Experience with the sprayer indicates it has met the design criteria. The shielding has been especially effective. Plots sprayed with cross winds up to 15 mph, the maximum wind in which the sprayer has been used to date, have not shown any drift on adjoining plots.

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**THE RELATIVE ACCURACY OF VISUAL RATINGS, STAND COUNTS, AND BIOMASS YIELD METHODS TO ESTIMATE WEED CONTROL EFFICACY.** G. E. Blaser, R. E. Whitesides, and G. S. Straquadine, Utah State University, Logan, UT 84322-4820.

Abstract. A 2 yr study conducted in 1990 and 1991 at the Ricks College Hillview Farm in Rexburg, Idaho, compared visual rating, sub-plot (quadrat) stand count, and sub-plot biomass yield methods for estimating weed

control efficacy. Wheat plots were treated in the spring with various rates of thifensulfuron herbicide. Broadleaf weed control was estimated by visual evaluation approximately 4 wk after treatment by a team of two experienced weed scientists. A visual rating scale of 0 to 100 was used to estimate percent control based on reduction in size, density, and competitive ability of broadleaf weeds in each plot. Visual ratings of the two evaluators were combined and averaged for each plot. Following visual evaluation, weeds were counted and harvested from within one randomly placed 1 m<sup>2</sup> quadrat/plot. Following quadrat data collection, all weeds were harvested from each entire 3 by 6 m plot. Harvested weeds were oven dried and weighed. Stand counts and harvests were conducted by personnel other than those performing the visual evaluations. Percent control was calculated in each of the quantitative methods by comparison with values from the non-treated check plot in each corresponding block. Percent weed control based on the biomass from entire plots was considered the "true" mean value for each treatment. Accuracy of the other three methods was compared based on their average deviation from the whole-plot means. Average deviations from whole-plot biomass percent control values indicate that the visual rating method of estimating herbicide efficacy can be as accurate as weed count subsample or biomass subsample methods.

Table 1. Percent control of broadleaf weeds as determined by visual rating, sub-plot weed counts, and sub-plot biomass harvest, compared to whole-plot biomass yields. 1990 evaluation, 4 wk after treatment.

Treatment	Visual rating		Sub-plot weed count		Sub-plot biomass		Whole-plot biomass
	% Cont <sup>a</sup>	Dev <sup>b</sup>	% Cont <sup>a</sup>	Dev <sup>b</sup>	% Cont <sup>a</sup>	Dev <sup>b</sup>	% Cont <sup>a</sup>
A	50	7.3	60	2.7	64	6.7	57.3
C	76	2.5	82	3.5	85	6.5	78.5
B	85	5.3	88	2.3	92	1.7	90.3
D	90	2.8	98	5.2	99	6.2	92.8
F	91	2.3	98	4.7	98	4.7	93.3
E	94	1.3	91	4.3	96	0.7	95.3
J	96	0.5	96	0.5	99	2.5	96.5
G	93	4.5	94	3.5	98	0.5	97.5
H	95	3.0	93	5.0	97	1.0	98.0
I	97	1.7	97	1.7	99	0.3	98.7
Avg Dev.		3.1		3.3		3.1	
LSD (0.05)	21		16		17		20.7

<sup>a</sup> Percent control based on comparison with presumed check plot (weediest plot) in each block. Checks not identified for evaluators.

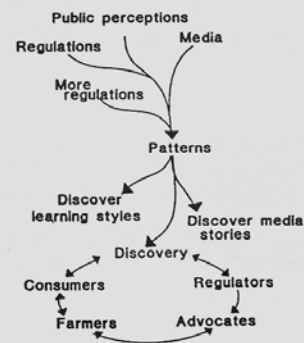
<sup>b</sup> Deviation (+/-) from corresponding whole-plot biomass treatment mean.

**PESTICIDE ISSUES AND SYSTEMS THINKING: LOOKING FOR LEVERAGE.** Ray D. William, Extension Horticulturist, Oregon State University, Corvallis, OR 97331.

INTRODUCTION

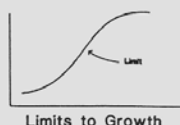
Farmers and ranchers were respected by the public during past decades. They produced safe foods and were considered stewards of the land. Technologies, government incentives, and the public's desire for greater disposable income all contributed to this sense of success.

Now, public perception and media portray agriculture as a villain; public advocates and regulators seek ways to fix things. Fixing means creating regulations faster than rabbits or weeds multiply! This leads to a vicious cycle of reaction, proaction, and more quick fixes. Patterns of we versus they develop, regulatory compliance leads toward more regulations, and farmers begin to wonder about the FUN of farming.



Recent inquiry to improve American businesses provides hope for putting FUN back into farming. This paper will explore systemic patterns with respect to pesticide issues along with systems approaches that respect diverse views, offer consensus as a decision strategy, and develop TRUST among people. The approach blends systematic reasoning with relational thinking and a systems context to achieve improvements in extremely complex biological or social situations.

### SYSTEMIC PATTERNS

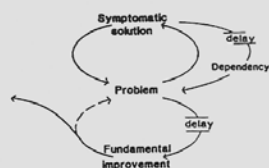


In America, public perceptions and concerns about size or quantity will eventually limit growth of companies, tonnage of chemicals used in agriculture, political power, etc. Initially, growth is rapid but some limit begins to change the dynamics within the system. Growth rates of sales, populations, regulations, governments, companies, etc. will change over time. This *limits to growth* pattern can be recognized in biological, economic, social, ecological, and political systems (22). By recognizing this pattern, we can identify key factors that influence this relationship.

Also in America, we prefer to solve problems with the first fix that comes to mind. *Fixes fail* because we rush toward a solution with minimal consideration of a wide variety of alternatives and consequences. Regulators fix regulations with more regulations, weed researchers consider more controls, or citizens fix political power with fixed terms of office. Key factors for improving this pattern include consideration of possible consequences, both long and short-term (22).



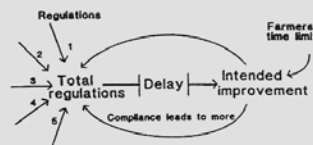
Fixes that Fail



Shifting the Burden

Quick fixes often become addictive which leads toward dependency and *shifting the burden*. Regulations force people toward compliance, and dependency on regulators to invent more regulations or define interpretations. This fosters the need for more compliance education and more regulations and...a shifting of the burden away from the initial intent of the regulation. A vicious cycle results. Although compliance is required in the short run, leverage or fundamental improvement occurs when we invest extra time or resources to consider a wide variety of alternatives and associated consequences (22).

A *tragedy of the commons* occurs when numerous individuals or components affect a common area negatively. The idea comes from a common grazing area where individual villagers grazed cattle such as the Boston Commons. Today, a city park might be considered a common area where both joggers and dogs run, sometimes with negative consequences! Another common might involve a farmer's time being devoted to regulatory compliance rather than farming. The tragedy is that farmers give up, farm workers lose their jobs, and regulators shift their focus to another sector. Improvement requires exploration of common interests and consensus decisions that make sense to all participants (22).



Tragedy of the Commons

Why do Americans do this? Recent thinking in business suggests that we view our world as if it were a machine, i.e., a machine metaphor (13). When a machine needs repair, we identify the problem and fix it. We focus on the symptomatic solution, thereby becoming addicted to quick fixes rather than exploring alternative approaches that might create fundamental improvements. As our minds create new gadgets or appendages, we add these to our machine metaphor. We fail to recognize the limits to growth! Eventually, our system collapses, so we build a bigger or faster machine!



## SYSTEMS THINKING AND LEVERAGE

In agriculture, we see these patterns but often feel overwhelmed by the complexity or diverse views and values expressed by others. Contrasting experience and thinking in engineering, business, and most recently in complex natural resource issues relies on these patterns and *learning* as a metaphor for inquiry and improvement. Systemic or relational considerations are blended with systematic logic, problem-solving, and facts. Inquiry, interactive learning, and action adds to success and accomplishments of this past century. Let's explore these opportunities briefly.

**Patterns.** Each systemic pattern previously mentioned contains leverage points; both positive and negative. Often, action must focus on short-term, quick fix solutions, followed by or in conjunction with longer-term fundamental improvements of *fixes that fail* and *shifting the burden*. Next, we discover ways to manage the *tragedy of the commons* by focusing on the commons with common sense.

Personal learning and action styles also influence complex agricultural situations. In previous years, we explored the contrast between relational (sensing and feeling) and reductionist (thinking) approaches to viewing our world (27). Half of society prefers each learning and action preference. People often use the same word, but mean vastly different things. Listening respectfully for these contrasts involving diverse views and values is fundamental for interactive learning and action. Collaborative learning between regulators, representatives of groups being protected, and farmers can improve situations fundamentally. Recent inquiry that involves asking farmers and two regulators how regulations can be improved has resulted in 70% to 80% of respondents suggesting interactive learning and respecting each other as the first response toward fundamental improvement.

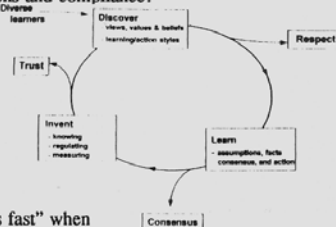


Media and their idea of unbiased reporting also merit our attention. Media stories represent two divergent views or opinions about a topic. These divergent views create a story with a bit of drama or tension. Most media people are careful to select divergent, but moderate views to avoid sensationalism at the extremes. Usually, two sides of each story are presented, although you may have experience where one side was presented with public comment for the other side.

Knowing this framework creates opportunities for agriculture or natural resource people to craft news stories. Farmers might explain how they choose pesticides with worker safety, personal health, and consumers in mind. Or they might invite the media to photograph deer or quail crossing their fields covered with crop residue or cover crops. There are many good stories, but they require the right framework that makes sense to the media with a moderate amount of learning tension or drama to capture the public's interest and sense of improvement.

**Interactive learning.** Agriculture and natural resource management became a lot more complex when segments of society began to criticize practices and basic assumptions about productivity and stewardship. People react followed by proactive education of the public. Considering possible consequences of these actions may provide insight and enhance our abilities to consider other options, as well. For example, what if *interactive learning and inquiry* were considered? What might happen if consumers, advocates, regulators, and farmers learned and inquired together? What actions might result? Could regulations be developed collaboratively? Would common sense and consensus prevail; or would we prefer to rely on regulations and compliance?

Interactive learning exhibits a pattern of discovery, learning, and invention that involves people designing new ways of knowing, new ways of regulating, and new ways of measuring improvement. Continuous and collaborative learning requires time to build respect, consensus, and TRUST. At first, this is slow. It must be facilitated (16, 17, 21). The learning process requires diverse learners building TRUST. Senge (22) says "slow is fast" when people explore common interests and concerns around issues such as worker protection, labor, pesticides, or water.



**Systems approaches.** Systems thinking (Table 1) involves numerous approaches. It adds dimensions of relationships, input/output, hierarchy, and consequences as feedback loops. Systems approaches can focus on optimizing production or improving human activity within a social, political, or interactive group process. Presently, we're applying these approaches to explore concerns and perceptions among diverse groups or agencies with the hope of developing consensus and common sense around regulations or other natural resource issues in Oregon. Our theme involves *putting the FUN back into farming!*

Table 1. Participatory approaches for complex, value-laden situations.

Approach	Purpose	Reference
Coordinated resource management planning (CRMP)	Ranchers and agency people (BLM/SFS) agree in managing livestock, wildlife, and forest/range habitat.	2
Negotiation, Conflict resolution (interest-based problem-solving)	Search for common interests, develop best alternatives to negotiated agreement (BATNA), and seek win/ win improvements and consensus.	11, 12, 18
Farming systems research and extension (FSRE)	Interdisciplinary (agron., soc., and econ.) and interactive approach with farmers to develop relevant research.	4
Total quality management (TQM)	Improve customer service, quality of goods and services, and involve people in the entire process.	9, 10
Participatory problem-solving, Organizational learning, and Strategic assumption surfacing and testing (SAST)	Participants represent diverse viewpoints, challenge assumptions, and work toward consensus.	19, 22, 26
Interactive or transactive planning	Participatory planning process involving learning, adaptation, and constant search for improvement.	14
"Hard" systems	Systems thinking and practice to optimize complex systems and achieve desired results.	1, 3, 8, 24
"Soft" systems	Participatory approach where interested persons share diverse values/beliefs, focus on consensus to improve complex situations, and use systems pictures/diagrams to see alternatives.	6, 7
Critical systems heuristics	Participatory approach with regulatory or other control agencies where "what is" and "what ought to be" are explored.	23
Total systems intervention (TSI)	Participatory approaches involving a dominant systems methodology linked with one or more supplemental approaches designed to improve complex, value-laden situations.	13

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**WORKER PROTECTION STANDARDS - PROGRAM IMPLEMENTATION AT THE STATE LEVEL.** Robert S. Hays, Chief, Bureau of Education and Compliance, Idaho State Department of Agriculture, Division of Agricultural Technology, P. O. Box 790, Boise, ID 83707.

Abstract. The implementation of the Worker Protection Standard at the state level varies state-to-state depending on which agency has the jurisdiction (State Land Agency), available resources (money and manpower), the political climate and the identified needs of the agricultural community.

Each state has a designated lead agency appointed by the Governor of that state. Many states consider this an agricultural issue and the state agricultural departments have jurisdiction over the enforcement of the standard. Some agricultural departments have made agreements with other agencies to run the program in their state. An example of this would be Oregon state, where the state OSHA agency has the enforcement of the program.

Resources include grant money from the USEPA to establish programs in each state and tribal nation. These grants are based on a match from the grantee agency. Additional resources come from established programs such as pesticide enforcement, labor complaints and environmental investigations.

Political climates vary and some states may elect not to have a program and turn enforcement of the standards back to EPA. Other states may consider the best way to address the standard is to be proactive and strive to get information and training to all individuals that have the responsibility (employers, contractors, commercial applicators, etc.) to be in compliance.

The need for a comprehensive program may be tempered by the agricultural practices of an area. An example would be that work is completed by the immediate family, therefore reducing the WP requirements, or the crops required no pesticides.

The intent is pesticide safety and may fall short, in that it does not address non-agricultural applications such as right-of-way or lawn care. But in the agricultural practices; training, notification, proper equipment and other items are required of employers, commercial applicators, and labor contractors.

For additional information, Idaho Department of Agriculture Worker Protection Specialist, Jose Sanchez, can be reached at (208) 334-3550 or P. O. Box 790, Boise, Idaho 83701.

## BASIC SCIENCES, ECOLOGY, BIOLOGY, PHYSIOLOGY, GENETICS AND CHEMISTRY

INTRODUCTION OF WEEDS INTO CALIFORNIA. Larry W. Mitich, Extension Weed Scientist, Section of Plant Biology, University of California, Davis, CA 95616.

### INTRODUCTION

Thanks to California's great geologic, topographic and climatic diversity, 5862 plant species have found a home there. Of these, 3423 species (58.4%) are native but not endemic, 1419 species (24.2%) are endemic, while 1020 species (17.4%) are exotic (10). Consider: California has the steepest elevation gradients in North America--from 4500 m (14,800 feet) above sea level to 93 m (280 feet) below sea level--in less than 130 km (80 miles) (10).

When varieties and forms are included, the total number of plants growing wild in California swells the number to nearly 8000 kinds, making it the richest state botanically. However, the percentage of exotic flora is well below that of many other states (10).

*The Jepson Manual: Higher Plants of California*, edited by James C. Hickman and with contributions by approximately 200 authors, was published in 1993. Ten yr of effort were required to complete this impressive work of 1400 pages and thousands of illustrations. Referred to as "the new Jepson Manual," it is a storehouse of current information on the state's flora. It recognizes 1020 naturalized alien species, mostly weeds, 151 of which were not reported previously (10). Fortunately, the rate of establishment of alien species has slowed during the last 25 yr (16).

But many already established alien plants continue to expand their range and influence in many of the state's habitats (16). Some prime examples:

<i>Aegilops</i> L. spp.	goatgrass
<i>Aubuiton theophrasti</i> Medicus	velvetleaf
<i>Cardaria</i> L. spp.	hoary cress
<i>Cirsium vulgare</i> (Savi) Tenore	bull thistle
<i>Cortaderia jubata</i> (Lemoine) Stapf.	jubatagrass
<i>Cyperus rotundus</i> L.	purple nutsedge
<i>Foeniculum vulgare</i> Mill	fennel
<i>Isatis tinctoria</i> L.	dyer's woad
<i>Senecio mikanioides</i> Otto ex Walp.	German ivy
<i>Tamarix</i> spp.	tamarisk
<i>Ulex europaeus</i> L.	gorse

Four other species in this category--artichoke thistle (*Cynara cardunculus*), Scotch broom (*Cytisus scoparius*), perennial pepperweed (*Lepidium latifolium*), and creeping wartcress (*Coronopus squamatus*)--are discussed later.

The country of origin of new aliens differs slightly from those of earlier introductions; while the majority are still of Eurasian origin, about a 15% increase occurred in the proportion of species introduced from South and Central America and 8% from southern Africa (16).

### THE MISSION PERIOD

The date of arrival of the first weeds in California is unknown, but the composition of California's unspoiled grasslands began changing even before Old World settlers reached the West Coast. Since travel and trade

existed between California, Arizona, and New Mexico Indians, this undoubtedly served as a regular mode of seed dissemination (5).

New plant species, including weeds, arrived with early explorers to the Americas. Weed seeds teemed in packing, hay and bedding [straw] and the manure from their livestock. Even when men did not come ashore, the crews of passing ships often jettisoned livestock manure and bedding, allowing weed seeds to reach land and become established in a new environment (13). Unhindered by presence of natural enemies, the weeds flourished, resulting in inevitable changes in the composition of the native flora.

During a 70-yr period, from 1697 to 1767, the Jesuits built 21 missions in Baja, California. Twelve yr later, the Franciscans began establishing the first of 21 missions in California, a 54-yr building period that lasted until 1823 (11,12,13,14).

Despite relatively good documentation of the numerous plants that were moved about as Spanish America was being settled, there is no formal record of these early plant introductions. The first documentation of plant introductions from precise localities occurred with the founding of the missions (8). Spanish ships arriving with crop seed and other supplies for the new settlements inadvertently introduced weed seeds. Additionally, weed seed arrived on the coats of imported animals and in the ship's packing materials and ballast (8).

The California missions provide a history of the weeds' approximate arrival time. The missions were constructed of adobe bricks made from mud mixed with straw and dried in the sun. When immersed in water, the bricks disintegrate after a few hr, revealing well-preserved plant materials (9). In the mid-1920s, bricks from six Franciscan missions and three buildings dating from the Mexican period (1822 to 1846) were collected and plant materials extracted from them and botanically analyzed. The crop and weed species obtained were identified and grouped by age according to the site of origin (9). Alien weed species were placed into three groups based on probable periods of introduction into California: the pre-mission period (before 1769), the mission period (1769 to 1824) and the post-mission period (after 1824).

The species introduced during the pre-mission period were found in the bricks from the oldest walls of several widely separated missions. Weeds were present in the bricks, and cereal remnants often were absent, indicating that the plant material present was from species occupying the site prior to the arrival of settlers (8, 9).

Weeds present during the mission period did not come from the oldest walls, but appeared in newer walls at the same site, frequently in the presence of crop residue. Such species arrived at a later date and gradually increased in number. They include typical grain field weeds and two probable escapes from cultivation (9).

Weeds that appeared in the post-mission period were not found in bricks used to construct the missions, but are now abundant on the mission sites, indicating that they were not present during the construction phase (9).

#### GROUP I: WEEDS INTRODUCED PRIOR TO 1769

<i>Erodium cicutarium</i> (L.) L'Her. ex Ait.	redstem filaree
<i>Rumex crispus</i> L.	curly dock
<i>Sonchus asper</i> (L.) Hill	spiny sowthistle

#### GROUP II: WEEDS INTRODUCED BETWEEN 1769 AND 1824

<i>Amaranthus retroflexus</i> L.	redroot pigweed
<i>Avena fatua</i> L.	wild oat
<i>Brassica nigra</i> (L.) W.J.D. Koch	black mustard
<i>Centaurea melitensis</i> L.	Malta starthistle
<i>Chenopodium album</i> L.	common lambsquarters
<i>Chenopodium murale</i> L.	nettleleaf goosefoot
<i>Daucus carota</i> L.	wild carrot
<i>Hordeum leporinum</i> Link	hare barley
<i>Lolium multiflorum</i> Lam.	Italian ryegrass
<i>Madia sativa</i> Molina	coast tarweed

<i>Malva parviflora</i> L.	little mallow
<i>Medicago polymorpha</i> L.	California burclover
<i>Melilotus indica</i> (L.) All.	Indian sweetclover
<i>Poa annua</i> L.	annual bluegrass
<i>Ranunculus repens</i> L.	creeping buttercup

#### GROUP III: WEEDS INTRODUCED AFTER 1824

<i>Anthemis cotula</i> L.	mayweed chamomile
<i>Brassica rapa</i> L.	birdrape mustard
<i>Centaurea solstitialis</i> L.	yellow starthistle
<i>Cirsium arvense</i> (L.) Scop.	Canada thistle
<i>Cirsium vulgare</i> (Savi) Tenore	bull thistle
<i>Convolvulus arvensis</i> L.	field bindweed
<i>Echinochloa crus-galli</i> (L.) Beauv.	barnyardgrass
<i>Lolium temulentum</i> L.	poison ryegrass
<i>Marrubium vulgare</i> L.	white horehound
<i>Melilotus alba</i> Medicus	white sweetclover
<i>Oxalis corniculata</i> L.	creeping woodsorrel
<i>Polygonum aviculare</i> L.	prostrate knotweed
<i>Raphanus raphanistrum</i> L.	wild radish
<i>Sinapis arvensis</i> L.	wild mustard
<i>Sisymbrium officinale</i> (L.) Scop.	hedge mustard
<i>Sorghum halepense</i> (L.) Pers.	johnsongrass

#### SOME INTRIGUING CALIFORNIA WEEDS

Some exotic weeds have interesting histories. In the 1850s, Chinese miners brought the seed of common St. Johnswort or Klamathweed (*Hypericum perforatum* L.) into Humboldt County in packing materials; it was first discovered around their habitations. It was spreading at an alarming rate, infesting 100,000 A of previously excellent rangeland and reducing its carrying capacity 75% (1). The weed was all but eradicated by the introduction of the Klamathweed beetle, a classic case of biological weed control. The Humboldt County Wool Growers' and Cattlemen's associations together erected a monument to show their gratitude for the beetle that saved their rangelands (6, 17).

Creeping wartcress [*Coronopus squamatus* (Forsk.) Ascherson], a European native, most likely from the Mediterranean region, was first collected in Berkeley in 1922 and then in Yolo County in 1955. The weed caused no problems and remained virtually unknown. But about 12 yr ago, it became an economically important weed in the Imperial Valley, where it has gained a toe-hold. Initially found in two seed onion fields, it has spread to nine locations, infesting 3,715 A in 54 fields (2, 3).

Silverleaf knotweed (*Polygonum argyrocoleon* Steud. ex Kunze) appeared in alfalfa seed harvested in the Imperial Valley in 1921; it remained unidentified for years. Finally its identity was confirmed by comparing it to an 1844 herbarium specimen at the Botanical Garden, University of Leipzig, Germany. That specimen had been grown from type collection seed brought from islands in the Tigris River near Mosul, Turkey. The environment in Imperial Valley alfalfa fields was conducive to its establishment (4).

Johnsongrass [*Sorghum halepense* (L.) Pers.] seed arrived in California in 1928 in consignments of infested Sudangrass seed grown in Texas and Oklahoma the previous year (17). It has become a weed of major importance in some prime agricultural areas.

Kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov.) was imported from Africa about 1925, propagated, and distributed to several coastal counties to prevent soil erosion in avocado and orange groves, and in lawns. It

soon became an orchard pest because a favorable environment made it exceedingly competitive with the trees (17).

Russian thistle (*Salsola iberica* Sennen and Pau) was introduced into the U.S. in flax seed imported from Russia to South Dakota in 1873. It spread like wildfire across the country, arriving in Antelope Valley in Los Angeles County, by 1895. Now it is found from Southern California to Lassen County in the north (17).

In 1844, Capt. John Fremont reported that redstem filaree, [*Erodium cicutarium* (L.) L'Her. ex Ait.] "covered the ground like a sward," and that in the lower San Joaquin Valley, he found "instead of grass, the whole surface of the country closely covered with it" (17). The weed must have been introduced decades earlier. It remains the most common and widespread of all the state's *Erodium* species. It is regarded highly as forage for all classes of livestock, providing excellent winter and early spring feed (17).

Mayweed chamomile (*Anthemis cotula* L.) was introduced into California from Europe during the days of the Early Spanish settlements and possibly grown as a medicinal herb. It had been prescribed in Europe during the medieval period as a tonic to mitigate a host of human ailments (15).

Perennial pepperweed (*Lepidium latifolium* L.) was introduced into California about 1940, possibly in sugarbeet seed imported from Montana. This Eurasia native, widespread in Mexico and along the New England coast, grows adjacent to beaches, tidal shores, roadsides, and in saline soils. It has formed dense and extensive infestations on rich delta lands in Yolo County (17, 18).

Rush skeletonweed (*Chondrilla juncea* L.), a Eurasia native, was introduced in the early 1940s. A biennial or perennial with milky sap, it is invasive in cropland and is difficult to control (16, 18).

Tree of heaven [*Ailanthus altissima* (Miller) Swingle], a native of eastern Asia, was introduced into California in the 1850s by Chinese miners, who planted it near their habitations. This weedy tree is now common in the Sierra Nevada foothills, especially at the sites of old Chinese settlements (16, 17).

European beachgrass [*Ammophila arenaria* (L.) Link] was imported from its native region in western Europe into California in the 1850s and planted to stabilize sand dunes along beaches, a ploy that worked all too well. Now beachgrass is an aggressive weed, successfully crowding out native vegetation (7, 16).

Appealing and conspicuous, Scotch broom [*Cytisus scoparius* (L.) Link] was introduced from its native home in Europe and northern Africa as an ornamental. It was planted extensively along highways in beautification enterprises. It adapted readily to its new environment, so much so that it has become a noxious weed, competing keenly with native vegetation (16, 18).

A related broom, [*Cytisus striatus* (Hill) Rothm.], a native of Spain and Portugal, was introduced as an ornamental about 20 yr ago to Golden Gate State Park in San Francisco. It has escaped and is becoming weedy (16).

A hybrid wild radish, a natural cross between radish (*Raphanus sativus* L.) and wild radish (*Raphanus raphanistrum* L.) emerged in California during the last few decades to become a weedy hybrid in cropland, confirming that new weeds can arise naturally. The hybrid is difficult to distinguish from its parents (16).

Another introduction gone wrong is Japanese millet [*Echinochloa crus-galli* (L.) P. Beauv. var. *frumentacea* Roxb.], a selection from barnyardgrass, which was introduced into California and grown for bird feed under the name Billion Dollar Grass before escaping cultivation and becoming weedy (16, 17).

Artichoke thistle (*Cynara cardunculus* L.) was imported from southern Europe about 1900 for use as a garden vegetable. It escaped and by 1950 it had infested 70,000 A. Due to its spines and spreading habit, infested pastures were rendered useless because cattle and sheep would not venture through them. Now at least

two farmers are growing it under the name cardoon for use in dry flower arrangements, but they are compelled by state law to control all off-site plants (17).

During the last decades of the 20th century, many species of eucalyptus were brought to California for ornamental and utilitarian purposes. Some species were planted to large acreages. Now after long establishment, a few species are becoming weedy, especially blue gum (*E. globulus*, Labill.).

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#### DIFFERENCES IN SPINELESS RUSSIAN THISTLE AND COMMON RUSSIAN THISTLE MORPHOLOGY AND RESPONSE TO HERBICIDE TREATMENT. P. Westra, Associate Professor, Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

**Abstract.** Russian thistle is a common weed of dryland and irrigated agriculture in Colorado. Common Russian thistle (*Salsola iberica*) is well known to most farmers and is the most common form found in Colorado. It has bracts that typically are at greater than a 45 degree angle from the stem, and the spine on each bract represents a major portion of the bract. Seeds are held in a shallow position in the floral structure and readily thresh out. Seeds are conical in shape and asymmetrical. Mature common Russian thistle plants assume a globose, compact structure. Common Russian thistle dominates the eastern Colorado plains as one moves westward toward the foothills of the Rocky Mountains.

Spineless Russian thistle (*Salsola collina*) is a very distinctive plant first described in Colorado botanical literature in the 1930's. It is a more erect growing plant, and has bracts that are located less than a 45 degree angle from the stem. The spine on each bract is relatively small and reduced compared to the rest of the bract structure. Seeds are held in a deep position in the floral structure and are more difficult to thresh out. The seeds are flattened and symmetrical. Mature spineless Russian thistle plants are erect and assume more of a Christmas tree type structure. This species is more prevalent in eastern Colorado, whereas from Eaton to Akron Colorado the two populations intermix.

Preliminary herbicide response studies with dicamba, 2,4-D, and UCC-4243 suggest that the spineless Russian thistle is more tolerant to herbicides than the common Russian thistle. The spineless Russian thistle also appears to grow at a faster rate early in the season. These differences warrant further investigation to determine whether these two species may respond differentially to management strategies, especially in dryland winter wheat production. These two species should be evaluated for potential differences in herbicide resistance, especially with ALS inhibiting herbicides.



**PLANT AND SEED DISPERSAL OF RUSSIAN THISTLE.** Carol A. Mallory-Smith, Donald C. Thill, and George P. Stallings, Research Scientist, Professor, and Graduate Assistant, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83843.

**Abstract.** Chlorsulfuron-resistant Russian thistle (*Salsola iberica* Senn. and Pau.) is widespread in Washington state, but little is known regarding seed dissemination of the resistance trait by this tumbleweed. Russian thistle plant movement and seed dispersal were studied in 1991 and 1992. Russian thistle plants were placed on two adjacent sites each year; one wheat stubble and one summer fallow ground planted to winter wheat with 24 plants on each site. Plants were allowed to tumble naturally. Individual plant movement was monitored and recorded weekly by a satellite global positioning system, and data were entered on a geographic information system to generate a map plotting relative plant movement and distribution over time. On an adjacent site, 24 plants were anchored to the ground to prevent tumbling. At 1 wk intervals for 6 wk, four designated plants from each site were collected, measured, weighed, and seed was counted. Average estimated seed number per plant at the beginning of the experiment was 57,400 in 1991 and 66,000 in 1992. Average seed loss in 1991 and 1992 for the anchored plants was 15 and 26%, and for tumbling plants was 48 and 66%, respectively. Seed from Russian thistle plants can be dispersed over long distances and gene flow through seed movement is an important method of spread for the sulfonylurea herbicide resistance trait. The distance plants moved depended on topography, plant size, soil surface conditions, wind patterns, and obstructions such as ditches and fence lines. The maximum distance a plant moved in 6 wk was 4,069 m while others only moved 60 m. As expected, the direction that plants moved was highly correlated with wind direction.

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**ISOLATION AND CHARACTERIZATION OF A cDNA FOR A GLUTATHIONE S-TRANSFERASE INDUCED BY THE HERBICIDE SAFENER BENOXACOR IN MAIZE.** G. P. Irzyk and E. P. Fuerst, Research Associate and Assistant Professor, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420.

**Abstract.** Benoxacor is a herbicide safener used to protect corn from injury by metolachlor. Treatment of corn with benoxacor results in the increased activity of specific glutathione S-transferase (GST) isozymes, which subsequently results in the enhanced metabolism of metolachlor to a nonphytotoxic glutathione conjugate. A highly-induced GST, capable of using metolachlor as a substrate, was purified to homogeneity, digested with trypsin and the amino acid sequence of several peptide fragments were obtained. The amino acid sequence information indicated that the purified GST was a unique maize GST, which we subsequently designated GST IV. The partial amino acid sequence obtained for GST IV was used to design degenerate primers for the PCR. A 450 bp product generated by the PCR was sequenced and found to share partial homology with the sequences of maize GST I and III. The 450 bp PCR product was subsequently used to screen a gt11 library constructed with cDNA from benoxacor-treated maize seedlings to obtain clones of GST IV.

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**PICLORAM-RESISTANT YELLOW STARHISTLE: CROSS-RESISTANCE AND ABSORPTION, TRANSLOCATION, AND METABOLISM OF PICLORAM.** E. Patrick Fuerst, Michael A. Norman, and Gerard P. Irzyk, Assistant Professor and Research Associates, Washington State University, Department of Crop & Soil Sciences, Pullman, WA 99164-6420 and Timothy S. Prather and Robert H. Callihan, Graduate Research Assistant and Professor, Plant Soil and Entomological Sciences, University of Idaho, Moscow, ID 83843.

**Abstract.** A biotype of yellow starthistle resistant to picloram was identified near Dayton, Washington by R. Schirman and resistance was confirmed in field and greenhouse studies. The level of resistance to picloram ranged from 3-fold to 20-fold in our studies. Factors affecting the level of resistance could have been genetic or environmental. The level of resistance to root- and leaf-applied picloram was similar. Cross-resistance studies

indicated that the resistant biotype was cross-resistant to clopyralid, fluroxypyr, dicamba, and possibly metsulfuron-methyl, but not to triclopyr or 2,4-D.

Several studies focused on determining the mechanism of resistance. Resistance is clearly not due to enhanced detoxification of picloram. Root absorption and root-to-shoot translocation were significantly reduced in the R biotype. The reduced translocation was 1) not due to reduced transpiration, since both biotypes had similar rates of transpiration, and 2) somewhat specific for picloram, since root-to-shoot translocation of atrazine was similar in the two biotypes. Leaf-to-root translocation has consistently been higher in the R biotype. In addition to the above observations, the resistance of germinating seedlings to picloram (F. E. Northam and R. H. Callihan), and the reduced production of ethylene in R biotype leaves and cell cultures (T. M. Sterling and N. K. Lownds) has been demonstrated by others. All of the above observations are consistent with the hypothesis that resistance may be due to reduced cellular absorption of picloram, i.e. transport across the plasmalemma. Mechanisms for this altered transport can be proposed, e.g. an increase in cell wall pH and/or decrease in cytoplasmic pH would reduce the ion-trapping-mediated absorption of this carboxylic acid.

Some future research priorities should include 1) evaluating the effect of environment, especially temperature and light intensity, on the level of resistance, 2) evaluating the genetics of resistance, 3) evaluating the cellular absorption hypothesis more directly, and 4) determining the role of a unique 19 kD protein that is synthesized in response to picloram in the R biotype but not the S.

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#### GLUFOSINATE-RESISTANT SAFFLOWER (*Carthamus tinctorius* L.): FROM IDEA TO REALITY.

Charleen M. Baker, Teresa Orlikowska, and William E. Dyer, Postdoctoral Research Associate, Visiting Professor, and Assistant Professor, Department of Plant, Soil and Environmental Science, Montana State University, Bozeman, MT 59717-0312.

**Abstract.** A significant agronomic problem in safflower production is a lack of effective herbicide choices. To address this problem, we have initiated research to develop a safflower cultivar resistant to the nonselective, nonresidual herbicide glufosinate (trade name Ignite). Initial studies established tissue culture conditions and shoot regeneration from cotyledon-derived callus of 'Centennial' and 'Montola' cultivars. Later studies optimized highly efficient direct shoot regeneration from 'Centennial' seedling explants, a system which avoids somaclonal and other undesirable variation associated with regeneration from callus. Seedling explants were transformed using *Agrobacterium tumefaciens* strain EHA105 containing a Ti plasmid construct with the CaMV 35S promoter-bar gene-35S terminator. The bar gene encodes an acetyltransferase that acetylates and thereby inactivates the herbicide. Regenerating shoots were selected on carbenicillin and 0.1 mg l<sup>-1</sup> glufosinate, from which about 1% to 5% putative transgenic shoots survived. Elongated transformed shoots were successfully rooted and transferred to soil in the growth chamber. Experiments are now underway to confirm transgenic plants using Southern hybridization and PCR. Heritability of the bar transgene will be determined in R1 progeny.

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#### MULTIPLE RESISTANCE IN GRASS WEEDS.

Ian Heap, Courtesy Associate Professor, Dept. of Crop and Soil Science, Oregon State University, Corvallis, OR 97331.

**Abstract.** Multiple resistance to dinitroaniline and ACCase-inhibiting herbicides was identified in a green foxtail population from Manitoba, Canada. In the late 1980's, many growers in southwest Manitoba had selected dinitroaniline-resistant green foxtail after using trifluralin for 10 to 15 yr. Similarly, growers in other regions of Manitoba had selected green foxtail resistant to ACCase inhibitors by repeated applications of diclofop-methyl and sethoxydim. A few growers alternated between DNA and ACCase-inhibiting herbicides. One foxtail

population (UM137) had been exposed to three applications of diclofop-methyl, seven applications of sethoxydim, and six applications of trifluralin since 1977. Resistance first appeared to trifluralin and then to sethoxydim. Under greenhouse conditions, this population exhibited greater than a 20-fold resistance to ACCase inhibitors (diclofop-methyl, fenoxaprop-p-ethyl, sethoxydim) and a 10-fold resistance to dinitroaniline herbicides (trifluralin and ethalfluralin) in comparison to a known susceptible foxtail (UM7). Individual plants within population UM137 were able to resist both dinitroaniline and ACCase inhibiting herbicides. Quinclorac, TCA, and propanil were still effective in controlling population UM137.

Rotation between herbicides with two different modes of action was not sufficient to avoid herbicide resistance. Intensive use of diclofop-methyl in the wheat cropping systems of the Willamette valley has led to the selection of diclofop-resistant annual ryegrass. These populations exhibited cross-resistance to other ACCase inhibitor herbicides. Two of the diclofop-resistance populations were also resistant to diuron, resulting from a prior history of diuron usage on these populations. Italian ryegrass with multiple-resistance to ACCase inhibitors and diuron can be controlled by alternatives such as triallate, pronamide, or metribuzin. However, growers should be concerned about how long these alternatives will last.

In Australia, rigid ryegrass has rapidly developed multiple-resistance to over 15 selective herbicides with many different modes of action. Rigid ryegrass is a very close relative to Italian ryegrass, with a similar genetic base. Italian ryegrass in the Willamette valley is likely to respond to herbicide selection pressures in a similar way to rigid ryegrass from Australia. Growers should be preparing for the loss of effective herbicides to control Italian ryegrass.

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**DIFFERENTIALLY EXPRESSED GENES IN DORMANT AND NONDORMANT WILD OAT (*Avena fatua* L.) EMBRYOS.** Russell R. Johnson, Harwood J. Cranston, and William E. Dyer, Postdoctoral Research Associate, Research Assistant, and Associate Professor, Department of Plant, Soil, and Environmental Sciences, Montana State University, Bozeman, MT 59717-0312.

Abstract. The high degree of seed dormancy present in weeds like wild oats renders them difficult to control. The mechanisms regulating seed dormancy are very poorly understood, but previous studies have suggested that the release of dormancy is controlled by specific genes in response to environmental cues. In an effort to better characterize the molecular events associated with dormancy and its release we have utilized the technique of mRNA differential display, in which cDNA fragments corresponding to the many mRNAs present in a plant organ or tissue at a particular stage of development are visualized. RNA from dormant and nondormant embryos was isolated at 6 hours after imbibition, reverse transcribed into cDNA, and displayed on sequencing gels. The patterns of cDNAs obtained from dormant and nondormant embryos were nearly identical; however, a few differentially expressed cDNAs were noted. We have isolated several clones corresponding to wild oat genes which are preferentially expressed in either dormant or nondormant embryos. These cDNA clones were sequenced to determine their identity, and the timing and tissue specificity of gene expression was examined by Northern analysis.

## ALTERNATIVE METHODS OF WEED CONTROL

### INTERPLANTING CEREALS AND GRASSES INTO THE LAST YEAR OF AN ALFALFA STAND.

Warren E. Bendixen and Tom Lanini, Farm Advisor and Extension Specialist, U. C. Cooperative Extension, 624 West Foster Road, Santa Maria, CA 93455, and Department of Agronomy and Botany, U. C. Davis Campus, Davis, CA 95616.

#### INTRODUCTION

A vigorously growing alfalfa field with a high plant population prevents the invasion of weeds. However, alfalfa stands naturally thin with age or other stresses, preventing rapid canopy closure and are more sensitive to weed invasion. Interplanting cereals into established alfalfa stands has been suggested as one means of increasing the first cutting yields and reducing weeds. Growers have also tried other grasses. The grasses increased forage yields, but unlike oats, they regrew after the first cutting and continued to grow during subsequent cuttings. The added cover provided by the grasses during the summer decreased weed competition. The objective of these studies were to evaluate interseeding of cereals, grasses, or mixtures into established alfalfa, as a means of improving the crop's competitive ability against weeds and its effect on hay yield.

#### MATERIALS AND METHODS

Field studies were conducted between 1989, 1990, 1991, and 1992 at the Gainey Ranch in Santa Ynez. Each year, different aspects of interseeding were evaluated. Yield determinations were made using a flail-type forage harvester, cutting a 3-foot wide swath in the center of each plot. The forage was then weighed and subsamples taken for moisture determination. Yields were determined by converting fresh weights to a dry weight basis, and all yields reported in tons/A. In all plots where nitrogen was added, ammonium nitrate (34-0-0) was used. Each trial was established in a randomized complete block design with four replications.

In 1989 two oat varieties, 'Montezuma' and 'Cal Red', were compared, each at three seeding rates, 25, 50 and 75 lb/A. Additional treatments included a paraquat application, cultivated plots, and untreated (no cultivation) check plots. This alfalfa field was originally planted to alfalfa in the spring of 1986 and was scheduled to be plowed out at the end of the 1989 season. The trial was established on January 4, 1989. Nitrogen was broadcast over all plots at the rate of 30 lb/A. Oats were seeded by broadcasting the seed on the various plots and then covered with a field cultivator.

In 1990, oat interseeding trials were established to evaluate seeding methods—broadcast versus drilled. Also compared were time and rates of nitrogen applications. 'Montezuma' oats were sown at 50 lb/A in all oat plots. The 1990 trial was planted on December 11, 1989. Oat treatments were compared to a paraquat treatment, cultivation (each applied the same day as oat interseeding), and an untreated check. Weed cover in each plot was visually assessed prior to each harvest.

In the 1991 trials, cereals and grasses were broadcast on December 12, 1990, and immediately incorporated with a field cultivator. Ryegrass was seeded at 20 lb/A, while 'Montezuma' oats were seeded at 50, 75, and 100 lb/A, and 'Dirkwin' wheat at 50 or 100 lb/A. Because winter rainfall was low, the site was sprinkle-irrigated the day of establishment and once in January and February. Nitrogen was applied to half of each plot at the rate of 30 lb/A to determine if there was an added benefit. In addition to yield determinations, species cover (alfalfa, grass, and weeds) was visually assessed prior to each harvest.

In 1992, cereals and grasses were broadcast seeded on December 17, 1991, and incorporated with a field cultivator. 'Montezuma' oats were planted at 50, 75, or 100 lb/A, 'Dirkwin' wheat at 50 or 100 lb/A, tetraploid annual ryegrass at 20 lb/A, two experimental oat varieties (UC 89 and UC 95), planted at 100 lb/A, 'Fawn' fescue at 20 lb/A, and a combination of 'Fawn' fescue and 'Montezuma' oats at 20 plus 50 lb/A. Nitrogen was added to all grass plots at 30 lb/A. Yield and species cover were determined at each harvest.

## RESULTS AND DISCUSSION

1989. Weed measurements made on March 24 indicated that oat interplanting did not significantly reduce the weed population, although some reduction occurred at the higher oat populations. First cutting yields were increased by the addition of oats (Table 1). The two varieties did not differ significantly in the yields, however, seeding rate differences were significant. 'Montezuma' oats produced the highest first cutting yields when seeded at 50 lb/A, while 'Cal Red' oats required 75 lb/A to achieve maximum yields. Some forage yield increase was seen in the second cutting as well, compared to untreated plots. In the other cuttings and the season total, significant differences were not observed.

1990. The April rating of winter annual weeds showed a reduced weed population in almost all instances by interseeding oats into alfalfa or applying paraquat, compared to untreated plots. In July and August, weed cover, primarily summer annuals, was greatest in paraquat-treated plots compared to all other treatments. Paraquat effectively controlled winter weed growth; however, this opened up space for summer weeds, primarily bristly foxtail (*Setaria verticillata*) to become established prior to the first cutting. Competition provided by either winter weeds or oats reduced or prevented the establishment of summer weeds until after the first cutting. Cultivation did not change weed cover relative to the untreated control.

Table 1. Forage yields 1989, five cuttings, Santa Ynez, California.

Treatment	Rate	Forage yields					Season total
		Apr 26	May 31	Jul 7	Aug 9	Sept 16	
	lb/A	T/A					
Montezuma oats	25	1.78	1.5	0.99	1.39	1.36	7.02
Montezuma oats	50	2.28	1.4	1.02	1.25	1.23	7.17
Montezuma oats	75	2.12	1.51	1.08	1.37	1.22	7.30
Cal Red oats	25	1.9	1.42	0.99	1.27	1.29	6.87
Cal Red oats	50	1.8	1.36	1.02	1.17	1.18	6.52
Cal Red oats	75	2.22	1.69	1.04	1.24	1.2	7.40
Paraquat	0.5	1.3	1.32	1.26	1.35	1.2	6.44
Cultivated check		1.03	1.27	1.27	1.38	1.39	6.34
Untreated (no cultivation)		1.16	1.17	1.32	1.4	1.24	6.28
LSD (0.05)		0.36	0.32	NS	NS	NS	NS

Yields for the first cutting were increased by the addition of oats relative to all non-oat treatments (Table 2). All treatments were significantly reduced by Egyptian alfalfa weevil; however, the effect was less on oat plots, either due to cultivation or the presence of oats interfering with movement. Broadcast planting appeared visually to be superior to drilling oat seed, but yield data indicated no differences. Rate and timing of nitrogen application to oats also failed to have a significant effect on yields. Paraquat treatments reduced yields relative to untreated or cultivated plots.

1991. Grasses significantly increased first cutting yields compared to non-grass plots (Table 3). In the second and subsequent cuttings, no significant yield differences were observed among treatments. Grasses increased seasonal yields, with the exception of oats at 50 lb/A, compared to untreated plots (Table 3). Differences in weed cover in the first cutting were evident among treatments, but did not show a statistically significant difference (Table 4). In the second cutting, only a small amount of grasses or weeds occurred. However, by the third cutting, ryegrass started to grow vigorously, displacing some alfalfa. In the fourth cutting, summer weeds were common in all treatments. Protein (prot.) was highest on plots without grass interseeding (Table 6). Acid detergent fiber (ADF) was about equal among treatments (Table 6).

1992. Interplanting cereals or grasses, with the exception of 'Fawn' fescue, increased the first cutting forage yields, compared to the untreated or cultivated plots (Table 5). Oat or wheat seeding rate did not result in significant differences in first cutting yield. Cuttings made after the initial harvest were generally not significantly different with respect to yield. Total season yields were significantly higher when cereals or grasses

were interplanted into alfalfa, compared to no interseeding, with the exception of the plots with 'Fawn' fescue by itself (Table 5). The fescue was slow to establish, and only in the last few cuttings was the grass growth significant.

Table 2. Forage yields 1990, five cuttings, Santa Ynez, California.

Treatment	Nitrogen	Forage yields					Season total
		Apr 25	Jun 4	Jul 7	Aug 21	Oct 10	
	lb/A	T/A					
Oat-broadcast	30	1.64	1.74	1.67	1.79	1.58	8.42
Oat-drilled	30	1.45	1.64	1.81	1.96	1.34	8.20
Oat-drilled	0	1.49	1.82	1.84	1.87	1.46	8.48
Oat-drilled	60	1.47	1.85	1.84	1.86	1.54	8.56
Oat-drilled	30+30	1.5	1.7	1.75	1.78	1.44	8.17
Paraquat 0.5 lb/A		0.53	1.5	1.68	1.6	1.5	6.82
Cultivated check		0.92	1.8	1.82	1.84	1.4	7.77
Untreated (no cultivation)		0.86	1.76	1.83	1.7	1.54	7.70
LSD (0.05)		0.27	0.22	NS	0.20	NS	0.66

Table 3. Forage yield 1991, five cuttings, Santa Ynez, California.

Treatment	Rate	Forage yields					Season total
		Apr 27	Jun 11	Jul 18	Sept 6	Oct 20	
	lb/A	T/A					
Montezuma oats	50	1.89	1.68	1.26	1.64	1.16	7.63
Montezuma oats	75	2.01	1.67	1.29	1.69	1.32	7.98
Montezuma oats	100	1.98	1.83	1.24	1.62	1.24	7.90
Dirkwin wheat	50	1.84	1.74	1.33	1.69	1.23	7.83
Dirkwin wheat	100	1.98	1.72	1.14	1.72	1.27	7.82
Tetraploid annual ryegrass		1.83	1.87	1.23	1.54	1.27	7.74
Cultivate		1.56	1.71	1.36	1.53	1.29	7.44
Untreated (no cultivation)		1.48	1.7	1.1	1.58	1.24	7.09
LSD (0.05)		0.25	NS	NS	NS	NS	0.62

Table 4. Forage composition 1991, two cuttings and quality for the first cutting at Santa Ynez, California.

Treatment	Rate	April 27					June 11			
		Alf	Grass	Weed	Prot.	ADF	Alf	Grass	Weed	
	lb/A	%								
Montezuma oats	50	58	40	2	19.5	38.6	96	4	0	
Montezuma oats	75	47	53	0	18.6	38.3	98	2	0	
Montezuma oats	100	44	56	0	19	39.2	98	2	0	
Dirkwin wheat	50	48	52	0	21.8	39	98	2	0	
Dirkwin wheat	100	46	53	1	18.4	39	99	0	1	
Tetraploid ann. ryegrass		35	65	0	19	35.6	100	0	0	
Cultivate		98	0	2	24	40.5	99	0	1	
Untreated (no cultivation)		97	0	3	24.6	38.2	100	0	0	
LSD (0.05)		20	18	NS	2.7	NS	NS	2	0	

## CONCLUSIONS

Interseeding cereals or ryegrass into established alfalfa has consistently increased forage yields compared to other options. Most of the increased yield was in the first cutting. Higher oat seeding rates have visually appeared to increase yields compared to lower seeding rates. However, because of variations within the trial, yields were not significantly different. Interseeding fescue failed to increase forage yield as it was slow to establish.

Table 5. Forage yields 1992, five cuttings, Santa Ynez, California.

Treatment	Rate	Forage yields					Season total
		Apr 21	Jun 4	Jul 13	Aug 20	Oct 3	
	lb/A				T/A		
Oat	50	2.84	1.46	1.57	1.33	1.64	8.84
Oat	75	2.93	1.60	1.64	1.36	1.68	9.21
Oat	100	3.02	1.50	1.61	1.47	1.57	9.17
Wheat	50	2.63	1.44	1.42	1.44	1.50	8.42
Wheat	100	2.70	1.54	1.52	1.60	1.70	9.06
Ann. ryegrass	20	2.58	1.66	1.28	1.38	1.60	8.48
UC 89 oat	100	2.86	1.48	1.58	1.58	1.66	9.16
UC 95 oat	100	3.03	1.52	1.37	1.40	1.65	8.96
Fescue	20	1.80	1.61	1.44	1.48	1.74	8.06
Fescue+oat	20+50	2.84	1.58	1.53	1.45	1.60	8.99
Fescue+ann. ryegrass	20+20	2.64	1.58	1.31	1.36	1.58	8.47
Cultivated check		1.70	1.56	1.50	1.42	1.62	7.81
Untreated (no cultivation)		1.51	1.66	1.62	1.48	1.53	7.82
LSD (0.05)		0.28	NS	0.21	NS	NS	0.61

Table 6. Forage composition 1992, five cuttings, Santa Ynez, California.

Treatment	Rate	April 21, 1992			June 4, 1992			1992 Season average		
		Alf	Grass	Weed	Alf	Grass	Weed	Alf	Grass	Weed
	lb/A	%			%			%		
Oat	50	19	79	2	97	4	0	73	21	6
Oat	75	21	79	0	99	0	0	77	20	3
Oat	100	14	85	1	100	0	0	74	22	4
Wheat	50	25	71	4	93	7	0	76	19	5
Wheat	100	37	63	0	88	12	0	79	19	2
Ann. ryegr.	20	25	73	2	52	48	0	63	35	2
UC 89	100	23	76	1	92	8	0	74	21	5
UC 95	100	26	72	2	96	4	0	77	19	4
Fescue	20	52	38	10	89	11	0	70	27	3
Fescue+oat	20+50	24	73	3	92	8	0	64	35	1
Fescue+ann. ryegrass		24	76	0	58	42	0	63	36	1
Cultivate		89	0	11	99	0	1	94	0	6
Untreated (no cultivation)		86	0	14	100	0	0	91	0	9
LSD (0.05)		12	11	7	6	6	NS	9	9	4

Although consistent reductions in weeds were not evident in all years or all cuttings, the trend was for less weeds where cereals or grasses were planted. The cultivation needed to plant the cereals or grasses eliminated most weeds, and the crop competition prevented most weeds from becoming established. The combination of a cereal, such as oats plus a perennial grass, offers the best chance at maintaining cover and preventing weed

growth. The growers in this area have accepted the results of this research and are interplanting oats because it has shown higher profits. The cost of an herbicide application is higher than the cost of interseeding cereals or grasses. The value of the oat/alfalfa hay is only slightly less (7 to 20%) than pure alfalfa hay, and the higher yields more than offset the lower value of the mixed oat/alfalfa hay. This practice also eliminates the potential for herbicide carryover into subsequent crops.

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**MECHANICAL WEED CONTROL STRATEGIES IN CORN EMPHASIZING AN IN-ROW CULTIVATOR.** M. J. VanGessel, E. E. Schweizer, and P. Westra, Graduate Research Assistant, Research Scientist, and Associate Professor, Colorado State University and USDA-ARS, Agricultural Engineering Research Center, Fort Collins, CO 80523.

**Abstract.** Corn producers are interested in reducing herbicide inputs for numerous reasons. Ground and surface water contamination, herbicide carry-over, and costs are some of the reasons growers cite. As a result, research efforts have attempted to replace or supplement soil-applied herbicides with cultivation. This experiment was designed to look at the interactions of weed seedbank levels, rotary hoeing, and standard and in-row (IR) cultivation. The experiment was conducted in 1992 and 1993 in Windsor, Colorado. Experimental design was split-split plot with four replications. Whole plots were weed seed bank (high or low). The first split was cultivator type, IR, or standard cultivator. The final split was rotary hoeing (none, once, twice). Whole plots were 4 rows wide (76 cm apart) and 60 m long. Weeds were identified and counted at four quadrats, (1.5 m by 17 cm) placed directly over the corn row in each sub-plot at layby. Grain was harvested and gross margin calculated.

Weed control with the IR cultivator plus one or two rotary hoeings provided similar weed control to the standard cultivator plus two rotary hoeings. Standard cultivator plus rotary hoeing provided similar weed control to IR cultivator without pre-cultivation weed control. IR cultivator reduced corn population compared to standard cultivator by 4% in 1992. Gross margin was significantly higher with the standard cultivator than IR cultivator; and with one rotary hoeing compared to no rotary hoeing in 1992. Gross margin did not differ among treatments in 1993.

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**GRASS INTERSEEDING IN AGING ALFALFA STANDS FOR WEED CONTROL, AN INTEGRATED PEST MANAGEMENT APPROACH.** Timothy Prather, Ronald Vargas, and Shannon Mueller, Regional Integrated Pest Management Specialist, Agronomy Farm Advisor and Agronomy Farm Advisor, Kearney Agricultural Center, University of California Cooperative Extension, Parlier, CA 93648.

**Abstract.** Alfalfa stands thin with age, making them susceptible to weed invasion during the last year of production. Weed control in the last year of production is usually accomplished with short-residual herbicides because other herbicides, with longer residual properties, have plant-back restrictions that limit crop rotation options. Filling the open spaces in the alfalfa stand with competitive forage grasses should control weeds through the competitive interactions of the grasses and the weeds. Furthermore, tillage during the dormant season can disrupt the life cycle of the alfalfa weevil, potentially reducing populations to below threshold levels. The objectives of this study were to contrast grass mixture interseeding with herbicide application by evaluating season-long weed control and to compute the economics of production when utilizing each weed control technique. Plots scheduled for seeding were harrowed, then annual and perennial forage grasses were planted as mixtures on December 22, 1992. Herbicides were applied on January 30, 1993. Each plot was 18 by 274 m with 12 plots total, arranged as a randomized complete block with four treatments and three blocks. Treatments consisted of tetraploid annual ryegrass plus orchardgrass, tetraploid annual ryegrass plus tall fescue, 0.34 kg/ha paraquat plus 1.57 kg/ha diuron, and an untreated control. Yield data were taken at each of seven harvests in an 18 by 183 m area by counting the number of bales and weighing four bales. At odd numbered harvests



(1, 3, and 5) forage samples were taken from each of four bales in each plot and combined into a single sample. In addition, species composition was determined by clipping a 0.25 m<sup>2</sup> area and then separated, drying and weighing each species. Alfalfa weevils were monitored by computing the average weevil number from 5, 180 degree sweeps.

Interseeded plots produced twice as much forage as the herbicide treated plots at the first harvest. Production was 20% higher for an interseeded plot, contrasted with herbicide treated plots at the second cutting. There was no trend in the data for the second through seventh cuttings, the yields were within 182 kg of each other at these later cuttings. Weeds composed 13% of the forage composition in the untreated control but weeds composed less than 2% for all other treatments at the first cutting. By the third cutting all treatments were below 1% weed composition and this continued through the fifth cutting. Total production was higher for interseeded plots than for herbicide treated plots but the interseeded plots did not differ from the untreated control.

Quality was not affected by any treatment. Total digestible nutrients (TDN) ranged from means of 52.7 to 56.1 and averaged 54.8 overall, but there were no significant differences between treatments. Alfalfa weevil populations remained below threshold levels at 4 weevils per sweep in the interseeded plots but were near threshold levels at 18 weevils per sweep in the herbicide treated and the untreated control. The economic analysis accounted for all aspects of production. Discounts were applied to hay containing grass or weeds. For treatments that were below threshold levels, no cost for insecticides were included.

The ryegrass plus fall fescue treatment was as profitable as the untreated control, \$368/ha and \$373/ha, respectively. Ryegrass plus orchardgrass was the least profitable treatment at the \$109/ha. Discounts may not be defensible, given the quality analysis. If discounts were not applied, then the alfalfa-grass hay profits would increase to \$494/ha. Interseeding grasses has a number of benefits that include weed control equivalent to herbicide treatment, a competitive profit margin, and the control of another pest, the alfalfa weevil.

## STUDENT PAPER COMPETITION

**SELECTIVE CONTROL OF DIFFUSE KNAPWEED IN FERAL BABYSBREATH.** Cindy T. Roché and Ben F. Roché, Jr., Graduate Student, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID 83844-2339 and Professor, Department of Natural Resource Sciences, Washington State University, Pullman, WA 99164-6410.

**Abstract.** Picloram applications required by county weed control boards for diffuse knapweed render feral babysbreath on rangelands unsalable in the dried floral industry. A 5 yr study was begun in 1989 to determine if spring application of a nonresidual herbicide (2,4-D) would control diffuse knapweed without damaging babysbreath. Four rates of 2,4-D amine (0, 0.56, 1.12 and 2.25 kg/ha) were applied in the spring before and after babysbreath emerged for 1, 2, or 3 yr in succession at Omak, Washington. Density of vegetative and reproductive diffuse knapweed was recorded each July. Knapweed control was similar for pre- and post-emergence applications except at the 0.56 kg/ha rate, for which pre-emergence did not differ from the control. All rates applied post-emergence damaged babysbreath by distorting or delaying flowers. No damage occurred with pre-emergence applications. Knapweed control levels were similar with the 2.25 and 1.12 kg/ha rates. Both rates controlled knapweed rosettes and mature plants during the year of application, resulting in fewer reproductive plants the year after treatment. Two yr after the final application, rosette densities were lower on plots that had been treated for 2 or 3 consecutive yr with 1.12 or 2.25 kg/ha than on the untreated plots, indicating a possible reduction in knapweed seed reserves. Diffuse knapweed density was negatively correlated ( $r=-0.89$ ) with density and cover of perennial grass on unsprayed plots, indicating that management for competitive vegetation could reduce herbicide use in the long term. In the short term, babysbreath growers can comply with county weed control regulations for diffuse knapweed by applying 1.12 kg/ha 2,4-D before babysbreath emergence.

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**THE RELATIONSHIP BETWEEN IMPACT LEVELS IN STOCK CAMPS AND THE ABUNDANCE OF SPOTTED KNAPWEED IN THE SELWAY-BITTERROOT WILDERNESS ON THE BITTERROOT NATIONAL FOREST IN IDAHO AND MONTANA.** Gary Milner, A. Marcus, K. Hanson, B. D. Maxwell, and P. K. Fay, Graduate Student, Assistant and Associate Professors, Earth Sciences Department, Montana State University, Assistant Professor and Professor, Plant, Soil and Environmental Science Department, Montana State University, Bozeman, MT 59717.

**Abstract.** Between June and August of 1993, 30 stock camps in the Selway-Bitterroot wilderness area were sampled to compare disturbance levels with the abundance of spotted knapweed. Disturbance levels fell into four categories: light, moderate, heavy and extreme. These categories were determined by using site impact worksheets used by wilderness rangers to monitor conditions in backcountry campsites. To quantify vegetation characteristics within the sites, the camps were segregated into horse and human areas. Eight 24 m transects were radiated from the centers of both areas. Six 2 m<sup>2</sup> quadrats were placed 4 m apart along each transect. Each stock camp contained 96 sample points unless natural features prevented transects from running the full 24 m. Percent cover of bare ground, rock, moss, forbs, grasses, litter, tress and spotted knapweed were recorded for each quadrat. Density and frequency of spotted knapweed was also recorded. Preliminary statistical analysis suggest no relationship between disturbance levels in stock camps and the abundance of spotted knapweed.

**ECOLOGICAL IMPLICATIONS OF RUSSIAN KNAPWEED INFESTATION: SMALL MAMMAL AND HABITAT ASSOCIATIONS.** K. H. Johnson, R. A. Olson, T. D. Whitson, R. J. Swearingen, G. L. Kurz, Research Assistant and Assistant Professor, Department of Range Management, Associate Professor and Research Assistant, Department of Plant, Soil, and Insect Sciences, and Research Assistant, Department of Range Management, University of Wyoming, Laramie, WY 82071.

#### INTRODUCTION

Invasion by noxious range weeds, including Russian knapweed, across western North America degrades land value and threatens ecosystem integrity. The lack of natural regulators and competitors, combined with the prolific seed production and allelopathic properties, allow Russian knapweed to dominate sites where it becomes established. Lacey and Olson (7) proposed that *Centaurea sp.* infestation sabotages wildlife habitat through displacement of native range plants and associated wildlife species.

While the potential threat to ecosystem integrity posed by Russian knapweed infestation has been addressed, details of the ecological implications are lacking. Assessment of plant and small mammal communities associated with infested versus pristine areas can be particularly useful in ascertaining overall ecological implications of Russian knapweed infestation.

We examined plant and small mammal communities in adjacent Russian knapweed-infested and native plots at locations in Wyoming and Colorado in 1993. Small mammal populations were considered to be dependant upon habitat (vegetation) characteristics. The status of observed plant and small mammal species relative to being native or non-native to the locations studied was a primary consideration in examining the implications of Russian knapweed infestation for biodiversity.

#### STUDY SITES AND METHODS

A site was selected near Boysen Reservoir, 12 km west of Shoshoni, Wyoming, and another on the Gordon Tileston ranch approximately 40 km north of Craig, Colorado. A 1 ha plot was established in each habitat type (native vs. infested) at each location. Three 49 m vegetation sampling transects were randomly located in each plot at Boysen; two transects were sufficient at Craig. Cover of plant species was measured using point-frame sampling at 7 m intervals along each transect. A fourth transect was added in the native plot at Boysen to achieve sample adequacy.

The Boysen site was sampled in May 1993, prior to bolting of Russian knapweed rosettes. Standing decadent Russian knapweed from 1992 production was included in cover measurement for that species at Boysen. The Craig site was sampled in August 1993. Due to the absence of a genuine pristine area at this heavily agriculturally developed site, a fallow hayfield was designated as the "native" plot.

A 10-by-10-station grid, 10 m between stations, with one Sherman livetrapp per station, was established in each plot. This arrangement samples 1 ha (6). Trapping was conducted for 5 consecutive nights at Boysen and 3 nights at Craig. Animals captured were identified to species, temporarily marked with unique toenail polish codes, and released. Mark-and-recapture data were used to generate Schnabel estimates of abundance for small mammal species encountered. Two sample analysis of variance was used to evaluate significance in differences of plant cover by species and small mammal population estimates between plots at each site.

#### RESULTS AND DISCUSSION

The native plot at Boysen had greater plant species richness (number of plant species observed) than did the infested plot (Table 1). Furthermore, the native plot had 3 species (all native) characterized by at least 5% aerial cover, whereas the infested plot had only 1, Russian knapweed. This suggests that the infested plot is relatively monotypic compared to the native plot in terms of vegetative cover. Overall vegetative cover was greater for the infested plot than for the native plot (77% vs. 27%).

Table 1. Cover by plant species and results of ANOVA comparisons (=vs.≠) at Boysen, WY 1993 ( $\alpha=10$ ).

Species	% Vegetative cover by species, Boysen, WY 1993		
	Infest	F-test result	Native
Russian knapweed			
<i>Centaurea repens</i>	71	≠	0
Hoary cress			
<i>Cardaria draba</i>	2	=	0
Kochia			
<i>Kochia americana</i>	3	≠	0
Poverty sumpweed			
<i>Iva axillaris</i>	1	=	0
Indian ricegrass			
<i>Oryzopsis hymenoides</i>	0	≠	8
Sand dropseed			
<i>Sporobolus cryptandrus</i>	0	=	6
Needle and thread			
<i>Stipa comata</i>	0	≠	10
Douglas rabbitbrush			
<i>Chrysothamnus viscidiflorus</i>	0	=	3
Bare ground	1	≠	54
Species richness	4	≠	18

Ord's kangaroo rat and 13-lined ground squirrel densities were significantly greater in the native plot than in the infested area (Table 2). Thirteen-lined ground squirrels were not observed in the infested plot. These species are characteristic of pristine, native habitat at this location (3, 8). The most abundant species in the Russian knapweed habitat was the western harvest mouse, a species associated with disturbed, early successional or weed-infested areas (3, 4, 10). Deer mouse abundance was also significantly greater in the infested plot; no deer mice were caught in the native area. This species is not considered to be as exclusive as the western harvest mouse in preferring weedy habitats (2, 3), but our results suggest that it may not be abundant in the relatively sparse native grassland habitat at Boysen.

Table 2. Comparative mammal population estimates (=vs.≠), Boysen, WY 1993 ( $\alpha=10$ ).

Species	Boysen, WY mammal population estimates (N) 1993		
	Infest	T-test result	Native
	no./ha		no./ha
Ord's kangaroo rat			
<i>Dipodomys ordii</i>	5.2	≠	10.3
13-lined ground squirrel			
<i>Spermophilus tridecemlineatus</i>	--	≠	12.0
Western harvest mouse			
<i>Reithrodontomys megalotis</i>	22.9	≠	--
Deer mouse			
<i>Peromyscus maniculatus</i>	12.9	≠	--

Russian knapweed was not as dominant in the infested plot at Craig as at Boysen (38% compared to 71% cover) (Table 3). Two other species contributed at least 5% aerial cover, oatgrass at 28% and reedgrass at 6% in the infested plot. The knapweed-free plot was strongly dominated by nonnative smooth brome. No other species contributed 5% or more aerial cover in the knapweed-free plot. This indicates that the infested plot featured greater structural vegetative diversity than did the noninfested plot. Plant species richness was, as at Boysen, greater in the noninfested area, but this difference was not statistically significant.

Table 4 shows small mammal abundance estimates for the Craig site. Only 2 species, the montane vole and the deer mouse, were caught at the Craig site (Table 4). Abundance estimates for the infested plot were significantly greater than for the knapweed-free plot. Evidence of Richardson's ground squirrels, specifically feces and burrows, was common in the knapweed-free plot. However, this species hibernates beginning in July (1, 3), and none were caught.

Table 3. Cover by plant species and results of ANOVA comparisons (-vs.+) at Craig, CO 1993 ( $\alpha=0.10$ ).

Species	% Vegetative cover by species, Craig, CO 1993		
	Infest	F-test result	Native
Russian knapweed			
<i>Centaurea repens</i>	38	≠	0
Oatgrass			
<i>Danthonia sp.</i>	28	≠	0
Field pennycress			
<i>Thlaspi arvense</i>	1	≠	0
Flixweed			
<i>Descurainia sophia</i>	2	≠	0
Reedgrass			
<i>Calamagrostis sp.</i>	6	=	3
Smooth brome			
<i>Bromus inermis</i>	0	≠	64
Daisy			
<i>Erigeron sp.</i>	0	=	1
Woods rose			
<i>Rosa woodsii</i>	0	=	1
Western yarrow			
<i>Achillea millefolium</i>	0	=	2
Rocky Mountain iris			
<i>Iris missouriensis</i>	0	=	1
Bare ground	4	=	11
Species richness	5	=	6

Table 4. Comparative mammal population estimates (-vs.+), Craig, CO 1993 ( $\alpha=0.10$ ).

Species	Craig, CO mammal population estimates (N) 1993		
	Infest	T-test result	Native
Deer mouse	no./ha		no./ha
<i>Peromyscus maniculatus</i>	23.8	≠	14.0
Montane vole			
<i>Microtus montanus</i>	6.0	≠	0

Displacement of native plant communities by nonnative vegetation results in losses of structural and functional habitat diversity and constitutes a principal mechanism for loss of biodiversity at regional and global scales (5, 7, 9). The results of the study at Boysen suggest that native species of small mammals and plants may be displaced by invading Russian knapweed. Species of small mammals associated with Russian knapweed-infested sites tend to be habitat generalists whose ranges have expanded in response to changes in habitat corresponding to commercial agricultural development (2, 3). Ranges of occupation of so-called specialist species that require pristine, native habitat decrease as this trend progresses. At Boysen, Ord's kangaroo rat and the 13-lined ground squirrel can be considered "specialists" for the native habitat type. Their apparent relative aversion to the Russian knapweed-infested area suggests that Russian knapweed invasion may constitute a genuine threat to regional and global biodiversity.

Results from the Craig site do not support this contention. However, the noninfested plot at Craig was actually a severely disturbed, low seral stage, arguably weed-infested community itself, and served as a poor representation of "native" conditions. Moreover, small mammal sampling was initiated too late in the year to obtain population estimates for Richardson's ground squirrels, perhaps one of the dominant small mammal species at the site. We suggest that the Craig site be considered independently of the Boysen site. Better site selection (finding a genuine pristine plot for comparison to the infested area) and timing of sampling at the Craig location for 1994 may yield much more useful information regarding the ecological implications of Russian knapweed infestation in north central Colorado.

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**BROOM SNAKEWEED CONTROL AND SEEDLING ESTABLISHMENT AFTER RANGELAND BURNING.** D. B. Carroll and K. C. McDaniel, Research Assistant and Professor, Department of Animal and Range Sciences, New Mexico State University, Las Cruces, NM 88003.

Abstract. Use of fire for management of broom snakeweed on New Mexico's blue grama dominated prairie has gained increased attention. A prescription for burning these low volatile grasslands in spring or summer (1990 to 1993) was developed by burning small plots (20 by 26.5 m) under varying fuel-load and air temperature regimes. The environmental prescription which requires at least 500 kg/ha of a fine and uniform fuel-load is: air temperature 20 to 28 C, relative humidity 10 to 20%, wind from southwest at 3 to 8 m S<sup>-1</sup>, soil temperature above 15 C, and fine-fuel moisture below 9%. We monitored fire intensity with a computerized multipoint thermocouple system which allowed direct measurement of fire temperature (FT), rate of fire spread (ROS), and duration of heat (DOH). In spring (Mar-Apr), fires burned cooler (average FT 250 C), faster (ROS 33 m/min) and were less intense (DOH >60 C = 37 sec) than during summer (June-July) fires (FT 291 C, ROS 20 m/min, DOH > 60 C = 49 sec). Broom snakeweed was less susceptible to fire in spring (84% average mortality) when primordial buds were clustered on lower stems than in summer (95% mortality) when leaves and branches were fully elongated. About one-third of mature plants not completely consumed by fire (burned to ground surface) resprouted from basal buds within 6 wk.

Broom snakeweed germination was dependent on high soil water content with greatest emergence in April and May (71% of total). In 1992, when rainfall was above normal in spring, nearly twice as many seedlings emerged from spring 1991 burned plots (0.65 m<sup>-2</sup>) and seven times as many in summer 1991 plots (2.7 m<sup>-2</sup>) compared to nonburned rangeland (0.37 m<sup>-2</sup>). Seedling emergence was related to increasing bare ground ( $r = 0.62$ ) and decreasing grass yield ( $r = -0.70$ ) which were directly related to fire intensity. A favorable microenvironment for broom snakeweed germination can result following fire because litter is removed, grass

competition is diminished, and seedling emergence occurs early in spring before growth of warm season grasses begins. By comparison, broom snakeweed control with picloram (99% mortality) resulted in few seedlings after treatment (0.01 m<sup>2</sup>) because grass cover and yield increased and formed a nearly closed canopy.

**CONTROL OF SEASIDE ARROWGRASS WITH METSULFURON.** R. J. Swearingen and T. D. Whitson, Research Assistant and Extension Weed Specialist, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82071.

**Abstract.** Seaside arrowgrass (*Triglochin maritimum L.*) is toxic to livestock and inhabits native hay meadows, sloughs, marshes and other wet places from the Prairie Provinces of Canada to Mexico in the central and western United States. Despite its wide distribution and its ability to poison livestock, no past control techniques have been developed. Therefore, herbicide screening studies were established in 1988 and 1989 to find a suitable chemical control. In these studies, metsulfuron provided the greatest control. Two additional studies were initiated in 1990 and 1992 to determine the lowest rate of metsulfuron that would give adequate control. Metsulfuron combined with X-77 at 0.25% v/v was applied in August during late seed formation, in native hay meadows after harvest, reducing the canopy coverage of the grasses, allowing for greater herbicide penetration. Control ranging from 96 to 100% was obtained with rates above 0.18 oz/A at both locations. Control decreased to less than 80% using rates lower than 0.18 oz/A.

Table 1. Seaside arrowgrass control with metsulfuron.

Herbicide	Rate	Hull <sup>a</sup>	Benik <sup>b</sup>
	oz/A		
Metsulfuron + X-77	0.06 + 0.25%	56	0
Metsulfuron + X-77	0.12 + 0.25%	67	77
Metsulfuron + X-77	0.18 + 0.25%	85	99
Metsulfuron + X-77	0.24 + 0.25%	99	97
Metsulfuron + X-77	0.30 + 0.25%	96	98
Metsulfuron + X-77	0.36 + 0.25%	98	98
Metsulfuron + X-77	0.42 + 0.25%	100	100
Metsulfuron + X-77	0.48 + 0.25%		100
Metsulfuron + X-77	0.54 + 0.25%		100
Control	-----	0	0
LSD (0.05)		24	3

<sup>a</sup> Applications made August 20, 1990 on the Noel Hull Ranch, Rock River, Wyoming.

<sup>b</sup> Applications made August 12, 1992 on the Benik Ranch, Laramie, Wyoming.

**THE WEED CLIPPER: A MECHANICAL WEED CONTROL DEVICE.** D. E. Wehrlin and P. K. Fay, Graduate Student and Professor, Department of Industrial and Management Engineering, Montana State University, Bozeman, MT 59771.

**Abstract.** The weed clipper is a mechanical device which reduces or eliminates weed seed production in specific cropping systems by removing seed heads before viable seed is produced. The prototype device is a series of "weed eaters" on a boom that was field tested in the summer of 1993. The device clips off weed seed heads of tall weed species in shorter crops. Nine electric motors each equipped with a string trimmer head were mounted on a boom 60 cm apart to provide a total cutting swath of 5.4 m. The device was mounted on either the three point hitch at the rear of a farm tractor or clamped on the bucket of a front end loader. A gas powered electric generator powered the electric motors. The clipper cut reliably at field speeds ranging from 2 to 6 mph depending on weed density. The cost for the prototype was \$240/m. Field tests were conducted successfully in wheat and barley for wild oat control, common rye control in winter wheat, general weed control in sugar beets,

strawberries, and pasture land. If the weed clipper could operate at the same rate of travel with similar boom widths as field sprayers applying herbicides, this method of weed control could compete favorably with herbicide use for some weed species since herbicides are expensive and must be annually applied. A durable weed clipper would last many seasons. The field tested prototype will be redesigned to accommodate a 12 m boom and provide a reliable cut at speeds up to 10 mph.

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**THE EFFECTS OF BENOXACOR TREATMENT ON PROTEIN SYNTHESIS AND GLUTATHIONE S-TRANSFERASE mRNA ABUNDANCE IN MAIZE.** K. D. Miller, G. P. Irzyk, and E. P. Fuerst, Graduate Research Assistant, Postdoctoral Research Associate, and Associate Professor, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420.

**Abstract.** Benoxacor is a herbicide safener used to protect maize against the toxic effects of the herbicide metolachlor. Benoxacor primarily functions by increasing the activity of glutathione S-transferase isozymes, which subsequently metabolize metolachlor to an inactive metolachlor-glutathione conjugate. To aid in elucidating the biochemical mechanism by which benoxacor treatment increases the activity of glutathione S-transferase isozymes, protein synthesis and mRNA abundance in benoxacor-treated Black Mexican Sweet (BMS) maize cell-suspension cultures was studied.

Seven-day-old BMS cells were treated with 10  $\mu$ M benoxacor for 2, 6, and 24 h, and pulse-labeled with [<sup>35</sup>S]methionine for 1 h prior to harvesting. Total soluble protein was extracted from the cells and subjected to two-dimensional sodium dodecyl sulfate-polyacrylamide gel electrophoresis to separate proteins, and fluorography to visualize radiolabeled polypeptides. The abundance of relatively few (i.e. < 10) polypeptides was increased 24 h after treatment (HAT), indicating that protein synthesis induced by benoxacor treatment is rather specific. One polypeptide, which was barely detectable in control cells, was highly induced by 24 HAT and was in the molecular weight range expected for GSTs.

Total RNA was extracted from BMS cells previously treated with 10  $\mu$ M benoxacor for 0, 0.5, 1, 3, 6, and 24 h. The RNA was size fractionated by denaturing agarose gel electrophoresis followed by capillary transfer to a nylon membrane. The immobilized RNA was then probed with a [<sup>32</sup>P]-labeled full length GST IV cDNA. The abundance of GST IV RNA was increased about five-fold as early as 30 min after treatment, while maximum increases were observed 6 HAT. By 24 HAT, benoxacor-induced increases in the abundance of GST IV RNA decreased to similar levels previously observed 30 min after treatment.

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**MECHANISM OF TRIALLATE RESISTANCE IN WILD OATS (*Avena fatua* L.): PRELIMINARY STUDIES.** Corey T. Colliver, Anthony J. Kern, William E. Dyer, and Bruce D. Maxwell, Graduate Research Assistant, Graduate Research Assistant, and Assistant Professors, Department of Plant, Soil and Environmental Science, Montana State University, Bozeman, MT 59717-0312.

**Abstract.** Triallate resistance in wild oats has been confirmed in several northwestern states and Canada. Triallate resistance in Montana was first identified on the Fairfield Bench in irrigated continuous malting barley fields. Dose response curves were conducted in the greenhouse and in the lab for determination of dosages to use during experimentation. To determine if differential herbicide uptake or translocation may be responsible for resistance, 0.045  $\mu$ Ci of <sup>14</sup>C-triallate was applied to 5 to 10 mm long coleoptiles of seedlings approximately 4 d post imbibition. Plant organs were harvested at 24, 48 and 60 h; rinsed; separated into treated coleoptile, shoot, seed and root; oxidized and <sup>14</sup>C-radiolabel amount determined by scintillation counting. Uptake differences are apparent between resistant and susceptible accessions by 60 h post treatment with the susceptible accessions accumulating ~1.9 times more radiolabel. Translocation differences occur by 48 h in the shoot tissue with ~3



times more radiolabel in the treated susceptible accessions and are maintained at 60 h. Metabolism studies were conducted in which 7 to 8 cm long excised shoot tissue was incubated in 10 ml of buffer containing 1.09  $\mu\text{Ci}$   $^{14}\text{C}$ -trillate for 24, 48 and 96 h. At all time points more radiolabel was contained in the metabolite portions of the susceptible accessions. Our results show differences of 7%, 4.5% and 22.5% at the three time points, respectively, with more metabolites produced by the susceptible accessions. HPLC was used to separate the peaks and an in-line radioisotope detector quantified the peak areas. (Dept. of Plant, Soil and Environmental Sciences Department, Montana State University, Bozeman, MT 59717).

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**WITHIN FIELD FREQUENCY AND SPATIAL DISTRIBUTION OF TRIALLATE RESISTANT WILD OATS (*Avena fatua* L.).** W. E. Malchow, B. D. Maxwell, P. K. Fay, and W. E. Dyer, Graduate Research Assistant, Assistant Professor, Professor and Assistant Professor, Plant, Soil and Environmental Science Department, Montana State University, Bozeman, MT 59717.

**Abstract.** Over 63% of the wild oat seed samples taken from 237 fields in an irrigated malt barley production region of Montana in 1992 contained wild oats resistant to triallate. A "W" method of within field sampling was used again in 1993 to assess any changes in the proportion of triallate resistant wild oats within fields. An average increase of 24% resistant seed was found in 11 fields that had received triallate in 1992 and 1993. Seven fields that received triallate in 1992 and imazamethabenz in 1993 also increased in 24% of resistance. The objective of this study was to determine the spatial pattern and frequency of resistance within a triallate treated and untreated field.

A systematic grid method of sampling wild oat plants was used to determine the frequency and spatial distribution of resistant plants within the triallate treated versus untreated portions of a field. A continuous malt barley field treated with triallate on one half of the field was used for the study site. A 3600 m<sup>2</sup> grid containing 144, 25 m<sup>2</sup> cells, was placed within both the treated and untreated halves of the field. Seed from an entire panicle was taken from a single wild oat plant nearest to the center of each cell within the blocks. Seed samples were screened for triallate resistance using a petri dish bioassay. Dose response curves indicated that a dose of 1  $\mu\text{l}$  of triallate (100 ppm), per seedling, provided the best delineation between susceptible and resistant seed. Seeds were prepared by removing the lemma and palea from the seed; the caryopsis was pierced on the dorsal side; and the seeds were surface sterilized in a 1.3% bleach solution. Samples were imbibed for 4 d. Twenty seedlings with coleoptiles 5 to 15 mm long were selected and the lengths recorded. Ten seedlings were divided into two petri dishes to be treated by placing 1  $\mu\text{l}$  triallate (100 ppm) on each coleoptile tip. The remaining 10 seedlings were divided into two dishes and left untreated. Petri dishes were sealed and placed in a growth chamber at 19 C in total darkness. Seven d later shoot length was recorded. Mean shoot growth for the treated and untreated portions of a sample were compared using a t-test at the 0.05 level of significance. Treated means significantly different than the untreated means were considered susceptible and conversely resistant when no difference was detected. Plant results were mapped for each cell and the frequency of resistance determined for each cell. Analysis of pattern was conducted using Moran's I autocorrelation.

Some samples responded to triallate in a highly variable fashion, appearing to have both susceptible and resistant seed from the same plant. This could possibly be the result of a heterozygous resistant mother plant or an out-crossing event. The triallate treated area contained 64% resistant cells and 36% susceptible cells. The untreated block contained 35% resistant cells and 65% susceptible cells, indicating that even after many years of triallate use and the continual selection of resistant wild oat seed, susceptible seed is still present and reproducing with and without the use of triallate. No pattern was found in either the treated or untreated block using Moran's I autocorrelation. The lack of pattern indicates that resistant types are randomly distributed and the resistance event may have occurred simultaneously throughout the field. (Dept. of Plant, Soil and Environmental Sciences, Montana State University, Bozeman, MT 59717).

**TRIALLATE RESISTANT WILD OATS (*Avena fatua* L.) ARE CROSS-RESISTANT TO DIFENZOQUAT.** Anthony J. Kern, Corey T. Colliver, Harwood J. Cranston, and William E. Dyer, Graduate Research Assistants, Research Associate, and Assistant Professor, Department of Plant, Soil, and Environmental Sciences, Montana State University, Bozeman, MT 59717-0312.

**Abstract.** Repeated use of triallate has selected for resistant wild oat populations in several states and Canada, and subsequent concern over the loss of effectiveness for this herbicide has prompted research into the mechanism of resistance. Greenhouse tests of triallate-resistant accessions collected from the Fairfield area in Montana have shown that all accessions display high levels of cross-resistance to the chemically unrelated post-emergence herbicide difenzoquat. To investigate the mechanism of resistance, studies were carried out comparing herbicide uptake and translocation in resistant and susceptible wild oat accessions. These studies were carried out using <sup>14</sup>C-difenzoquat applied to the third leaf of 4-leaf stage plants. Plant material was separated into treated leaves, untreated leaves and shoots, meristematic regions, and roots, and <sup>14</sup>C distribution determined by oxidation and scintillation counting.

**IMPACT OF ALTERNATIVE CROPPING SYSTEMS ON THE POPULATION DYNAMICS OF WILD OATS (*Avena fatua* L.).** S. R. Canner and B. D. Maxwell, Graduate Research Assistant and Assistant Professor, Department of Plant, Soil, and Environmental Sciences, Montana State University, Bozeman, MT 59717.

**Abstract.** Several dryland organic farmers in Montana are utilizing recropping, alternative cash crops, and green manures to improve efficiency, stabilize income and diversify marketing opportunities. Many of these producers are replacing summer fallow with green manure cover crops which may be terminated upon using an allotted amount of soil moisture, leaving adequate moisture for a subsequent cash crop. If moisture permits, cover crops may be harvested for forage or seed. The use of green manure crops reduces erosion by providing cover and improving infiltration, reduces groundwater contamination and saline seep through utilization of excess moisture, and may provide economically valuable quantities of nitrogen to the subsequent crop by means of scavenging nitrates mineralized during the fallow year and, in the case of a legume crop, fixing additional atmospheric nitrogen. These producers are concerned about the weed management implications of these otherwise beneficial practices. Wild oats are the most persistent and troublesome weeds in dryland Montana agriculture. This experiment was instigated to evaluate the effects of green manure and alternative cash crops on wild oat population dynamics in a certified organic spring cropping system.

This experiment was established in spring of 1993 at locations on two organic farms in the vicinity of Big Sandy, in north central Montana. A randomized complete block design was established with three replications and the following 8 treatments (hyphenated treatments indicate interseeded legume crop):

<u>1993</u>	<u>1994 (planned)</u>	<u>1995 (planned)</u>
No crop	No crop	No crop
Fallow	Spring grain	Fallow
Barley	Fallow	Barley
Barley-alfalfa	Alfalfa	Spr. grain-clover
Barley-medic	Black medic	Spr. grain-medic
Buckwheat	Peas-oats	Cash crop
Buckwheat-alfalfa	Alfalfa	Alfalfa
Peas	Spring grain	Peas-oats

Plots were 3 by 9 m, blocked with varying wild oat density. Wild oat plant densities were estimated in each plot using quadrats of 0.25 m<sup>2</sup> at the Quinn site and quadrats of 0.10 m<sup>2</sup> at the Tester site. Wild oat seed production was estimated by the weight of wild oat seed gathered and retained by the combine in each plot. The pea treatment was terminated by harvesting as hay on August 12.

Wild oat plant densities were highly variable at both sites. There were no significant differences in wild oat density among treatments, suggesting that seedling recruitment is not significantly affected by crop. Wild oat seed production from those plots which were not terminated early is shown (Figure). All but one cropping treatment at one site yielded significantly less than did the no-crop control. Barley treatments tended to reduce wild oat seed production more than did buckwheat treatments. Intercrops did not significantly affect wild oat seed production except in the case of the buckwheat-alfalfa intercrop at the Quinn Site. In all cases of alfalfa intercrop, there appears to be a non-significant trend toward increased wild oat seed production over other treatments with the same main crop. There were no mature wild oat plants on the plots which had been fallowed or harvested as hay as of September 10.

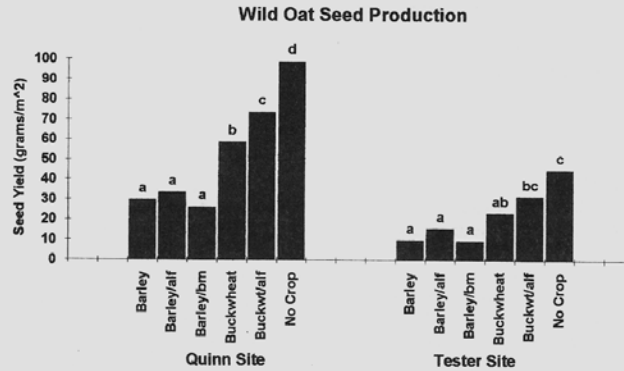


Figure. Wild oat seed production.

Interference between the crop and the weed appears to have significant effects on seed production. There is some suggestion from the trends we have seen in treatments containing alfalfa intercrops that there is an interaction between alfalfa and the main crop which may reduce the crop's ability to suppress wild oats.

In ongoing research, weed seedling recruitment and survival will be watched more closely in comparing fallow treatments to green manure treatments, as differences due to tillage or biotic effects could have implications for seed bank dynamics. The rate of seed maturation prior to an early harvest or termination, and shoot regeneration after harvest or termination are important aspects of wild oat population dynamics in green manures, hay crops, and fallow, and will be followed closely in future experiments.

**INFLUENCE OF TILLAGE PRACTICES ON EMERGENCE OF JOINTED GOATGRASS IN FALL PLANTED WINTER WHEAT.** T. M. Price, J. O. Evans, and S. A. Dewey, Research Assistant, Professor, and Associate Professor, Department of Plants, Soils, and Biometeorology, Utah State University, Logan, UT 84322-4820.

**Abstract.** Six tillage programs were initiated in the fall of 1992 in a grower's stubble field containing about 1000 to 2000 jointed goatgrass seedlings m<sup>-2</sup> to determine interactions of tillage and jointed goatgrass densities in the subsequent winter wheat crop. Fall and spring tillage operations were chosen to represent major tillage regimes commonly used in the intermountain region including no-tillage, conservation, and conventional tillage (Table). Jointed goatgrass populations were determined using a 75 cm<sup>2</sup> sampler that extracted a soil sample 10 cm deep

centered over the wheat row. The sample was divided into a surface fraction and two soil fractions; 0- to 5-cm and 5- to 10-cm deep. Jointed goatgrass seedlings and non-germinated seeds were recorded in each fraction.

The number of jointed goatgrass seedlings emerging with winter wheat in non-tilled plots was nearly double the number emerging in any other tillage practice, and the jointed goatgrass densities following conservation tillage were approximately double those following conventional tillage. Only the non-tilled plots contained greater numbers of jointed goatgrass in the 0 to 5 cm soil depth when compared with other tillage practices. The most effective tillage practice to reduce jointed goatgrass emergence in winter wheat appears to be spring chisel plow followed by repeated summer rod weeding. Conventional tillage practices were more effective in curtailing jointed goatgrass in wheat than conservation tillage while the latter was more effective than no tillage.

Table. Numbers of jointed goatgrass seedlings and seed joints in winter wheat following no-tillage, conservation, and conventional tillage.

Tillage regime	Jointed goatgrass			Total seed
	Surface	Seedlings		
		0 to 5 cm	5 to 10 cm	
	no. m <sup>2</sup>			
No-tillage				
Non-tilled	2176	2338	98	898
Conservation tillage				
Chisel plow (F*) skewtreader (Sp*)	1300	1134	66	281
Subsoiler (F) skewtreader (Sp)	1343	1343	171	303
Conventional tillage				
Chisel plow (F) rodweeder (Su*)	0	779	130	11
Chisel plow (Sp) rodweeder (Su)	0	390	0	0
Subsoiler (F) rodweeder (Su)	0	1201	65	11
LSD (0.05)		860	110	

\*F=Fall 1992, Sp=Spring 1993, Su=Summer 1993.

**DOWNY BROME CONTROL IN ESTABLISHED ALFALFA WITH GLYPHOSATE.** J. L. Wright and P. K. Fay, Research Associate and Professor, Department of Plant and Soil Science, Montana State University, Bozeman, MT 59717.

**Abstract.** Downy brome is a common weed in established alfalfa in Montana. It reduces hay quality and is detrimental to livestock because it causes lump jaw, blocks salivary glands, and impacts teeth. Glyphosate is widely used for downy control in dormant alfalfa. However, it is not presently labeled. The manufacturer has been reluctant to label the treatment because of crop injury potential. Field trials were established to test the efficacy on downy brome and the crop injury potential when glyphosate was applied at different growth stages of alfalfa. The field trials were established in two locations, Bozeman and Moccasin, Montana. At the Moccasin location, glyphosate was applied at rates of 215, 317, 431 g ha<sup>-1</sup>, and 215 g ha<sup>-1</sup> glyphosate with 2% w/w ammonium sulfate when the alfalfa was 1, 4, 8 cm tall. The plots were 3.7 by 7.7 m arranged in randomized complete block design with four replications. At the Bozeman location glyphosate was applied at rates of 283, 431, 567 g ha<sup>-1</sup>, and 283 g ha<sup>-1</sup> glyphosate with 2% w/w ammonium sulfate when the alfalfa was 13, 15, 25, and 31 cm tall. Plots were 2.1 by 7.7 m arranged in randomized complete block design with four replications. Alfalfa height and phytotoxicity were evaluated weekly after spraying.

**Bozeman.** Alfalfa yield was measured July 7, 1993. Downy brome control was good to excellent for all treatments. The only treatment that did not reduce crop yield was glyphosate applied at 283 grams ha<sup>-1</sup> when the

alfalfa was 13 cm tall. Glyphosate provided excellent downy brome control at the lowest rate tested (283 g ha<sup>-1</sup>) at each time application.

**Moccasin.** Alfalfa yield was measured June 15, 1993. Downy brome control was excellent for all treatments. There was no yield reduction for any of the treatments. Glyphosate provided excellent downy brome control at the lowest rate tested (215 g ha<sup>-1</sup>). Injury was visually undetectable for all treatments by 60 dat when compared to an untreated check. The interval for safe application in the spring in Montana appears to be short. (Dept. of Plant, Soils, & Ent. Sci., Montana State University, Bozeman, 59717).

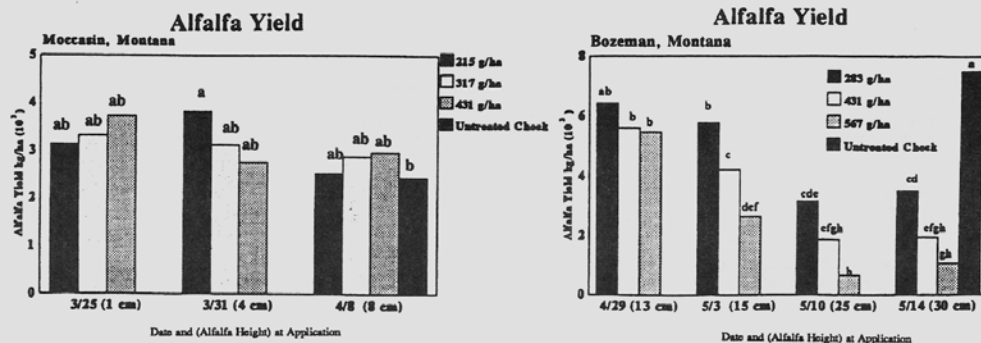


Figure. Alfalfa yield at Moccasin and Bozeman, Montana.

**OPTIMIZATION AND MECHANISM OF ACTION OF SEED-APPLIED HERBICIDE SAFENERS IN WINTER WHEAT.** D. E. Riechers, E. P. Fuerst, and C. M. Boerboom, Graduate Research Assistant, Associate Professor, and Extension Weed Specialist, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420.

**Abstract.** Winter wheat can be safened from chloroacetamide herbicides, which could provide the potential for control of several troublesome winter annual grass weeds in wheat. Greenhouse studies examined safening 'Madsen' wheat from metolachlor, acetochlor, and dimethenamid with the seed-applied safeners oxabetrinil, benoxacor, flurazole, fluxofenim, and CGA-185072. Dimethenamid demonstrated a high level of activity against grass weeds and showed good potential for safening in wheat, so further studies optimized safener rate against dimethenamid injury. All safeners, except flurazole, provided various levels of safening from dimethenamid in 'Madsen' wheat. Fluxofenim and CGA-185072 showed the highest unit activity for safening. CGA-185072 at 1.25 g/kg seed provided the highest level of protection (approx. 90% of the unsafened, no herbicide control) against 1.1 kg/ha dimethenamid. In contrast, oxabetrinil and benoxacor had to be applied at a high rate (10 g ai/kg seed) to achieve maximum safening; however, they also were effective safeners at this rate.

Laboratory studies were initiated to examine the mechanism of action of the herbicide safener fluxofenim. The metabolic half-life of dimethenamid in intact, excised shoots was decreased by a factor of about ten in fluxofenim-treated wheat, indicating safeners increase the ability of wheat to rapidly metabolize the herbicide. Thin-layer chromatography (TLC) was used to examine the metabolite profiles of dimethenamid in unsafened and fluxofenim-treated wheat. The route of metabolism appeared similar in fluxofenim-treated and unsafened wheat; however, an increase in three polar metabolites of dimethenamid was observed in response to fluxofenim

treatment. The initial metabolite co-chromatographed with a synthetic glutathione conjugate of dimethenamid, and appeared to be rapidly catabolized to a dipeptide and cysteine conjugate of dimethenamid. Total glutathione S-transferase (GST) activity was increased approximately ten-fold by fluxofenim treatment. Total GST activity was resolved using fast protein liquid chromatography (FPLC) anion exchange into several component activities (isozymes), which differ with respect to substrate specificity to dimethenamid and 1-chloro-2,4-dinitrobenzene (CDNB), and their inducibility by fluxofenim.

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**SPRING CROPS FOR WINTER ANNUAL GRASS MANAGEMENT IN A WHEAT-FALLOW ROTATION.** T. L. Neider and S. D. Miller, Graduate Assistant and Professor, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82071.

**Abstract.** Winter annual grass weeds infesting winter wheat are a serious problem in dryland winter wheat producing areas of the United States. The introduction of conservation tillage practices and effective broadleaf herbicides has influenced the establishment of winter annual grasses such as downy brome (*Bromus tectorum* L.), jointed goatgrass (*Aegilops cylindrica* Host) and volunteer rye (*Secale cereale* L.). Research was initiated in the fall of 1991 at the Archer Research and Extension Center, Wyoming under no-till dryland conditions to determine the effects of winter annual grasses on winter wheat, and the effect of winter wheat, summer fallow and spring seeded crops on the soil seed bank levels of these grass weeds. Downy brome, jointed goatgrass and volunteer rye seed banks were established at 1,500,000 viable seeds/ha<sup>-1</sup> and four different crop rotations were initiated. The rotations consisted of different winter wheat, summer fallow, proso millet and sunflower combinations.

Volunteer rye densities in winter wheat were higher than both downy brome or jointed goatgrass, and rye had the greatest influence on winter wheat. Downy brome and jointed goatgrass seed bank levels increased in winter wheat while rye seeds were not detected after the initial seed bank determination. Volunteer rye seeds were effectively removed when winter wheat was harvested and not returned to the soil seed reserve. Downy brome and jointed goatgrass seed bank levels were reduced during the spring rotational crop or summer fallow period. However, 1 yr out of winter wheat production is not long enough to reduce seed bank levels in soil to non-problem levels.

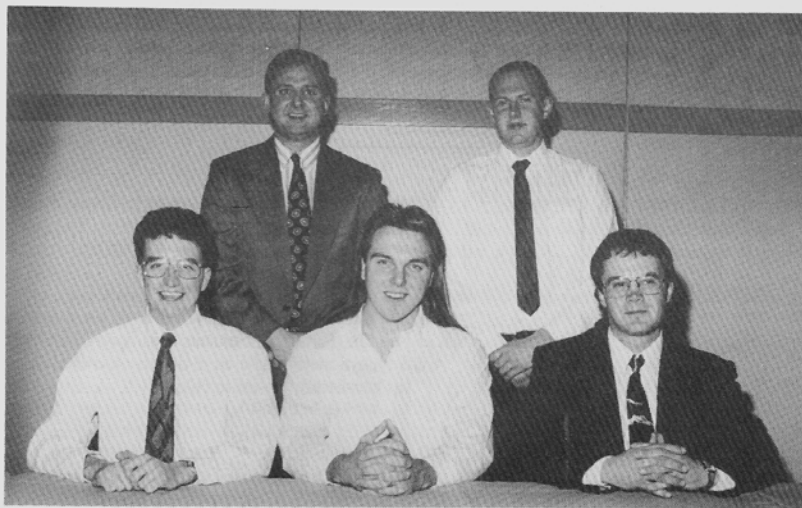
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**EFFECTS OF TILLAGE AND FERTILIZER SYSTEMS ON CORN AND WEED RESPONSE.** Patrick Renner, Steve Miller, and Jim Fornstrom, Graduate Assistant and Professors, Department of Plant, Soil and Insect Sciences and Department of Civil Engineering, University of Wyoming, Laramie, WY 82071.

**Abstract.** Field studies were conducted, at the University of Wyoming Research and Extension Center, Torrington, Wyoming, to determine the effects of timing and placement of nitrogen fertilizer on weed and corn yield under 3 tillage systems, conventional, minimum and no-till. Fertilizer treatments consisted of both dry surface broadcast and liquid spoke wheel injection. A chlorophyll meter was used to determine corn response to the various fertilizer treatments. The unfertilized check was consistently lowest in chlorophyll content during the nine sampling periods over 2 yr however, the chlorophyll meter was not sensitive enough to measure difference between the other fertilizer treatments. Weed counts and weed dry matter yields were significantly higher under the minimum and no-till tillage systems however fertilizer placement method didn't have a significant impact. No significance, other than the unfertilized checks, was found in corn silage yields during 1993. During 1992, corn silage yield were significantly higher 27.2 T/A for the conventional tillage system than for the no-till system 21.4 T/A however, no significant differences were found in corn grain yield between tillage and fertilizer treatments.

**ASSESSMENT OF FIELD PENNYCRESS COMPETITION IN CANOLA.** Jeffery S. Brennan and Donald C. Thill, Graduate Research Assistant and Professor, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID 83844-2339.

**Abstract.** Canola is an important oil seed crop in the Pacific Northwest that can be grown in rotation with cereals. Field pennycress is a Brassicaceous weed species widely distributed through the United States and is found commonly in Idaho cereal acres. Field pennycress is not controlled by herbicides currently registered for use in canola in the United States. Little is known about the competitive and quality effects field pennycress has on canola. A field experiment was established at the University of Idaho Plant Science Farm near Moscow, Idaho to assess the effects of competition between canola and field pennycress and determine the impact of field pennycress on canola seed yield and oil quality. The experiment was a randomized complete block strip plot design with treatments arranged as an addition series with four replications. The experiment consisted of two factors; canola and field pennycress seeded to achieve target densities of 0, 75, 150, 225, 300 plants/m<sup>2</sup>. Actual plant densities for canola were 45, 76, 94, and 140 plants/m<sup>2</sup> and field pennycress densities were 30, 56, 65, and 92 plants/m<sup>2</sup>. Canola was harvested at low (20 cm) and high (50 cm) harvest heights to include or exclude field pennycress in the harvested canola seed. Canola seed yield at low and high harvest height decreased as field pennycress density increased. After cleaning field pennycress seed from low harvested canola, less canola seed remained than from the high harvest height. Canola seed contaminated with 13 to 21% field pennycress seed did not affect the three major fatty acid components oleic acid (18:1), linoleic acid (18:2), or linolenic acid (18:3), but increased erucic acid (22:1) levels. Erucic acid level did not exceed the maximum 2% allowed for canola quality. Increasing canola density greatly reduced field pennycress seed yield. Canola densities of 75 to 140 plants/m<sup>2</sup> reduced field pennycress seed yield similarly for field pennycress densities of 30 and 92 plants/m<sup>2</sup>. This experiment will be repeated in 1994 to validate these data.



1994 WESTERN SOCIETY OF WEED SCIENCE STUDENT PAPER AND STUDENT POSTER WINNERS.  
Seated (L to R): Wade Malchow (1st-Paper), Corey Colliver (1st-Paper), Kris Johnson (1st-Poster).  
Standing (L to R): Dean Riechers (2nd-Paper), Anthony Kern (2nd-Paper).

**PROJECT 1: WEEDS OF RANGE AND FOREST**

Chairperson: Keith Duncan

Subject: Research Update on Broom Snakeweed

1. Physiology of broom snakeweed. Tracy Sterling, New Mexico State University, Las Cruces, NM.

Tracy provided an overview of the plants distribution throughout western North America and described broom snakeweed as a highly variable species able to grow under a wide variety of environmental conditions, such as different temperatures, relative humidity levels, soil types, and altitudes. Morphology differences and its ability to grow in many environments suggest broom snakeweed may have a high level of inherent variation.

Broom snakeweed collected from eight New Mexico locations representing different environmental conditions and planted in a common garden near Las Cruces retained their indigenous growth form suggesting genetic variation, and not environment, contributes to morphology differences. Isozyme analysis of these populations indicated genetic variability among and within broom snakeweed populations. The response of biological control agents to genetic variability in each population is being studied.

Tracy also discussed picloram uptake by broom snakeweed and reported absorption to be similar by leaf, stem, and bud tissue. Maximum uptake into leaves occurred within 15 minutes of application and was about 15% of applied. Changes in relative humidity and pH, and addition of surfactant or crop oil altered the amount of picloram taken up by leaves. Increasing relative humidity from 11% to 95% increased picloram uptake by about 10 times. Organosilicone surfactants and crop oil concentrate increased uptake six times. Some discussion followed that perhaps uptake is not limiting when absorption exceeds a threshold amount (i.e. 15%), thereafter translocation becomes limiting.

2. Control measures of broom snakeweed. Kirk McDaniel, New Mexico State University, Las Cruces, NM.

Commercial aerial applications for broom snakeweed control on rangeland became widespread (approx. 100,000 to 200,000 A annually) in the southwest in 1984 following registration of picloram for this use in 1982. Most acreage is treated by private ranchers without cost-share monies. Picloram applied at 0.25 lb/A at post-flower (October to December) is the most common practice. Research designed to lower picloram rates have shown the addition of surfactants do not enhance plant control. Plants sprayed in high vigor following prolific blooming are more receptive to chemical control than plants in low vigor (i.e. water stressed and poor flower production).

There is increased interest by ranchers for broom snakeweed control by prescribed burning. Experimental fires within the shortgrass prairie ecotype dominated by blue grama and broom snakeweed indicate March burns are faster and cooler relative to fires in June, which were hotter, of larger duration, and more intense. Experience indicates that fire-fuel loads of less than 350 lb/A are inadequate to carry a fire sufficiently on blue grama prairie regardless of season. When fire-fuel loads exceed about 500 lb/A, fire uniformly consumes the fuel load irrespective of most environmental conditions. Due to the potential for seedling reinvasion and initial damage to grasses, burning during June was not recommended despite fires killing more than 90% of broom snakeweed. Burning during March killed about 75% of broom snakeweed but grass production was similar to nonburned rangeland.

3. Biological control of broom snakeweed. David Thompson, New Mexico State University, Las Cruces, NM.

David described several insects native to New Mexico that may be used in the biological control of snakeweed. One insect, *Hesperotettix viridis*, more commonly called the snakeweed grasshopper or the red-kneed grasshopper feeds almost exclusively on snakeweed in New Mexico. Given a choice between broom snakeweed, threadleaf snakeweed, rabbitbrush, burrowweed, and several grasses in the laboratory these grasshoppers preferred the snakeweeds. In laboratory studies the grasshoppers consume almost one-half their



own body weight each day. At these rates 2 grasshoppers will completely defoliate a small plant. Snakeweed grasshoppers significantly reduced above-ground biomass of snakeweed while not damaging the predominant perennial grass, blue grama. The average reduction in above ground snakeweed biomass is 36% at 1 grasshopper/plant, 61% at 3 grasshoppers/plant, and 80% at 5 grasshoppers/plant.

Studies were discussed which might determine the economics and feasibility of managing snakeweed grasshopper populations on rangelands. If techniques to manage snakeweed grasshopper populations can be perfected, this insect could play a major role in the biological control of snakeweed.

4. Toxicology and animal reproduction associated with broom snakeweed. Tim Ross, New Mexico State University, Las Cruces, NM.

Although unpalatable, livestock and wildlife graze on snakeweeds. Snakeweed consumption by pregnant cows and mares causes abortion and premature birth of weak offspring. Excessive grazing of snakeweeds can be fatal. Whether ingestion of snakeweed foliage by livestock before mating impairs fertility or embryonic mortality or if consumption after conception affects offspring mortality remains questionable. Little is known about which toxins in snakeweeds actually poison animals. Snakeweed toxicosis has been recognized by livestock ranchers for many years. This plant is purported to cause abortions, retained placentas, and the birth of weak or dead offspring in many livestock species. Most reproductive losses occur when native range grasses are shifting from winter dormancy to spring growth. In the spring, range livestock are forced to eat the early-greening snakeweed while native range forages are still relatively dormant. Under nutrition and the stresses of pregnancy may contribute to an animal's susceptibility to plant toxins. Late gestation seems to be a key time for snakeweed poisoning.

New Mexico State University studies have shown that sheep and cattle seem to tolerate ingested snakeweed foliage better than rats, especially if livestock are well nourished. Findings with rats may predict similar responses in poorly nourished sheep and cattle that ingest snakeweeds excessively. Using rats to elucidate snakeweed toxicology and evaluate prospective treatments for livestock that graze snakeweeds excessively has proven useful, and further studies are in progress.

1995 Officers of Project 1:

Chairperson: Kirk C. McDaniel  
Box 31, Dept. Range Sci.  
New Mexico State Univ.  
Las Cruces, NM 88003  
(505) 646-1191

Chairperson-elect: Steve Dewey  
Plant Science Dept.  
Utah State Univ.  
Logan, UT 84322  
(801) 750-2256

#### PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Chairperson: Mark G. Sybouts

Subject: Alternatives to Methyl Bromide Use in Horticultural Crops.

This discussion session was held 15 March at 3:00 pm. and was adjourned at 4:30 pm. Three discussion leaders gave short presentations to introduce subject matter for discussion.

1. Regulatory status of methyl bromide. Dave Lawson, Zeneca Ag. Products, Roseville, CA.

On November 30, 1993, the EPA added methyl bromide to the Clean Air Act list of class I ozone depleting substances. The EPA final rule will freeze U.S. production and importation of methyl bromide in 1994 at 1991 levels with a phase out of production and importation by the year 2001. This rule is more stringent than the Montreal Protocol freeze on production in 1995 at 1991 levels. A punitive tax structure may be implemented on methyl bromide with increasing amounts each year to 2001.

A very small part of the Clean Air Act involves the regulation of methyl bromide and it will take an act of Congress to rescind these restrictions. It was stated that it is highly improbable methyl bromide can be saved.

2. Introduction and status of Telone fumigant. Jesse Richardson, DowElanco, Hesperia, CA.

Telone is a fumigant that is very active on soil nematodes but is not as effective on weeds. In California, use was restricted by the Air Resources Board due to high levels of Telone in the air after application. DowElanco is putting a large amount of effort and money to mitigate the amount of Telone that escapes the soil after application in order to remove the restrictions. Its use can replace some of the need for methyl bromide, but does not fill all of the pest control capabilities.

3. Alternative research in vegetables and strawberries. Harry Agamalian, University of California, Salina, CA.

Research work in vegetables and strawberries was presented showing weed control and growth response from Vapam and Basamid soil fumigants. The use of aciflourfen-sodium to control weeds in strawberries was also presented. Weed control was excellent with the proper use of these materials.

The consensus of the attendees was that weed control does not depend on methyl bromide: adequate alternatives exist if they are registered for the crop in question. It was decided that the shortcomings of the alternatives are in nematode and disease control.

1995 Officers of Project 2:

Chairperson: Rick Arnold  
NMSU Ag. Science Center  
P.O. Box 1018  
Farmington, NM 87499  
(505) 327-7757

Chairperson-elect: Carl Bell  
U. C. Cooperative Ext.  
1050 E. Holton Rd.  
Holtville, CA 92250  
(619) 352-9474

**COMBINED DISCUSSION SECTIONS:**

**PROJECT 3: WEEDS OF AGRONOMIC CROPS**

Chairperson: Neal Hageman

**PROJECT 6: BASIC SCIENCES**

Chairperson: Bill McCloskey

Subject: Herbicide Resistant Crops

Dr. Bill Dyer (Montana State University, Bozeman, MT) began the discussion section with an overview of the development of herbicide resistant crops. This was followed by presentations on bromoxynil resistant cotton, glyphosate resistant crops, and glufosinate resistant safflower given by Drs. Cathy Houck (Calgene, Davis, CA), Tom Lee (Monsanto, St. Louis, MO) and Bill Dyer, respectively. The discussion continued with a presentation by Dr. Bruce Maxwell (Montana State University, Bozeman, MT) on the potential problems and concerns associated with herbicide resistant crops. The registration of herbicide resistant crops (HRC) and public perceptions regarding HRC were addressed by Dr. Lee and were the final topics of discussion.

Herbicide resistant crops currently comprise about 50 species that are resistant to one of six herbicides. All important crops can now be transformed following the introduction of herbicide resistance genes so that the development of HRC is limited largely by commercial considerations. It is predicted that more herbicide resistance genes will be discovered and that new herbicide resistance mechanisms or strategies will be employed. Crops with multiple herbicide resistance or with multiple resistances (*e.g.*, herbicide and insect resistance) will be developed.

Bromoxynil resistant cotton development began in 1984 with the signing of a joint venture agreement between Rhône-Poulenc, the manufacturer of bromoxynil, and Stoneville Seed Company, a subsidiary of Calgene. In 1986 a gene encoding a nitrilase enzyme that degrades bromoxynil was isolated from a soil bacterium and transferred to cotton using the *Agrobacterium* system. The promoter used for expression of the bromoxynil degradation gene (BXN gene) is from a light-induced ribulose biphosphate small subunit gene so that the BXN gene is expressed in photosynthetic tissue. Since bromoxynil is a photosynthetic inhibitor, expression of the degradation gene in cotton leaves confers a high level of bromoxynil resistance in both heterozygous and homozygous cotton plants. Field tests with bromoxynil resistant cotton which began in 1989 have shown no yield differences between plants containing the nitrilase degradation gene and the same variety without the gene. It was noted that farmers do not buy herbicide resistance genes, they buy cotton seed with good agronomic characteristics. Thus, variety development is an ongoing process at Stoneville and the BXN gene is introduced into promising lines using a traditional backcross program. Bromoxynil resistant cotton has several potential benefits including, a) over-the-top herbicide applications that provide excellent broadleaf weed control, b) reduction of total herbicide applied by eliminating the need for preplant incorporated broadleaf herbicides such as cyanazine, diuron, fluometuron, and prometryn as well as reducing the need for later postemergence applications of these herbicides, c) increased application flexibility for growers in terms of timing and control of spray pattern placement, and d) optimization of production practices for cotton growth rather than weed control.

Glyphosate resistance crops have been developed by Monsanto using a combination of target site modification and metabolic inactivation. Glyphosate inhibits an enzyme in the shikimic acid pathway, 5-enolpyruvylshikimic-3-phosphate (EPSP) synthase, that also binds phosphoenol pyruvate (PEP). Thus, a requirement for glyphosate resistance would be the expression of an EPSP synthase with reduced sensitivity to glyphosate (*i.e.*, reduced  $K_i$ ) but good binding properties (*i.e.*,  $K_m$ ) with respect to PEP. Such a modified EPSP enzyme could be obtained by applying selection pressure (*i.e.*, glyphosate in growth medium) and isolating glyphosate tolerant cells or by insertion of a foreign gene. The former often results in tolerance due to over-expression of EPSP synthase. Monsanto has isolated a gene with the desired characteristics called the CP4 gene and has obtained good glyphosate tolerance by using the *Agrobacterium* system or the particle gun to insert the CP4 gene in crop plants. Monsanto has also discovered an enzyme, glyphosate oxidoreductase, that degrades glyphosate and has expressed the gene for this enzyme in crop plants to enhance resistance to glyphosate. The combination of the modified EPSP synthase gene and the degradation gene confer commercial resistance to crop plants. For example, soybeans treated with a 64 oz/A application of formulated glyphosate showed no effect from glyphosate application including no yield reduction. The benefits cited for glyphosate resistant crops were the similar to those listed above for bromoxynil resistant cotton and additional included the wide spectrum of weed control obtained with glyphosate and the fact that glyphosate is an environmentally sound herbicide.

Dr. Bill Dyer discussed the development of glufosinate resistant safflower from the perspective of the public sector developing herbicide resistant minor crops [see *Glufosinate-Resistant Safflower (Carthamus tinctorius L.): From Idea to Reality*, p. 89]. Dr. Dyer indicated that their first choice was to develop glyphosate resistant safflower but they were unable to obtain Monsanto's cooperation. It was noted that industry cooperation is essential both to obtain the right to use a herbicide resistance gene and to obtain registration of the herbicide for the resistant crop. Dr. Fuerst has had some cooperation from Monsanto in working on glyphosate resistant crops although the cooperation has weakened recently. Dr. Fuerst felt that it was still worthwhile to develop HRC even if they were not commercialized because the development of the technology was important. During the discussion it became clear that in order for the public sector to successfully develop HRC there has to be cooperation between industry, universities and the EPA and other regulatory agencies. The important issues are what resistance genes are available to the public sector, where the funding required for labelling will come from, and how the resistant crops will be marketed.

Another issue addressed was the criteria used to select herbicides for which resistance will be developed. Dr. Dyer noted that it was important to choose an environmentally acceptable herbicide and used 2,4-D as an example of a herbicide that degrades to metabolites that raise environmental concerns such that 2,4-D is probably not a good candidate herbicide for HRC. At this point the environmental safety of bromoxynil was questioned because it was previously classified as a restricted use herbicide. In response, Dr. Houck indicated that there were three issues that Rhône-Poulenc addressed with respect to bromoxynil; worker safety, half-life in the environment, and residues in the crop. Rhône-Poulenc has reformulated bromoxynil into water soluble gel packs to reduce worker exposure, has determined that the half-life of bromoxynil in the environment is 7 to 10 d, and has found that the bromoxynil degradation gene removes all bromoxynil residues from the crop. As a result, bromoxynil is no longer a restricted use herbicide and appears to be an environmentally safe herbicide.

Dr. Bruce Maxwell listed four areas that form the basis for public concern about the development of HRC: 1) the potential for resistance genes to escape from HRC to weeds, 2) the potential for HRC production systems to select for additional herbicide resistant (HR) weeds, 3) the problem of controlling volunteer HRC species, and 4) is this the best application of biotechnology? Studies have been conducted on a case by case basis to assess the potential likelihood that HR can be transferred from HRC to weeds by pollen transfer. With respect to cotton and safflower, the lack of closely related weed species makes this type of gene transfer a remote possibility. With commodities grown in association with related weeds such as *Brassica* species, the transfer by pollen of HR is of much more concern. Transfer of HR between crops and weeds may also occur in crop/weed hybrids. A cause for further concern is the fact that there may be other means of DNA transfer between crops and weeds that are currently poorly understood. It was recently reported that insects that pierce plant cells and move from plant to plant may be capable of transferring DNA and thus HR genes from HRC to weeds. Fungal endophytes may also provide a mechanism for gene flow between HRC and weeds. Although these mechanisms of DNA transfer exist, how likely they are to result in gene transfer is not known.

The potential for HRC production systems to select for additional herbicide resistant weeds does not represent a situation that is fundamentally different from current crop production systems that use herbicides. Shifts in weed species composition and appearance of HR weeds occurs in many crops. It was noted that if several major commodities were genetically engineered to be resistant to a single herbicide (e.g., glyphosate), the use of that herbicide could increase dramatically in a given area. This could result in much greater selection pressure for the development of HR weeds than presently occurs. Another concern is that the strategies (i.e., herbicides) used to control volunteer HRC and HR weeds may result in greater herbicide use and pesticide load on the environment.

The social, ethical and business concerns associated with HRC need to be assessed in answering the question of whether the development of HRC is the best use of biotechnology. HRC will compete in the market place as do all new product introductions and will only be successful if they are an improvement over current technology. If HRC are successful there is concern that companies that do not develop HRC will lose their competitive edge and that this may ultimately result in a reduction of the number of registered herbicides. This would be an undesirable outcome at a time when the appearance of HR weeds increases the need for a variety of weed control tools. There was also concern that the development of genetically altered crops may lead to a reduction in the numbers of varieties developed and a narrowing of the genetic base supporting agricultural production. It was suggested that this would not occur because genetic engineering of crop species would become routine and the demand for variety development by the marketplace will remain unchanged. It was noted that the level of public awareness and education about biotechnology needs to be greatly increased if fear and condemnation of the technology are to be avoided.

The regulation of HRC is done by three agencies, the USDA through its Animal and Plant Health Inspection Service (APHIS), the FDA, and the EPA. Genetically engineered crops have been considered regulated articles because they contain gene sequences (vectors, promoters and terminators) derived from plant pathogenic sources. APHIS must determine that the vectors and other elements are disarmed and that there is no risk of plant pest introduction or dissemination as a result of HRC development and that the HRC will not have a significant impact on the quality of the human environment. This process includes an assessment of the risks of outcrossing

or gene transfer by other mechanisms from HRC to other plants and the potential of the HRC to become a pest. The FDA must determine that the inserted DNA and new proteins expressed in HRC do not pose a health risk and that the genetically engineered organism is safe with respect to use for animal feed or for human consumption. As part of this process, the FDA assesses the allergenicity of genetically altered organisms. The EPA is involved in the development of HRC through the normal herbicide registration process for a new herbicide use. At the time this discussion section was held no genetically altered organisms had made it through all the regulatory agencies for registration although some products are close to receiving all the necessary approvals.

1995 Officers of Project 3:

Chairperson: Joan Lish  
PSES Department  
Univ. of Idaho  
Moscow, ID 83843-2339  
(208) 885-7730  
FAX 885-7760

Chairperson-elect: Phil Stahlman  
Fort Hays Exp. Station  
Hays, KS 67601-9228  
(913) 625-3425

1995 Officers of Project 6:

Chairperson: Carol Mallory-Smith  
PSES Department  
Univ. of Idaho  
Moscow, ID 83843-2339  
(208) 885-7730  
FAX 885-7760

Chairperson-elect: Pat Fuerst  
Crop/Soil Science Dept.  
Washington State Univ.  
Pullman, WA 99164-6420  
(509) 335-7484

**PROJECT 4: EXTENSION, EDUCATION, AND REGULATORY**

Chairperson: Phil J. Petersen

Subject: Recertification and Continuing Education and Dealing with Regulations for Reduced Inputs

Three panel members were invited to take about 5 minutes to discuss the two topics chosen for the discussion session. The panelists were Mr. John Arvik of Monsanto Chemical Company, Dr. Don Morishita of the University of Idaho, and Mr. Harry Riehle the Washington State Agronomist for the SCS.

The topics of discussion were:

1. Content of, need for, and proposed methods of providing weed science related adult education training to meet the needs of those needing recertification and/or continuing education credits for state and national certification programs.
2. How should the weed science community respond to legislative or regulatory agency mandates to government agencies to develop management systems requiring reduction of inputs of crop protection products and plant food by a certain percentage?

Mr. Arvik said that we need to help the public be unafraid of what we do. He stated that he believes that mandatory training is a recipe for failure but that quality training is critical. Mr. Arvik warned of the negative mindset of people when they hear the term "Adult Education". He said that from his experience adult education is thought of as recreational education not serious training for current practical use. Mr. Arvik warned against reactive responses to problems and said they would fail. He said that we need to be politically active and play to win.

Dr. Morishita said that his recertification program tries to provide new information on issues of timely importance with the goal of increasing the technical competence of field consultants. Don said that people who come to recertification programs often have a poor mindset. The goal should be to get people to want to voluntarily improve their competence, to want to come to the meetings to learn. Don said that more training is needed in adult learning psychology. Another need is for adults to appreciate the need for more education above and beyond just what herbicide rate to use for what weed. Don also agreed that we needed to be ahead of problems not just responding to them. He senses that crop consultants get turned off by futuristic information. They want take-home information that they can use today. Resources are very limited in both research and extension.

Mr. Riehle discussed the need to educate the general public and the legislators that represent them. He felt that this is the weakest link in the educational process. Professional training for field agronomists is also an important area of training emphasis.

During the general discussion the following key points were made:

A holistic view of training is very important. Air and water quality issues are two big issues facing us. Discussion suggested that the 1995 Farm Bill would affect Weed Science as would reauthorization of the Clean Water Act.

Hands on training opportunities are very important and more effective than classroom lecture techniques. Live plants are valuable tools.

It was suggested that we attempt to make students able to communicate to the non-scientific public. One participant suggested that one basic message that needs to be communicated to the public is "Why do we need to manage weeds?" An industry representative mentioned that access to the public is very difficult and that certain sectors of the industry have little credibility when discussing controversial issues.

It was suggested that the WSWS should get involved in preparing materials for the school children such as Plant Doctor, Ag. in the Classroom, Power Ranger and Benny Broccoli. It was recommended that we not just tell people that our food supply system is safe. They need to know much more than that. It was suggested that we must get "permission" from the consumer to use pesticides. To get that permission we will need to educate the public in layman terms. It was recommended that weed scientists and agronomists need to go to community meetings and environmental meetings as private citizens and get to know the people that are interested in environmental issues.

One extension worker was concerned that extension was very concerned about the number of people taught and not as concerned about the quality of what was taught. Some new concepts in adult education were discussed and creativity in training was encouraged. There are new methods of reaching an audience that we should look into.

Toward the end of the season the group diverted their attention from the specific topics to the general emphasis given to the Extension, Education, and Regulatory project. Some suggested that more emphasis needed to be placed on these issues for they were critical to the future of progress in weed science. The fact that this section was held after the business meeting and after we had been requested to turn in our name tags and after most of the participants of the WSWS meeting had left the hotel was of concern. It was suggested that we recommend that this section be moved in the general heart of the meeting and not as an after thought. Some members of the group called for an action committee that would work together to address seriously the needs to work in the education and regulatory arenas. They suggested that the executive board be petitioned for a Standing Committee that actively worked to address educational and regulatory issues.

1995 Officers of Project 4:

Chairperson: Richard Zollinger  
Extension Weed Specialist  
Crop and Weed Sciences Department  
North Dakota State University  
Box 5051, Fargo, ND 58105  
(701) 237-8757

Chairperson-elect: Beverly Durgan  
Extension Weed Scientist  
411 Borlaug Hall  
1991 Buford Circle  
University of Minnesota  
Minneapolis, MN 55108  
(612) 625-7262

**PROJECT 5: WEEDS OF AQUATIC, INDUSTRIAL, AND NON-CROP AREAS**

Chairperson: Scott Stenquist

Subject: Ecology and Management of Reed Canarygrass

Stephen I. Apfelbaum, Applied Ecological Services, Inc., Brodhead, WI.

Mr. Apfelbaum was not able to attend the discussion, and a conference call question and answer session was not possible due to the high cost. Chair Scott Stenquist presented Mr. Apfelbaum's discussion.

Prescribed burning is effective on reed canarygrass (*Phalaris arundinacea*) when a native species component exists in the system. The native species can be present either in vegetative or seed form. Burning is more successful when conducted in late spring, early summer, mid-summer, or early to mid-fall. It was previously thought that early spring burning in March to April or early May was the most desirable time for reed canarygrass management. However, this burning regime stimulates the production of shoots, increases stem density, and stimulates the growth of reed canarygrass.

A second option of using the herbicide glyphosate applied through a wicking device or sprayed on reed canarygrass is effective if followed 2 to 3 wk later by prescribed burning. If prescribed burning occurs in late May or early June after application of glyphosate, or in the fall, the reed canarygrass is exposed to potential summer drought and/or freeze-thaw conditions in the winter. These circumstances reduce the opportunity for reed canarygrass to thrive.

The final option is to completely remove the reed canarygrass sod mass with earth moving equipment through excavation. This method disturbs the entire system and is used in highly disturbed areas. After excavation, the site must be reseeded with competitive vegetation.

Some work in the Yakima, Washington area showed that a 1% solution of glyphosate was effective in retarding growth of reed canarygrass. It appears that fall (September or October) application of glyphosate may have the best effect on reed canarygrass. Biological controls are not being considered for reed canarygrass since this species is also grown as a commercial crop and is considered a native species.

Subject: Eurasian Watermilfoil Biology and Control

Dr. Rayman Newman, University of Minnesota, St. Paul, MN.

Dr. Newman provided a videocassette discussion of his work since he was not able to attend the discussion, and a conference call question and answer session was not possible due to cost. Chair Scott Stenquist presented the video cassette and coordinated the discussion.

Eurasian watermilfoil (*Myriophyllum spicatum*) management techniques include mechanical harvesting through cutting, aquatic-approved herbicides such as 2,4-D and fluridone, and biological controls. Biological control work done by Dr. Newman include the use of a weevil (*Euhrychiopsis lecontei*), caterpillar (*Acentria ephemerella*), and milfoil midge (*Cricotopus myriophylli*). Stem damage was positively related to *E. lecontei*

densities, but leaf damage was not. The caddisfly (*Nectopsyche albida*) can cause leaf damage but will feed on a broad range of plants and is not a good specialist biocontrol candidate. A monitoring survey for the lower Columbia River conducted in 1993 found that *E. lecontei* is present, and may exist in sufficient densities to keep Eurasian water milfoil in check.

Subject: Biocontrol Update

Dr. Jack DeLoach, Grassland, Soil, and Water Research Laboratory, Temple, TX.

The deciduous shrub, saltcedar (*Tamarix ramosissima*), a native of central Asia has invaded large areas of western river bottoms and lake shores. It has displaced native vegetation forming thickets of pure saltcedar, greatly reduced habitat quality for wildlife and birds, increased soil salinity, blocked stream channels, and increased sedimentation. However, it has minor beneficial values as an ornamental, for nesting habitat of the whitewinged dove, and for honeybees. The closely related large evergreen tree, athel (*T. aphylla*), also an introduced exotic, is less weedy and also has some beneficial values. A careful analysis of these values, plus a thorough economic analysis, revealed that the harmful values greatly outweigh the beneficial values. An agreement in principle for a biological control project was reached with USDA-APHIS in late-1989.

Many promising candidate insect biocontrol agents have been found in Israel, Pakistan, southern Europe, China, and Turkmenistan. Host range and biological testing is underway in these areas.

Two of the most promising of these insects have been tested in the USDA-ARS Quarantine Facility at Temple, Texas. Both have proven to be specific to the genus *Tamarix* and do not reproduce on any other plants that grow in North America. The mealybug (*Trabutina mannipara*) sucks sap from the twigs and killed saltcedar plants in the quarantine tests. It is not cold-tolerant, so it can be effective only in the most southern areas of the United States.

The leaf beetle (*Diorhabda elongata*) feeds on the foliage and has killed saltcedar plants in the field in China. Petitions have been prepared seeking APHIS authorization to release both insects in the US during 1994. There is some evidence that the removal of saltcedar can allow surface water and ground water to be replenished and return to historic, pre-saltcedar levels.

1995 Officers of Project 5:

Chairperson:	Barbara Mullin, Weed Specialist Montana Department of Agriculture Agricultural Sciences Division Agriculture/Livestock Building Post Office Box 200201 Helena, MT 59620-0201 (406) 444-2944 FAX (406) 444-5409	Chairperson-elect:	Robert H. Callahan Extension Weed Specialist Plant Science Department University of Idaho Moscow, ID 83843 (208) 885-6617 (208) 885-6276 FAX (208) 885-7760
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#### PROJECT 7: ALTERNATIVE METHODS OF WEED CONTROL

Chairperson: Daniel A. Ball

Subject: Cover Crops, Living Mulches, and Green Manure Crops for Weed Management

Rick Boydston, USDA-ARS, Prosser, WA discussed the use of *Brassica* spp. such as white mustard and rapeseed as green manure crops. High glucosinolate rapeseed varieties have been used for nematode suppression in potatoes. Boydston used 'Juniper' rapeseed, plowed down, to suppress weed growth in potatoes by 50%. Rapeseed dry matter of 1.8 to 2 tons/A was soil incorporated. Glucosinolates break down to isothiocyanate compounds similar to metam in soil, however it is uncertain if glucosinolates are responsible for weed control in



this study. This concept needs further investigation. Various cultural practices influence glucosinolate concentrations in plants, including high sulfur and low nitrogen levels in soil. Others researching the effects of *Brassica* spp. on weed control include: Kassim Al-Khatib, WSU, Mt. Vernon, WA; S. Nissen, Lincoln, NE; C. Eberlein, Aberdeen, ID; and S. Vaughan, Peoria, IL. Jim Krall, Univ. of Wyoming has a contact in Longmont, CO that supplies seed for high glucosinolate *Brassica* spp.

Tom Lanini, University of California, Davis, discussed work he has conducted over the past 8 yr with cover cropping. He presented some distinctions: cover crops are tilled under when they begin growth, while living mulches remain on the soil surface. A good cover crop suppresses weeds, facilitates N fertility, and aids in cultural practices. Tom has worked with several different plant species for cover cropping including subclovers, ryegrasses, Indian mustard, and various vetch spp. He has utilized a "roto-spader" type of implement for incorporation of cover crops, and experimented with a "mow and blow" technique to mulch over growing crops. This technique utilizes a mower which chops and blows living mulch material onto adjacent crop plants. Living mulches should really be called "dying mulches," that is they should die naturally or be easily killed. Mulches that are too thick will inhibit seedling establishment.

Barley has been used as a cover crop in cotton and facilitates weed control. Oregon State Univ. researcher Ed Peachy has used 'Micah' barley as a cover crop prior to seeding vegetables. Mention was made of WRCC-61, a USDA Western Regional Coordinating Committee devoted to discussion of cover cropping technologies.

Annual medics are being investigated by Jim Krall, Univ. of Wyoming, Torrington for inclusion in dryland wheat systems. Australia has many varieties of medic and maintains a registry of cover crop varieties and varietal mixtures.

Bruce Maxwell, Montana State University, Bozeman, discussed some problems associated with cover cropping. In Montana, the fallow year in wheat/fallow rotations can be a problem in terms of soil erosion and weed control. An intercrop that fills the niche being occupied by weeds is needed. He is investigating the nitrogen benefits and wild oat suppressiveness of various green manure crops. The theoretical basis for the ideal cover crop includes: an ability to cover bare ground, provide a nitrogen benefit, suppress weeds, and have a taproot to help break up hard pans.

A discussion of medics followed in relation to their potential in wheat/fallow systems. Jim Krall has planted commercial medic varieties at six locations to evaluate winter hardiness. Two sources of medic seed were mentioned including: Timeless Seed Co. in Montana and Shaffer and Barns in Minnesota.

1995 Officers of Project 7:

Chairperson: Bruce Maxwell  
Dept of Plant, Soil & Environ. Sci  
Montana State University  
Bozeman, MT 59717  
(406) 994-5717

Chairperson-elect: Kassim Al-Khatib  
Washington State University  
1468 Memorial Way  
Mt. Vernon, WA 98273  
(206) 424-6121

**MINUTES OF THE BUSINESS MEETING**  
**WESTERN SOCIETY OF WEED SCIENCE**  
**47TH ANNUAL BUSINESS MEETING**  
**COEUR d'ALENE RESORT, COEUR d'ALENE, IDAHO**  
**MARCH 17, 1994**

The meeting was called to order by President Doug Ryerson at 7:35 a.m. Minutes of the 1993 business meeting were approved. M/S/C

**Local Arrangements Committee.** John Orr

- a. Both the facilities and support from hotel personnel were excellent.

**Program Committee.** Tom Whitson

- a. Breakdown of papers:
  - 69 Volunteered papers, including 17 graduate student presentations
  - 21 Posters
  - 4 Invited presentations
- b. The facilities were excellent
- c. Thanks to Miles, Inc. and Ciba Plant Protection for sponsoring the graduate student breakfasts; Zeneca Ag Products for sponsoring the spouses breakfast; DowElanco for sponsoring the business meeting breakfast; and Sandoz Agro for sponsoring all breaks during the meeting.

**Research Section Report.** Bill Dyer

- a. Papers presented in each section were as follows:

Research Section 1: Weeds of Range and Forest	13
Research Section 2: Weeds of Horticultural Crops	4
Research Section 3: Weeds of Agronomic Crops	18
Research Section 4: Extension, Education and Regulatory	6
Research Section 5: Weeds of Aquatic, Industrial, and Non-Crop Areas	0
Research Section 6: Basic Sciences: Ecology, Biology, Physiology, Genetics, and Chemistry	8
Research Section 7: Alternative Methods of Weed Control	3
- b. Steve Miller has been appointed as Editor, WSWS Research Progress Reports.

**Extension, Education and Regulatory Report.** Vanelle Carrithers

- a. Six papers were presented in this section.

**Finance Committee Report.** Larry Jeffery

- a. Wanda Graves was called home for a funeral and not able to present the Business Manager/Treasurer Report; however the records of the Business Manager were examined and found to be in good order.
- b. The WSWS is in strong financial shape with 2.5 yr operating budget in the bank.

**Past President's Report.** Steve Miller

- a. Developed guidelines for dedicating the WSWS Proceedings, which were approved at the summer Executive Committee meeting.
- b. Promoted sales of the WSWS History book to libraries in the Western U.S. and to members of the NCWSS.
- c. Developed new guidelines for publication of the WSWS Research Progress Report, which resulted in substantial reduction of printing costs.

**Member-at-Large.** Steve Dewey

- a. Investigated possible changes in program format for WSWS meetings. It was decided at the summer Executive Committee meeting that the Program Chair should make decisions on program format.

**CAST Report.** Jack Evans

- a. CAST moved to permanent headquarters in Ames, IA.
- b. CAST will publish more issue papers, which are short, concise, scientific reports on key national issues in food, agriculture, and the environment. Target audiences include policy makers, news media, and the public.
- c. WWS members are encouraged to become individual members of CAST.

**WSSA Representative.** Rod Lym

- a. WSSA met in St. Louis, MO on February 7 to 10, 1994.
- b. WWS is well-represented on the WSSA Board of Directors:  
Alex Ogg - President  
Charlotte Eberlein - Secretary  
Jodie Holt - Member-at-Large  
Pete Fay - Member-at-Large
- c. Weed Science has its own NRICGP panel this year; 100 good quality proposals will need to be submitted to the Competitive Grants program this fall in order to maintain a separate Weed Science panel.
- d. The Weed Science Symposium in Washington, D.C. was very successful; members are urged to encourage contact between congressional aides and grower groups supporting the need for increased funding of weed science.

**Resolutions Committee.** Carol Mallory-Smith

- a. Three resolutions were presented to the membership:

1. "WHEREAS; The 1994 program presented a timely and interesting message, and

WHEREAS; The meetings were run smoothly and efficiently, and

WHEREAS; The facilities were excellent and the staff helpful and courteous,

Be it resolved that the Western Society of Weed Science expresses its appreciation to the 1994 WWS Program Committee, to John Orr and the Local Arrangements Committee, and to the management and staff of the Coeur d'Alene Resort." Motion was made to accept the resolution. M/S/C

2. "WHEREAS; Weed resistance to herbicides is being documented with increasing regularity, and

WHEREAS; The reversal of herbicide resistance occurs slowly, if at all, and

WHEREAS; Herbicides are an important weed management tool for crop production,

Be it therefore resolved that the Western Society of Weed Science does hereby encourage public and open acknowledgment of the existence of and potential for herbicide resistance by all concerned parties as part of good product stewardship.

Be it further resolved that all concerned parties should adopt and promote integrated programs of weed management to prevent or delay selection for herbicide resistance." Motion was made to accept the resolution. M/S/C

3. "WHEREAS; Jointed goatgrass continues to spread and to reduce winter wheat production in the United States, and

WHEREAS; Jointed goatgrass reduces domestic and export value of U.S. wheat, and

WHEREAS; There currently are no effective measures to selectively control jointed goatgrass in winter wheat,

Be it therefore resolved that the Western Society of Weed Science acknowledges jointed goatgrass as a major weed of national significance that merits special attention.

Be it further resolved that the Western Society of Weed Science requests that national funding be made available for research, technology transfer, and extension projects to reduce the spread and impact of jointed goatgrass on winter wheat production." Motion was made to accept the resolution. M/S/C

**Nominations Committee.** Jim Jessen

- a. New officers for WSWs are:
  - President-Elect - Gus Foster
  - Secretary - Don Morishita
  - Research Section Chair-Elect - Jill Schroeder
  - Education Section Chair-Elect - Kai Umeda

**Fellows and Honorary Members Committee.** Donn Thill

- a. 1994 Fellows:
  - Gus Foster
  - Sheldon Blank
- b. 1994 Honorary Member:
  - Will Carpenter
- c. Nominations for Fellows and Honorary Members are due May 1, 1994.

**Public Relations Committee.** Jack Schlesselman

- a. Various agricultural publications and organizations were notified of the 47th meeting of the WSWs.
- b. Photographs will be taken of the 1994-95 WSWs Officers and Executive Committee members, contest winners, and award recipients.
- c. Sign-up sheets for continuing education credit for Pest Control Advisors/Ag Consultants were made available during the meeting.

**Site Selection Committee.** Celestine Lacey-Duncan

- a. The possibility of meeting in Hawaii in 1998 was discussed. Members are encouraged to express their opinions on the Hawaii site to Celestine Lacey or other members of the Site Selection Committee.

**Awards Committee.** Kenneth Dunster

- a. 1994 Outstanding Weed Scientist:
  - Larry Burrill - Public Sector

**Student Paper Judging Committee.** Joan Lish

- a. Seventeen students participated in the oral paper contest, and four participated in the poster contest.
- b. 1994 WSWs Student Paper Contest Winners:
  - Division 1
    - 1st Place - Wade Malchow, Montana State University
    - 2nd Place - Dean Riechers, Washington State University
  - Division 2
    - 1st Place - Corey Colliver, Montana State University
    - 2nd Place - Anthony Kern, Montana State University
- c. 1994 WSWs Student Poster Contest Winner
  - 1st Place - Kris Johnson, University of Wyoming
- d. New guidelines were developed for the committee and approved at the February 14, 1994 Executive Committee meeting.
- e. The following changes to the Constitution and Bylaws were proposed:

CONSTITUTION Article VII, Section 13 to change as follows:

The Student Paper Judging Committee shall consist of a Chairperson and eight additional members. Terms of office of this committee shall be three years, established to expire ~~so that six members continue over each year. The Chairperson shall be elected annually by the committee.~~

The Student Paper Judging Committee shall consist of a Chairperson and two additional members. Terms of office of this committee shall be three years, established to expire alternately so that at least two members continue over each year. The member serving his/her second year of the term shall serve as Chairperson.

BYLAW Article VII, Section 12 to change as follows:

The Student Paper Judging Committee shall consist of a Chairperson and ~~eight~~ additional members. Terms of office of this committee shall be three years, established to expire ~~so that six members continue over each year. The Chairperson shall be elected annually by the committee.~~

The Student Paper Judging Committee shall consist of a Chairperson and two additional members. Terms of office of this committee shall be three years, established to expire alternately so that at least two members continue over each year. The member serving his/her second year of the term shall serve as Chairperson.

Motion was made to accept the changes to the Constitution and Bylaws. M/S/C

**Necrology Committee.** Gil Cook

- a. Deaths during the past year: Robert G. Morrison; Jimmy Dukes; and Jackie Burrill, wife of Larry Burrill.

**Poster Committee.** David Gealy

- a. Twenty-one abstracts were submitted for presentation as posters at the 1994 WSWs meeting.

**Sustaining Membership Committee.** Jeff Tichota

- a. Sustaining Membership was increased from 18 companies in 1993 to 21 companies in 1994. Total dollars contributed by sustaining members were \$7,000.

**Publications Committee.** Tom Whitson

- a. 10,000 copies of *Weeds of the West* were reprinted in September. There are 3,050 copies of that printing left.
- b. The current *Weeds of the West* account balance is \$58,237.
- c. The committee is considering development of a weed seed and seedling identification book, and a poster on plants that are allergenic.

**Legislative (Ad Hoc) Committee.** George Beck

- a. Several environmental groups have been active in helping to finalize and support the amended Federal Noxious Weed Act of 1974.
- b. INWAC members were invited to participate in the U.S. Forest Service Noxious Weed Management Review in Regions 2 and 6 last summer and also took part in the National Grazing Lands Forum held in Washington, D.C. in December, 1993.

**Editorial (Ad Hoc) Committee.** Rod Lym, Steve Miller

- a. The Editorial Committee was officially dissolved at the summer Executive Committee meeting and Rod Lym and Steve Miller were added to the Publications Committee.
- b. Volume 46 of the WSWs Proceedings contained 100 papers and was 180 pages long. The volume sold out and generated \$1425 over costs.
- c. It was agreed to submit abstracts and disks to the Proceedings editor in early March (date to be announced) rather than at the WSWs meeting.
- d. The 1994 WSWs Research Progress Report contained 121 reports and was 206 pages long. Using a photoreduction process allowed the report size to be reduced by one-half, which saved about \$1600 in printing costs.

**Weed Management Short Course (Ad Hoc) Committee.** Barbara Mullin

- a. Steve Dewey presented the report. The committee was created to evaluate the need for weed management short courses and develop courses as needed. The introductory course has been on-going for several years. Federal agencies have not expressed interest in supporting an intermediate course. Since the committee has completed its assigned tasks, the committee recommends that it be dissolved.

**Herbicide Resistant Weeds (Ad Hoc) Committee.** Monte Anderson

- a. The educational video on herbicide resistant weeds is nearly complete. Many thanks to Chris Boerboom and his sub-committee for their efforts in this regard.

- b. The informal summer workshop on herbicide resistant weeds will be held July 21 to 23 near Sandpoint, ID. Contact Pat Fuerst at Washington State University for further information.

**Student Education Enhancement (Ad Hoc) Committee. Paul Ogg**

- a. Five students participated in the program in 1992; no students participated in 1993.
- b. Dean Riechers, Washington State University and Ron Swearingen, University of Wyoming reported on their experiences with 1992 Student Education Enhancement Program. Both individuals had high praise for the program and the opportunities it gave them to broaden their perspectives of weed science.

**New Business**

- a. The membership was reminded of the need to submit 100 good quality proposals to the NRICG Program in order to maintain a Weed Science panel.
- b. WSWS will host a Retiree Recognition at next year's meeting.
- c. Incoming President Tom Whitson presented a plaque of appreciation to Doug Ryerson for his year of fine service as President of the Western Society of Weed Science.

The meeting was adjourned by President Tom Whitson at 9:08 a.m.

Respectfully submitted:

Charlotte Eberlein, Secretary  
Western Society of Weed Science



1994-95 WESTERN SOCIETY OF WEED SCIENCE OFFICERS AND EXECUTIVE COMMITTEE.  
Seated (L to R): Doug Ryerson, Immediate Past President; Rod Lym, WSSA Representative; Don Morishita, Secretary; Tom Whitson, President. Standing (L to R): Rick Boydston, Research Section Chairman, Gus Foster, President-Elect; Stott Howard, Education and Regulatory Section Chairman. Not photographed: Wanda Graves, Treasurer/Business Manager; Vanelle Carrithers, Member-At-Large; and John O. Evans, CAST Representative.

WESTERN SOCIETY OF WEED SCIENCE  
FINANCIAL STATEMENT  
MARCH 1, 1993 THROUGH MARCH 31, 1994

CAPITAL

1992-93 Brought Forward	\$102,179.11
Current Earnings	<u>55,245.49</u>
	\$160,699.96

DISTRIBUTION OF CAPITAL

Mutual Funds	\$ 69,925.00
Certificate of Deposit	15,000.00
Money Market Savings	61,547.70
Checking	<u>14,227.26</u>
	\$160,699.96

INCOME

	1993	1994	
Conference Registration	\$ 5,545.00	15,539.27	
Spouse Registration	45.00	390.00	
Membership	760.00	30.00	
Research Progress Report	2,591.05	2,391.00	
Proceedings	2,433.59	2,530.00	
History Book	1,944.00		
Weeds of the West Book	132,561.95		
Conference BBQ & Transportation	2,463.31		
Conference Monday Tour	182.00		
Bank Interest	1,291.58		
Tax Refund	15.17		
Sustaining Membership		7,400.00	
	TOTAL INCOME YTD		<u>\$178,112.92</u>

EXPENSES

Office Supplies	\$ 226.93		
Phone	360.66		
Postage	1,933.57		
Post Office Box Rental	49.00		
Bulk Mail Handling	57.77		
Annual State Filing Fee	5.00		
California State Tax	10.00		
Tax Accountant	160.00		
CAST Membership Dues	562.00		
Business Manager	4,488.00		
Proceedings & RPR Editors Expenses	265.00		
CAST Representative Travel Expense	249.30		
Printing			
Newsletter, Stationary, Misc.	1,021.66		
Proceedings (inc typist, UPS to Newark)	3,148.46		
1994 Program	461.65		
Research Progress Reports	3,768.05	1,985.24	
Weeds of the West	92,075.99		
1994 Conference Planning Meetings	441.98		
1994 Conference Awards Luncheon	3,092.19		
Conference Guest Speaker	351.17		
Spouse Program	662.17		
Monday Tour-Annual Meeting	418.50		
Conference BBQ	378.00		
Graduate Student Room Subsidy	690.00		
Registration Refunds	120.00	195.00	
Award Plaques		117.45	
Society Members Retirement Gifts	315.88		
Registration Help	30.00	56.00	
Student Awards	400.00	525.00	
Audio Visual	3,077.39	931.92	
Miscellaneous (bank checks, mileage)	236.50		
	TOTAL EXPENSES TO DATE		<u>\$122,867.43</u>

**1994 FELLOW AWARD**  
**WESTERN SOCIETY OF WEED SCIENCE**

**Sheldon Blank**

Dr. Sheldon Blank is a Senior Product Development Associate with Monsanto Agricultural Company. He has worked for Monsanto since 1975. Sheldon received a B.S. in agronomy from Washington State University in 1972. He received his M.S. and Ph.D. in Agronomy from the University of Minnesota in 1974 and 1976, respectively.

Dr. Blank received the Monsanto Distinguished Development Award and the Monsanto Personal Performance Award, each twice. He is an Honorary Member of the Washington State Weed Association and received the WSWS Outstanding Weed Scientist Award in 1993.

Sheldon has been an active member of the WSWS since 1975. He has served as chair of the Finance Committee, Secretary, Chair of the Education and Regulatory Section, Program Chair, and President. Dr. Blank also is a member of the Weed Science Society of America, Washington State Weed Association, Oregon Society of Weed Science, and Idaho Weed Control Association.

The following are a few comments from letters supporting Dr. Blank's nomination as WSWS Fellow. "Sheldon's meritorious service to the Society and contributions to the discipline of Weed Science are unselfish and exemplary." "This award (the WSWS Outstanding Weed Scientist Award in 1993) recognized his contributions and expertise in reduced tillage weed management and advancements in field bindweed, cereal rye, Russian thistle, and downy brome management." "Dr. Blank has been a strong supporter of cooperative relations between industry and academia and his efforts have added greatly to the overall advancement of Weed Science and agriculture in the western U.S."

**1994 FELLOW AWARD**  
**WESTERN SOCIETY OF WEED SCIENCE**

**Gus Foster**

Mr. Gus Foster is a Field Scientist, Product Development, with Sandoz Crop Protection Corporation. He has been employed by Sandoz since 1986. From 1978 until 1986, Gus was a Field Development Representative with Velsicol Chemical Corporation. Sandoz and Velsicol merged in 1986. Mr. Foster received a B.S. and M.S. in Agronomy from Colorado State University in 1972 and 1976, respectively. He served as an agronomist for Navajo Community College from 1976 to 1978.

Gus was a member of the 1989 Governor's task force to develop a report on the impact of jointed goatgrass on Colorado wheat production. In 1991, he served on the Colorado Legislative Committee which helped develop a new state-wide weed law. Foster is an active member of the Colorado-Wyoming task force group working on a plastic container recycling effort for agriculture. He helped establish the Colorado Weed Control Association which later became the Colorado Weed Management Association.

Gus has served the WSWS in many capacities: he chaired the Placement Committee, Perennial and Herbaceous Weeds Section, and Education and Regulatory Section; he has served on numerous other committees; and attended the WSWS annual meeting regularly. He was chair of the WSSA Local Arrangements Committee in 1993 when the meeting was held in Denver.

One of the supporting letters for Mr. Foster says a lot about Gus. "Throughout his professional career he has been a supporter of the Western Society of Weed Science. He is known by many in the Rocky Mountain West as a congenial, cooperative man. Many will recognize him as a source of research ideas and careful thought about issues of weed control and weed management. He was an integrator of people and techniques before the word became popular."



**1994 HONORARY MEMBER AWARD  
WESTERN SOCIETY OF WEED SCIENCE**

**Will D. Carpenter**

Will Carpenter is Chairman of the Board of Agridyne Technologies, Inc. He retired from Monsanto in 1992 after 34 years with his final assignment as Vice-President and General Manager, New Products Division, for the agricultural group.

A native of Moorhead, Mississippi, he received a B.S. in agronomy from Mississippi State University in 1952, and M.S. and Ph.D. degrees in 1956 and 1958, respectively, both in plant physiology from Purdue University. In 1987, Dr. Carpenter received the Mississippi State University Agricultural Alumni Achievement Award and was named an Alumni Fellow of the University in 1991. Also in 1991, he received Purdue's School of Science Distinguished Alumni Award. In 1992, he was named Executive-In-Residence at Mississippi State University.

Dr. Carpenter is an active member of the Weed Science Society of America and served as President of the Society during 1980. He was named Society Fellow in 1983. During 1977, he served as President of the North Central Weed Control Conference and was elected to Honorary Membership in 1982. He has been an active member of the Western, Southern, and Northeastern regional weed science organizations. He is a member of the Board of Directors of CAST.

Dr. Carpenter has served on and chaired numerous national committees such as the Center for Strategic and International Study Group on Chemical Arms Control, the National Agricultural Chemicals Association, and the Keystone National Advisory Committee for Biotechnology.

**1994 OUTSTANDING WEED SCIENTIST AWARD  
PUBLIC SECTOR**

**Larry C. Burrill**

Larry Burrill has been actively involved in the worldwide development and extension of weed science technology since joining the Crop Science staff of Oregon State University in 1962. The experience gained in coordinating the extensive OSU multi-crop herbicide screening program conducted at Corvallis and in Hawaii, provided excellent background for his 1968 appointment as International Agronomist for the International Plant Protection Center. While emphasis was placed on liaison of international activities, Larry continued multi-crop screening trials and found time to serve as Secretary of the International Weed Science Society and as a member of the Board of Directors of the Asian-Pacific Weed Science Society. He accepted the Extension Weed Control Specialist position at OSU in 1986 where he continues to build and maintain status as a world class authority on weed control programs and practices.

An enthusiastic contributor to weed science society functions, Larry has been a consistent participant in WSSS program activities and administrative tasks. He has served as chairman of the Agronomic and Research Sections, chairman of the Program Committee, Member-at-Large and as President in 1980. He was named a WSSS Fellow in 1984. He is an active member of the Weed Science Society of America where he has served on several committees and as the WSSA representative to the International Weed Science Society. Larry attained the rank of WSSA Fellow in 1986 and received the Outstanding Extension Worker Award in 1993. He also received the WSSA Outstanding Photographer Award in 1991 and again in 1993. The Oregon Society of Weed Science continues to rely on Larry as an annual participant and member of the Board of Directors and presented him with the Distinguished Service Award in 1993. In 1992, Larry became one of only two people in the world to receive the prestigious IWSS Achievement Award.



1994 WESTERN SOCIETY OF WEED SCIENCE HONORARY MEMBER  
Will D. Carpenter



1994 WESTERN SOCIETY OF WEED SCIENCE FELLOWS, MERIT AWARD WINNER AND  
OUTSTANDING WEED SCIENTIST  
(L to R): Gus Foster (Fellow), Sheldon Blank (Fellow), Rod Lym (Merit Award), and Larry Burrill  
(Outstanding Weed Scientist).

Larry is recognized at the state, regional, national and international levels for his ability to provide and explain practical weed control solutions. He has reviewed and produced a considerable number of Extension Service publications and is a co-author of the widely used books "*Weeds of the West*" and "*A Guide to Selected Weeds of Oregon*". He has produced video and weed identification slide presentations which are widely used in weed control training sessions. Larry has served as a popular graduate student adviser for 7 MS and 2 PhD candidates in weed science. More than 1,000 undergraduate students and a legion of associates including weed researchers, extension agents, growers and industry personnel have benefitted from his reservoir of weed science technology.

**1994 PRESIDENTIAL AWARD OF MERIT  
WESTERN SOCIETY OF WEED SCIENCE**

**Rodney G. Lym**

President Doug Ryerson awarded Rod Lym the 1994 Presidential Award of Merit in recognition of his contributions to the Western Society of Weed Science. Rod has been project chairman of Range and Forest and Herbaceous Perennial Weeds (when they were separate), Member at Large and currently is the WSWs representative to the Weed Science Society of America. He became editor of the proceedings in 1989. Together with Tom Whitson, Rod started the WSWs Retirees Recognition Social in 1994.

**1994 RETIREES RECOGNITION  
WESTERN SOCIETY OF WEED SCIENCE**

The Western Society of Weed Science recognized four members who will soon retire. Arnold Appleby, Larry Burrill both of Oregon State University, and Larry Mitich of the University of California, Davis, attended their last WSWs meeting in an official capacity. Al Baber is also retiring but was unable to attend. They were recognized during a special social Monday evening and presented retirement golf balls complete with the WSWs logo as a memento of their long-time society membership and service to WSWs.

#### 1994 NECROLOGY REPORT

**Robert G. Morrison** was born in Denver, CO July 4, 1947. After graduating from high school in Denver, he obtained a B.A. in history from the University of Colorado at Boulder in 1970 and both an M.A.T. in 1988 as well as a B.S. in Botany at Western New Mexico University in 1990. Some of his previous employment was as a bank manager and restaurant owner. Three days before his death, March 29, 1993, Bob successfully defended his Master's thesis entitled '*Picloram uptake, translocation and picloram-induced ethylene production in relation to water status of Russian knapweed (Centaurea repens L.)*' Mr. Morrison's research was conducted under the co-advisers, Dr. Norm Lownds and Dr. Tracy Sterling of New Mexico State University. Bob was an active member of WSWS and presented a research paper at the WSWS meeting in Salt Lake City in March 1992. He had a great dedication to and love of science, learning and teaching. In December of 1992, he became sick with what was diagnosed as pneumonia and later was determined as colon cancer. The disease was so advanced that it could not be controlled. Bob is survived by his mother, two brothers and a daughter, Stephanie, who is currently a student at New Mexico State University.

**James Henderson Dukes Jr.** was born in Atlanta on December 1, 1958. Following graduation from Milton High School, Florida, he entered Auburn University and graduated Summa Cum Laude in 1981 with a B.S. degree in Forest Management. He continued his studies at Auburn earning an M.S. degree in 1984 in Forest Physiology under the direction of Dean H. Gjerstad. After a period of service in Africa with the Peace Corps, he returned to the United States and in January 1987 was accepted into a Ph.D. program at Oregon State University where he worked under the direction of Dr. Steve Radosevich. His research was in the area of stress physiology with specific reference to the effects of competition and resource limitations on photosynthesis in two forest species. The research was essentially completed and he had passed both his written and oral preliminary examinations for the Ph.D. degree by June 1989. He had by that time already been accepted for post-doctoral study at the Institut National de la Recherche Agronomique in France. On June 10, 1989, he was involved in an automobile accident and suffered a serious head injury. Following the accident he never fully regained consciousness and died on August 6, 1993 at his mother's home in Milton. He is survived by his mother Mrs. Thelma Chance Dukes of Milton, his father Dr. James Henderson Dukes of Pensacola, Florida, and two sisters Mrs. Teresa Patton of Nashville, Tennessee, and Mrs. Cecilia Smith of Atlanta, Georgia.

## 1994 REGISTRATION LIST

<p>Dale Aaberg Monsanto 2209 Oddic Blvd Sparks NV 89431 702-331-4141</p>	<p>Joe Antognini USDA-ARS-NPS Room 237, Bldg 005 Beltsville MD 20705 301-504-6470</p>	<p>Brooks Bauer Sandoz Agro 20592 Ayers Ave Escalon CA 95320 209-599-7806</p>
<p>Harry Agamalian UC Cooperative Ext 6 San Carlos Drive Salinas CA 93901 408-758-4636</p>	<p>Arnold Appleby Crop Science Dept Oregon State University Corvallis OR 97331 503-337-4715</p>	<p>George Beck Colorado State University 116 Weed Research Lab Ft Collins CO 80550 303-491-7568</p>
<p>Ali Akhavein Zeneca Ag Products 1200 So 47th Street Richmond CA 94804 510-231-1274</p>	<p>Rick Arnold NMSU Ag Science Center P O Box 1018 Farmington NM 87499 505-327-7757</p>	<p>Lance Boem Rhone Poulenc 1449 Towse Drive Woodland CA 95776 916-666-6377</p>
<p>Ted Alby American Cyanamid 12817 SE Angus St Vancouver WA 98684 206-896-8280</p>	<p>David Austin PBI/Gordon Corp P O Box 014090 Kansas City MO 64101 816-421-4070</p>	<p>Carl Bell UC Cooperative Ext 1050 E Holton Road Holtville CA 92250 619-352-9474</p>
<p>Shafteek Ali Alberta Agriculture 6903 - 116th Street Edmonton Alta CN T6H 4P2 403-427-7098</p>	<p>Al Baber Ag Research &amp; Consulting 673 Rosecrans St San Diego CA 92106 619-222-8110</p>	<p>Wayne Belles Sandoz Agro 1240 Joyce Road Moscow ID 83843 208-882-3040</p>
<p>Kassim Al-Khatib Washington State Univ 1468 Memorial Hwy Mt Vernon WA 98273 206-424-6121</p>	<p>Jim Bahr FMC Corp P O Box 8 Princeton NJ 08525 609-951-3605</p>	<p>Warren Bendixen UC Cooperative Ext 624 W Foster Road Santa Maria CA 93455 805-934-6240</p>
<p>David Anderson Western Biochemical P O Box 344 Hubbard OR 97032 503-982-2712</p>	<p>Dan Ball Oregon State University P O Box 370 Pendleton OR 97801 503-278-4186</p>	<p>Bob Blackshaw Agriculture &amp; Agri-Food P O Box 3000, Main Lethbridge Alberta CN T1J 4B1 403-327-4561</p>
<p>Lars Anderson USDA-Aquatic Weed University of CA Davis CA 95616 916-752-6260</p>	<p>Jeff Barnes Sandoz Agro 118 S University St Vermillion SD 57069 605-624-8716</p>	<p>Sheldon Blank Monsanto 3805 S Dennis Kennewick WA 99337 509-586-4113</p>
<p>Monte Anderson AgriEvo South 11611 Keeney Rd Spokane WA 99204 509-448-4419</p>	<p>Gwen Barnes Sandoz Agro 118 S University St Vermillion SD 57069 605-624-8702</p>	<p>Greg Blaser University of Idaho 5448 North 5000 W Rexburg ID</p>
<p>Jacob Andresen Pan Ag Labs 32380 Avenue 10 Madera CA 93638 209-675-0889</p>	<p>David Barton University of Idaho 300 N Lincoln #111 Jerome ID 83338 208-324-7578</p>	<p>Steve Bowe Sandoz Agro 1300 E Touhy Ave Des Plaines IL 60018 708-390-3804</p>

Ray Boyd  
US Forest Service  
1221 S Main  
Moscow ID 83843  
208-883-2352

Rick Boydston  
USDA-ARS  
Rt 2 Box 2953A  
Prosser WA 99350  
509-786-2226

Traci Brammer  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-6236

Monica Brelsford  
Plant, Soil & Env Dept  
Montana State University  
Bozeman MT 59717  
406-994-5880

Ron Brenchley  
Miles Inc  
3841 E 1400 N  
Ashton ID 83420  
208-652-3911

Jeff Brennan  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-6236

James Breuninger  
DowElanco  
3841 W Freeway #170  
Sacramento CA 95834  
916-921-0356

Bart Brinkman  
Sandoz Agro  
5130 2nd Avenue SE  
Salem OR 97306  
503-363-1934

Harold Brown  
Cyanamid Canada  
320 Monroe Avenue  
Saskatoon Sask CN 57N 1J9  
306-653-3821

Carl Buchholz  
Ciba  
12413 Wide Hollow Road  
Yakima WA 98908  
509-966-5740

Larry Burrill  
Crop Science Dept  
Oregon State University  
Corvallis OR 97330  
503-737-5856

Marvin Butler  
Oregon State University  
850 NW Dogwood  
Madras OR 97741  
503-475-3808

Bob Callihan  
PSES  
University of Idaho  
Moscow ID 83843  
208-885-6617

Marsha Campbell  
U C Cooperative Ext  
733 County Center 3  
Modesto CA 95355  
209-525-6654

Mick Canevari  
UC Cooperative Ext  
420 S Wilson Way  
Stockton CA 95205  
209-468-2085

Stephen Canner  
Plant, Soil & Environmental  
Montana State University  
Bozeman MT 59717  
406-994-5880

Vanelle Carrithers  
DowElanco  
28884 S Marshall  
Mulino OR 97042  
503-829-4933

Bert Carson  
University of Idaho  
405 N Howard  
Moscow ID 83843  
208-882-6043

Claudia Clark  
Grant Co Noxious Weed Cont  
P O Box 1115  
Ephrata WA 98823  
509-754-2011

William Cobb  
Cobb Consulting Service  
815 S Kellogg  
Kennewick WA 99336  
509-783-3429

Don Colbert  
American Cyanamid  
2133 Jackson St  
Lodi CA 95242  
209-369-1102

Corey Colliver  
P S E Science Dept  
Montana State University  
Bozeman MT 59717  
406-994-5880

Dick Comes  
Retired  
946 Parkside Drive  
Prosser WA 99350  
509-786-2324

Harwood Cranston  
Plant & Soil Science Dept  
Montana State University  
Bozeman MT 59717  
406-994-4156

Charlie Crittendon  
Uniroyal Chemical  
1530 E Shaw Avenue  
Fresno CA 93710  
209-435-0933

Ron Crockett  
Monsanto  
17004 NE 37th Circle  
Vancouver WA 98682  
206-892-9884

Dave Cudney  
UC Cooperative Ext  
University of CA  
Riverside CA 92521  
909-787-5305

Dan Curtis  
Agripac Inc  
P O Box 5346  
Salem OR 97304  
503-371-5743

Jim Daniel  
Zeneca Agro  
P O Box 2260  
Greeley CO 80632  
303-356-5051

Lee Darlington  
USDA/ARS/WSL  
10300 Baltimore Ave  
Beltsville MD 20705  
301-504-6070

Rob Davidson  
Plant & Soil Science  
Montana State University  
Bozeman MT 59717  
406-994-5880

Linda DeFoliart  
RDA  
966 Road 2150  
Austin CO 81410  
303-835-8133

Steve Dennis  
Zeneca  
962 Keith Drive  
Roseville CA 95661  
916-773-5514

Doug Derksen  
Agriculture Canada  
P O Box 760  
Indian Head Sask CN SOG 2K0  
306-695-2274

Steve Dewey  
Plant Science Dept  
Utah State University  
Logan UT 84322  
801-750-2256

Joe Dorr  
Ciba  
1920 Vista Creek Dr  
Roseville CA 95661  
916-786-8833

Charles Doty  
Zeneca Agro  
1104 Coulter Ct  
Fairfield CA 94533  
707-422-3880

Robert Downard  
University of Idaho  
P O Box 1827  
Twin Falls ID 83303  
208-736-3600

Don Drader  
Zeneca  
9288 Albert Way SE  
Moses Lake WA 98837  
509-765-5755

Celestine Duncan  
Weed Management Services  
P O Box 9055  
Helena MT 59604  
406-443-1469

Keith Duncan  
New Mexico State Univ  
67 East Four Dinkus Road  
Artesia NM 88210  
505-748-1228

Bob Dunlap  
Rhône Poulenc  
3239 E Vartikian Ave  
Fresno CA 93710  
209-298-3997

Ken Dunster  
Rhône Poulenc  
P O Box 598  
Byron CA 94514  
510-634-0996

Bev Durgin  
University of Minnesota  
411 Borlang Hall  
St Paul MN 55108  
612-625-7262

Bill Dyer  
Plant & Soil Science  
Montana State University  
Bozeman MT 59717  
406-994-5063

Charlotte Eberlein  
University of Idaho  
P O Box AA  
Aberdeen ID 83210  
208-397-4181

Matt Ehlhardt  
AgrEvo  
257 Picholine Way  
Chico CA 95928  
916-891-0651

John Ellis  
Ciba  
410 Swing Road  
Greensboro NC 27419  
910-632-1717

Paul Escobar  
SSI Mobley  
1324 E Woodvine Ct  
Boise ID 83706  
208-331-3189

Steve Eskelsen  
WSU Food & Environmental  
100 Sprout Road  
Richland WA 99352  
509-375-9393

Jack Evans  
Plants, Soil & Bio  
University of Utah  
Logan UT 84322  
801-797-2242

Pete Fay  
Montana State University  
705 Johnson Hall  
Bozeman MT 59717  
406-994-5061

Todd Feldick  
Washington State University  
168 Johnson Hall  
Pullman WA 99164  
509-335-1551

John Fennell  
Dupont Company  
Barley Mill Plaza WM4-150  
Wilmington DE 19898  
302-992-2499

Saralynn Fenwick  
University of Idaho  
3700 Hwy 8 East #5  
Moscow ID 83843  
208-882-0212

Mark Ferrell  
University of Wyoming  
Box 3354  
Laramie WY 82071  
307-766-5381

Paul Figueroa  
Weyerhaeuser Company  
505 No Pearl Street  
Centralia WA 98531  
206-330-1745

Bruce Fishburn  
University of Wyoming  
P O Box 3475  
Laramie WY 82071  
307-742-9006

Kevin Forney  
American Cyanamid  
8307 Trenton Ave  
Lubbock TX 79424  
806-798-7588

Gus Foster  
Sandoz Agro  
812 E Elizabeth  
Ft Collins CO 80524  
303-484-8925

Jim Freeman  
Cascade County  
521 1st Avenue NW  
Great Falls MT 59404  
406-454-6920

Pat Fuerst  
Crop & Soil Sciences  
Washington State Univ  
Pullman WA 99164  
509-335-7484

David Gealy  
USDA-ARS  
Box 287  
Stuttgart AR 72160  
501-673-2661

Jay Gehrett  
Spray Tech  
Rt 3 Box 27  
Walla Walla WA 99362  
509-525-0146

Gale Gingrich  
OSU Extension Service  
3180 Center Street NE  
Salem OR 97301  
503-588-5301

Gaylan Goddard  
American Cyanamid  
1100 Itasca  
Plainview TX 79072  
806-296-5373

Thaddeus Gourd  
American Cyanamid  
305 W Magnolia  
Ft Collins CO 80521  
303-490-2509

Wanda Graves  
Western Soc of Weed Science  
P O Box 963  
Newark CA 94563  
510-793-4169

Joe Gregory  
NMSU Ag Science Center  
Box 1018  
Farmington NM 87499  
505-327-7757

Bob Gunnell  
Agraserv  
866 North 3200 West  
Weston ID 83286  
208-747-3717

Mary Guttieri  
University of Idaho  
P O Box AA  
Aberdeen ID 83210  
208-397-4181

Neil Hackett  
American Cyanamid  
1600 Airport Fwy  
Bedford TX 76022  
817-571-3535

Neal Hageman  
Monsanto  
9348 Crosspointe Dr  
Highlands Ranch CO 80126  
303-791-9371

Elaine Hale  
Hale Res & Environ Consulting  
P O Box 734  
Santa Maria CA 93456  
805-925-4518

Mary Halstvedt  
DowElanco  
2155 Carriage Drive  
Estes Park CO 80517  
303-586-6964

Kathryn Hamilton  
P S E S Dept  
University of Idaho  
Moscow ID 83844  
208-885-6236

Steve Hansen  
J R Simplot Company  
1326 N 3875 E  
Ashton ID 83420  
208-652-7375

Eric Hanson  
Dept of Forest Science  
Oregon State University  
Corvallis OR 97331  
503-737-6086

Robert Hays  
Dept of Agriculture  
P O Box 790  
Boise ID 83701  
208-334-3550

Ian Heap  
Crop & Soil Science  
Oregon State University  
Corvallis OR 97331  
503-737-5885

David Heering  
American Cyanamid  
2038 N Nyburg Way  
Meridian ID 83642  
208-887-2280

Jim Helmer  
DowElanco  
6495 N Palm Ave #101  
Fresno CA 93704  
209-261-3602

Terry Henderson  
DowElanco  
9330 Zionsville Road  
Indianapolis IN 46268  
317-337-4798

Jerry Hensley  
Ciba  
P O Box 158  
Sanger CA 93657  
209-875-6075

Ann Henson  
Dupont  
926 Yucca Court  
Longmont CO 80501  
303-651-0206

Charlie Hicks  
Rhône Poulenc  
105 Mt Moriah Road  
Livermore CO 80536  
303-490-2993

K. Hirata  
Nissan Chemical America  
303 So Broadway  
Tarrytown NY 10591  
914-332-4745

George Hittle  
Wyoming Dept of Agriculture  
P O Box 4101  
Cheyenne WY 82003  
307-777-6585

Jodie Holt  
Botany & Plant Science  
University of California  
Riverside CA 92521  
909-787-3801

Cathy Houck  
Calgene Inc  
1920 5th Street  
Davis CA 95616  
800-992-4363

Stott Howard  
Zeneca Ag Products  
4553 Knoll Park Cir  
Antioch CA 94509  
510-779-0783

James Hunter  
Agriculture Canada  
P O Box 760  
Indian Head Sask CN SOG 2K0  
306-695-2274

Pamela Hutchinson  
American Cyanamid  
2458 N Archery Way  
Meridian ID 83642  
208-887-1367

Chris Ishida  
BASF Corporation  
P O Box 2278  
Vancouver WA 98668  
208-260-0775

Nelroy Jackson  
Monsanto  
400 S Ramona Avenue  
Corona CA 91720  
909-279-7787

Larry Jeffery  
Brigham Young University  
275 WIDB Box 2513  
Provo UT 84602  
801-378-2760

Paul Jenkins  
Caribou County Weed Control  
P O Box 775  
Soda Springs ID 83276  
208-547-4483

James Jessen  
Zeneca Ag Products  
Box 575  
Lingle WY 82223  
307-837-2104

Budge Johl  
Sandoz Agro  
5653 Monterey Road  
Gilroy CA 95020  
408-848-1474



Doug Johnson  
Rhone Poulenc  
1123 W Tenaya Way  
Fresno CA 93711  
209-431-2713

Kris Johnson  
University of Wyoming  
Range Dept Box 3354  
Laramie WY 82071  
307-745-6867

Russell Johnson  
Plant & Soil Science  
Montana State University  
Bozeman MT 59717  
406-994-4156

Don Joy  
Uniroyal Chemical  
4205 Barge Street  
Yakima WA 98908  
509-966-5472

Larry Justesen  
Carbon County  
Box 1126  
Rawlins WY 82301  
307-324-6584

Diane Kaufman  
No Willamette Res & Ext  
Oregon State Univ  
Aurora OR 97002  
503-678-1264

Todd Keener  
No Western Ag Research-MSU  
4570 Montana #35  
Kalispell MT 59901  
406-257-4957

Don Kelley  
Rohm & Haas Co  
1520 E Shaw Ave #119  
Fresno CA 93710  
209-224-0158

Bruce Kelpas  
Northwest Chemical Corp  
4560 Ridge Drive NE  
Salem OR 97303  
503-390-3030

Rod Kepner  
American Cyanamid  
2167 E Pinedale Ave  
Fresno CA 93720  
209-323-7825

Tony Kern  
Plant & Soil Sciences  
Montana State University  
Bozeman MT 59717  
406-994-4156

Elmar Kibler  
BASF Corporation  
10181 Avenue 416  
Dinuba CA 93618  
209-591-2548

Ken Kirkland  
Agriculture Canada  
P O Box 10  
Scott Sask CN SOK 4A0  
306-247-2011

Jim Klauzer  
K-Farm Research  
P O Box 329  
Kuna ID 83634  
208-922-4322

Bob Klein  
University of Nebraska  
Rt 4 Box 46A  
North Platte NE 69101  
308-532-3611

Jeff Klundt  
FMC Corp  
P O Box 1622  
Walla Walla WA 99362  
509-529-5950

Kitty Knaphus  
Cascade Co Weed District  
521 1st Avenue NW  
Great Falls MT 59404  
406-454-6920

Paul Koetz  
University of Wyoming  
P O Box 3354  
Laramie WY 82071  
307-766-3949

Bill Kral  
Dupont Company  
1739 Julie Lane  
Twin Falls ID 83301  
208-734-9726

Jim Krall  
University of Wyoming  
Route 1, Box 374  
Torrington WY 82240  
307-532-7126

Gregg Kurz  
University of Wyoming  
Box 3354  
Laramie WY 82071  
307-766-6867

Tom Lanini  
University of California  
104 Robbins Hall  
Davis CA 95616  
916-752-0612

Larry Lass  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-7629

Dave Lawson  
Zeneca Ag Products  
2999 Douglas Blvd  
Roseville CA 95661  
916-283-7467

Thomas Lee  
Monsanto  
700 Chesterfield Pkwy  
St Louis MO 63198  
314-537-7458

Bob Lindemann  
Valent  
5910 No Monroe Ave  
Fresno CA 93722  
209-276-5311

Dan Lindgren  
Zeneca  
6-2135 32nd Ave NE  
Calgary AB CN T2E 6Z6  
403-250-2872

Ken Linville  
Ball Research  
P O Box 1411  
East Lansing MI 48826  
517-332-5070

Joan Lish  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-7730

Heather Loeppky  
Agriculture Canada  
Box 1240  
Melfort Sask CN SOE 1A0  
306-752-2776

Kelly Luff  
Rhone Poulenc  
3554 East 4000 North  
Kimberly ID 83341  
208-423-6371

Cindy Lunte  
The Nature Conservancy  
P O Box 165  
Sun Valley ID 83353  
208-726-3007

Rod Lym  
North Dakota State Univ  
P O Box 5051  
Fargo ND 58105  
701-237-8996

Drew Lyon  
University of Nebraska  
4502 Avenue I  
Scottsbluff NE 69361  
308-632-1266

Bill Mace  
Utah State University  
140 N 100 E  
Hyde Park UT 84318  
801-563-6757

Wade Malchow  
Plant & Soil Science Dept  
Montana State Univ  
Bozeman MT 59717  
406-994-5880

Carol Mallory-Smith  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-7730

Bruce Maxwell  
Plant & Soil Science  
Montana State Univ  
Bozeman MT 59717  
406-994-5717

Terry Mayberry  
AgrEvo  
1112 NW Hom  
Pendleton OR 97801  
503-278-2217

Rick Meinicoe  
IR-4/PIAP Western Region  
University of CA  
Davis CA 95616  
916-752-7633

Keith Miller  
Crop & Soil Science Dept  
Washington State University  
Pullman WA 99164  
509-335-7850

Steve Miller  
Plant, Soil & Insect Science  
University of Wyoming  
Laramie WY 82071  
307-766-3112

Tim Miller  
Collins Ag Consultant  
13381 Road 5 NE  
Moses Lake WA 98837  
509-766-7589

Tim Miller  
PSES Dept  
University of Idaho  
Moscow ID 83843  
208-885-7831

Gary Milner  
Plant & Soil Science  
Montana State Dept  
Bozeman MT 59717  
406-994-5880

Larry Mitich  
Plant Biology  
University of California  
Davis CA 95616  
916-752-0612

Don Morishita  
University of ID  
P O Box 1827  
Twin Falls ID 83303  
208-736-3600

Michael Mostats  
Sandoz Agro  
975 California Avenue  
Palo Alto CA 94304  
415-354-3543

Phil Motooka  
University of Hawaii  
P O Box 208  
Kealahou HI 96750  
808-324-0488

George Mueller-Warrant  
USDA-ARS  
3450 SW Campus Way  
Corvallis OR 97331  
503-750-8738

Bob Mullen  
UC Cooperative Extension  
420 South Wilson  
Stockton CA 95205  
209-468-2085

Barbara Mullin  
Montana Dept of Agriculture  
920 No Benton  
Helena MT 59601  
406-444-2944

Bill McCloskey  
Plant Science Dept  
University of California  
Tucson AZ 85721  
602-621-7613

Kirk McDaniel  
NMSU Range Science Dept  
Box 31  
Las Cruces NM 88001  
505-646-1191

Jim McDonell  
Pan Ag Labs  
32380 Avenue 10  
Madera CA 93638  
209-675-0889

James McKinley  
Rhone Poulenc  
424 Aero View  
Yakima WA 98908  
509-965-6203

Terry Neider  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-7802

Tom Neidlinger  
Rohm and Haas  
16580 SE Bel Air Drive  
Clackamas OR 97015  
503-658-8233

Bruce Nielsen  
Bonneville County Weed Dept  
605 N Capital Avenue  
Idaho Falls ID 83402  
208-529-1397

Robert Norris  
Section of Biology  
University of California  
Davis CA 95616  
916-752-0619

Ross O'Connell  
Calif Dept Food & Agriculture  
1220 N Street Room A357  
Sacramento CA 95814  
916-654-0768

Mary O'Dea  
Forest Science Dept  
Oregon State University  
Corvallis OR 97331  
503-737-6103

John O'Donovan  
Alberta Environmental Centre  
Postal Bag 4000  
Vegreville Alberta CN T9C 1T4  
403-632-8208

Alex Ogg, Jr.  
WSU, USDA-ARS  
165 Johnson Hall  
Pullman WA 99164  
509-335-1551

Paul Ogg  
American Cyanamid  
3619 Mountain View Avenue  
Longmont CO 80503  
303-772-0843

Chris Olsen  
Rhone Poulenc  
28908 NE 39th Street  
Camas WA 98607  
206-834-1089

Bill O'Neal  
Sandoz Agro  
432 Town Place Circle  
Buffalo Grove IL 60089  
708-390-3607

Jack Orr  
UC Cooperative Extension  
4145 Branch Center Road  
Sacramento CA 95827  
916-366-2013

John Orr  
Zeneca Ag Products  
251 N Longhorn Avenue  
Eagle ID 83616  
208-286-9300

Charles Osgood  
BASF Corporation  
11134 Chickadee Drive  
Boise ID 83709  
208-322-5616

Ron Paden  
RDA  
2345 E 16th Street  
Yuma AZ 85365  
602-783-3552

Bob Park  
Dupont Company  
1202 Spaich Drive  
San Jose CA 95117  
408-249-1225

Bob Parker  
Washington State University  
Rt 2 Box 2953A  
Prosser WA 99350  
509-786-2226

Steven Parker  
Ciba  
1231 Magnolia  
Walla Walla WA 99362  
509-529-9696

James Parochetti  
CSRS  
United States Dept of Agric.  
Washington DC 20250  
202-401-4354

Gary Pastushok  
Zeneca Agro  
3206 Wells Avenue  
Saskatoon Sask CN S7K 5W5  
306-933-4283

Ron Peachey  
Horticulture Dept  
Oregon State University  
Corvallis OR 97330  
503-737-5442

Phil Petersen  
Cenex/Land O' Lakes  
11275 Avalon Road NE  
Moses Lake WA 98837  
509-766-7539

Tim Prather  
U C Statewide IPM Project  
9240 S Riverbend Avenue  
Parlier CA 93648  
209-891-2500

Troy Price  
Utah State University  
2025 N 1250 E  
N Logan UT 84321  
801-750-0989

Bill Price  
College of Agriculture  
University of Idaho  
Moscow ID 83844

Ivan Rash  
Nalco  
2809 Tam O' Shanter  
Richardson TX 75080  
214-231-5526

Carol Lambert Regusci  
BASF Corporation  
4337 Kiernan  
Modesto CA 95356  
209-545-0401

Roy Reichenbach  
Converse County Weed & Pest  
P O Box 728  
Douglas WY 82633  
307-358-2775

Pat Renner  
PSES Dept  
University of Wyoming  
Laramie WY 82071  
307-745-3769

Wendell Rich  
Agraserv Inc.  
1200 North 3861 East  
Ashton ID 83420  
208-652-7860

Jesse Richardson  
DowElanco  
9330 10th Avenue  
Hesperia CA 92345  
619-949-2565

David Rickard  
Pan Ag Labs  
32380 Avenue 10  
Madera CA 93638  
209-675-0889

Dean Riechers  
Crop & Soil Science  
Washington State University  
Paullman WA 99164  
509-335-7817

Bruce Roberts  
UC Cooperative Extension  
680 N Campus Drive  
Hanford CA 93230  
209-582-3211

Cindy Roche  
PSES Department  
University of Idaho  
Moscow ID 83844  
208-885-6236

Robin Rose  
Veg Management Coop  
Oregon State University  
Corvallis OR 97331  
503-737-6580

Claude Ross  
FMC Corporation  
4343 Redbird Ct  
Loveland CO 80537  
303-669-3622

Tim Ross  
New Mexico State Univ  
Box 3I  
Las Cruces NM 88003  
505-646-3402

Fred Ryan  
USDA Aquatic Weeds  
University of California  
Davis CA 95616  
916-752-6260

Doug Ryerson  
Monsanto  
408 Deer Drive  
Great Falls MT 59404  
406-771-1920

Curtis Sandberg  
Pan Ag Labs  
32380 Avenue 10  
Madera CA 93638  
209-675-0889

Roland Schirman  
WSU Cooperative Ext  
202 S Second  
Dayton WA 99328  
509-382-4741

Jack Schlesselman  
Rohm & Haas Company  
726 E Kip Patrick  
Reedley CA 93654  
209-638-7003

Jerry Schmierer  
UC Cooperative Ext  
1205 Main Street  
Susanville CA 96130  
916-251-8132

Galen Schroeder  
Sandoz Agro  
P O Box 2277  
Fargo ND 58108  
701-237-5382

Jill Schroeder  
New Mexico State Univ  
Box 30003, Dept 3BE  
Las Cruces NM 88003  
505-646-2328

Gary Schultz  
Monsanto Company  
2209 Oddie Blvd #362  
Sparks NV 89431  
702-331-4144

Tim Schultz  
Dept of Agric-Pesticide Div  
17805 N West Shore Road  
Nine Mile Falls WA 99026  
509-466-6540

Ed Schweizer  
USDA/ARS, AERC  
Colorado State Univ  
Ft Collins CO 80521  
303-491-8520

Steve Seefeldt  
Washington State Univ  
165 Johnson Hall  
Pullman WA 99164  
509-335-7739

Clarence Seely  
Retired  
430 Lewis  
Moscow ID 83843  
208-882-5253

David Shields  
BASF Corporation  
10181 Avenue 416  
Dinuba CA 93618  
209-591-2548

Ed Sieckert  
Monsanto Company  
2415 Rockingham Lane  
Lodi CA 95242  
209-334-4234

Ralph Sinnacher  
Sweetwater Co Weed & Pest  
P O Box 173  
Farson WY 82932  
307-273-9683

Phillip Stahlman  
Kansas State University  
1232 240th Avenue  
Hays KS 67601  
913-625-3425

Gil Stallknecht  
Montana State Univ  
Southern Ag Research Center  
Huntley MT 59037  
406-348-3400

Kevin Staska  
Hoechst-Roussel Agri-Vet  
1701 E 79th St #2  
Blomington MN 55425  
612-858-8873

Scott Stenquist  
US Fish & Wildlife Service  
911 NE 11th Avenue  
Portland OR 97232  
503-231-6171

Harold Stepper  
Montana Dept of Agric  
P O Box 200201  
Helena MT 59620  
406-444-2944

Tracy Sterling  
New Mexico State University  
Dept 3BE Box 30003  
Las Cruces NM 88003  
505-646-6177

Vern Stewart  
ALMACO  
117 Sherwood Lane  
Kalispell MT 59901  
406-752-8062

Bob Stougaard  
Montana State University  
4570 Montana 35  
Kalispell MT 59901  
406-755-4303

Clair Stymiest  
So Dakota State University  
801 San Francisco St  
Rapid City SD 57701  
605-394-2236

Dean Swan  
Retired  
S W 822 Crestview  
Pullman WA 99163  
509-334-1836

Ron Swearinger  
University of Wyoming  
Box 3354  
Laramie WY 82071  
307-766-3113

Mark Sybouts  
BASF Corporation  
6650 E Olive Avenue  
Fresno CA 93727  
209-255-5301

Donn Thill  
Plant Science Dept  
University of Idaho  
Moscow ID 83843  
208-885-6214

Curtis Thompson  
Kansas State University  
1501 Fulton Terrace  
Garden City KS 67846

David Thompson  
New Mexico State Univ  
Box 30003 Dept 3BE  
Las Cruces NM 88003  
505-646-2740

Jeff Tichota  
Sandoz Agro  
7720 E Belleview #210  
Englewood CO 80111  
303-1220-0834

Barry Ticks  
University of Arizona  
198 S Main Street, 3rd Floor  
Yuma AZ 85364  
602-329-2150

Dennis Tonks  
Plant Pathology  
Colorado State University  
Ft Collins CO 80523  
303-491-5667

Paul Tresham  
Wilbur-Ellis Co  
P O Box 640  
Umatilla OR 97882  
503-922-3278

Harvey Tripple  
Tripple Consulting  
4995 East Lake Place  
Littleton CO 80121  
303-773-6028

Stuart A Turner  
Turner & Company  
303 Gage Blvd #318  
Richland WA 99352  
509-627-6428

Vincent Ulstad  
BASF Corporation  
4120 15th Street South  
Fargo ND 58104  
701-232-5651

Kai Umeda  
Univ of Arizona Coop Ext  
4341 E Broadway  
Phoenix AZ 85040  
602-255-4456

Joe Vandepute  
CDFA  
3415 Morro Bay Ave  
Davis CA 95616  
916-324-3951

Ron Vargas  
UC Cooperative Ext  
328 Madera Avenue  
Madera CA 93637  
209-675-7879

Tim Vargas  
VARCO Ag Research  
180 W 100 N  
Jerome ID 83338  
208-324-4080

Kurt Volker  
Zeneca Ag Products  
7610 Scenic Drive  
Yakima WA 95908  
509-966-1081

Hans Von Amsberg  
BASF Corporation  
Box 13528  
Res Triangle Pk NC 27709  
919-248-6525

Paul Walgenbach  
American Cyanamid  
789 Lakecrest Drive  
El Dorado Hills CA 95762  
916-933-3180

Ted Warfield  
FMC Corporation  
11128 John Galt Blvd #310  
Omaha NE 68137  
402-592-5090

Jack Warren  
Miles Inc  
P O Box 97  
Beaver Creek OR 97004  
503-632-6210

Todd Wasinger  
Monsanto  
1501 13th NW #3  
Minot ND 58701  
701-852-6017

Steven Watkins  
Zeneca Ag Products  
P O Box 4817  
Yuma AZ 85366  
602-726-1509

David Wehrin  
MSU Plant & Soil Sci  
P O Box 4186  
Bozeman MT 59772  
406-585-9162

Len Welch  
Valent USA  
5910 N Monroe  
Fresno CA 93722  
209-276-5309

Doug West  
Rohm & Haas Company  
4000 Meder Road  
Shingle Springs CA 95682  
916-677-6886

Philip Westra  
Colorado State University  
112 Weed Science Lab  
Ft Collins CO 80523  
303-491-5219

Tom Whitson  
University of Wyoming  
Box 3354  
Laramie WY 82071  
307-766-3113

Duke Wiley  
BASF Corporation  
P O Box 2198  
Paradise CA 95967  
916-872-8006

Michael Wille  
PSES Dept  
University of Idaho  
Moscow ID 83844  
208-885-6236

Roger Willemsen  
Rhône-Poulenc  
7100 N Financial Dr #109  
Fresno CA 93720  
209-449-0630

Ray William  
Horticulture Dept  
Oregon State University  
Corvallis OR 97331  
503-737-5441

Bob Wilson  
Intermountain Canola  
2300 N Yellowstone  
Idaho Falls ID 83401  
208-522-4113

Bob Wilson  
University of Nebraska  
4502 Avenue I  
Scottsbluff NE 69361  
308-632-1263

Barry Wingfield  
Pueblo Chemical  
P O Box E  
Greeley CO 80632  
303-834-2607

Sandy Wingfield  
Agrisan  
P O Box 323  
Eaton CO 80615  
303-834-2607

Randall Wittie  
Ciba  
406 Hollywood Ct  
Reedley CA 93654  
209-638-3320

Josette Wright  
Montana State Univ  
Leon Johnson Hall  
Bozeman MT 59717  
406-994-6841

Steve Wright  
UC Cooperative Ext  
County Civic Center  
Visalia CA 93292  
209-733-6482

Wayne Wright  
DowElanco  
9330 Zionsville Road  
Indianapolis IN 46268  
317-337-4424

Frank Young  
USDA-ARS  
165 Johnson Hall, WSU  
Pullman WA 99164  
509-335-1551

Jake Zaccaria  
Ciba  
5408 Summerwind Way  
Bakersfield CA 93308  
805-393-4981

Richard Zollinger  
North Dakota State Univ  
Box 5051  
Fargo ND 58105  
701-237-8157

## AUTHOR INDEX

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Gregory, E. J. . . . .	16,17	Parra, R. R. . . . .	13		
Guttieri, M. J. . . . .	60	Parreira, J. A. . . . .	18		
Halstvedt, M. B. . . . .	52,55	Prather, T. S. . . . .	88,95		
Hamilton, K. A. . . . .	11	Price, T. M. . . . .	106		
Hanson, D. E. . . . .	50	Radosevich, S. R. . . . .	50		
Hanson, K. . . . .	97	Renner, P. G. . . . .	109		
Hays, R. S. . . . .	82	Riechers, D. E. . . . .	108		
Heap, I. . . . .	89	Roché, Jr., B. F. . . . .	97		
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Hunter, J. H. . . . .	65	Roncoroni, J. . . . .	66		
Irzyk, G. P. . . . .	88,103	Rose, R. W. . . . .	50		
Jackson, N. . . . .	64	Ross, C. G. . . . .	71		
Johnson, K. H. . . . .	10,98	Ryerson, D. . . . .	1		
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